African Rice (*Oryza glaberrima* Steud) and its Wild Progenitor (*Oryza barthii* A.Chev. & Roehr) under Threat in the Volta Region of Ghana

Nana M. Opuni[1], Eureka E. A. Adomako[2*] and James K. Adomako[2]

[1]Department of Crop Science, University of Ghana, Legon
[2]Department of Plant and Environmental Biology, University of Ghana, Legon
*Corresponding author: eadomako@ug.edu.gh

ABSTRACT

A study was conducted to assess the status of African rice (*Oryza glaberrima* Steud) and its wild progenitor (*Oryza barthii* A. Chev. & Roehr) in the Volta Region of Ghana. Surveys were undertaken in more than thirty rice fields in five districts of the Volta Region known to grow African rice. Accessions of African rice were, however, found in less than 50% of fields surveyed. Soil analyses data confirmed the ability of African rice to survive in nutrient-poor soils, but field observations revealed that it has been largely replaced by Asian rice (*Oryza sativa* Linn.) in farmers' fields. Of the seven accessions believed to be *O. glaberrima* at the time of sampling, only three were confirmed after agro-morphological characterization. Farmers cited low grain yield, low consumer demand and difficulty in de-husking of seeds as some of the factors underlying the reduced cultivation of *O. glaberrima*. Nevertheless, for the people of Likpe Bakwa, *O. glaberrima* remains the preferred rice for specific socio-cultural practices (e.g. marriage ceremony) due to its peculiar grain colour and flavour. *O. glaberrima* also has desirable traits which can be harnessed in breeding programs (e.g. pest and disease resistance, drought tolerance, and longer shelf-life of cooked grain). The wild rice species, *O. barthii*, was not found in the rice fields because farmers regard it as a weed and therefore tend to destroy it. It was found along a river bank in the Adaklu-Anyigbe District, where it is threatened by dependence of the community on the river water as well as increased human traffic across the river to neighbouring farms. Thus, agricultural expansion and increased demand for the higher yielding Asian rice pose severe threats to African rice and its wild progenitor in the Volta Region and attempts must be made towards their conservation.

Keywords: African rice, *Oryza glaberrima*, *Oryza barthii*, wild rice species, agro-morphological characterisation

Introduction

The rice genus (*Oryza*) consists of about 25 annual and perennial grass species distributed across diverse climatic zones in Africa, Asia, Australia and Southern America. Only two of these rice species are cultivated; the rest occur in the wild (Global Rice Science Partnership, 2013). The wild rice species possess greater genetic diversity because they have not undergone the process of domestication which reduces the diversity available to breeders. They therefore present a reservoir of useful traits for crop improvement (Maxted *et al.*, 2012). There are five wild rice species present in Africa, namely *Oryza barthii* A. Chev. & Roehr, *O. brachyantha, O. eichingeri* Peter, *O. longistaminata* A. Chev. & Roehr, and *O. punctata* Kotschy ex Steud (Aladejana & Faluyi, 2007; Nayar, 2012). Our review of Ghana Herbarium records and national gene bank data indicate that three of these wild species (i.e. *O. barthii, O. longistaminata* and *O. punctata*) occur in Ghana.

The wild rice species are closely related progenitors of the two cultivated rice species: the universally cultivated Asian rice (*Oryza sativa* Linn.) and African rice (*Oryza* *glaberrima* Steud) which is endemic to West Africa. *O. glaberrima* was domesticated about 3000 years ago from the wild annual progenitor, *O. barthii* (synonymous with *O. breviligulata*). *Oryza barthii* is described as an annual bunchgrass with erect to decumbent culms that grow to about 1.5 m in height. The roots formed from the lower nodes are spongy, striate and glabrous. It produces edible grains which tend to shatter easily. It is found in shallow water, in ponds and marshes, and may occur as weeds in rice cultivation areas. It occurs at an altitude of about 1500 m and may form pure stands, but is often found in mixed stands with other aquatic grasses (Brink & Belay, 2006; Aladejana & Fulayi, 2007; Agnoun *et al*., 2012).

Oryza glaberrima is described as an annual species that grows to about 1.2 m tall in upland or irrigated conditions, but can grow up to 5 m tall in floating conditions. It possesses fibrous roots and the stems are without ramifications. Unlike Asian rice which has long and pointed ligules and panicles that droop after flowering, the stems of *O. glaberrima* bear distinct round and short ligules at the junction between the leaf base and leaf sheath, and its panicles are erect at maturity. The caryopsis (grain) is often reddish and tightly enveloped by the lemma (glume inferior) and palea (glume superior) which is usually without apical awn and may be coloured (Agnoun *et al*., 2012).

In a parallel evolutionary pathway, *O. sativa* was domesticated some 6,000-14,000 years ago in Asia from the wild annual ancestor of *O. nivara*, which evolved from the wild perennial rice *O. rufipogon*, synonymous with *O. perennis* (Linares, 2002; Maxted & Kell, 2009). According to Sié *et al*. (2012), Africa is the only continent where the two cultivated species co-exist.

African rice differs in many quantitative and qualitative traits when compared to Asian rice (Li, Zheng & Ge, 2011). The grains of African rice have a red or brownish pericarp and are generally more glabrous, hence the species name *glaberrima*. It possesses many important traits including weed competitiveness, drought tolerance and ability to respond to low input conditions. It is more resistant to pests and diseases and can survive in a wide range of difficult ecosystems. It can tolerate phosphorus, iron and aluminium toxicity (Sarla & Swamy, 2005). In Ghana and other West African countries, African rice continues to play an important role in the socio-cultural life of rural communities (Linares 2002; Teeken *et al*., 2012). In the Central African Republic, its root is eaten raw as herbal remedy for diarrhoea (Aladejana & Fulayi, 2007).

Despite its uses, the genetic diversity of African rice and its wild relative is under threat of erosion due to unsustainable land management practices and the ecological impacts of climate change. This means that the genetic pool from which useful traits could be harnessed for improvement of the rice crop is being diminished. Since more than half of the world's population depends on rice as a dietary food staple, the need to conserve the genetic diversity of this important crop for the purposes of breeding high-yielding, biotic and abiotic stress resistant varieties in the face of climate change is an issue of global concern (Vincent *et al*., 2013).

Data on rice germplasm collections obtained from the national gene bank of Ghana, which is housed by the Plant Genetic Resources Research Institute (PGRRI) of the Council for Scientific and Industrial Research (CSIR), confirmed past efforts at conserving the country's rice germplasm. However, at the time of conception of this study in 2014-2015, there had been no rice germplasm collections in the country for over twenty (20) years due to financial and political constraints (Howes, 1981; Bennett-Lartey *et al*., 1997).

This study therefore set out to ascertain the distribution of African rice and its wild relative in the study area, to assess the quality of soils in which these rice species occur, to conduct agro-morphological studies to confirm the identity of rice collections, to determine the socio-cultural significance of African rice and its wild relative to the communities in which they occur, and to understand the threats to their existence.

Methods

Field survey

The selection of field survey sites was based on information gathered from herbarium vouchers in the Ghana Herbarium (sited in the Department of Plant and Environmental Biology, University of Ghana) and rice passport data obtained from the national gene bank (located at the Plant Genetic Resources Research Institute (PGRRI) at Bunso in the Eastern Region of Ghana). These two national databases showed evidence of past collections of domesticated and wild rice species from the main rice-producing regions, i.e. Northern, Upper East and Volta. Due to financial constraints, the Volta Region (which has the least travelling distance) was chosen for the current study as an initial step, with a view to expanding the scope with future funding.

Rice fields were surveyed in five districts of the Volta Region, namely Hohoe, Jasikan, Ho Municipal, Biakoye and Adaklu-Anyigbe. More than 30 paddy fields were visited as the survey team travelled from one district to another. Rice germplasm collections were, however, made only when the species of interest were encountered. Rice seeds were collected from mature rice plants and were placed in well-labelled brown envelopes. Labelling included name of species and collection site. The sample collection sites were geo-referenced with a Global Positioning System (GPS) (GPSMAP® 60CSx).

Collection and preparation of soil samples for analysis

Soil samples were collected with a soil auger at a depth of 0-10 cm at each sampling location. Three replicate soil samples were collected for each rice sample. Soils were kept in soil sampling bags and labelled according to the name of the corresponding rice variety. The soils were air-dried for 5 days, pulverized and passed through a 2-mm diameter sieve, then stored in sealable plastic bags prior to analysis. Soil particle size, pH, electrical conductivity (EC) as well as the concentrations of nitrogen (N), potassium (K), phosphorus (P), iron (Fe), zinc (Zn), copper (Cu), lead (Pb), cadmium (Cd) and arsenic (As) were determined using standard protocols (Van Reeuwijk, 2002).

Plant Identification

The local names of the rice samples collected were obtained from the rice farmers and local field guides. As far as practicable, the species to which they belong were confirmed on the basis of information found on herbarium vouchers and in the literature.

Agro-morphological Studies

The identity of four of the rice accessions encountered in the field could not be readily confirmed because they had morphological features that contrasted with the descriptors of African rice obtained from the literature and the Ghana herbarium. The farm owners, however, insisted that they were varieties of African rice. In order to confirm their identity, all the cultivated rice accessions were subjected to agro-botanical studies in the greenhouse of the Department of Plant and Environmental Biology, University of Ghana. A randomized block experimental design was used with three replicates of each accession. The seeds were sown in sizeable buckets of equal dimensions containing 5.0 kg of soil each. The plants were watered daily with an equal volume of water. Fertilizer (NPK: 15-15-15) was applied 20 days after sowing at a rate of five grams per pot (5g/pot). At tillering, 1.5g/pot of urea was applied.

Agro-morphological evaluation was conducted in the green house using rice descriptors in accordance with the method described by Bioversity International, IRRI & WARDA (2007). The qualitative and quantitative agro-morphological traits were evaluated for all replicate plants and the results for quantitative traits were averaged for each accession.

Farmer Interviews

Semi-structured questionnaires were designed to guide interviews with the rice farmers encountered during the field survey. The interviews were conducted mostly in

Ewe, a local dialect spoken throughout the Volta Region, and responses were translated by the corresponding author. The interviews aimed to establish the socio-cultural importance of African rice and to ascertain farmers' reasons for cultivating or not cultivating the crop.

Data Analysis

The data obtained from soil analysis and agro-morphological studies were statistically analysed using Gen-Stat package version 12. One-way analysis of variance (ANOVA) was computed at 95% confidence level and a Post Hoc test for values with $p \leq 0.05$ was carried out using Fisher's Least Significant Difference.

The Unweighted Pair Group Method using Arithmetic Average (UPGMA) was used to determine variations among the agro-morphological traits of the different accessions. This was done with the Numerical Taxonomy System (NTSYS) software programme version 2.1 (Rohlf, 2000). A dissimilarity matrix (DIST coefficient) based on all traits was created for each group from the transformed data using average taxonomic distance *sensu* Sneath & Sokal (1973). The product moment correlation (CORR coefficient) for each group was also calculated for all possible pairs. The DIST and CORR coefficients calculated were used to obtain the respective transformation matrices, which in turn were used to create the dendrogram. The co-phenetic correlation for the dendrogram was computed as a measure of goodness of fit (Mantel t-test) for the method of clustering used. The distance matrix was constructed by means of the Jaccard coefficient.

Results

Geographic distribution of cultivated and wild rice species

Figure 1 is a map of the Volta Region showing the rice germplasm collection sites. Although more than thirty rice fields were visited during the field survey, *O. glaberrima* plants were found in only fourteen locations (representing less than 50% of fields surveyed). Mature seeds of cultivated rice were obtained from only 7 locations. Table 1 provides a list of the different rice accessions collected and their locations. The four accessions classified simply as *Oryza* species in Table 1 were not conclusively confirmed in the field as being African or Asian rice. Two of these were identified by farmers in Wegbe and Worawora as "*Ewe Moli*" (literally translated as the "Rice of the Ewes"). The other two, *Mansa* and *Viwotor*, were obtained from Likpe Bakwa.

All the rice collection sites were within upland rainfed ecosystems, but a number of lowland paddy fields were also encountered during the survey.

O. glaberrima collections were mainly from Likpe Bakwa and Akpafu Mempeasem, both in the Hohoe District of the Volta Region. The surrounding vegetation was representative of the forest-savanna transition zone. Tree species found growing on most farms included *Ceiba pentandra*, *Triplochiton scleroxylon*, *Elaeis guineensis*, *Khaya senegalensis*, *Cocos nucifera* and *Musa sapientum*. In most cases, African rice was found intercropped with Asian rice (*O. sativa*), with the latter taking up a significant proportion of the cultivated area. At Akpafu Memepeasem, farmers also intercropped the rice with sugarcane (*Saccharum officinarum*).

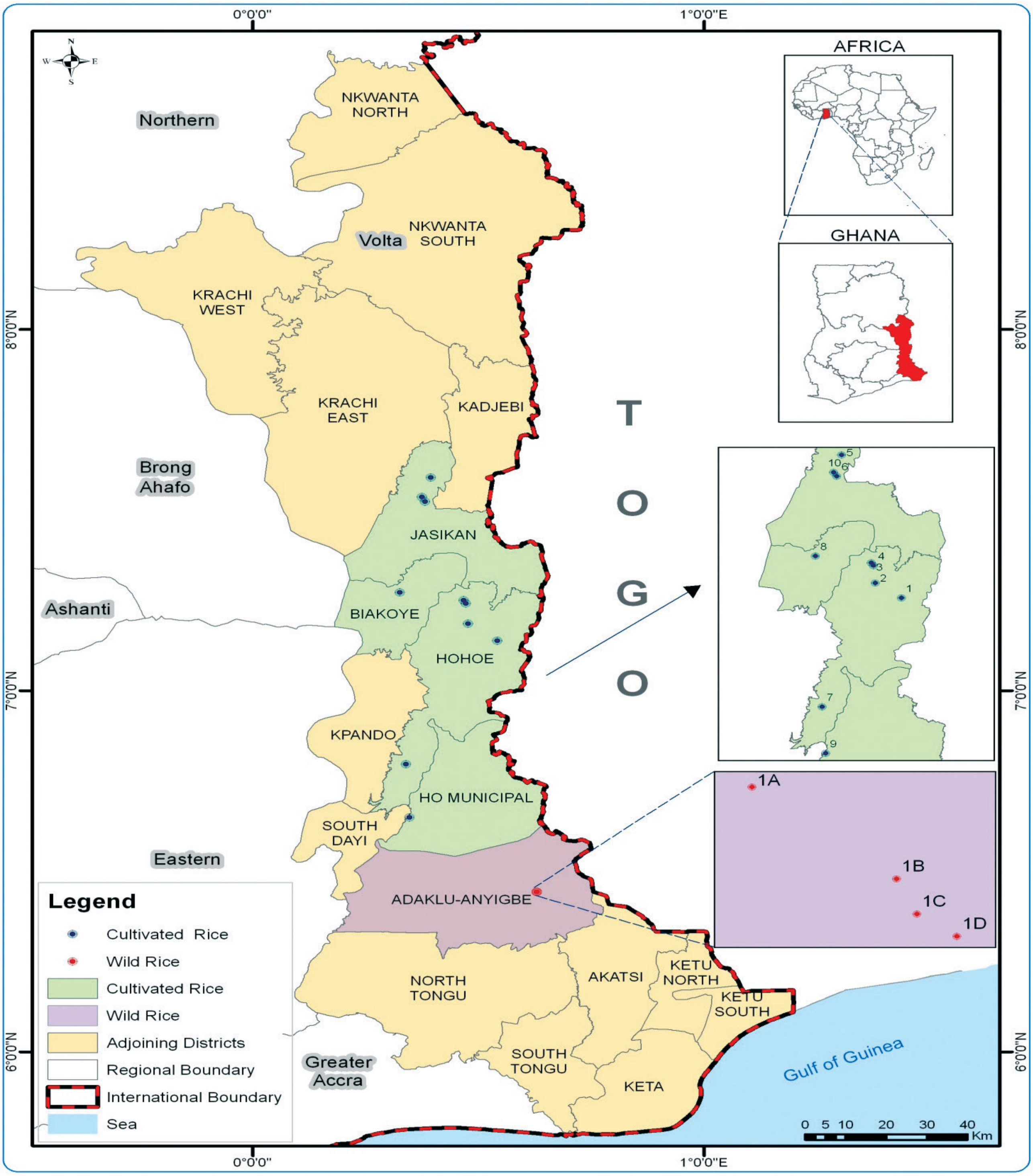

Fig. 1: Map of Volta Region of Ghana showing rice collection sites

Table 1: List of rice samples collected from survey area

Local/Common Name	Scientific name	Town	District	Latitude	Longitude
Kawomor (Red)	*Oryza glaberimma*	Akpafu Mempeasem	Hohoe	N07.24457	E000.46929
Kamowor (Black)	*Oryza glaberimma*	Akpafu Mempeasem	Hohoe	N07.24457	E000.46929
Kamugbaa	*Oryza glaberrima*	Likpe Bakwa	Hohoe	N07.13830	E000.54255
Mansa	*Oryza* sp.	Likpe Bakwa	Hohoe	N07.13830	E000.54255
Viwotor	*Oryza* sp.	Likpe Bakwa	Hohoe	N07.13830	E000.54255
Ewe Moli (Wegbe)	*Oryza* sp.	Wegbe	Ho municipal	N06.64898	E000.37498
Ewe Moli (Worawora)	*Oryza* sp.	Worawora	Jasikan	N07.53436	E000.37987
Wild rice	*Oryza barthii*	Adaklu Waya	Adaklu	N06.44272	E000.62962

No wild rice species were found growing in the rice fields visited. Interviews with the farmers revealed that the wild rice species are regarded as weeds and so efforts are made to eradicate them. *O. barthii* was found in only the Adaklu District, growing along the bank of a small river (River Tedzitsor) at Adaklu Waya. It was found in mixed stands with other grasses, mainly *Panicum* species. Communication with the local field guide indicated that the wild rice species is not eaten or used as medicine by the local community, and hence is not exploited in any way. Nonetheless, field observations revealed that the continued existence of *O. barthii* in the current location is under threat. The field guide attributed the observed destruction of sections of the wild rice population to a heavy-duty vehicle which was used by a contractor to convey water from River Tedzitsor for building purposes. Recent agricultural expansion on the lands beyond the river bank also poses a threat to the wild rice species as it has led to increased human traffic across the river.

Properties of soils supporting growth of rice species

The physical properties of the soil samples collected from rice fields are presented in Table 2. The soils varied significantly with respect to pH, EC and particle size. Soil pH was generally acidic and ranged from 4.68 ± 0.14 to 6.71 ± 0.16. The EC values ranged from 98.0 ± 16.6 μScm^{-1} in soils of the accession Ewe Moli (Worawora) to 222.3 ± 21.4 μScm^{-1} in soils of the accession Ewe Moli (Wegbe).

Analysis of soil particle size showed that soil texture ranged from sandy clay to sandy clay loam to sandy loam to loamy sand (Table 2). The sand content of the soils averaged 68.2 ± 7.9 % while the clay content averaged 18.9 ± 4.7 %. According to Bell and Seng (2005), soil is termed 'sandy' if it contains <18 % clay and > 65 % sand. The soils in the current study could therefore be broadly described as sandy.

The mean concentrations of As, Cd, Cu and Pb in soils of the different rice accessions are presented in Table 3 and those of N, P, K, Fe and Zn are presented in Table 4. Analysis of variance (ANOVA) tests indicated that the soils did not differ with respect to Cu and Pb concentrations, but differed significantly with respect to N, P, K, Fe and Zn concentrations. The *O. barthii* soil recorded the least concentrations of N, P and K (Table 4).

Table 2: pH, Electrical Conductivity (EC) and Texture of Soils Supporting Growth of Different Rice Accessions

Rice Accession	pH	EC(μScm^{-1})	Silt (%)	Clay (%)	Sand (%)	Textural class
Kawomor	5.69 ± 0.07^{c}	128.67 ± 23.18^{a,b,c}	16.35±7.03^{b,c}	28.84±6.13^{c}	54.81±12.03^{a}	Sandy clay
Ewe Moli (Worawora)	4.68 ± 0.14^{a}	98.00 ± 16.64^{a}	15.53±4.56^{b,c}	21.66±2.29^{b,c}	62.80±6.83^{a,b}	Sandy clay loam
Kamugbaa	6.08 ± 0.28^{d}	165.33 ± 63.41^{c}	9.08±5.38^{a,b}	16.42±9.16^{a,b}	76.50±11.90^{b,c}	Sandy loam
Viwotor	5.83 ± 0.24^{c,d}	117.33 ± 23.24^{a,b,c}	19.86±1.72^{c}	19.86±1.72^{b,c}	60.27±3.43^{a}	Sandy clay loam
Mansa	5.31 ± 0.17^{b}	109.00 ± 32.51^{a,b}	18.93±6.02^{c}	27.56±5.30^{c}	53.51±9.08^{a}	Sandy clay loam
Ewe Moli (Wegbe)	6.71 ± 0.16^{e}	222.33 ± 21.39^{d}	4.84±2.91^{a}	9.68±5.81^{a}	85.48±8.72^{c}	Loamy sand
O. barthii	6.45 ± 0.05^{e}	163.33 ± 5.77^{b,c}	7.96±0.75^{a}	8.35±2.59^{a}	83.70±3.17^{c}	Loamy sand
P value	< 0.001	0.004	0.003	0.002	0.001	

Means in the same column with the same superscript are not significantly different at $p \leq 0.05$

Table 3: Concentrations of As, Cd, Cu and Pb in Soils of Different Rice Accessions

Accessions	As (mg/kg)	Cd (mg/kg)	Cu (mg/kg)	Pb (mg/kg)
Kawomor	BD	BD	4.29 ± 1.68	0.02±0.01
Ewe Moli (Worawora)	BD	BD	3.20 ± 1.21	0.26± 0.16
Kamugbaa	BD	BD	3.30 ± 1.77	0.18 ± 0.13
Viwotor	BD	BD	4.02 ± 1.09	0.11± 0.06
Mansa	BD	BD	3.77 ± 1.19	0.07±0.04
Ewe Moli (Wegbe)	BD	BD	2.84 ± 0.66	0.10 ± 0.08
O. barthii	BD	BD	6.02 ± 0.57	0.12 ± 0.03
P Value	-	-	0.112	0.098

BD: Below detection

Table 4: Concentrations of N, P, K, Fe and Zn in Soils of Different Rice Accessions

Rice Accession	Total N (%)	Total P (%)	Total K (%)	Fe (mg/kg)	Zn (mg/kg)
Kawomor	0.26 ± 0.01^{b,c}	0.17 ± 0.01^{c}	0.22 ± 0.04^{c}	0.43 ± 0.10^{b}	0.04±0.02^{a}
Ewe Moli (Worawora)	0.21 ± 0.01^{b,c}	0.16 ± 0.01^{b}	0.13±0.01^{b,c}	0.11 ± 0.04^{a}	0.05 ± 0.02^{a}
Kamugbaa	0.23 ± 0.04^{b,c}	0.16 ± 0.01^{b}	0.17 ± 0.04^{c,d}	0.36 ± 0.21^{b}	0.08 ± 0.03^{a,b}
Viwotor	0.30 ± 0.16^{c}	0.16 ± 0.00^{b}	0.16 ± 0.02^{c}	0.25 ± 0.16^{a,b}	0.05 ± 0.01^{a}
Mansa	0.17 ± 0.04^{b}	0.16 ± 0.01^{b}	0.18 ± 0.03^{a,b}	0.16 ± 0.07^{a}	0.08 ± 0.05^{a,b}
Ewe Moli (Wegbe)	0.15 ± 0.03^{a,b}	0.16 ± 0.01^{b}	0.08 ± 0.06^{c,d}	0.28 ± 0.04^{a,b}	0.04 ± 0.01^{a}
O. barthii	0.05 ± 0.01^{a}	0.02 ± 0.00^{a}	0.03 ± 0.01^{a}	0.12 ± 0.02^{a}	0.12 ± 0.02^{b}
P Value	0.006	< 0.001	< 0.001	0.022	0.023

Means in the same column with the same superscript are not significantly different at $p \leq 0.05$

Agro-morphological characterization of rice accessions

The summary statistics for 12 quantitative agro-morphological traits evaluated for all seven cultivated rice accessions are presented in Table 5. ANOVA performed on the composite data showed that observed variations in leaf blade length (LBW), flag leaf length (FLL) and Grain Length (GL) were not significant. Table 6 therefore provides a ranking of the rice accessions based on mean values of the remaining 9 quantitative variables for which variations were found to be statistically significant.

Figure 2 shows the associations among the 7 rice accessions revealed by UPGMA cluster analysis using Jaccard's coefficient of similarity. This analysis included not only the quantitative variables but also some qualitative variables. The dendrogram classified the accessions into two main clusters. Cluster 1 consisted of *Kamugbaa*, *Kawomor* (black) and *Kawomor* (red). Cluster 2 consisted of *Ewe Moli* (Worawora), *Mansa*, *Viwotor* and *Ewe Moli* (Wegbe). Traits that showed distinct variations between the two groups were number of days to first heading, number of days to main heading, number of days to maturity, ligule length, ligule shape, leaf blade width, flag leaf width, culm length, grain width, 100-grain weight, awn presence, culm strength and panicle attitude of branches.

Cluster 1 accessions had short and truncated ligules, weak culms, short awns and erect to semi-erect panicles. They were also early maturing and had heavier 100-grain weight, wider flag leaf width and leaf blade width. Accessions in Cluster 2 had drooping panicles, no awns, strong culms, long ligules which are 2-cleft in shape, a longer crop cycle, narrower leaf blade width and flag leaf width.

Table 5: Summary statistics for 12 quantitative agro-morphological traits evaluated for 7 rice accessions

Quantitative variable	Min	Max	Mean ± SD	CV (%)
Number of days from seedling to first heading: FH	46	66	56.71 ± 9.55	16.84
Number of days from seedling to main heading: MH	61	87	75.29 ± 12.80	17.00
Number of days from seedling to maturity: Cycle	84	109	97.71 ± 12.08	12.36
Ligule length: LL (mm)	0.30	1.60	0.94 ± 0.60	63.83
Leaf blade length: LBL (mm)	26.73	44.10	37.04 ± 6.06	16.36
Leaf blade width: LBW (mm)	0.70	1.13	0.93 ± 0.19	20.43
Flag leaf length: FLL (mm)	29.50	38.57	32.91±3.11	9.45
Flag leaf width: FLW (mm)	0.53	1.60	1.14 ± 0.41	35.96
Culm length: CL (mm)	31.50	82.27	47.83 ± 17.84	37.30
Grain length: GL (mm)	9.16	10.26	9.80 ± 0.43	4.39
Grain width: GW (mm)	1.17	2.60	1.71 ± 0.61	58.48
100-grain weight: HGW (g)	2.46	2.94	2.68 ± 0.18	6.72

Min: minimum; Max: maximum; SD: standard deviation; CV: Coefficient of Variation

Table 6: Ranking of rice accessions with statistically significant quantitative agro-morphological traits

Accessions	FH	MH	Cycle	LL	LBW	FLW	CL	GW	HGW
Kamugbaa	47.00[b]	61.00[b]	84.00[b]	0.33[b]	1.13[a]	1.57[a]	56.97[b]	1.40[b]	2.73[b]
Kawomor (black)	47.00[b]	62.00[b]	86.00[b]	0.30[b]	1.13[a]	1.47[a]	37.17[c]	1.17[b]	2.84[a,b]
Kawomor (red)	46.00[b]	62.00[b]	85.00[b]	0.30[b]	1.10[a]	1.60[a]	46.43[b,c]	1.32[b]	2.94[a]
Ewe Moli (Worawora)	65.00[a]	86.00[a]	109.00[a]	1.47[a]	0.77[b]	0.53[c]	48.63[b,c]	1.52[b]	2.46[d]
Mansa	66.00[a]	87.00[a]	109.00[a]	1.30[a]	0.80[b]	0.93[b]	31.83[c]	2.60[a]	2.47[d]
Viwotor	63.00[a]	86.00[a]	108.00[a]	1.30[a]	0.70[b]	0.93[b]	31.50[c]	1.40[b]	2.60[c]
Ewe Moli (Wegbe)	63.00[a]	83.00[a]	103.00[a]	1.60[a]	0.87[a,b]	0.97[b]	82.27[a]	2.58[a]	2.73[b]
P Value	< 0.001	< 0.001	< 0.001	< 0.001	0.012	< 0.001	< 0.001	0.002	< 0.001

Means in the same column with the same superscript are not significantly different at $p \leq 0.05$

Refer to Table 5 for meanings of abbreviations of the different agro-morphological traits.

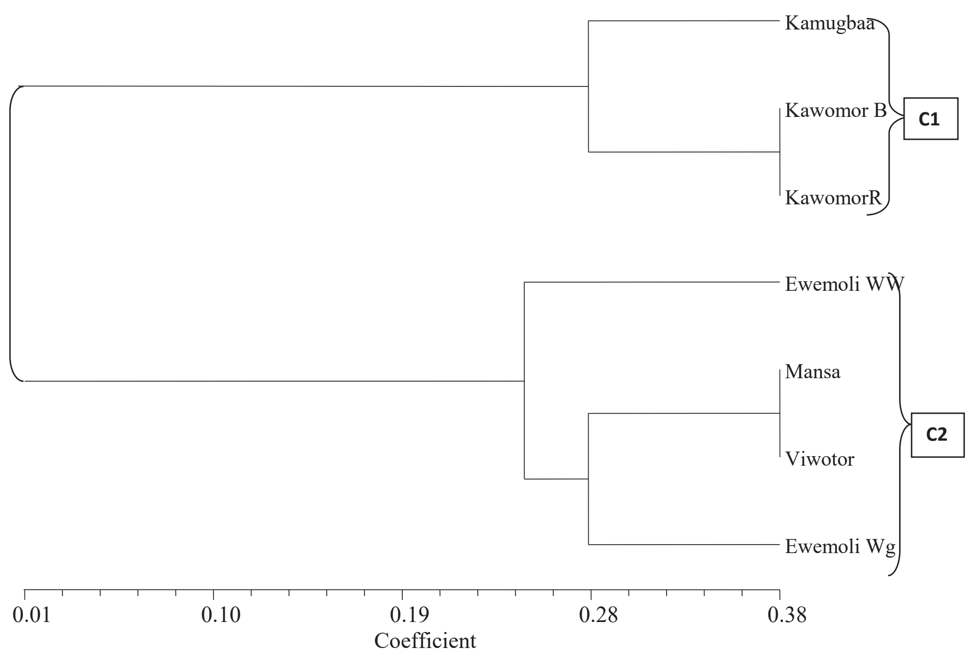

Fig.2: Dendrogram based on 16 agro-morphological characters for seven rice accessions generated by UPGMA clustering

Socio-cultural significance of African rice

It appears that rice farming in the Volta Region is gender biased. Of the 60 farmers encountered and interviewed, 37 were females and 23 were males. The older female rice farmers (>50 years of age) had a better knowledge of the uses of African rice than their male counterparts or the younger farmers. Information gathered from interviews with older female farmers revealed that in spite of the drastic reduction in its cultivation, African rice still plays a role in the socio-cultural life of some ethnic groups in the Volta Region.

Farmers who cultivate African rice cited drought tolerance and disease/pest resistance as some of its desirable traits. Other reasons given by most of the respondents in favour of African rice bordered on taste and cooking quality. It was argued that some local dishes require a distinct flavour which can only be obtained with African rice, which also has a longer shelf-life when cooked compared to Asian rice. All the respondents, however, mentioned that African rice has a lower yield, lodges easily under flooded conditions, and has seeds that shatter easily and are more difficult to de-husk. These, in addition to low consumer demand, were the reasons given for the reduced cultivation of African rice.

Regardless of farmers' perception of African rice, many expressed concerns about the impact that the dwindling interest in African rice production has on their festivals and other customary rites. A respondent in Likpe Bakwa indicated that milled flour of African rice is used to prepare a special dish for their marriage ceremonies. It is also used in the preparation of the libation offered as part of the rituals for the enstoolment of a chief.

Discussion

The study results indicate that a combination of ecological and socio-economic factors affect the diversity of rice germplasm in Africa. This finding agrees with that reported by Teeken *et al*. (2010) who argued that the maintenance or abandonment of African rice production across West Africa is determined by different interactions between social and ecological factors. The relatively low yield of African rice, coupled with increased consumer demand for Asian rice, has resulted in reduced cultivation of African rice in farmers' fields in the Volta region. The general perception of *O. barthii* as a weed has also led to its eradication from farmers' fields in the study area. Johnson (2000) reported similar findings from studies in the Northern part of Ghana, Mali and Tanzania. While the need to maximize yield of the cultivated rice is understandable, the widespread eradication of wild rice species from farmers' fields has grave implications for the conservation of the genetic diversity required for crop improvement purposes. Both African rice and its wild progenitor were, however, found growing well in nutrient deficient soils and hence show promise of contributing useful genetic traits for crop improvement.

The physico-chemical properties of the soils in which *O. glaberrima* and *O. barthii* were found growing confirm reports of their ability to survive in a wide range of difficult ecosystems (Sarla & Swamy, 2005; Teeken *et al*., 2012). The most favorable pH for rice ranges from 5.5 – 7.0; but rice is known to grow under a wider pH range of 4.2 – 8.5 (Fo *et al*., 2012). The pH values of soils of the various rice accessions sampled for this study therefore fall within acceptable limits. The recorded range of EC values ($98.0 \pm 16.6\ \mu Scm^{-1}$ to $222.3 \pm 21.4\ \mu Scm^{-1}$) also falls within acceptable limits (Munns &Tester, 2008).

The concentrations of As and Cd in all the soil samples were below detection. This may be a result of the inability of the AAS (Atomic Absorption Spectrometer) to detect the existing levels. It is worth noting, however, that previous soil analyses using ICPMS (Inductively Coupled Plasma Mass Spectrometer) also reported low As and Cd concentrations in Ghanaian paddy soils, except for soils from gold mining impacted paddy fields (Adomako, Deacon & Meharg, 2010; 2014).

All the soils analysed for this study were generally low in nutrients (particularly Fe and Zn), a situation which could be attributed to the soil texture. Sandy soils are prone to leaching which results in loss of nutrients to deeper levels as water percolates through soils (Bell & Seng, 2005).

The findings of the UPGMA cluster analysis highlight the importance of agro-morphological studies as a means of validating information obtained from the field. The characteristics of the accessions in Cluster 2 suggest that they are varieties of Asian rice. It is not surprising that some farmers mistakenly identified varieties of Asian rice as African rice. Teeken *et al*. (2012) reported that *Viono* - an Asian rice variety that resembles African rice in taste, pericarp colour and cooking quality - dominates rice farms owned by the Lolobi and Akpafu ethnic groups of Ghana. It is worth noting that *Viono* (pronounced Vi-o-nor) and *Viwotor* are both cultivars of the same variety. The latter was also classified in Cluster 2 of the dendrogram, although farmers in Likpe Bakwa regard it as an indigenous species. Arguably, the choice of varieties for socio-cultural purposes is based not so much on knowledge of the origin of the species as on the taste, colour and cooking quality of the grains.

Efforts at conserving African rice on farmers' fields through seed selection may be easier in communities like Likpe Bakwa where it is still regarded as a cultural asset. The undesirable traits of African rice cited by farmers (i.e. low yield, easily lodging plants, easily shattering seeds that are difficult to de-husk) could, however, militate against *in situ* conservation efforts. Similarly, the apparent lack of direct benefits of *O. barthii* to the people of Adaklu Waya may result in a gradual loss of the species.

It is worth noting that in 2016 the national gene bank (PGRRI, Bunso) obtained a grant from the Global Crop Diversity Trust to embark on a collection exercise targeting specific crop wild relatives including wild rice species. The sample collection sites of this study were re-visited by the 2016 collection team to obtain seed collections and voucher specimens of *O. glaberrima* and *O. barthii* for conservation. There remains the need to extend the scope of the study to other regions of the country, not only for seed collection but also to ensure accurate mapping of the distribution of the country's domesticated and wild rice species.

Conclusion

The study has established that African rice (*O. glaberrima*) and its wild progenitor (*O. barthii*) are gradually being lost from previously noted habitats in the Volta Region of Ghana. Extensive field surveys in five districts of the region revealed that Asian rice varieties dominate rice production in the region. Evaluation of agro-morphological traits for seven rice accessions obtained from the survey, followed by UPGMA cluster analysis, was useful in verifying the identity of the rice accessions. The resulting dendrogram revealed that the survey yielded only 3 accessions of *O. glaberrima*, the remaining 4 accessions being varieties of *O. sativa*. Contrary to information in the literature, *O. barthii* was also not found on cultivated rice fields as efforts had been made by farmers to eradicate it. Clearly, there is the need to intensify efforts at determining and mapping the distribution of this important genetic resource. This would inform decisions regarding future *in situ* and *ex situ* conservation initiatives.

Acknowledgements

We wish to express our gratitude to Mr. Roger Ofori, Mr. Timothy Osakpa and Mr. Seyram Fiati for their immeasurable assistance in the field; and to Mr. Bashara Ahmed of the Center for Remote Sensing and Geographic Information Services (CERSGIS), University of Ghana, for help in creating the map of rice collection sites.

References

Adomako, E. E. A., Deacon, C. S. & Meharg, A. A. (2014). Impacts of gold mining on rice production in the Anum Valley of Ghana. *Agricultural Sciences*, 5, 793-804. http://dx.doi.org/10.4236/as.2014.59084

Adomako, E. E., Deacon, C. & Meharg, A. A. (2010). Variations in concentrations of arsenic and other potentially toxic elements in mine and paddy soils and irrigation waters from southern Ghana. *Water Quality Exposure and Health*, 2, 115-124. doi: 10.1007/s12403-010-0029-0

Agnoun, Y., Biaou, S. S. H., Sié, M., Vodouhè, R. S., & Ahanchédé, A. (2012). The African Rice *Oryza glaberrima* Steud : Knowledge, Distribution and Prospects. *International Journal of Biology*, 4(3), 158–180. doi:10.5539/ijb.v4.3.158.

Aladejana, F. & Faluyi, J. O. (2007). Agrobotanical characterisitics of some West African indigenous species of the A genome complex of the genus *Oryza* Linn. *International Journal of Botany*, 3, 229-239. doi: 10.3923/ijb.2007.229.239

Bell, R.W., & Seng, V. (2005). The management of the agro-ecosystems associated with sandy soils. In K. Kaen (Ed.), *Proceedings of FAO workshop on management of tropical sandy soils for sustainable agriculture* (pp 19-25). Thailand: FAO.

Bennett-Lartey, S. O., Ayensu, F. K., Monma, S., & Ito, K. (1997). Vegetable germplasm collecting in Ghana. *Plant Genetic Resources Newsletter*, 111(1), 69-71.

Bioversity International, IRRI & WARDA (2007). *Descriptors for wild and cultivated rice (Oryza spp.)*. Rome, Italy; Los Bańos , Phillipines; Cotonou, Benin.

Brink, M., & Belay, G. (2006). *Plant Resources of Tropical Africa 1, Cereal and Pulses, PROTA Foundation*. (p 298). Wagenigen, Netherlands: Backhuys Publishers.

Fo, T., Omoko, M., Boukong, A., Ad, M. Z., Bitondo, D., & Fuh, C.C. (2012). Evaluation of lowland rice (*Oryza sativa*) production system and management recommendations for Logone and Chari flood plain – Republic of Cameroon, *Agricultural Science Research Journal*. Retrieved from http://resjournals.com/arj.

Howes, C. (1981). Guidelines for developing descriptor lists. *FAO/IBPGR Plant Genetic Resources Newsletter*, 45:26-32.

Johnson, D.E., Riches, C.R., Kayeke, J., Sarra, S. & Tuor, F.A. (2000). *Wild rice in sub-Saharan Africa: its incidence and scope for improved management*. Proceedings of FAO Global Workshop on Red rice Control, pp 87-94. Cuba, FAO.

Li, Z.M., Zheng, X.-M., & Ge, S. (2011). Genetic diversity and domestication history of African rice (*Oryza glaberrima*) as inferred from multiple gene sequences. *Theoretical and Applied Genetics*, 123(1), 21–31. doi:10.1007/s00122-011-1563-2.

Linares, O.F. (2002). African rice (*Oryza glaberrima*): history and future potential. *Proceedings of the National Academy of Science*, 99, 16360-16365. doi:10.1073/pnas.252604599.

Maxted, N. & Kell, S. (2009). *Establishment of a global network for the in situ conservation of crop wild relatives: status and needs*. Rome, Italy: FAO Commission on Genetic Resources for Food and Agriculture..

Maxted, N., Kell, S., Ford-Lloyd, B. Dulloo, E. & Toledo, A. (2012). Toward the Systematic Conservation of Global Crop Wild Relative Diversity. *Crop Science*, 52(2), 774-785 doi:10.2135/cropsci2011.08.0415.

Munns, R., & Tester, M. (2008). Mechanisms of salinity tolerance. *The Annual Review of Plant Biology*, 59:651-681. doi: 10.1146/annurev.arplant.59.032607.092911.

Nayar, N. M. (2012). Evolution of the African rice: a historical and biological perspective. *Crop Science*, 52(2), 505 doi:10.2135/2010.10.0605.

Rohlf, F. J. (2000). Numerical taxonomy and multivariate analysis system. NTSYS-pc. Version 2.1, Exeter Software, New York, USA.

Sarla, N., & Swamy, B. P. M. (2005). *Oryza glaberrima*: a source for the improvement of *Oryza sativa*. *Current Science*, 89 (6) 955-963.

Sié, M., Sanni, K., Futakuchi, K., Manneh, B., Mandé, S., Vodouhé, R., Dougbe, S., Drame, K.N., Ogunbayo, A., Ndjiondjop, M.N., Traore, K.(2012). Towards a rational use of African rice (*Oryza glaberrima* Steud.) for breeding in Sub-Saharan Africa. *Global Science Books*, 6 (1) 1-7.

Sneath, P. H. A. & Sokal, R. R. (1973). *Numerical taxonomy: the principles and practice of numerical classification*. San Francisco, California, USA: W. H. Freeman and Co.

Teeken, B., Nuijten, E., Temudo, M. P., Okry, F., Mokuwa, A., Struik, P. C., & Richards, P. (2012). Maintaining or abandoning African rice: lessons for understanding processes of seed innovation. *Human Ecology*, 40(6), 879–892. doi:10.1007/s10745-012-9528-x

Van Reeuwijk, L.P. (2002). *Procedures for soil analysis, 6th Edition*. ISBN: 90-6672-044-1. Wageningen: International Soil Reference and Information Center.

Vincent, H., Wiersema, J., Kell, S., Fielder, H., Dobbie, S., Castaneda-Alvarez, N. P., Guarino, L., Eastwood, R., Leon, B. & Maxted, N. (2013). A prioritized crop wild relative inventory to underpin global food security. *Biological Conservation*, 167, 265-275.