Journal of Agricultural Science; Vol. 12, No. 11; 2020
ISSN 1916-9752 E-ISSN 1916-9760
Published by Canadian Center of Science and Education

Farmers' Preferences for Varietal Traits, Their Knowledge and Perceptions in Traditional Management of Drought Constraints in Rice Cropping in Benin: Implications for Rice Breeding

Blandine Y. Fatondji[1], Hubert Adoukonou-Sagbadja[1], Ndanikou Sognigbe[3], Christophe Gandonou[2] & Raymond S. Vodouhè[1,3]

[1] Laboratory of Genetic Resources and Molecular Breeding (LaREGAME), Department of Genetics and Biotechnology, Faculty of Sciences and Techniques, University of Abomey-Calavi, Abomey-Calavi, Benin Republic

[2] Department of Plant Biology, Faculty of Sciences and Techniques, University of Abomey-Calavi, Abomey-Calavi, Benin Republic

[3] Bioversity International, West and Central Africa Office, Cotonou, Benin Republic

Correspondence: Hubert Adoukonou-Sagbadja, Laboratory of Genetic Resources and Molecular Breeding (LaREGAME), Department of Genetics and Biotechnology, Faculty of Sciences and Techniques, University of Abomey-Calavi, BP 1947 Abomey-Calavi, Benin Republic. Tel: 229-95-852-838/96-727-605. E-mail: hadoukas@yahoo.fr

Received: August 3, 2020 Accepted: September 9, 2020 Online Published: October 15, 2020

doi:10.5539/jas.v12n11p56 URL: https://doi.org/10.5539/jas.v12n11p56

The research is financed by proper funds of Laboratory of Genetic Resources and Molecular Breeding (LaREGAME).

Abstract

Rice (*Oryza* spp.) is one of the most important crops that significantly contribute to food security in Benin. In the current context of climate change, drought is known to be the main abiotic stress in crops and a major yield-limiting factor for agricultural production worldwide. To assess farmers' knowledge, the preference traits of the rice cultivars in use, their perceptions and management of drought stress in rice production in Benin, an ethnobotanical investigation was conducted in 50 villages throughout the major zones. The results showed that High yield combined with good grain quality (including good taste, softness after cooking, less starch, white pericarp, long grain length and swelling when cooked), medium maturing and tolerance to drought and flood were the most desired traits motivating farmers for growing rice cultivars. Taste and high yield were the paramount traits of IR841, the most popular rice variety currently cropped in Benin followed by its fragrance. Drought constraints was reported as the most damaging abiotic stress across the villages surveyed with field lost estimated up to 100% at the flowering stage. Changing sowing date (80%), the use of irrigation systems (10%) and the cropping of early maturing cultivars (7%) were the most traditional strategies to reduce drought impacts. Needs for tolerant varieties were clearly expressed by farmers to mitigate drought effects on rice production in Benin. The results of this survey emphasize the need for rice breeders to focus more on improving grain quality in addition to high yield potential and tolerance to abiotic stresses mainly drought.

Keywords: Benin, drought constraints, farmers' perceptions, preferences, rice cropping

1. Introduction

Agriculture is considered as an economic sector in the world. It contributes to 24% of global Gross Domestic Product and provides employment to 1.3 billion people or 22% of the world's population (Smith et al., 2007). Increasing agricultural production in the developing countries, has been one of the most important priorities for agricultural development programs (Hosseini et al., 2010; Subedi et al., 2009). Benin, like other developing countries, depends on its agriculture sector to fulfill demand for more food especially rice. Agriculture is likewise the most important economic sector in West-Africa which is highly dependent on climate.

Rice is one of the primary food source for more than half of the world's population (Roy et al., 2016). It represents an important place in human nutrition, providing 20% of the calories and 15% of proteins consumed by world's population (Sajid et al., 2015). The global paddy rice production has increased from 743.2 million tons from the years 2013-2015 to 759.6 million tons (equivalent of 503.9 million tons milled basis) in 2017 with forecast of 769.9 million tons in 2018. However, the production in Africa has increased from 29.2 million tons (2013-2015) to 32.1 million tons in 2017 with forecast of 33.3 million tons in 2018. In the same period, West Africa has recorded the increasing of its production from 14.9 million tons to 18.0 million tons (11.4 million tons milled basis) in 2017 (FAO, 2018). Notwithstanding this report, most African countries are not self-sufficient in term of rice production, and so depend on huge amounts of imported rice that is estimated at 17.0 million tons in 2017 (FAO, 2018) making therefore Africa the largest rice importing region in the world.

Indeed, rice production in West-Africa including Benin encounters several problems such as drought, diseases, low yielding varieties, lack of knowledge on good agronomic practices by farmers, the unavailability of suitable and improved rice varieties for diverse environments and the low quality of locally processed rice (Adolph & Chancellor, 2006; Chuwa & Mabagala, 2013). Among them, the escalation of drought condition caused by the climate change and the low competitiveness of rice locally produced in Benin compared to imported rice are more critical and need therefore to be taken into account for the national breeding programs.

Rainfall is the ultimate source of water, affecting crop production by directly influencing ground water irrigation as well as soil-moisture status and supporting surface. It has been reported that during the last one decade, the monsoon rains are very much deviating from its predictions and the region which never experiences sharp drought comes under such natural disaster (Roy & Hirway, 2007). Various Asian countries likewise saw cropping activities disrupted by floods or drought during their main-crop cycles (FAO, 2018). It results in economic, social and environmental impacts that are complex to understand and difficult to anticipate. Statistics compiled by the Secretariat for the International Decade for Natural Disaster Reduction indicated that among all the natural hazards, drought ranks first in terms of the number of people directly affected. It accounts for 22% of the damage from all disasters worldwide, 33% of the number of persons affected by disasters, and 3% of the number of deaths attributed to natural disasters (Hewitt, 1997; Wilhite, 2000).

Actually, drought is a creeping phenomenon, hard to define and understand due to differences in socio-economic factors and hydro-meteorological variables along with the stochastic nature of water demand in various areas of the world. Although explicit definitions of drought may fluctuate by sector and region, it is basically an extended time period in which precipitation is less than the annual average, resulting in water scarcity (Wilhite, 2000). Insufficient rainfall leads to greater drought frequency and intensity, while high evaporation increases the chance of complete crop failure (Liu et al., 2010; Reid et al., 2007). The climate forecast for West-Africa predicts increasing temperatures and irregular rainfall (Callo-Concha, 2018). In other words, drought is now the most complex of all-natural hazards, and more people are affected by it than any other hazard.

In Benin, milled rice production has increased up to 179,000 tons in the year 2018/2019 while its consumption during the same period was reported to 799,000 tons. This fact consequently, increase considerably rice importation that is estimated today at 620,000 tons per year and represent huge amount dollars' deficit to local economy (USDA, 2019). To reduce the rice import, the government has tried to increase local rice production. Providing fertilizer and high yielding improved varieties at low cost to farmers through an international and national research centers are amongst the measures taken to boost rice production in Benin. Although these measures have contributed to increase substantially rice production in the country (MAEP, 2011), the production gap remains very high creating important economic deficit and food security dependence. Besides, as in most SSA countries, imported improved varieties have been poorly adopted as they do not meet farmer's requirements for both cropping and consumption, and therefore, most farmers still prefer growing landraces or old varieties (Derera et al., 2006; Efisue et al., 2008; Kam et al., 2013; Manu-Aduening et al., 2006; Witcombe et al., 1996). Developing locally new high yielding varieties that better fit traditional agricultural conditions and meet farmers and consumers' preferences is mandatory for sustainable rice production in Benin.

Participatory research approaches (PRA) in breeding have been proposed as a way to increase farmer adoption of new varieties (Ceccarelli & Grando, 2009; Joshi et al., 2001; Efisue et al., 2008; Kiros-Meles & Abang, 2008). The idea is to generate information about target population's knowledge and opinions about their production system and to use the information to design and manage future breeding project. Besides, it has been proven that participatory plant breeding (PPB) that involves farmers in selecting genotypes for use as parents is more effective for wide adoption of improved varieties than the participatory variety selection (PVS) that provides merely polished breeding products to farmers for final evaluation in their farms (Atlin et al., 2001; Witcombe et al., 2003). A successful participatory varietal selection program relies on four phases (Witcombe et al., 1996): a

means of identifying farmers' needs in a cultivar; a search for a suitable material to test with farmers; determining acceptability in farmers' fields; and wider dissemination of farmer-preferred cultivars. Therefore, this study was designed to meet following specific objectives: (i) to describe farmer's socio-demographic characteristics and rice farming management in the Republic of Benin, (ii) to ascertain rice traits and cultivars preferred by farmers and (iii) to capture farmers' perceptions on major rice constraints with emphasis to drought and its traditional management. The outcome of this research should provide valuable information in support to participatory rice breeding programs in Benin and any other West-African countries to deliver novel but acceptable rice varieties that meet farmer as well as consumer preferences.

2. Methodology

2.1 Survey Procedure and Data Collection

The study was conducted in 19 districts through 9 regions (Alibori, Atacora, Borgou, Collines, Couffo**,** Donga, Mono, Ouémé and Zou) of highest rice production in Benin (West Africa). In total, fifty (50) representative villages were selected following their easy accessibility and their effective production of rice. The map location of these surveyed villages was indicated in Figure 1.

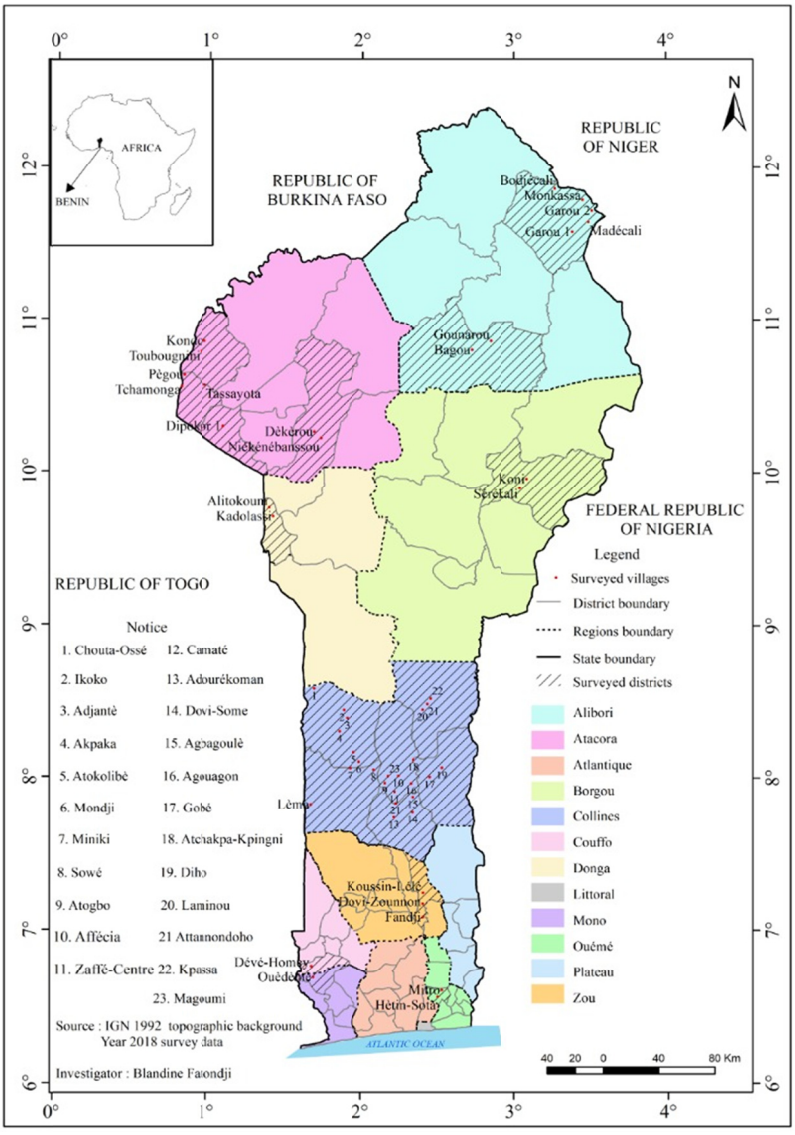

Figure 1. Location map of study area showing the geographical position of surveyed villages

In order to study farmers' perceptions on drought and its local management in rice farming, 236 farmers including 145 men and 91 women from the different agro-ecological regions were surveyed from April to May 2018. Agriculture is the major land use in the study area. The data were collected through focus group discussions, individual interviews using questionnaires and transect walks on field visits following the methodology described by Adoukonou-Sagbadja et al. (2006) and successfully applied on rice in Ghana, Mali, Burkina Faso and Niger respectively by Asante et al. (2013), Efisue et al. (2008), Kam et al. (2013), and Sow et al. (2015). The questionnaire written was administrated in the most spoken local language in each community group involved in the survey for better understanding. Therefore, specialized translators fluent in both French and mother tongue from each area were considered. Prior to the survey, this questionnaire was pre-tested with sub-sets of the targeted population (*i.e.*, few farmers from two villages) to check the missing information, redundancy, and relevancy of the questions. The questionnaire was then adjusted based on pre-test results and recommendations.

To conduct the survey, the agricultural extension units of each relevant region were prior contacted. A meeting was scheduled with farmers mainly through the head of farmer's local union or the local authorities. Group discussions were first organized with farmers to obtain community level information on their rice farming practices and constraint perceptions with emphasis to drought through questionnaire and pictures. After the group discussion, about 10 farmers were randomly selected for an individual interview. This survey enabled targeted farmers to express their own point of view without any influence from the community. It first focused on the socio-economic characteristics of the producers. Later, open and structured questions were asked to respondents on their cropping management, rice traits and rice cultivars they preferred and their perception and management of constraints with an emphasis on drought constraints. Several techniques such as iteration, probing, direct observations and pair wise ranking were used (Adoukonou-Sagbadja et al., 2006). In iteration, the same question was asked more than once in different ways in order to confirm the answer. This technique is recommended in the situation where most of the people in the community are illiterate (Efisue et al., 2008). Pictures were shown to the groups in order to easily identify drought stress between other threats occurring in their fields.

2.2 Data Analysis

The primary data were processed and statistically analyzed using R 3.5.1 Software Package. Descriptive statistics were employed to assess farmer's perceptions and management strategies. Frequencies and percentage of responses were computed using Excel spreadsheet. Graphs were drawn to illustrate the outputs. A Factorial Correspondence Analysis (FCA) was performed to describe the relationships between the cropping seasons, agro-systems, rice varieties and the regions. The Khi squared Pearson correlation test conducted to assess its significance.

3. Results

3.1 Characteristics of Surveyed Rice Producers

In the study area, men and women are both involved in rice farming. Men were more represented (61%) than women (39%). The result indicated that only 10% of farmers were younger than 30 years old, 85% of them were within the age range of 30-60 and respondents' average age was 44 years old. Most of them (94.5%) were married and the overall household size averaged of 8±3.75 with the minimum of one person and the maximum of 35 persons. Respondents with no education had the highest prevalence in the sample (50%) while 9% were alphabetized. Data on education likewise indicated that 29%, 11% and 1% of respondents had completed their primary, secondary and higher education, respectively. The majority of the interviewees had been cropping rice for 15±6.64 years in average with a minimum of one year and a maximum of 40 years. Rice farming was the main activity for 77% and full-time occupation for 10% of farmers involved in the survey while 13% considered it as secondary occupation. Fourteen different ethnic groups were recorded. The *Nago* ethnic group is the most represented (30% of respondents) followed by *Mahi* (17%), *Batonou* (9%), *Dendi* (7%), *Wémé* (7%), *Biali* (6%), *Adja* (4%) *Ditammaribè* (4%), *Fon* (4%), *Bariba* (3%), *Lokpa* (3%), *Wama* (3%), *Zerma* (2%) and *Cotafon* (1%) ethnic groups (Figure 2).

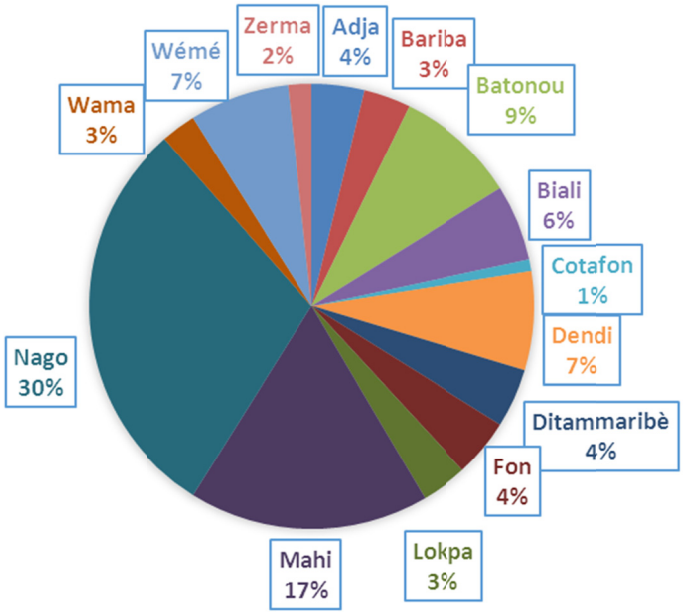

Figure 2. Distribution of rice farmers per ethnic groups surveyed in Benin

The majority of farmers (96%) that belonged to local farmers' cooperatives was trained on farming practices. The remaining 4% farmers did not attend any training but were informed through the other farmers or relied solely on their traditional practices. The duration of their membership varied from 1 to 30 years with a mean of 12±3.64 years. With regard to the arable land holding, the land was mostly acquired by inheritance from fathers to sons (46%) while mother inheritance (5%) was less represented. In the study area, farming lands were obtained mostly by gift (23%) and purchase (13%), but also at low level by free occupation in public area (5%), loan (5%) and renting (4%)

The number of arable lands per farmer varied from one to 15 with the mean of 2±0.82 lands. Pearson's Khi squared test performed between land holding modes and the sex of farmers revealed that the mode of land acquisition depends on the sex of the farmer (χ^2 = 33.139; p-value < 0.001; degree of freedom = 6) at 0.05 probability levels. Finally, the majority of respondents (56.2%) were medium-scale farmers with one to three hectares of land, 31.5% had more than 3 hectares of land and can thus be regarded as large-scale farmers. Few respondents (12.3%) were small-scale farmers, with only one hectare or less of land. The land superficies devoted to rice cropping by farmers varied from 0.2 ha to 42.5 ha with a mean of 3.18±1.90 ha.

3.2 Agricultural Practices in Rice Cultivation in Benin

In the study areas, diverse crops were grown by rice farmers. Indeed, in addition to rice, the majority of respondents grew in decreasing importance maize (28%), cassava and yam (10% each), soybean, groundnut and cowpea (8% each), cotton and pepper (6% each), sorghum (4%), okra and pearl millet (3% each), tomato (2%), onion and vegetables (1% each) (Figure 3A). Considering their cash income crops, rice was far the most important followed by maize, cotton and pepper (Figure 3B).

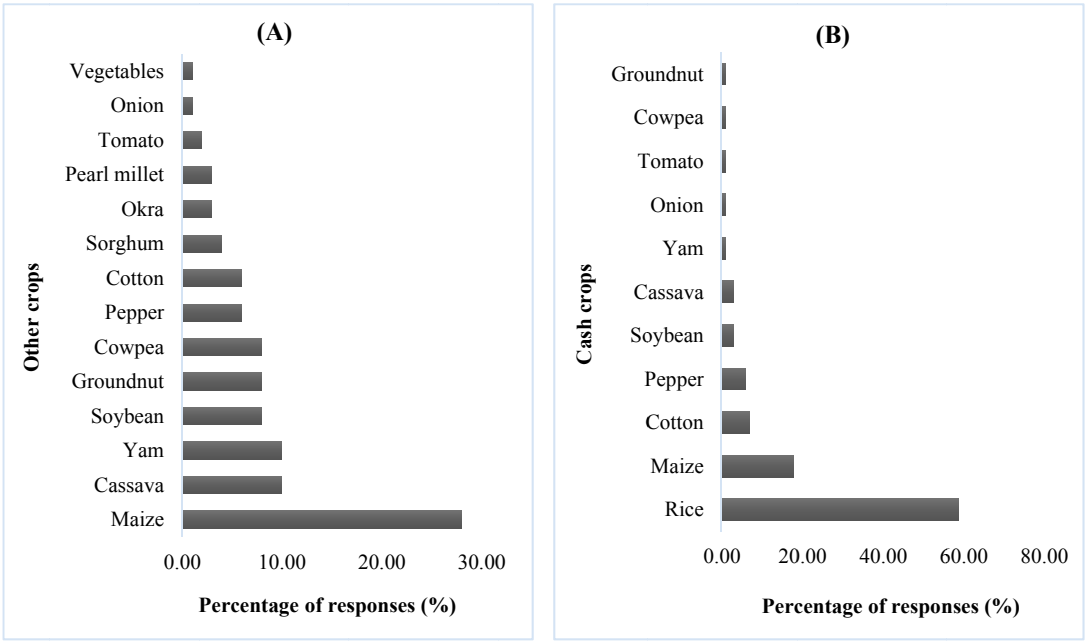

Figure 3. Importance of other crops practiced (A) by farmers in rice production system in Benin and (B) principally cash crops

With regard to cropping management, rice is grown in both rainy and dry seasons. A factorial correspondence analysis was performed to describe the relationships between the cropping seasons and the regions. The result showed that the first two axis explained 100% of observed variation, ensuring thus the accuracy of the interpretation. Farmers of 6 regions out of the 9 surveyed (Atacora, Borgou, Collines, Couffo, Donga and Mono) cropped rice mainly in rainy season while farmers of the region of Ouémé grew rice during the dry season following the recession of rivers. Farmers of Zou and Alibori regions grew rice at all the time (Figure 4). This observed relationship between the region and rice cropping season was proved with the Pearson's Khi squared test (χ^2 = 397.04; p-value = 1.52 e^{-7}) at 0.05 probability level. The few farmers growing rice at all the time had access to irrigation with controlled water management.

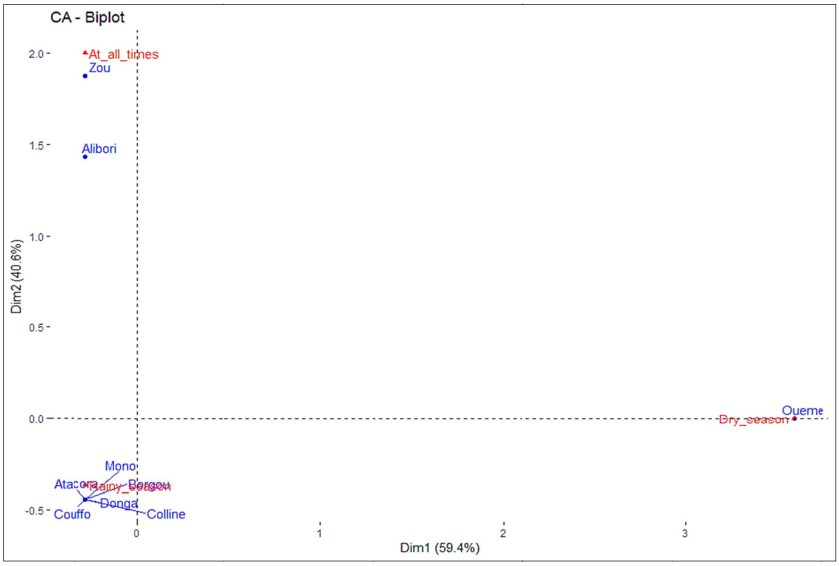

Figure 4. Biplot Factorial Correspondence Analysis between rice cropping seasons and the different rice production regions in Benin

In the producing regions surveyed, the majority of farmers (75%) cultivated rice in rainfed lowland areas. Few farmers (14%) growing rice in rainfed lowland conditions practiced irrigation with controlled water management system. Flooding upland, rainfed upland and flooded lowland were other rice agro-systems recorded in low frequencies in the study areas.

A factorial correspondence analysis performed between the agro-systems and regions involved in the survey shows that 93% of observed variation was explained by the two first axis. It appears that farmers of the region of Ouémé grew rice in flooded lowland while those of the regions of Alibori and Zou grew rice mainly in rainfed upland and rainfed lowland assisted by irrigation. However, farmers of the majority of the regions surveyed (Atacora, Borgou, Collines, Couffo, Donga and Mono) were found to grow rice mainly in rainfed lowland and flooding upland (Figure 5). In rainfed lowland and flooding upland agro-systems, a single cropping is practiced every year from May-July to October-December. In addition, farmers growing rice in flooded lowland did a single cropping per year mainly from October-November to February-March. In irrigated agro-systems, double and/or triple cropping was recorded. Most of farmers (99%) practiced sole rice farming (pure) while a few farmers combined rice with okra and other vegetables.

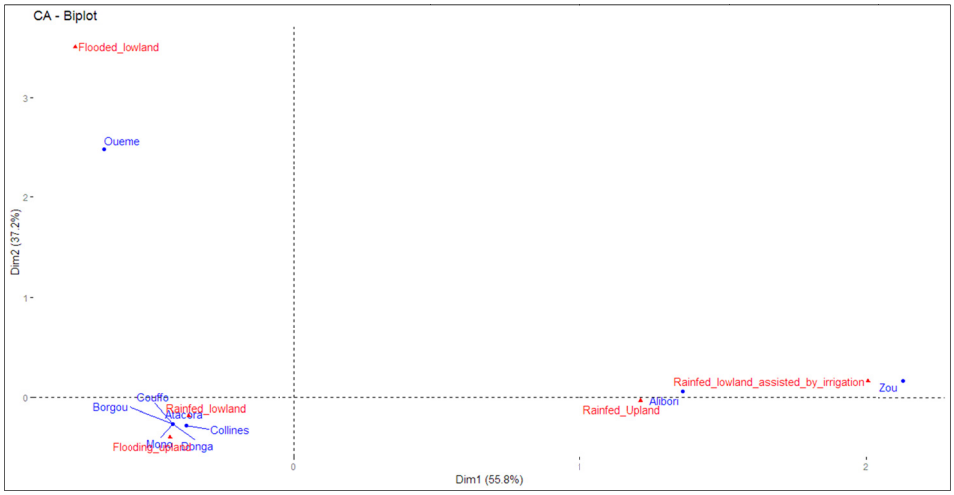

Figure 5. Biplot Factorial Correspondence Analysis between rice cropping agro-systems and producing regions in Benin

Prior to planting, most of farmers used animal traction for their field preparation. Different ways of crop establishment were noticed in the study area. Direct sowing by hand was used by 75% of farmers and nursery establishment and transplantation by 9% of them while 16% of respondents practiced both of the two modes of sowing (Figure 6A).

After sowing, hand as well as chemical (herbicide) weeding was practiced by farmers in the surveyed areas. In total, 29% and 13% of farmers used respectively only chemical weeding or only hand weeding while the majority of them (58%) used both systems (Figure 6B). The large majority of farmers (82%) practiced two weeding during the cropping season while 3% and 15% weeded once or more than twice, respectively (Figure 6C). Fertilizers such as urea and NPK (15:15:15) were applied by all of respondents (100%) in various rate ranging from 50 to 200 kg ha^{-1} and 100 to 300 kg ha^{-1}, respectively. The majority of them (51% and 52%) applied urea at the rate of 100 kg ha^{-1} and NPK: 15:15:15 at 200 kg ha^{-1}, respectively. Finally, weeding activities were generally done by both household members and laborers (55%). However, certain farmers used only household members (34%) or only laborers (11%) to ensure their field weeding (Figure 6D).

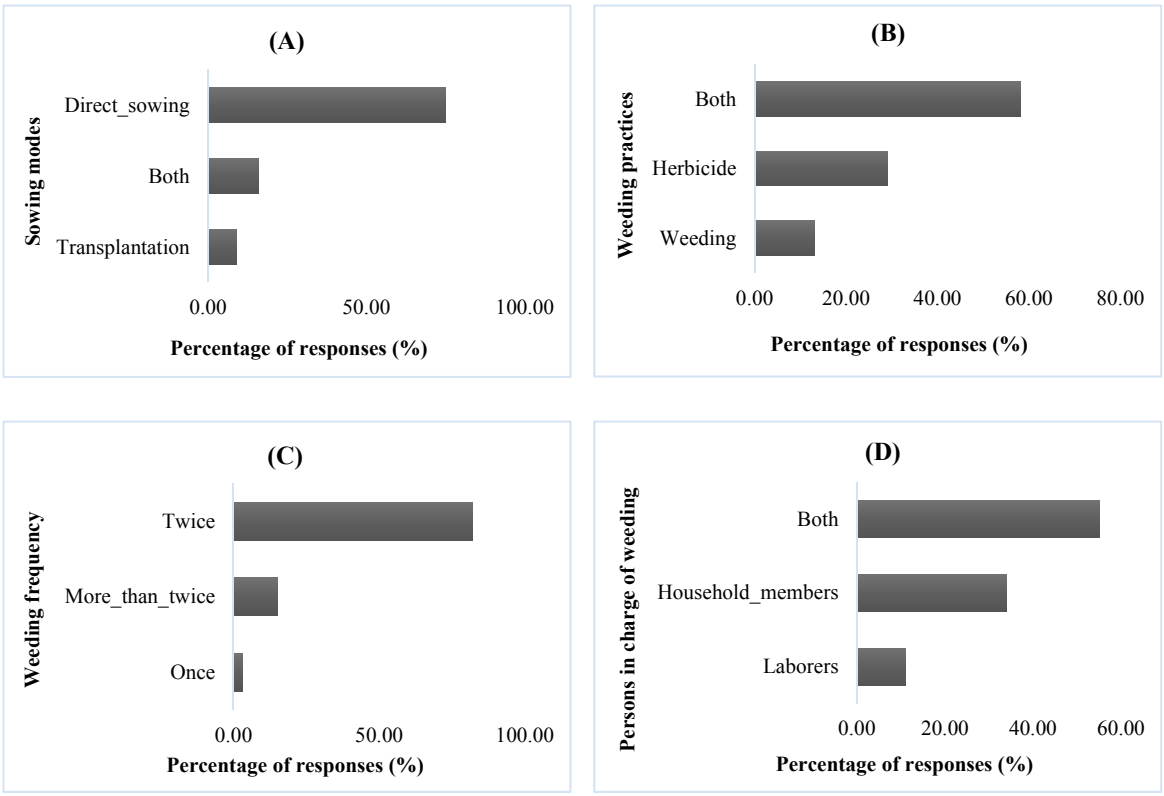

Figure 6. Agricultural practices in rice farming in Benin (A) Sowing modes, (B) Weeding practices, (C) Weeding frequency and (D) Persons in charge of weeding

3.3 Seed System and Management of Rice Produced by Farmers in Benin

Rice planting seeds used by farmers to ensure their cropping were mainly certified seeds (87%) purchased most of the time (82%) from the national agricultural extension offices known as Territorial Agencies of Agricultural Development (ATDA, ex CARDER). Less farmers (10%) used seeds from their previous harvest to ensure the current crop campaign while 3% borrowed seeds from neighbors within village. Besides the ATDA source, seeds were likewise bought in low frequencies (9%, 7% and 3%) from ESOP (Farmer Enterprise and Service Organization), VECO (an active Non-Governmental Organization) and seeds producers, respectively.

Rice produced by farmers were self-consumed and sold on the local markets by most of farmers. However, some of them sold their production as well at the neighboring district markets (23%), to the regional Rice Farmers' Union of Zou-Collines departments (UNIRIZ-C) (17%) and NGOs like ESOP (7%). Exporting the rice produced by farmers to neighboring countries mainly Togo (11%) and Nigeria (7%) was likewise reported during the survey (Figure 7).

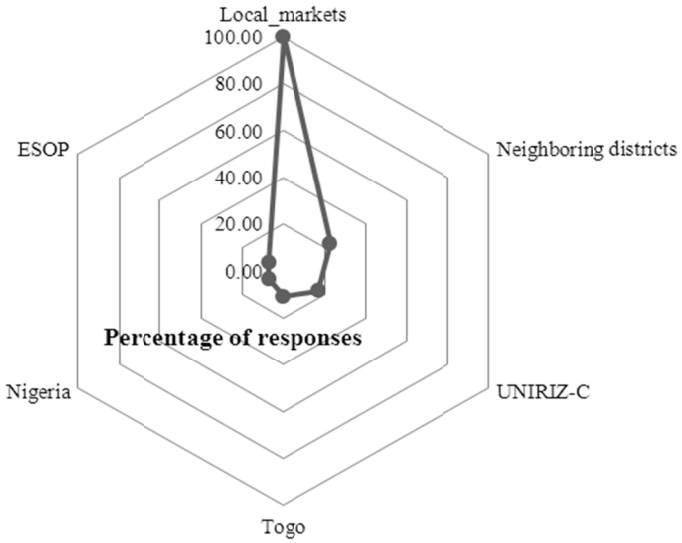

Figure 7. Rice markets in Benin

3.4 Cultivar Diversity of Rice in Growing Areas of Benin

In the study area, ten different generic names of rice were recorded in various local languages in the different sociolinguistic groups surveyed. These were Amouan in Lokpa, Bagui in Wama sociolinguistic group, Imouan in Ditamari, Rèssi in Nago, Lèssi in Wémé, Mon in Dendi and Zerma, Mongni in Biali, Monlou in Adja and Cotafon, Monlikoun in Fon and Mahi and Monri in Bariba. With regard to the rice types grown in the study areas, a total of 38 different rice cultivars including improved varieties and traditional cultivars (landraces) were cited by farmers. Among them, 23 cultivars were still really cultivated across the surveyed villages while 15 other cultivars were practiced in the past time (Table 1). However, height rice cultivars mostly cropped by farmers in the past appear to be still practiced by few farmers as attested by their low frequency of citation. There are the popular traditional variety Gambiaka (7.3%) followed by improved interspecific high yielding variety such as Nerica20 (4.4%), Nerica4 (2.2%), Nerica14 (1.1%) and other introduced varieties namely Béris21, R8, Djimbo and ADNY11 (Table 1).

Regarding rice cultivars preferred by farmers, the improved rice variety IR841 was cited as the most cropped rice variety (55.3%) in Benin. In addition to IR841, other rice cultivars such as Gambiaka, Nerica20, Waabi, Imonpia, Fondiézé, Shapshap, Gbemga, R16, Nerica4 and Samassagoumi were relatively cultivated by few farmers in descending order (Table 1). Rice cultivars R16 and Briz10B were improved drought tolerant rice varieties newly introduced for testing in 2017 by Africa Rice center which did not completely match farmers' preferences.

Table 1. Rice cultivars diversity in farming system in Benin: a) present and (b) past cropping status

Rice cultivars actually in use		Rice Cultivars cropped in the past	
Cultivars' name	Citation frequency (%)	Cultivars' name	Citation frequency (%)
IR841	55.3	Nerica20*	20
Gambiaka*	7.3	Gambiaka*	19
Nerica20*	4.4	Nerica4*	15
Waabi	2.7	Béris21*	13
Imonpia	2.7	Tox rond	6
Fondiézé	2.4	Nerica6	4
Shapshap	2.4	WAB32-80	3
Gbemga	2.4	Nerica14*	3
R16	2.4	R8*	2
Nerica4*	2.2	BL19	2
Samassagoumi	2.2	Bobo oura	1
Pika	1.6	Imonda	1
Wita4	1.6	Djimbo*	1
R8*	1.6	Gountou	1
Parakou kouro bouro	1.6	Lombilombi	1
Riz togolais	1.6	RAM	1
Béris21*	1.1	Mongni tchétiégué	1
Nerica14*	1.1	De Gaulle court	1
ADNY11*	0.8	De Gaulle long	1
Djimbo*	0.8	ADNY11*	1
Riz parfumé	0.6	Bogaboga	1
Briz10B	0.6	Danzaria	1
Sirirou caborou	0.6	Mongni papahoun	1

Note. * Cultivars practiced in the past but still cropped by few farmers.

In the study area, rice cultivars preferred by farmers varied from one region to another. A χ^2 test performed on the data revealed significant differences ($P = 2.2\ e^{-16}$) in farmers' preferences for rice cultivars and the growing region ($\chi^2 = 653.02$; $P = 2.2\ e^{-16}$). The Factorial Correspondence Analysis performed to infer the relationships between rice cultivars and growing regions, indicated that the first two axes explained 74% of the total variation observed within the collection. The farmers of the region of Borgou cultivated mainly rice cultivars Wita4, R8 and Sirirou caborou while those of the region of Alibori mainly cropped Fondiézé, Shapshap, Gbemga, Parakou kouro bouro, Djimbo, Samassagoumi, Pika and ADNY11. Farmers of the remaining seven other regions (Atacora, Collines, Couffo, Donga, Mono, Ouémé and Zou) mostly cultivated cultivars such as Béris21, Briz10B, Imonpia, IR841, Nerica14, R16, Riz-parfumé, Riz-togolais and Waabi. From all surveyed regions, Gambiaka, Nerica4 and Nerica20 were the three other varieties cropped by all farmers (Figure 8). At individual farmer level, the majority of farmers (69%) still cultivated only one rice cultivar per season, while 12.7% of the farmers grew two, 8.5% grew three and 9.8% of them grew up to four rice cultivars per season. Apparently, the IR841 was most adopted rice cultivar by farmers because of its good traits and its pleasant aroma.

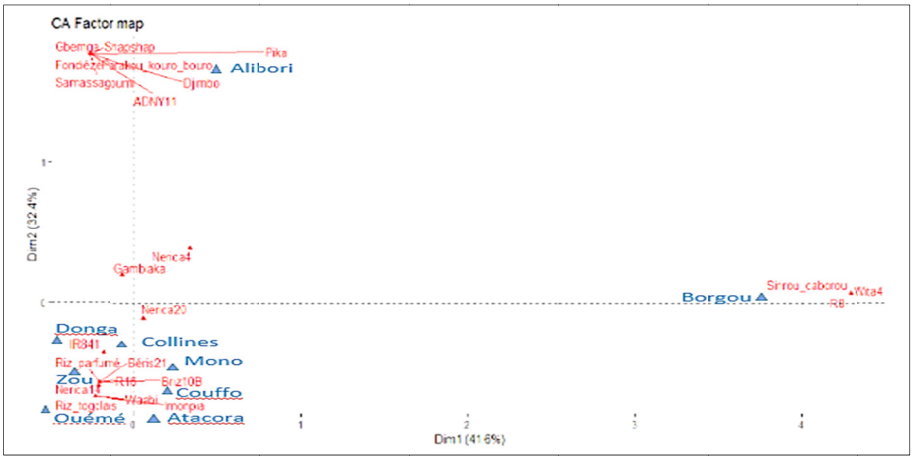

Figure 8. Biplot analysis showing rice cultivars grown per cultivating regions in Benin

3.5 Farmers' Preferences for Varietal Traits and Cultivars in Rice Production

The analysis of farmers' preferences for varietal traits on rice revealed that these relied on certain plant characteristics and some environmental attributes. Indeed, the varietal traits such as good taste and high yield were equally the paramount preferred traits (28% each) for making varietal choice, followed by pleasant aroma cited by 24% of respondents. These three traits are characteristics of IR841, the improved rice cultivar mostly preferred and consequently cultivated by the majority of farmers. Other traits of interest cited at low frequencies by farmers were medium cycle (9%), drought tolerance (6%), less starch (2%), white pericarp, long grain length and swelling when cooked (Table 2).

With regard to the motivated reasons leading farmers to adopt and crop rice cultivars, it was clearly noticed that high yield followed by the combination good taste and high yield were the most important characteristics required by farmers to adopt a rice cultivar. Other preferred traits such as good taste, medium cycle, drought tolerance, and good grain quality added to economic factor market availability were other key attributes of interest in cultivar adoption (Table 2).

Besides the good attributes that sustained farmers' preferences, several (10) traits were considered as undesirable and motivated farmers' reasons to abandon certain rice cultivars. The traits like hardness after cooking, bad taste and late maturing, were the first three major drawback traits cited by farmers. These traits were followed by drought susceptibility (12%), tall plant height (9%), low yield (4%), bad kernel quality (3%), and at very low frequencies, short kernel length, susceptibility to flooding and too short plant height. Finally, other parameters such as the introduction of novel variety (15%) and market unavailability (3%) were reported to motivate farmers to abandon some cultivars with comparably less desirable or promising attributes (Table 2).

Table 2. Desired and undesired cultivars' traits and parameters motivating their adoption or their abandon in Benin

Traits/parameters of cultivars	Desired (%)*	Motivating (%)	Traits/parameters of cultivars	Undesired (%)
Good taste	28	21	Hardness after cooking	17
High yield	28	29	Bad taste	17
Combined good taste-high yield	0	23	Late maturing	17
Fragrance	24	0	Introduction of novel variety	15
Medium maturing	9	12	Drought susceptibility	12
Drought tolerance	6	6	Tall plant height	9
Less starch	2	0	Low yield	4
White pericarp	1	0	Market unavailability	3
Long kernel length	1	0	Bad kernel quality	3
Swelling when cooked	1	0	Short kernel length	1
Market availability	0	7	Flood susceptibility	1
Good kernel quality	0	2	Too short plant height	1

Note. * Percentage of respondents.

To sum up, rice traits preferred by farmers in the study area can be summarized as high yield combined with good grain quality (including good taste, softness after cooking, less starch, white pericarp, long grain length and swelling when cooked), fragrance, early or medium maturing cycle, medium plant height and tolerance to drought and flood.

3.6 Rice Production Constraints in Benin

The Table 3 summarizes the diverse constraints in rice farming in Benin. In total, ten different constraints unanimously recognized by farmers to threaten rice farming were reported in the study area. Bird attacks and weeds were equally cited by all farmers (100%) and globally ranked first as major constraints. However, they were not perceived as the most damaging since the mitigating measures were found and applied. Globally ranked third (85%), drought stress was perceived as the most important and most damaging constraints affecting rice production in farmers' fields.

Table 3. Rice farming constraints frequencies per district and their ranking

Districts	Nematodes	Insect_pests	Blast disease	Flood	Drought	Weeds	Rodents	Birds	Sheep	Beefs
Bantè	0	100	60	0	100	100	100	100	0	0
Boukombé	0	50	0	0	100	100	100	100	50	50
Cobly	50	0	0	0	100	100	50	100	100	100
Covè	0	100	0	50	50	100	0	100	0	0
Dangbo	0	100	0	50	50	100	50	100	0	0
Dassa-zoumè	100	0	0	0	100	100	33	100	0	67
Dogbo	0	100	0	0	100	100	0	100	0	100
Glazoué	57	43	0	15	100	100	0	100	14	14
Gogounou	0	0	0	0	100	100	50	100	0	50
Kouandé	0	0	0	70	30	100	100	100	50	50
Lokossa	0	100	0	0	100	100	100	100	0	100
Malanville	0	100	0	20	100	100	100	100	60	60
Matéri	0	0	0	0	100	100	0	100	100	100
Nikki	0	100	0	0	100	100	100	100	50	100
Ouaké	50	50	0	0	100	100	50	100	100	100
Ouèssé	0	100	0	0	100	100	0	100	0	0
Savalou	50	50	0	0	100	100	0	100	100	100
Savè	67	33	100	0	100	100	33	100	67	100
Zagnanado	0	100	0	100	0	100	0	100	0	0
Mean (%)	20	59	8	15	85	100	46	100	36	57
Ranking	**8**	**4**	**10**	**9**	**3**	**1**	**6**	**1**	**7**	**5**

In contrast to the majority of districts surveyed, the whole rice farming system was affected by flooding (15%) in Zagnanado district and constituted an important producing constraints in this district. In some other districts like Covè, Dangbo, Malanville and Kouandé, both constraints were observed affecting rice fields: for one side (uplands), drought was the main constraint while in the other side (lowlands), flooding was the most important constraint. In term of importance, drought stress was followed by insect-pest which globally was reported by 59% of respondents living in 14 of the 19 districts surveyed. Apart from the district of Zagnanado, rice production in the 13 remaining districts was constrained by both insect-pest and drought. Animal damages such as beefs (57%) and sheep (36%) were reported in more than 10 districts. Rodent's damage (46%) caused by wild mice and rats was likewise reported by farmers. Nematodes, flood and blast disease were respectively the last three constraints in rice cropping in Benin (Table 3).

3.7 Farmers' Perception on Drought Constraints and Its Management

The ranking of the major constraints in the farmers' fields across the districts surveyed revealed that drought is currently perceived as the most serious and damaging stress affecting rice farming in Benin. The respondents recognized drought effects in their fields mainly through its common visual symptoms on the plant such as leaf yellowing, rolling and burning, plant height, tillering and grain filling capacity reduction. For the majority of farmers, droughts were perceived as a natural phenomenon of unknown causes (75% of respondents) while the

minority of them perceived it as a phenomenon caused by climate change (22%) or by the lack of rivers (3% of respondents).

Out of the 236 farmers interviewed, drought constraint was not relevant for 36 respondents representing only 15% of them. The remaining 85% of farmers were directly affected by drought effects characterized by various crop failures and yield losses observed in their fields after harvest. Drought occurred mainly at both seedling and flowering stages of the plant growth and the yield loss was variously appreciated by farmers. Indeed, farmers' estimations of paddy yield lost in fields ranged from 25 to 100% at seedling stage with the vast majority of farmers (85% of respondents) indicating about 50% yield lost (Figure 9). At the flowering stage, yield lost estimations ranged from 50 to 100% with the majority of farmers (58% of respondents) supporting 100% paddy yield lost. In general, all the surveyed farmers agreed that yield loss is higher at the flowering stage than seedling stage. Several rice field damage events caused by drought were reported by farmers during the five years of 2013-2017 with the most severe occurring at the 2015 production season.

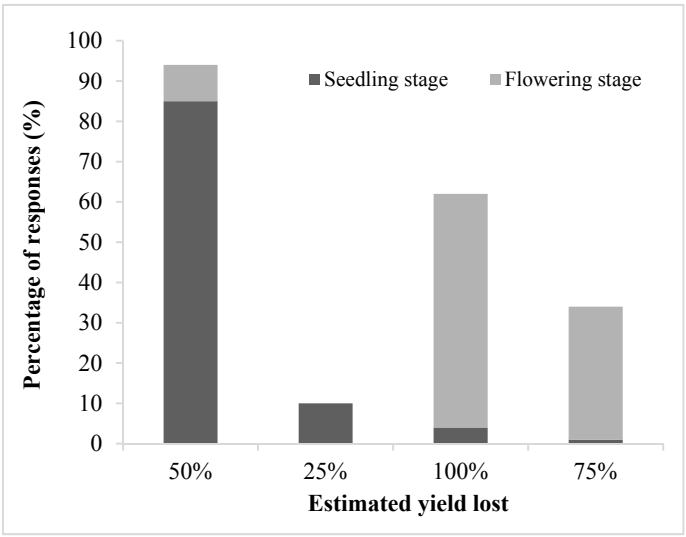

Figure 9. Yield loss rate estimated under drought effects

Diverse mitigating strategies to reduce drought impact were applied by farmers. The first and most popular endogenous management strategy was the changing of the sowing date (80% of respondents) followed by the use of irrigation system (10%) and the use of early maturing cultivars (7%). Few farmers (2%) had moved to other fields or had temporarily abandon rice cropping (1%) for other crops (Figure 10).

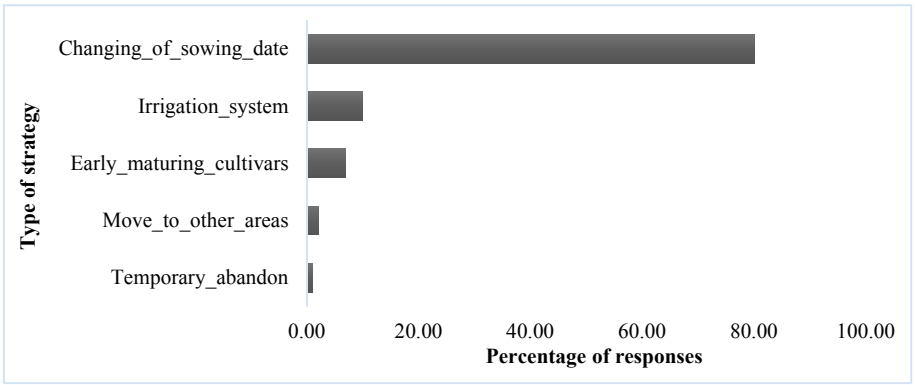

Figure 10. Traditional mitigating strategies for drought effects on rice production in Benin

No formal use of drought tolerant varieties was observed, except R16 and Briz10B introduced as improved drought tolerant rice varieties for testing in 2017 by Africa Rice center, but unfortunately did not completely match farmers' preferences. The needs for tolerant varieties were clearly expressed by local farmers across villages to mitigate drought effects on rice production in Benin.

4. Discussion

4.1 Characteristics of Rice Producers Surveyed

The survey shows that rice farming in Benin is the activity of both men and women. Although land cultivation is known as men activity, an important proportion (two/fifth) of women was recorded among rice farmers. This trend was already observed on fonio millet cropping in Togo (Adoukonou-Sagbadja et al., 2006) as well on rice farming in many African countries such as Ghana, Mali, Tanzania and Kenya (Asante et al., 2013; Efisue et al., 2008; Hashim et al., 2018; Kimani et al., 2011) where women implications to farming activities were recorded up to 46%. However, rice farmers in Niger were in quasi-totality (98%) constituted of men (Sow et al., 2015) while rice farming was dominated by women in the Cascade region of Burkina Faso (Kam et al., 2013) and the coastal rainfed lowland region of Kenya (Musila et al., 2018). For any situation, women are known as the principal actors in post-harvest activities such as processing, parboiling and selling as it has well noted by Zossou et al. (2010). Besides, as in the most of African countries, rice farming is practiced in Benin by people holding very less or no education. Their average age was 44 years and they were in majority married. Some of women encountered were widow or divorced. The similar case was reported in Togo on fonio millet farming (Adoukonou-Sagbadja et al., 2006). In addition, farmers were organized in well active associations with many years-membership experiences. The majority of them had rice cropping as main occupation and was most experienced in rice farming. In contrast to the rice farming in Burkina-Faso (Kam et al., 2013), the land was mostly held by inheritance from fathers to sons and the knowledge of rice cultivation is therefore transmitted from fathers to sons. In opposite to Kenyan farmers (Kimani et al., 2011), rice land was little rented in Benin. Moreover, the majority of respondents were medium-scale farmers with one to three hectares' land size. Finally, out of the fourteen different ethnic groups surveyed, the *Nago* and *Mahi* groups living mainly the region of Collines in the center of the country are more represented. This could be explained by the fact that the region of Zou-Collines comes top in term of lowlands' potential for rice farming in Benin (MAEP, 2011).

4.2 Agricultural practices in rice cultivation in Benin

Agricultural productivity primarily relies on a good management of farming practices. As many West-African producers, Beninese rice farmers are polyvalent crop growers as they were involved in many other crops mainly maize, cassava, yam, soybean, groundnut, cowpea, cotton and pepper. In the whole survey areas, rice is grown as "cash income crops" like many other crops such as maize, cotton and pepper. This result contrasts the practice in Msambweni region of Kenya where only 8% of the respondents grew rice purely for cash income purpose (Musila et al., 2018). In general, rice is mostly grown in monoculture, except few farmers who combined rice with okra and vegetables. This practice is common in rice cropping (Sow et al., 2015) as well in other crops like fonio millet (Adoukonou-Sagbadja et al., 2006), sorghum (Missihoun et al., 2012) etc. Apart from a few farmers, almost every activity from land preparation to harvesting, threshing and drying was manually done. As underlined by Asante et al. (2013), the lack of or limiting use of machinery for the completion of rice production activities results in high cost of labor adding to the challenges faced by farmers. It appears from the study that farmers need harvesters, threshers and dryers to be able to maintain grain quality and compete with imported rice.

As in several growing countries, rice producers in Benin produced rice at both rainy and dry seasons. They cropped rice in single, double and three sowing/harvesting periods per year following the various agro-systems of rice cropping recorded in the study area. In general, farmers from northern and central parts (Atacora, Borgou, Collines, Donga) as well as those in south-western zone (Mono-Couffo) of the country practiced a single rice cropping, mainly in rainfed lowland conditions while in the south-eastern region (Ouémé) of Benin, rice is likewise single cropped but in flooded lowland conditions during the dry season following the recession of rivers. Exceptionally, few farmers from the regions of Zou (center) and Alibori (far north) had access to irrigation and practiced rice farming with controlled water management. This rainfed lowland rice farming assisted by irrigation system help farmers to crop rice two or three times per year. Water availability is an important factor that limits the option of double and more rice cropping and likewise poses a serious problem during the growing season. In the absence of rains, rice plants are exposed to drought which affects the vegetative growth rate and grain yield (Tao et al., 2006). Inversely, abundant rainfall causes flash flooding where the entire plant of most

rice cultivars dies within seven days of complete submergence (Bailey-Serres et al., 2010). Both situations are then known to induce severe damage in farmer's fields.

Out of the two different ways of crop establishment inventoried, the direct sowing of seeds was practiced by the majority of farmers and judged to be less time consuming. In contrast, transplantation is known as time consuming but has the advantage of reducing weeds competitiveness. The dominance of direct sowing in rice cultivation is reported in Cascades region of Burkina Faso (Kam et al., 2013) as well in small millets including fonio (Adoukonou-Sagbadja et al., 2006).

It is important to note that after sowing, the field is mainly twice weeded through both chemical (herbicides) and hand weeding mostly ensured by both laborers and members of households. Selective and mainly non-selective herbicides were used by farmers, because they find it cheaper than hiring labor for the weeding. Rice seeds used by farmers to ensure their cropping were mainly certified seeds purchased most of the time from the territorial agencies of agricultural development (ATDA, ex CARDER). The use of seeds from their own previous harvest to establish new season crop was not practiced by farmers. This agricultural practice conducted in order to avoid seeds contamination contrasts with farmers from Burkina Faso (Kam et al., 2013), Niger (Sow et al., 2015), Kenya (Musila et al., 2018) and Tanzania (Hashim et al., 2018). Finally, rice produced by farmers were not only self-consumed but also sold as milled or paddy rice type for cash to finance family needs mainly on the local markets of the country or in two neighboring countries, Nigeria and Togo.

4.3 Varietal Traits and Cultivars Preference in Rice Production

The survey revealed that farmers' preferences in rice cultivars selection are mainly based on certain plant characteristics such as high grain yield, good cooking and eating qualities (including good taste, followed by fragrance), medium maturing cycle, tolerance to drought stress, etc. In a recent study in Senegal, the authors recommended that, any investment project in rice production must be more focused on investments in grain-quality and post-harvest infrastructure to improve the marketability and competitiveness of domestic rice relative to imported ones in West Africa (Demont & Rizzoto, 2012). In Kenya, farmers selected the cultivar they grow mainly on grain quality (Kimani et al., 2011).

In Benin, yield comes up as the highest farmer's priority and the paramount desired trait closely followed by taste as it was reported in Ghana and Niger (Asante et al., 2013; Sow et al., 2015), This fact highlights the market oriented of rice production in the country in contrast to the Cascade region of Burkina Faso (Kam et al., 2013) and other West-African countries (Efisue et al., 2008; Musila et al., 2018) where rice is produced mainly for domestic consumption. Besides, although they did not want to compromise on yield, Beninese farmers ranked also grain quality almost as important as yield. Good quality took into account certain milled rice traits such as less starch (or grain expansion), white pericarp, long grain length, swelling when cooked, softness after cooking and good taste. However, hardness after cooking and bad taste were the main reasons motivating most of respondents to abandon Nerica20 despite its high yield and capability to be grown under upland ecosystems.

It is important to highlight here that rice aroma was considered as a good trait of rice cultivar by most of respondents, but it was not a key factor when adopting a cultivar. In fact, although preferences fluctuate from one group of consumers to another, rice grains with a soft texture and attractive fragrance frequently achieve higher prices in national and international markets (Al-Hassan et al., 2008; Nguyen & Bui, 2008). The great majority of farmers surveyed adopted improved rice variety IR841 mainly for its aroma and its grain qualities. As it was reported in Ghana (Asante et al., 2013) and Kenya (Kimani et al., 2011), over 75% and 34% of farmers interviewed preferred cropping Jasmine 85 and Basmati370 rice varieties respectively because of their good taste, pleasant aroma and good cooking quality resulting in a better market compared to other varieties. Obviously, Basmati370 and Thai Jasmine are well known good and fragrant rice cultivars commercially important on the international market and represent a model variety for studying genes controlling grain quality and aroma. As highlighted by Traoré et al. (2015), marketability was reported to increase farmers' preference while the introduction of new variety is an important sociological reason leading them to abandon some rice cultivars (Kimani et al., 2011).

In addition, other preferred traits cited by farmers in the survey areas were medium maturing, tolerance to drought and flood, medium plant height. These desired traits were similarly important for other African farmers cropping rice, especially in Tanzania (Hashim et al., 2018), Niger (Sow et al., 2015), Burkina Faso (Kam et al., 2013), Ghana (Asante et al., 2013), Kenya and Mali (Efisue et al., 2008). Rice cultivar with long maturing cycle, tall and too short plant height were no longer appreciated nor sought by farmers. According to them, tall plant cultivars are more sensitive to lodging while the shortest one are difficult to harvest. Similar results were found by Ouedraogo et al. (2017) in sorghum, Sow et al. (2015) and Kam et al. (2013) in rice. Conversely, farmers at

Nkawie in the Ashanti region of Ghana preferred short varieties because they were less susceptible to bird attack while farmers at Aframso in the same country preferred taller rice varieties that were able to compete with *Ischaemumrugosum*, a prevalent weed in this region (Asante et al., 2013). It is likewise reported that other farmers preferred tall rice varieties to the model of dwarf varieties that breeders usually select, because tall varieties were easier to harvest by hand than the dwarf ones that are near the ground and thus, rodent, flooding and splash water and termites tend to destroy the grain (Atlin et al., 2001; Efisue et al., 2008; Kimani et al., 2011).

Teka (2014) found a positive relationship between tolerance to stresses especially Striga, drought, diseases and insect pests and farmers' preferences for improved maize varieties in Western Kenya. Farmers would thus prefer improved rice varieties with high tolerance to these stresses. This emphasizes the need to develop new varieties that are drought tolerant, high yielding and adaptable to farmers' needs. Across the country, most farmers preferred varieties that are high yielding, medium plant height and earlier or medium maturing, suggesting that rice breeders should pay attention to these traits in developing new varieties for Benin and similar niches in West Africa. Currently, few varieties with such traits are available in the region. One mechanism would be the introgression of genes controlling most of farmers' preferred traits into the genetic background of high-yielding stable varieties. The landraces favored by farmers should be used as donor or recurrent parent regarding the genetic basis of the trait they harbored. This strategy could greatly enhance variety development and latter its adoption and production. Besides, with regard to rice cultivars preferred by farmers, it's well observed that the improved rice variety named IR841 is the most widespread cultivar currently cropped across the villages surveyed although rice cultivar currently cropped varied from one region to another. The majority of farmers finally adopted only IR841 rice variety for their farming because it harbors many of desired traits sought by farmers. The most widespread landrace recorded is Gambiaka.

In general, farmers still cropped their local rice cultivars due to their good milling qualities, drought tolerance, early maturity and cooking qualities like good aroma and taste (Kam et al., 2013; Sow et al., 2015; Hubert et al., 2014). Certain rice cultivars already rejected by farmers in one region were still cropped by farmers of other regions. This fact indicates the differences in perception of farmers because of their divergent needs, for instance in term of coping with the environment requirements (Adoukonou-Sagbadja et al., 2006; Dansi et al., 2010). Although data is not shown, the comparison of the shortlist of rice cultivars recorded in 2011 by Akakpo. (2011) and in 2018 by the current study in the same villages revealed that 13 cultivars have really disappeared. These are Koukourikè, Polaguè, Lakpoaga, Tchoumbouèkè, Tomiessi from the district of Matéri, Tchidamaraya, Imorikokonga, Kumulumwanga and Nadréki from Cobly, Labéka and Méada from Nikki and Togo grain from Savalou. Farmers did not recognize them even through their name. These findings indicate that urgent conservation actions are needed to safeguard the rice genetic resources traditionally maintained by farmers. This is important as it is yet well known these traditional varieties hold many adaptive genes that are useful for future breeding. Among the cultivars actually in use, eight landraces such as Waabi, Imonda, Shapshap, Jimbo, Parakou kouro bouro, Pika, Gambiaka and Sirirou caborou and two improved varieties (IR841 and Nerica) were suggested by farmers for the future breeding programs.

4.4 Rice Production Constraints in Benin

Many constraints were recorded as limiting factors in rice production in Benin. Although bird attacks and weeds were the most cited, they seem not to be the most damaging constraints since hired guardians and frequent fields' weeding were applied to mitigate their effects, respectively. Ranked third, drought became the most important rice production constraints because it was the major damaging constraints affecting the great majority of farmers' fields. Similar results were reported by Efisue et al. (2008); Hashim et al. (2018); Kimani et al. (2011). In contrast, drought effect was not relevant for certain farmers whose fields were irrigated by natural water source (rivers) as in the sites of *Dovi-zounou* and *Koussin-lélé* in the districts of Zagnanado and Covè. Nematode and blast disease were less cited. This could be explained by the limited knowledge of farmers in their identification in the fields. Certain farmers had stated that insect pests and diseases occurred when drought occurred. This statement has confirmed the association of rice blast disease with drought reported by Hashim et al. (2018) in Tanzania. Besides constraints occurred in farmers' fields, difficulty to access fertilizer, labor cost, seed purity, lack of micro-credit and irrigated land are other factors with major influence on rice farming in Benin.

4.5 Farmers' Perception on Drought Constraints and Its Management

In a context of global water scarcity, drought was perceived as a natural phenomenon, a recurrent event and the most damaging stress affecting crop farming (Udmale et al., 2014). Flowering stage drought is the most damageable and irreversible stage of rice plant growth (Efisue et al., 2008). In Benin, farmers recognized

drought effects in their rice fields mainly through its visual symptoms on the plant such as leaf yellowing, rolling and burning, plant height, tillering and grain filling capacity reduction. Soil desiccation is other key visual drought indication observed in the rainfed lowland fields. Although some farmers' fields visited were not affected, drought effects were perceptible in many fields and crop failure recorded as yield loss after harvest estimated in majority from 75 to 100% when drought occurred at flowering stage. For instance, during the survey, a farmer in Collines region clearly stated to have in 2015 campaign harvested 250 kg instead of 6 tons because of drought occurrence. Similar drop in yield was reported by farmers in Maharashtra State of India (Udmale et al., 2014). Indebtedness, poverty and school abandon are social and economic impacts related to this yield drop in rice production in affected areas. According to Udmale et al. (2014), farmers from frequent and severe drought affected areas believed that drought was one of the major causes of suicidal tendencies due to less income and indebtedness of farmers. Similar socio-economic impacts were likewise reported in earlier studies (Ashraf & Routray, 2013; Guha, 2012; Karpisheh, 2010; Keshavarz et al., 2013).

In the survey areas, several coping and adaptive methods were employed by farmers in order to alleviate more or less the impact of this abiotic stress on their incomes. The measure mostly used by the majority of farmers was the adjusting rice cropping following to the starting of the rainy season. Other reported measure was the use of early maturing cultivars. These two measures were also recorded from farmers cropping rice in Mali (Efisue et al., 2008) and sorghum in Burkina Faso (Ouedraogo et al., 2017). According to farmers, the use of early maturing landraces allowed them to overcome hunger before the maturity of their local long cycle varieties. In the same vein to the report of Cooper et al. (1999), farmers adopt early planting varieties that are early maturing (or short in duration) not only to free-up the land (after harvest) for other food crops cultivation but as a drought escape mechanism. It was observed that the majority of farmers preferred to change their cropping calendar. This measure is not cost consuming. Farmers from the study area used another adaptive strategy by irrigating their fields through system of drilling and water pumps. This adaptation method was not popular, due to high initial investment and high cost needed to buy fuel. Moving from their fields to another places where they can find wells and a temporarily abandon of rice cultivation were the easiest measures taken by few farmers in Benin to mitigate drought. Earlier studies reported in the literature discussed similar agricultural adaptation practices (Dhaka et al., 2010; Gandure et al., 2013; Habiba et al., 2012; Roy & Hirway, 2007; Sahu & Mishra, 2013). None of these measures is advantageous and appropriate to farmers. The need of good quality tolerant rice variety was then expressed by farmers to better facing drought constraints. Screening of landraces for drought and for grain quality must be necessary to identify those harboring favorable genes and QTLs. The exploitation of local cultivars coupled with molecular techniques to identify and to transfer the favorable genes to high yielding varieties is a promising way to cope with drought and to more value the rice locally produced in West-Africa.

4.6 Implications of the Findings for Rice Breeding

As it was observed in the current study and also in other surveys, the rice sector in Benin and in general in West-Africa is characterized by a low level of investment, resulting in poor grain quality, low yields and great dependence on imported rice. Rice yield, grain quality traits, resistance to biotic and abiotic stresses and other targeted traits are heritable and then, controlled by genes, QTLs and the environment. Most of these genes and QTLs were already identified and the specific primers linked to specific alleles were designed. Rice breeders can therefore screen the existing germplasm conserved in different seed banks through allelic diversity and mining studies to identify the superior genotypes that carrying genes of interest. Breeders in Benin and in West-African sub-region must therefore work to breed high yielding varieties that are tolerant to stresses in each environment, especially drought stress and grain qualities preferred by consumers. This is possible through Marker Assisted Selection (MAS).

The present study highlights farmers' preference in varietal traits and the necessity of prioritizing drought stress in designing new and adoptable varieties in Benin. Drought stress problem at the vegetative and reproductive stages was common in all ecologies (Efisue et al., 2008), indicating the need to breed for drought tolerance. Specific markers that were linked to various QTLs related to various drought tolerance traits were available and successfully used by Site et al. (2013). Besides, previous studies on consumers' preferences indicated that long grain rice with low to intermediate amylose content (16 to 22%) and fragrance were the most prioritized and these quality traits were approximately the same across the sub-region (Sow et al., 2015; Kam et al., 2013; Asante et al., 2013). In addition to drought, rice breeding in Benin and West-Africa may therefore integrate grain appearance, cooking and eating as well nutritional traits in order to select the appropriate parents for crosses. The best and cost efficient method to select the desired grain quality genotype is the use of molecular markers. Molecular markers for kernel length (Fan et al., 2009; Wang et al., 2011), aroma (Bradbury et al., 2005), amylose

content (Ayres et al., 1997; Chen et al., 2008), gelatinization temperature (Bao et al., 2006; Jin et al., 2010; Waters et al., 2006) and viscosity profiles (Chen et al., 2008) have been also developed. These markers have been efficient in selecting for the desired grain qualities in other regions of the world (Chen et al., 2010). It is important for rice breeding programs in Benin and West-Africa to fully embrace the use of molecular markers in breeding for improved grain quality, yield and tolerance to biotic and abiotic stresses by exploiting useful genes in the huge African rice germplasm detained by farmers or conserved in national and international gene banks.

5. Conclusion

The present study conducted in the main rice cropping areas of Benin explored farmers' preferences for varietal traits, their knowledge and perceptions in traditional management of drought constraints in rice cropping in Benin. Farmers were both men and women with less or no education. They were in the majority medium-scale farmers cultivating rice in rainfed lowland conditions. Almost all of the agricultural activities were manually done. Rice is grown mainly in pure culture but rarely in combination with okra and other vegetables. In the study area, the cultivar diversity detected is imported with a total of 38 different rice cultivars including both improved varieties and traditional cultivars identified. Farmers' preferences in cultivar selection relied on certain plant characteristics with yield followed by taste coming up as the highest farmer's priority and the paramount desired traits. Based on farmers' perceptions, drought appeared as an important constraints limiting rice production in Benin with significant yield loss due to crop failure and many indirect impacts such as income reduction, indebtedness and school drop. Changing of the sowing date, building irrigation facilities or using early maturing cultivars were the traditional mitigating approaches applied by farmers. In most the survey areas, drought tolerant rice varieties were acknowledged. Although yield is yet the paramount trait value in most of rice breeding programs in Africa to achieve food security, farmers' willingness to adopt high drought tolerant and good grain quality improved varieties was obviously high. Rice breeders are then urged to couple good yield with drought tolerance and high grain quality to meet farmers' production orientations towards self-consumption and markets requirements. Good grain quality including good eating and cooking quality and a pleasant texture of rice grain. The finding of the present study is crucial for future rice breeding programs in Benin and important to avoid earlier rejection of novel and improved varieties.

References

Adolph, B., & Chancellor, T. (2006). Rice research in the DFID RNRRS programmes. *Lessons learnt and implications for future research* (p. 71). University of Greenwich, United Kingdom.

Adoukonou-Sagbadja, H., Dansi, A., Vodouhè, R., & Akpagana, K. (2006). Indigenous knowledge and traditional conservation of fonio millet *(Digitariaexilis, Digitariaiburua*) in Togo. *Biodivers. Conserv., 15*, 2379-2395. https://doi.org/10.1007/s10531-004-2938-3

Al-Hassan, R. M., Agbekpornu, H. G., & Sarpong, D. B. (2008). Consumer Preferences for Rice Quality Characteristics in Accra. *Agric. Food Sci. J. Ghana, 7*, 575-591. https://doi.org/10.4314/afsjg.v7i1.43035

Asante, M. D., Asante, B. O., Acheampong, G. K., Offei, S. K., Gracen, V., Adu-Dapaah, H., & Danquah, E. Y. (2013). Farmer and consumer preferences for rice in the Ashanti region of Ghana: Implications for rice breeding in West Africa. *J. Plant Breed. Crop. Sci., 5*, 229-238. https://doi.org/10.5897/JPBCS13.0409

Ashraf, M., & Routray, J. K. (2013). Perception and understanding of drought and coping strategies of farming households in north-west Balochistan. *Int. J. Disaster Risk Reduct., 5*, 49-60. https://doi.org/10.1016/j.ijdrr.2013.05.002

Atlin, G. N., Cooper, M., & Bjørnstad, A. A. (2001). A comparison of formal and participatory breeding approaches using selection theory. *Euphytica, 122*, 463-475. https://doi.org/10.1023/A:1017557307800

Ayres, N. M., McClung, A. M., Larkin, P. D., Bligh, H. F. J., Jones, C. A., & Park, W. D. (1997). Microsatellites and a single-nucleotide polymorphism differentiate apparent amylose classes in an extended pedigree of US rice germplasm. *Theor. Appl. Genet., 94*, 773-781. https://doi.org/10.1007/s001220050477

Bailey-Serres, J., Fukao, T., Ronald, P., Ismail, A., Heuer, S., & Mackill, D. (2010). Submergence Tolerant Rice: SUB1's Journey from Landrace to Modern Cultivar. *Rice, 3*, 138-147. https://doi.org/10.1007/s12284-010-9048-5

Bao, J. S., Corke, H., & Sun, M. (2006). Nucleotide diversity in starch synthase IIa and validation of single nucleotide polymorphisms in relation to starch gelatinization temperature and other physicochemical properties in rice (*Oryza sativa* L.). *Theor. Appl. Genet., 113*, 1171-1183. https://doi.org/10.1007/s00122-006-0355-6

Bradbury, L. M. T., Henry, R. J., Jin, Q., Reinke, R. F., & Waters, D. L. E. (2005). A Perfect Marker for Fragrance Genotyping in Rice. *Mol Breed, 16*, 279-283. https://doi.org/10.1007/s11032-005-0776-y

Callo-Concha, D. (2018). Farmer Perceptions and Climate Change Adaptation in the West Africa Sudan Savannah: Reality Check in Dassari, Benin, and Dano, Burkina Faso. *Climate, 6*, 44. https://doi.org/10.3390/cli6020044

Ceccarelli, S., & Stefania, G. (2009). *Participatory plant breeding in cereals* (pp. 395-414). Springer. https://doi.org/10.1007/978-0-387-72297-9_13

Chen, M.-H., Bergman, C., Pinson, S., & Fjellstrom, R. (2008). Waxy gene haplotypes: Associations with apparent amylose content and the effect by the environment in an international rice germplasm collection. *J. Cereal Sci., 47*, 536-545. https://doi.org/10.1016/j.jcs.2007.06.013

Chen, M.-H., Fjellstrom, R. G., Christensen, E. F., & Bergman, C. J. (2010). Development of three allele-specific codominant rice Waxy gene PCR markers suitable for marker-assisted selection of amylose content and paste viscosity. *Mol. Breed., 26*, 513-523. https://doi.org/10.1007/s11032-010-9419-z

Chuwa, C. J., & Mabagala, R. B. (2013). Assessment of Grain Yield Losses Caused by Rice Blast Disease in Major Rice Growing Areas in Tanzania. *Inter. J. Sci. Res., 4*, 8.

Cooper, M., Rajatasereekul, S., Immark, S., Fukai, S., & Basnayake, J. (1999). Rainfed lowland rice breeding strategies for Northeast Thailand. *Field Crops Res., 64*, 131-151. https://doi.org/10.1016/S0378-4290(99)00056-8

Dansi, A., Adoukonou-Sagbadja, H., & Vodouhè, R. (2010). Diversity, conservation and related wild species of Fonio millet (*Digitaria spp*.) in the northwest of Benin. *Genet. Resour. Crop Evol., 57*, 827-839. https://doi.org/10.1007/s10722-009-9522-3

Demont, M., & Rizzotto, A. C. (2012). Policy Sequencing and the Development of Rice Value Chains in Senegal. *Dev. Policy Rev., 30*, 451-472 https://doi.org/10.1111/j.1467-7679.2012.00584.x

Derera, J., Tongoona, P., Langyintuo, A., Laing, M. D., & Vivek, B. (2006). Farmer perceptions on maize cultivars in the marginal eastern belt of Zimbabwe and their implications for breeding. *Afr. Crop Sci. J., 14*, 1-15.

Dhaka, B. L., Chayal, K., Poonia, M. K., & Kendra, K. V. (2010). Analysis of farmers' perception and adaptation strategies to climate change. *Libyan Agric. Res. Cent. J. Int., 1*, 388-390.

Efisue, A., Tongoona, P., Derera, J., Langyintuo, A., Laing, M., & Ubi, B. (2008). Farmers' Perceptions on Rice Varieties in Sikasso Region of Mali and their Implications for Rice Breeding. *J. Agron. Crop Sci., 194*, 393-400. https://doi.org/10.1111/j.1439-037X.2008.00324.x

Fan, C., Yu, S., Wang, C., & Xing, Y. (2009). A causal C-A mutation in the second exon of GS3 highly associated with rice grain length and validated as a functional marker. *Theor. Appl. Genet., 118*, 465-472. https://doi.org/10.1007/s00122-008-0913-1

FAO (Food and Agriculture Organization). (2018) Rice Market Monitor. *Production, International Trade, Rice Utilization and Domestic Prices*. FAO, Rome.

Gandure, S., Walker, S., & Botha, J. J. (2013). Farmers' perceptions of adaptation to climate change and water stress in a South African rural community. *Environ. Dev., 5*, 39-53. https://doi.org/10.1016/j.envdev.2012.11.004

Guha, J. (2012). *Farmer Suicides in Maharashtra, India: Facts, Factors, and Possible Fixes* (Thesis, p. 64).

Habiba, U., Shaw, R., & Takeuchi, Y. (2012). Farmer's perception and adaptation practices to cope with drought: Perspectives from Northwestern Bangladesh. *Int. J. Disaster Risk Reduct., 1*, 72-84. https://doi.org/10.1016/j.ijdrr.2012.05.004

Hashim, I., Mamiro, D. P., Mabagala, R. B., & Tefera, T. (2018). Smallholder Farmers' Knowledge, Perception and Management of Rice Blast Disease in Upland Rice Production in Tanzania. *J. Agric. Sci., 10*, 137. https://doi.org/10.5539/jas.v10n7p137

Hewitt, K. (1997). Regions of risk: A geographical introduction to disasters. *Themes in resource management* (p. 389). Longman, Harlow.

Hosseini, S. J. F., Mohammadi, F., Mirdamadi, S. M., & Hosseini, S. M. (2010). The Perception of Greenhouse Owners about Environmental, Economic and Social Aspects of Sustainable Agriculture in Iran. *Inter. J. Agric. Sci. Res., 1*, 11.

Hubert, J., Luzi-Kihupi, A. L., Hébrard, E., & Lyimo, H. J. F. (2014). Farmers' knowledge and perception of rice Yellow mottle virus in selected rice growing areas in Tanzania. *International Journal of Science and Research, 5*, 549-559.

Jin, L., Lu, Y., Shao, Y., Zhang, G., Xiao, P., Shen, S., Corke, H., & Bao, J. (2010). Molecular marker assisted selection for improvement of the eating, cooking and sensory quality of rice (*Oryza sativa* L.). *J. Cereal Sci., 51*, 159-164. https://doi.org/10.1016/j.jcs.2009.11.007

Joshi, K. D., Sthapit, B. R., & Witcombe, J. R. (2001). How narrowly adapted are the products of decentralised breeding? The spread of rice varieties from a participatory plant breeding programme in Nepal. *Euphytica, 122*, 589-597. https://doi.org/10.1023/A:1017553206891

Kam, H., Laing, M. D., Ouoba, J., & Ndjiondjop, M.-N. (2013). Rice traits preferred by farmers and their perceptions of rice yellow mottle virus (RYMV) disease in Cascades Region of Burkina Faso. *Afr. J. Agric. Res., 8*, 2703-2712.

Karpisheh, L., Mirdamadi, M., Hosseini, J. F., & Chizari, M. (2010). Iranian Farmers Attitudes and Management Strategies Dealing with Drought: A Case Study in Fars Province. *World Appl. Sci. J., 10*, 1122-1128.

Keshavarz, M., Karami, E., & Vanclay, F. (2013). The social experience of drought in rural Iran. *Land Use Policy, 30*, 120-129. https://doi.org/10.1016/j.landusepol.2012.03.003

Kimani, J. M., Tongoona, P., Derera, J., & Nyende, A. B. (2011). Upland rice varieties development through participatory plant breeding. *ARPN J. Agric. Biol. Sci., 6*, 39-49.

Kiros-Meles, A., & Abang, M. M. (2008). Farmers' knowledge of crop diseases and control strategies in the Regional State of Tigrai, northern Ethiopia: Implications for farmer-researcher collaboration in disease management. *Agric. Hum. Values, 25*, 433-452. https://doi.org/10.1007/s10460-007-9109-6

Liu, S., Mo, X., Lin, Z., Xu, Y., Ji, J., Wen, G., & Richey, J. (2010). Crop yield responses to climate change in the Huang-Huai-Hai Plain of China. *Agric. Water Manag., 97*, 1195-1209. https://doi.org/10.1016/j.agwat.2010.03.001

MAEP (Ministry of Food and Agriculture). (2011). *National Rice Development Strategy for Benin* (p. 29). Cotonou, Benin.

Missihoun, A. A., Adoukonou-Sagbadja, H., Dagba, R. A., Ahanhanzo, C., & Agbangla, C. (2012). Impacts des pratiques culturales sur l'organisation génétique des sorghos cultivés par les Lokpa au Nord-Ouest du Bénin, révélés par les marqueurs SSRs. *J. Appl. Biosci., 60*, 4394-4409.

Musila, R. N., Sibiya, J., Derera, J., Kimani, J. M., Tongoona, P., & Danda, K. (2018). Farmers' perception of, and preferred traits in, rice varieties in the Coastal region of Kenya and their implications for breeding. *J. Intl. Cooper Agric. Dev., 16*, 20-30.

Nguyen, T. L., & Bui, C. B. (2008). Fine mapping for drought tolerance in rice (*Oryza sativa* L.). *Omonrice, 16*, 9-15.

Ouedraogo, N., Sanou, J., Kam, H., Traore, H., Adam, M., Gracen, V., & Danquah, E. Y. (2017). Farmers' perception on impact of drought and their preference for sorghum cultivars in Burkina Faso. *J. Agric. Sci. Res., 7*, 277-284.

Reid, S., Smit, B., Caldwell, W., & Belliveau, S. (2007). Vulnerability and adaptation to climate risks in Ontario agriculture. *Mitig Adapt Strateg Glob Change, 12*, 609-637. https://doi.org/10.1007/s11027-006-9051-8

Roy, A. K., & Hirway, I. (2007). *Multiple Impacts of Droughts and Assessment of Drought Policy in Major Drought Prone States in India Report* (p. 219).

Roy, S., Marndi, B. C., Mawkhlieng, B., Banerjee, A., Yadav, R. M., Misra, A. K., & Bansal, K. C. (2016). Genetic diversity and structure in hill rice (*Oryza sativa* L.) landraces from the North-Eastern Himalayas of India. *BMC Genet., 17*, 107. https://doi.org/10.1186/s12863-016-0414-1

Sahu, N. C., & Mishra, D. (2013). Analysis of Perception and Adaptability Strategies of the Farmers to Climate Change in Odisha, India. *APCBEE Procedia, 5*, 123-127. https://doi.org/10.1016/j.apcbee.2013.05.022

Sajid, M., Khan, S. A., Khurshid, H., Iqbal, J., Muhammad, A., Saleem, N., & Shah, S. M. A. (2015). Characterization of rice (*Oryza Sativa* L.) germplasm through various agro-morphological traits. *Sci Agri, 9*, 83-88. https://doi.org/10.15192/PSCP.SA.2015.9.2.8388

Site, N., Borromeo, T. H., Nestor, N. C., Diaz, G. M., & Arvind, K. (2013). Diversity assessment of Malaysian rice germplasm accessions for drought tolerant grain yield QTLs. *J. Trop. Agric. Food Sci., 41*, 27-40.

Smith, P., Martino, D., Cai, Z., Gwary, D., Janzen, H., Kumar, P., … Ogle, S. (2007). In B. Metz, O. R. Davidson, P. R. Bosch, R. Dave, & L. A. Meyer (Eds.), *Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change* (pp. 497-540). Cambridge University Press: Cambridge, UK.

Sow, M., Seck, P. A., Maiga, I. M., Laing, M., Ortiz, R., & Ndjiondjop, M.-N. (2015). Farmers' rice knowledge and adoption of new cultivars in the Tillabéry region of western Niger. *Agric. Food Secur., 4*, 10 https://doi.org/10.1186/s40066-015-0024-6

Subedi, M., Hocking, T. J., Fullen, M. A., McCrea, A. R., Milne, E., Mitchell, D. J., & Bo-Zhi, W. U. (2009). An evaluation of the introduction of modified cropping practices in Yunnan Province, China, using surveys of farmers' households. *Agric. Sci. China, 8*, 188-202. https://doi.org/10.1016/S1671-2927(09)60027-4

Tao, H., Brueck, H., Dittert, K., Kreye, C., Lin, S., & Sattelmacher, B. (2006). Growth and yield formation for rice (*Oryza sativa* L.) in the water-saving ground cover rice production system (GCRPS). *Field Crop Research, 95*(1), 1-12. https://doi.org/10.1016/j.fcr.2005.01.019

Teka, H. B. (2014). Advance research on Striga control: A review. *Afr. J. Plant Sci., 8*, 492-506.

Traoré, V. S., Néya, B. J., Camara, M., Vernon Gracen, V., Offei, S. K., & Traoré, O. (2015). Farmers' Perception and Impact of Rice Yellow Mottle Disease on Rice Yields in Burkina Faso. *Agricultural Sciences, 6*(9), 943-952. http://doi.org/10.1007/978-3-540-74543-3

Udmale, P., Ichikawa, Y., Manandhar, S., Ishidaira, H., & Kiem, A. S. (2014). Farmers' perception of drought impacts, local adaptation and administrative mitigation measures in Maharashtra State. *India Int. J. Disaster Risk Reduct., 10*, 250-269. https://doi.org/10.1016/j.ijdrr.2014.09.011

USDA (United States Department of Agriculture). (2019). *Milled Rice Production, Consumption, Imports and Area harvested by Country in 1000 MT—Country Rankings*. Retrieved from https://www.indexmundi.com/agriculture

Vanavichit, A., Kamolsukyeunyong, W., Siangliw, M., Siangliw, J. L., Traprab, S., Ruengphayak, S., … Tragoonrung, S. (2018). Thai Hom Mali Rice: Origin and Breeding for Subsistence Rainfed Lowland Rice System. *Rice, 11*(20). https://doi.org/10.1186/s12284-018-0212-7

Wang, C., Chen, S., & Yu, S. (2011). Functional markers developed from multiple loci in GS3 for fine marker-assisted selection of grain length in rice. *Theor. Appl. Genet., 122*, 905-913. https://doi.org/10.1007/s00122-010-1497-0

Waters, D. L. E., Henry, R. J., Reinke, R. F., & Fitzgerald, M. A. (2006). Gelatinization temperature of rice explained by polymorphisms in starch synthase. *Plant Biotechnol. J., 4*, 115-122. https://doi.org/10.1111/j.1467-7652.2005.00162.x

Wilhite, D. A. (2000). *Drought as a Natural Hazard: Concepts and Definitions* (p. 22). University of Nebraska-Lincoln, USA.

Witcombe, J. R., Joshi, A., & Goyal, S. N. (2003). Participatory plant breeding in maize: A case study from Gujarat, India. *Euphytica, 130*, 413-422. https://doi.org/10.1023/A:1023036730919

Witcombe, J. R., Joshi, A., Joshi, K. D., &Sthapit, B. R. (1996). Farmer participatory crop improvement. I. Varietal selection and breeding methods and their impact on biodiversity. *Exp. Agric., 32*, 445-460. https://doi.org/10.1017/S001447970000380X

Yi, M., New, K. T., Vanavichit, A., Chai-arree, W., & Toojinda, T. (2009). Marker assisted backcross breeding to improve cooking quality traits in Myanmar rice cultivar Manawthukha. *Field Crops Res., 113*, 178-186. https://doi.org/10.1016/j.fcr.2009.05.006

Zossou, E., VanMele, P., Vodouhè, S. D., & Wanvoeke, J. (2010). Women groups formed in response to public video screenings on rice processing in Benin. *Int. J. Agric. Sustain., 8*, 270-277. https://doi.org/10.3763/ijas.2010.0499