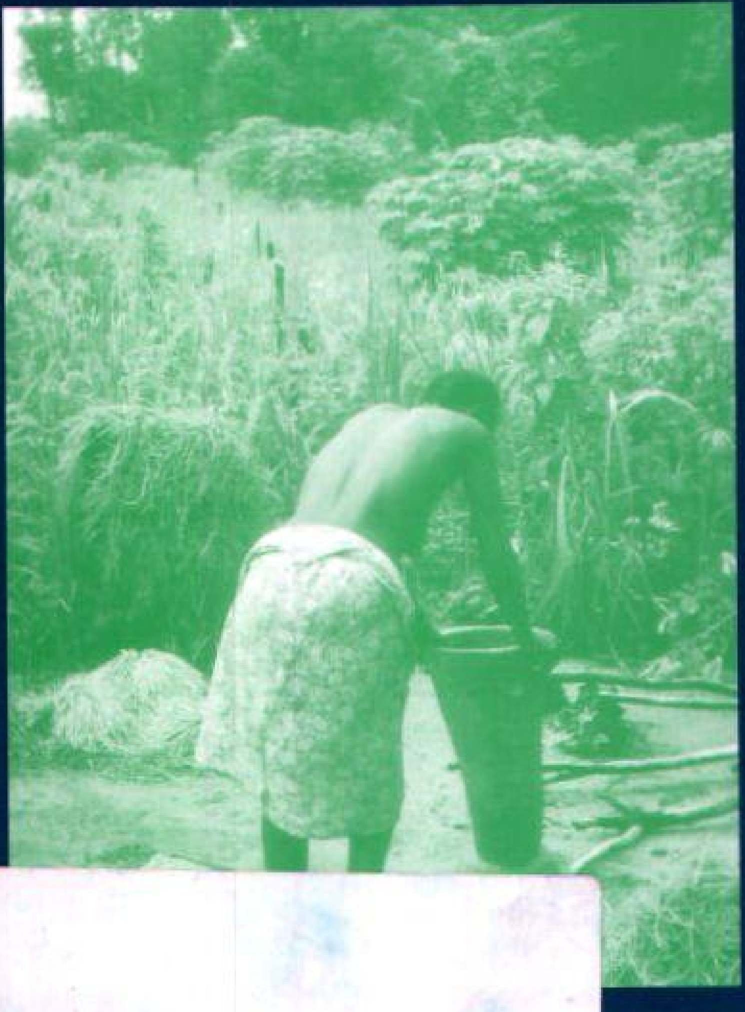
Management of Genetic Variability in rice (*Oryza sativa L. and O. glaberrima* Steud.) by Breeders and Farmers in Sierra Leone



Malcolm Sellu Jusu

Propositions

1. Never say never, for crosses between O. sativa and O. glaberrima species, given enough time and opportunities, where broad out-crossing is concerned (Norman Simmonds, pers. comm.). (This thesis).

2. Acknowledging local knowledge and cultural difference is essential in varietal development and for varietal adoption. Breeders must begin to take into account the local knowledge and culture (E_2) in addition to the conventional Genotype (G) and Environmental (E_1) interaction in breeding. (This thesis).

3. Farmers' choices are associated with local culture, historical and environmental circumstances. (This thesis).

4. Low resource farmers in difficult environments select appropriate planting material but need the skill and genetic diversity from both within and outside their locality. (This thesis).

5. Although women are considered as major players in genetic resource conservation, but the role of gender in this activity also depends on the economic importance of the crop and the leadership role in the family. (This thesis).

6. There is a large conceptual gap between what breeders and farmers think is important, but when both are selecting on the same range of materials, farmer-scientist selection exercises are feasible. (This thesis).

7. Growing rice varieties in mixtures may provide opportunities for out-crossing to take place and this may provide farmers with genetic diversity for further selection. (This thesis).

8. Farmer selection may be highly relevant to new approaches to plant improvement through apomixis. (This thesis).

9. Management of plant genetic resources by farmers and scientists is a socio-technical ensemble. (Paul Richards, 1995).

10. A bottom-up approach is necessary in technology development and adoption. (CBDC, 1993).

11. "If you do not know where you are going, you have to remember where you come from". (a Mende proverb).

12. " The rat is a great sorcerer but he never prays on a cat skin". (Krio proverb meaning development must always be appropriate to its context).

Malcolm Sellu Jusu
Wageningen University and Research Center, December 21, 1999

Management of Genetic Variability in rice (*Oryza sativa L. and O. glaberrima* Steud.) by Breeders and Farmers in Sierra Leone.

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The cover photograph comes from the fieldwork collection of Paul Richards. "The lady doing science with her feet" is Ngadi Tommy of Mogbuama village, Kamajei Chiefdom, Central Sierra Leone.

Finally, I would like to thank my wife Musu Jusu and my children, especially Elizabeth, Sia and Sahr, who were left behind without fatherly care in a war situation, while I was in The Netherlands writing this thesis.

Abbreviations

AA	Action Aid, Sierra Leone
ai	active ingredient
ADB	Africa Development Bank
ADP	Agricultural Development Project, Sierra Leone
ACRE	Adaptive Crop Research and Extension Project, Sierra Leone
ASSP	Agricultural Sector Support Program, Sierra Leone
ANOVA	Analysis of Variance
CBDC	Community Biodiversity Development and Conservation Program
CGN	Center for Genetic Resources, The Netherlands
CPRO	Center for Plant Breeding and Reproduction Research, The Netherlands.
cv	coefficient of variation
CVA	Canonical Variate Analysis
DLO	Agricultural Research Department, The Netherlands.
eg	exampli gratia, for example
EDF	European Development Fund
EU	European Union
FASP	Farmer's Association Support Project , Sierra Leone
G x E	Genotype by Environmental (interaction)
GEU	Genetic Evaluation and Utilization
GRAIN	Genetic Resources Action International
GRP,	Green Revolution Program, Sierra Leone
GTZ	Gesellschaft fur Technische Zusammenarbeit
IADP	Integrated Agricultural Development Project
IDA	International Development Agency
IFAD	International Fund for Agricultural Development
IITA	International Institute for Tropical Agriculture, Nigeria
IRD	Informal Research and Development
IVS	Inland Valley Swamps
INGER	International Network for the Genetic Evaluation of Rice in Africa
IRRI	International Rice Research Institute , Philippines
LSD	Least Significant Difference
M.A.F.E.	Ministry of Agriculture Forestry and Environment. , Sierra Leone
MOP	Murate of Potash
MS	Mean Squares
NAPCO	National Agricultural Produce Company, Sierra Leone
NARS	National Agricultural Research Systems
ODA	Oversea Development Administration, United Kingdom
PCA	Principal Component Analysis
PCI	Participatory Crop Improvement
Ph D	Doctor of Philosophy
PPB	Participatory Plant Breeding
PVS	Participatory Varietal Selection
RCC	Relative Crowding Coefficient
RRS	Rice Research Station , Sierra Leone

RSA	Replacement Series Analysis
RY	Relative Yield
RYT	Relative Yield Total
SD	Standard Deviation
SED	Standard Error of Difference
SMP	Seed Multiplication Project, Sierra Leone
SS	Sum of Squares
SSP	Single Superphosphate
SES	Standard Evaluation System for rice
TAO	Technology and Agrarian Development Group, Wageningen University, The Netherlands
UNDP	United Nations Development Program
USA	United States of America
USAID	United States Agency for International Development
V-ratio	Variance Ratio
WARDA,	West African Rice Development Association
WARRS	West African Rice Research Station
WARZ	West African Rice Zone
WAU	Wageningen Agricultural University, The Netherlands.
Y_{aa}	performance of variety a in pure stand
Y_{ab}	performance of variety a in mixture with variety b
Y_{ba}	performance of variety b in mixture with variety a
Y_{bb}	performance of variety b in pure stand
Z_{ab}	proportion of inter-crop area initially allocated to variety a
Z_{ba}	proportion of inter-crop area initially allocated to variety b

1 INTRODUCTION

1.1 Background

Sometime in November 1987 the anthropologist Paul Richards brought Malcolm Sellu Jusu, a rice breeder, an interesting rice sample from Kamba, a Temne-speaking village about 10 km from the national Rice Research Station at Rokupr. Kamba lies on an old (and more or less motorable) trade track to Barmoi on the Little Scarcies rivers, and certainly could not be described as remote. Villagers often made the trek to Rokupr wharf daily to buy and sell produce, passing right by the gates of the research station. Richards was working in Kamba because he was carrying out a national study of the impact of improved rice varieties, and had found a 1967 report in the Rokupr files by the anthropologist David Gamble about the introduction of an earlier improved upland rice variety, *Anethoda*, in Kamba. The variety had failed and Gamble suggested people had been deterred from visiting Rokupr-managed on-farm trials in the village for fear of being accused of witchcraft. Richards wanted to follow up the *Anethoda* story 20 years later.

He records that some of the older farmers he talked to remembered the *Anethoda* trials, though they claimed the variety failed because it did not grow well, not because of witches (Richards, pers. comm.). The Rice Research Station withdrew the recommendation a few years later because *Anethoda* lacks resistance to blast, a major disease of upland rice in Sierra Leone. "This led the conversation in the direction of whether the farmers had other Rokupr releases they liked better. Yes, they said, and started to talk about one variety in particular, a rapid-growing, red-skinned, small-grained variety they called pa *tiri mont*, highly valued for its good taste and filling properties (it keeps long in the stomach, they said)." (Richards, pers. comm.).

Knowing that "pa" is the Temne noun-classifier for rice (and the small-grain millet *Digitaria exilis*) Richards concluded "tiri mont" was in effect English "three month". Farmers explained *pa three month* ripened in about 90-100 days. An "English" name might be expected in a research release.

But was the variety in fact a Rokupr release? The plant had many of the morphological characteristics of one of the native African Rices of the region (short ligule, simple branching of the panicle, small pear-shaped grains with red bran). Richards had already ascertained that Kamba farmers still grew an unusually large proportion of low-yielding but hardy African Rice varieties (40 per cent of all rice planted according to his surveys) and that this was related to high population, reduction in fallow interval and poor, weedy soils (Richards 1997). African Rice and "hungry rice" (*Digitaria exilis*) were making something of a comeback among local farmers with little money for fertilizer.

Knowing that Jusu was particularly interested in African Rice (*Oryza glaberrima*) Richards collected samples and visited Rokupr. Jusu was quickly able to confirm that *pathree month* indeed had some morphological features suggesting *O. glaberrima* affiliation, but that it could not be a station release (as the people of Kamba insisted). An earlier suggestion to work on O. glaberrima made by the Station Director. Jordan, in the 1950s had never been followed up. Thus there were no releases. One suspicion was that *pa three month* might have been once planted in a Rice Research Station observation trial and discarded, at which point it might have been rescued by one of the Rokupr labourers, many of whom come from surrounding villages.

Surprised by local enthusiasm for the variety, Richards tracked *pa three month* across Magbema Chiefdom, and found it widespread in areas with the poorest soils. As he reports

(Richards pers. comm.) "Everywhere it was described not as an age-old African Rice, but as a recent innovation. I took a small sample of the seed to central Sierra Leone, where it was eagerly seized upon by farmers, and in two or three years spread over a radius of some 25 km. from Mogbuama". [a long-term field work site in Kamajei Chiefdom, cf. Richards 1986]. It was later bought by relief agencies working in Pujehun District for distribution to farmers displaced by fighting in the Sierra Leone civil war in 1991. It was highly welcomed - praised for its speed and hardiness, when an evaluation study was carried out in 1992 (Richards & Ruivenkamp 1997).

Richards (pers. comm.) continues: "*Pa three month* had all the characteristics of a successful innovation. And yet - seemingly - it was an African Rice. African Rice is indigenous to the West African region, domesticated perhaps two or three millennia BP in the Upper Niger basin. Where has *pa "three month"* been all those years? Or is it, in fact, a "new" rice?"

For some years at Rokupr Jusu had been in the habit of noting some entries in the station germplasm collection as "intermediate" in morphology between *Oryza sativa* and *O. glaberrima*. This raised the question whether or not such "intermediate" types had arisen as inter-specific hybrids.

Jusu, Richards, Mondeh, and Longley then proposed (in 1990) an investigation into the possibilities of improving *O. glaberrima*, bearing in mind the needs of small-scale farmers working the poorest soils in northern Sierra Leone. At times Rokupr research station itself ran out of fertilizers for experimental work, and Jusu had noticed in work with a soil scientist colleague that the only varieties to survive lack of fertilizer on weed-choked upland experimental sites were *O. glaberrima* types, or the farmer varieties listed as "intermediate" types (Monde *et al*, 1991).

In establishing links for this proposed study Jusu and Longley traveled to the Republic of Guinea. In Guinea we met a French expert who advised us against any such initiative, and especially that it might be possible to hybridize *O. sativa* and *O. glaberrima*. He noted that the French had tried and failed for years, due to sterility barriers.

Richards then wrote to the distinguished British tropical plant breeder Norman Simmonds in 1991. Simmonds offered rather different advice. "Never say never" given enough time and opportunity, where broad out-crossing is concerned.

Encouraged by this second response, the team then developed and submitted a proposal for collaborative research on the topic to the European Union.

In 1992 the proposal was rejected as scientifically uninteresting and unimportant for agricultural development.

Fortunately, however, colleagues at the West African Rice Development Association (WARDA), to whom the proposal had been shown, were not so easily deterred, and were able to propose their own program, with Japanese funding assistance, to look again at the possibilities of hybridization of the two rice species.

WARDA has since been able to overcome the sterility barrier through back-crossing and embryo rescue, and new and promising hardy inter-specific hybrids are at an advanced pre-release stage (Jones et al. 1997).

Meanwhile Jusu reorganised his own research plans around the idea of work on the origin and significance of *pa three month*, as a possible instance in which the WARDA break-through had been anticipated by farmers. Richards moved to Wageningen in 1993, and the research project now reported in this thesis began to take shape.

1.2 The purpose of the present study

With WARDA having taken up the *O. sativa* x *O. glaberrima* hybridisation work it now seemed more important to ask "what is the general significance of *pa three month* and other hardy rices developed under farmer selection?".

Whatever its origin, the apparent local success of *pa three month* is apparent, where varieties like *Anethoda* failed, tells us something about the kinds of rices low-resource West African rice farmers are looking for. Of releases from RRS since c. 1965 the main successful releases are pure-line selections from local varieties (e.g. ROK 3, ROK 16, ROK 17) or crosses with local material in their parentage. Very little material of IRRI provenance has succeeded in Sierra Leone (Lipton, Pain & Richards, 1995).

But if *pa three month* is a product of local selection what would that tell us about the processes upon which farmer selection depends?

That rice farmers do select their planting materials, and that the products of selection often approximate true lines, has been proposed for low-resource farming systems in Sierra Leone (Longley 1999; Richards 1986; 1995; 1996a; 1996b; 1997). But what can we say about geneflow, without which farmer selection would tend to experience diminishing returns?

Dennis (1989), working in Thailand, reports that "innovative" farmers in districts where Green Revolution varieties are present maintain traditional selections alongside modern varieties, and every few years turn over their selections to try different rices. Dennis argues that these Thai rice farmers are aware that selection and maintenance of varieties is not by itself enough to maintain adaptability and productivity. There must also be genetic diversity. Using isozyme markers he establishes that there is less genetic diversity among the rices cultivated by "traditional" hill tribe cultivators than in the more accessible areas penetrated by the Green Revolution releases. IRRI releases have here acted as vehicles to enrich local gene pools. Although Dennis does not deal with the point directly it seems that, potentially, local selection is boosted by the introduction of exotic material, and enhanced possibility for out-crossing between different bodies of material.

It is this kind of consideration that lies behind a now quite sizeable body of literature (reviewed below) advocating a new kind of relationship between crop scientists and farmers in difficult environments - the idea of participatory crop improvement.

The present thesis is intended as a contribution to that field.

The main issues considered include:

- how close or far apart are breeders' and farmers' conceptions of the appropriate ideotype for upland rice in difficult conditions in North-western Sierra Leone (a region of poor soils and some population pressure, experiencing desiccation as a result of vegetation cover and run-off changes)?
- how do different groups of farmers select, or otherwise manage, their rice planting materials?

- what is the morphological evidence for "intermediate" rices (hypothesised as farmer-managed innovations from spontaneous hybridisation between African and Asian Rice)?
- what are the opportunities for geneflow under farmer management of rice varieties?

The focus on farmer selections in the *O. glaberrima* species, or selections morphologically "intermediate" between *O. glaberrima* and *O. sativa,* is a common thread running through the various chapters.

Why is this kind of work important? Understanding farmer selection, and the processes affecting geneflow through which farmer selection adds value, might only be important as a way of understanding, historically, how farming populations have slowly improved their crops over the centuries. Some would argue that, at best, participatory improvement is currently relevant only to a diminishing number of farmers in very harsh subsistence environments, who sooner or later will come within reach of the market and modern plant improvement methods. Even that might be enough to justify interest in the approach as a medium-term strategy at Rokupr Rice Research Station, a small national facility in what is now the world's poorest country, according to the UNDP social development index. Rokupr's clients include some of the most disadvantaged rice farmers in the world, now resettling after nine years of brutal civil war. If they prefer hardy *O. glaberrima* varieties, or *O. glaberrima* x *O. sativa* hybrids, because they give a moderate but secure yield in low-input conditions, and if they can develop these varieties through their own efforts, boosted by breeder support (e.g. releases from the WARDA hybridisation programme) then we should try and assist.

But there are also larger scenarios where farmer selection might once again be called into play. Currently, IRRI considers that F_1 hybrids in rice may be the way forward. F_1 hybrids for rice are not as attractive to the commercial sector as F_1 hybrids in maize, but the Chinese have shown that F_1 hybrids for rice are feasible where there is a strong state sector. F_1 hybrid seed production is a specialist activity and farmer selection skills become a thing of the past. But an alternative technology scenario envisages the development of approaches to plant improvement through control of apomixis (embryo formation without fertilisation). Apomixis applied to rice as public interest research might lead to a situation in which breeders make large numbers of crosses and fix them through apomixis leaving it to farmers (no longer dependent on natural geneflow) to sort through the candidate releases and find which ones work locally. The apomictic seed would reproduce true to the maternal line indefinitely. In contrast to F1 hybrids parental homozygosity is not necessary, so that any early introgression progeny or intermediate hybrid is a potential parent - giving farmers a potential role in both parent and progeny selection (S. G. Hughes, Per. comm.). Apomixis would emphasise farmer selection skills rather than rendering them redundant. The 1998 Bellagio Declaration by a group of apomixis researchers suggest ways of developing apomixis and making it freely available to poor farmers beyond reach of the market for seeds. If such developments take place then findings about how, and with what purpose, farmers manage and select among seed types will prove important.

1.3 Chapter outline

Chapter 2 introduces small-scale rice farming in North-western Sierra Leone (the research area), considers the history of rice farming and rice research in the area, discusses ethnicity and the history of slavery as factors in shaping the attitudes of different ethnic groups to their rice varieties, and outlines the main production ecologies for rice farming in the region.

Chapter 3 looks at how farmers in North-western Sierra Leone manage seed. It discusses the organization of farm labor, farmer seed selection and development activities, the role of gender in seed processing, and considers all the stages in seed processing through harvesting into storage. The chapter concludes with comments on farmers' knowledge of varieties and soil types, and information about the original sources of farmer varieties.

Chapter 4 reports the results of a number of experiments to discover what farmers consider important in selecting rice varieties. Farmers were invited to make selections from a large number of farmer varieties, station release and pre-release materials (including WARDA inter-specific hybrids) on three village trial sites. What farmers chose and why is subject to analysis.

Chapter 5 submits a representative collection of farmer varieties, including varieties of *O. glaberrima* and *O. sativa*, together with "intermediate" types, research releases and advanced lines, to detailed morphological analysis using multivariate methods.

Chapter 6 analyses one aspect of farmer varietal management in detail. In preliminary fieldwork it was discovered that Limba farmers in one of the case-study chiefdoms (Tonko Limba) took a rather rigorous approach to rogueing (see Chapter 3). Limba farmers generally maintained very pure varietal stands. But the rice plots of neighbouring Susu farmers were often rather mixed. In a parallel anthropological study, Katherine Longley (1999), working with Susu farmers, discovered that farmers sometimes chose to interplant different rice varieties in the same field. According to the farmers there were definite advantages in this practice. The chapter submits this farmer practice to experimental scrutiny, with ratherstriking results. SA certain degree of co-adaptation appears to take place, supporting farmer claims.

Chapter 7 focuses on flowering in rice, as the crucial "window of opportunity" for natural outcrossing.

In chapter 8 the general significance of the research is discussed in a short conclusion. Low-resource farmers in difficult environments need international germplasm and local selections. National programmes cannot be regulated by the IRRI ideotype alone. The kind of farmer selection experiments described in the thesis need to be institutionalised, so that breeders and farmers work in partnership. Potential biotechnology developments may make farmer selection and experimentation more, not less, valuable than in the past.

2 BACKGROUND TO THE RESEARCH AREA AND TO THE HISTORY OF RICE DEVELOPMENT IN SIERRA LEONE

The purpose of this chapter is to set the scene for discussion of management of rice genetic resources by farmers and researchers in the case study region (three chiefdoms in Kambia District, North-western Sierra Leone).

2.1 General Background

Sierra Leone is a small country in West Africa with a total land area of 72,000 km^2. It is located between 7° and 10° N and 10° and 14° W and lies along the Atlantic coast between the Republic of Guinea to the north and north-east, and Liberia to the south. Its climate is tropical with high relative humidity of 95 - 100 % and rainfall ranging from 2,000 mm in the far north to 5,000 mm in the coastal area (Birchall *et al.* 1980) (Map 2.2). The population of the country was about 4 million before the war started in 1991.

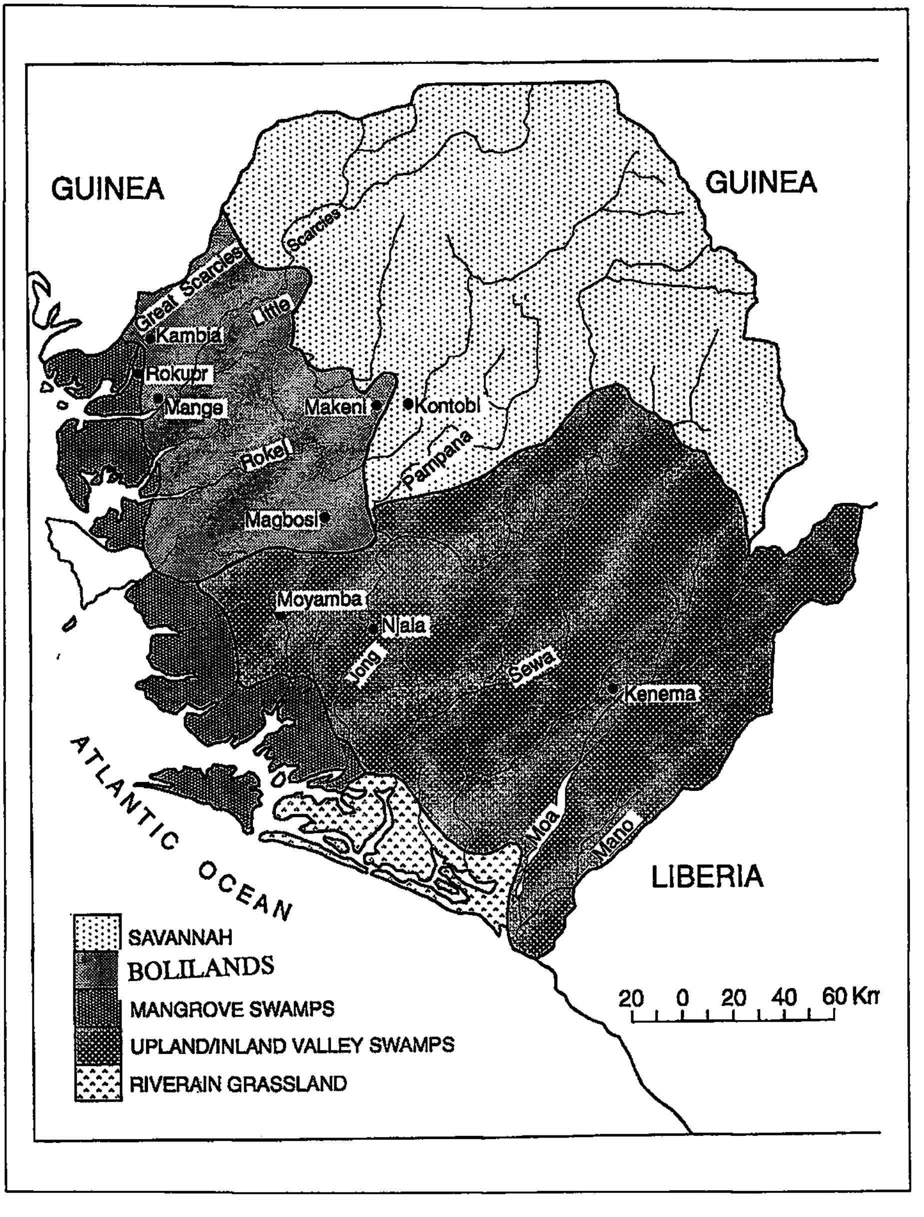
Rice is the staple food and therefore the most important crop in Sierra Leone. The annual per capita consumption of 116 kilograms ranks this country 13th in West Africa and 27th in sub-Sahara Africa in terms of cereals consumption. However in terms of the share of cereals in total calorie intake, Sierra Leone ranks 4th and 13th respectively in both regions. It has the highest percentage in sub-Saharan Africa in terms of the contribution of rice to the total calorie intake. In short, Sierra Leoneans are highly dependent on rice consumption to meet their daily energy requirements. This places in context the importance the nation attaches to rice as the major staple crop (M.A.F.E.,1994).

Table 2.1: The basic data on the agricultural sector in Sierra Leone

INDICATORS	WORLD	WEST AFRICA	SIERRA LEONE
Population (million)	5,505	210	4.6
Cultivated land (x 1000 ha)	1,443,999	62,377	540
Agric. Pop. (million)	2,367	1367	2.8
Agric Pop. as % of Total pop.	43	65	61
Agric. Labour Force (million)	1,088	56.3	0.91
Fertiliser Use (kg ha^{-1})	87.0	7.0	3.0
Improved Varieties Use (%)	26.0		5.0
Farm Power Tractor (1000 ha^{-1})	18.0	2.0	1.0
Area per capita (m^2)	2,624	1,297	1,173
Agric. Labour Force as % of population	20.0	25.0	65.0

Source: FAO Country Tables 1994 – Basic data on the Agricultural Sector.

Up to 75% of the total land area is arable. It is divided into five major agricultural ecologies for rice cultivation, viz. uplands (70%), inland swamps (17%), mangrove swamps (9%), bolilands (2%), and riverain grasslands (2%) (Map 2.1). Some of these ecologies are confined to specific regions of the country like the mangrove swamps, which are situated in the north-west and south-west bordering the Atlantic Ocean; the riverain grasslands occur in the south-western flank of the country. Note: the uplands and the Inland Valley Swamps are scattered all over the country.

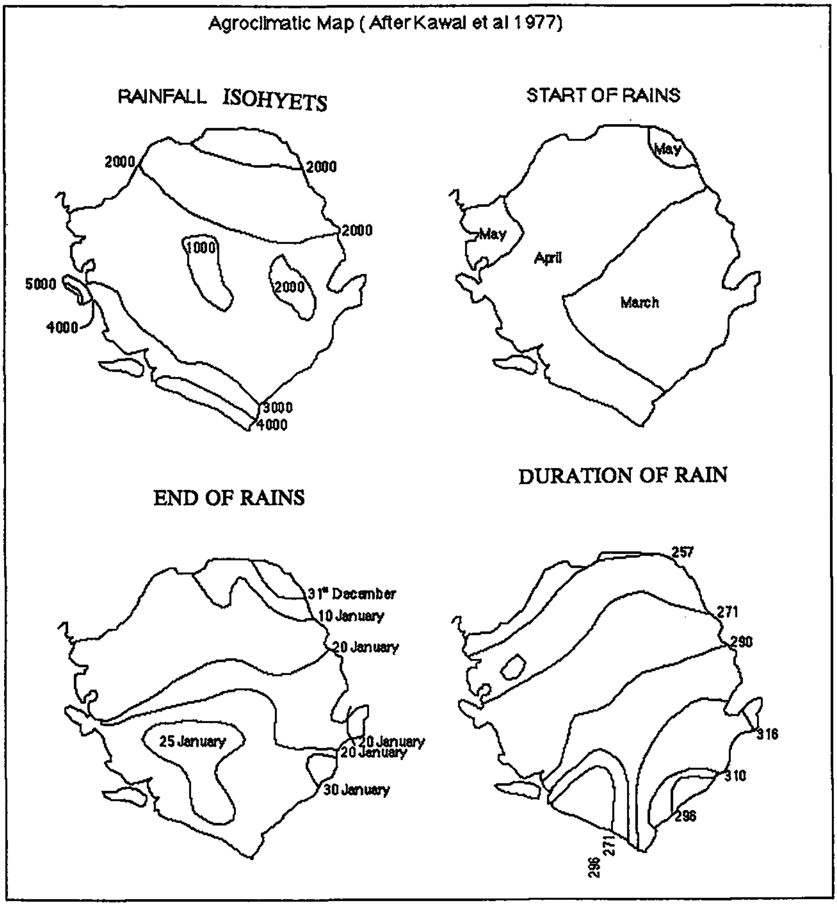


Map 2.1: Map of Sierra Leone showing the rice growing ecologies.

From 1960 to 1975 production of rice increased through the expansion of cultivated land area (44%), and increases in yield (40%). In 1975 Sierra Leone experienced net self-sufficiency in rice. However the estimated 630,000 tonnes of paddy produced in 1978/79 declined to 500,000 tonnes in 1983/84. In the subsequent decade production fell drastically while per capita consumption climbed to one of the highest in West Africa (WARDA, 1994). This problem, compounded by a 2.3% annual growth rate of an estimated 4 million inhabitants, created a rice deficit of 185,000 tonnes in 1985 and close to 296,000 tonnes in 1991 (Rogers, 1991). During the period under review total imports continued to be dominated by rice. Sierra Leone spends its meagre resources to import rice to the tune of $40 million annually. One reason is a concentration on alluvial diamond mining at the expense investment in agricultural research and development.

Up to 70% of the population is rural small holder farmers who cultivate rice mixtures with other cereals, roots and tubers, and vegetables.

Farming practices are based on hand tools, and planting of low yielding but locally adapted varieties. Farmers produce rice first for subsistence and sell any surplus. Generally, rice production technologies vary from one eco-zone to the other based on soil type and available moisture during the cropping season.



Agroclimatic Map (After Kawal et al 1977)

Map 2.2: Map of Sierra Leone showing the agro-climatic features

Kambia District in North-west Sierra Leone (the field work locale) has an estimated population of 186,231 with a growth rate of 1.66 per annum (World Bank, 1993). The major occupation of the people is agriculture employing over 75% of the population.

The rainfall pattern is monomodal with the year distinctly divided into rainy and dry seasons. The wet season starts in April and May (Map 2.2b) and ends December to January (Map 2.2c). The amount of rainfall ranges from 5000 mm along the coast to 2000 mm in the far north of the district (Map 2.2a). The duration of the rainy season varies from approximately 215 to 271 days (Map 2.2d). Average temperature ranges from 19.7 °C in the harmartan in January to 32.3 °C at the peak of the dry season in March and the relative humidity from 50% in March to 90% in August.

2.2 Historical Background on rice and rice research in the area .

Rice cultivation is knowledge intensive (Bray, 1986) and requires a sophisticated knowledge of the terrain. Soil types and the properties of different types of rice and the type of rice growing practices in the research area are related to climatic factors and features of social organization. The evolution of rice culture in West Africa is independent of the history of the development of rice cultivation in Asia (Littlefield, 1981). Knowledge of rice production in West Africa has several focuses. These include the Niger basin of the Upper Niger and the western extension of the upper Guinea forest block (Table 2.3).

According to Porteres (1976) African Rice (*O. glaberrima*) was first domesticated in ancient times in the Upper Niger basin and spread coastwards, where it began to be replaced by Asian Rice (*O. sativa*) from the 16th century (though major displacement seems not to have occurred until the dawn of the colonial period in the 19th century.

Kambia District - the focus of this study - lies at the western extremity of the Upper Guinean forest formation in West Africa, only a few hundred kilometers from the headwaters of the Upper Niger. The district extends inland from the estuaries of the Great and Little Scarcies rivers, well-known for coastal wetland rice cultivation in the 19th century. But the main emphasis in this study is with the inland portion of Kambia District where upland (or dryland) rice farming is the predominant focus, supplemented by wetland cultivation in inland valley swamps, often at the foot of catenary sequences planted to a succession of dryland rice types.

Rice farming in Kambia District appears to owe something historically to the presence of a major inland trade route, passing from coastally-oriented trading terminuses such as Port Loko (in Sierra Leone) and Forecariah (in Guinea) to the Fouta Djallon highlands in Guinea, and beyond into the Upper Niger and Senegal River basins (Moore-Sieray, 1988). Along this route, dominated by traders speaking Mande languages, various influences spread, including Islam, and technological innovations, both from coast and interior. But commercial rivalries also promoted war, and these wars resulted in large numbers of captives, sold as slaves or kept to work on farms.

Rice cultivation in the vicinity of long-distance trading routes has long been connected to the institution of slavery in West Africa. The emperor of Songhai, along the Niger, for example, possessed hundreds of slaves devoted to the cultivation of rice (Littlefield 1981).

The Sierra Leone coast was no exception (Rodney 1970). A slave trader resident two years in this region estimated that three-fourths of the population where he stayed was in some form of local servitude. Many of these people were employed in cultivating land and were entirely subject to their master's will. He reported that slaves brought from the interior before the beginning of the rainy season were employed on plantations of the coastal people before being sold to Europeans or were transferred locally from one master to the other after the rice had been planted (Littlefield 1981).

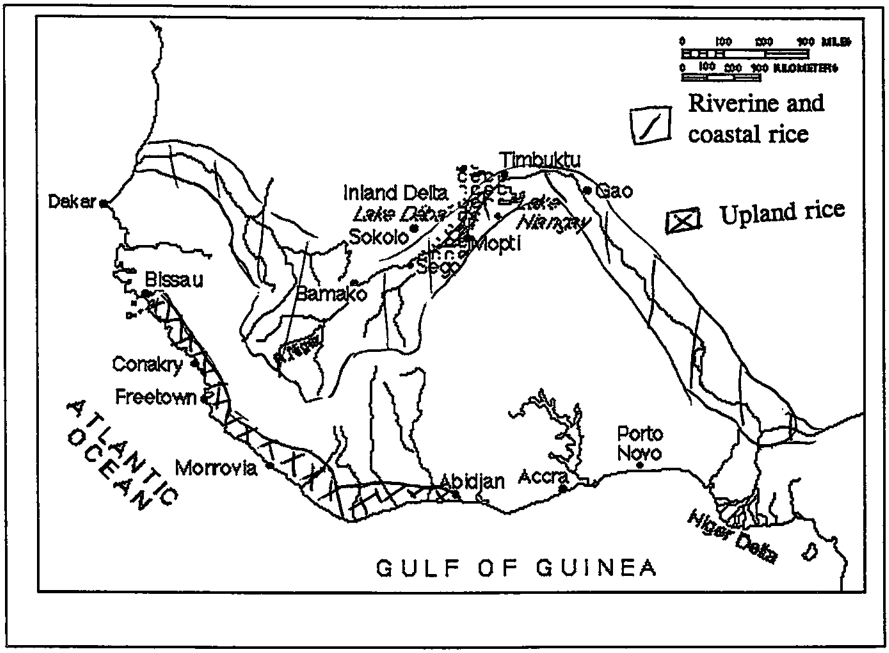
The availability of slaves from the region, and their knowledge of rice agriculture, was well-known to Carolina planters, who had a preference from slaves from the West African Coastal Rice Zone, from Cape Mount to The Gambia (Littlefield 1981).

The issue of who were rice slaves and who remained free has consequences in a region like Kambia District even today.

The present study looks at rice cultivation in three chiefdoms in upper Kambia District. The Susu of Bramaia Chiefdom settled as frontiersmen, and slavery was very important in the establishment of Susu communities. The Susu were originally granted land by local Tonko Limba chiefs, but gradually extended their power north and south of Kukuna, (the Susu commercial capital in the 18^{th} century) along the Great Scarcies River,as a key element in the Futa Djallon-Scarcies trading corridor. A considerable proportion of the Susu community was made up of slaves, and slaves opened up new land and may even have pioneered agricultural technologies. The Susu were thus perhaps fully incorporated into the regional trading economy even prior to the arrival of Europeans on the coast.

The Temne of Magbema Chiefdom were also highly involved in the regional slave trade. As among the Susu, a "big man's" acquisition of resources was based on the labour, skill and productive capacity of his household dependents. Slavery and polygynous marriage were the options to increase the number of dependent labourers. Like the Susu, Temne chiefs opted for a heavy involvement in regional trade to achieve local political advancement (Howard 1972). When British influence drew near, and Freetown opened up as a nearby market for food, a number of Temne trade-oriented chiefs shifted their interest to opening up mangrove swamps behind the coast for rice farming, drawing upon the labour of hundreds of household dependents (a mangrove swamp requires four years of heavy work before it starts to yield rice). This mangrove zone became the rice bowl of Sierra Leone from the late 19th century, One part of the site on which the Rice Research Station was established, Roboli, was still in effect a slave town, even as the station was being opened in 1934.

By contrast, the Limba of Tonko Chiefdom tended to remain more introverted, turning their backs on (or being excluded from) regional trade and sticking to subsistence agriculture. They appear to have been raided for slaves, or maybe their introversion stemmed from being a refuge from commerce, which equated with slave trading at the time. The Limba did have some slaves, but on a much smaller scale (Moore-Sieray 1988). After the slave trade was abolished, Limba slaves became completely absorbed into Limba society, and it is difficult to differentiate former slaves and owners in a Limba community. Even today, the Limba are distinctive as an ethnic group by their degree of concentration on classic "subsistence" activities such as upland rice cultivation and palm wine tapping.



Map 2.3: Map where the West Africa Rice Zone (WARZ) in the 16th Century

Although British law outlawed the international slave trade in 1807, it took many years before slavery was abolished in Sierra Leone, especially along the Scarcies Rivers. Slaves formed a significant labor force among the Susu, and up to 33% of the Susu were slaves at the time of manumission in 1928 (Thayer, 1982). The use of communal labor by chiefs continued until after the riot of 1955-57 in the Northern Province directed mainly against chiefs and tribal authorities and their abuse of power (Cartwright, 1978).

It is therefore clear that the agricultural development of the research area in terms of rice production was heavily dependent on the resources acquired from the Futa Djallon - Scarcies trade corridor. Slaves were the main labor force in developing the mangrove swamps and other rice growing ecologies in Kambia District. The rice produced in this area was sold to slave ships that visited the navigable Scarcies estuaries in the 17th to 19th centuries. The technology of rice production may have been transferred from the upper part of the trade route or developed independently by the slaves and big men along the trade route. We are not here dealing today with an isolated and backward rice technological system but one open to commerce and large distance movement of labor, tools and planting materials over a long period of time.

Historically, knowledge of swamp rice cultivation in this area is among the oldest in Sierra Leone and in the early 1920, local farmers were taken to other parts of Sierra Leone, to teach farmers there the technique of lowland rice production. Slaves were used up to the 1920s to clear the mangrove vegetation and the virgin forest in the uplands where rice and other crops were cultivated.

The next section will highlight what followed after the abolition of slavery in the hinterland of Sierra Leone leading to the establishment Rice Research Station (RRS), and to importance of technology development and adoption in Sierra Leone. This has involved both interaction among farmers and farmers and between RRS. Some aspects of this interaction between farmers' practices and development initiatives of the Government of Sierra Leone will now be discussed.

2.3 Rice Research in Sierra Leone

Research on rice was initiated by the food shortages of 1919 and emphasized after famine in 1940, then again stimulated by the diamond boom from c.1955 (Richards, 1986). The Sierra Leone Government had to import large quantities of rice to feed the population at all these moments. Policy makers attributed rice shortages to the slow rate of change of farmers from primitive to modern agriculture. They particularly blamed cultivation of rice in the uplands, where yields were generally low, and suggested the intensification of swamp rice production via technology transfer drawing on examples from the Asian experience, to reduce pressure on uplands, which could then be released for production of other crops (particularly oil palm).

The poor rice harvest in 1918, which led to public disorder in 1919, was due to the early rains in March, which prevented the burning of upland farms. The influenza out-break in September 1918 coincided with the bird-scaring period and harvesting of rice on upland farms. This reduced the supply of labor for these activities. Upland rice farming in Sierra Leone uses a "slash and burn" method with a well-defined calendar of operations related to rainfall pattern. The land preparation for the upland starts in February and the farm is ready for burning between March and April in the South and East and this period can extend up to May in the North where the rains start late. The farm is burnt to reduce biomass so that farmer can easily clear the debris from the land before seeding and to release phosphorus. Early rains between January and March when the farmlands are brushed and are not ready for burning would therefore increase labor input in land preparation. The labor requirement is also high during bird scaring between flowering and maturity, and at harvest. Any labor crisis at the time of flowering and harvest (between August for early maturing rice varieties and November for late maturing types) will increase the chances of rice been eaten by birds and rodents. These are the agro-technical factors behind the 1919 rice crisis.

2.3.1 Technology Transfer

2.3.1.1 Asian options for technology transfer

When public order was restored after the food riots in 1919, the colonial administration started addressing the problems that led to the poor rice harvest and the famine. The first option was to replace upland shifting cultivation, which was seen as primitive technology. But even the policy of the colonial government to transfer the head-quarters of the Department of Agriculture from the capital to the interior (Njala) in 1912 for the purpose of conducting research on major crops and to transfer technologies to farmers, did not avert famine (the joint product of a universal and a local event, i.e a pandemic and early rain). Governor Wilkinson in 1920 suggested that the agricultural policy of Sierra Leone must shift from upland to river-basin irrigation. The headquarters for the Department of Agriculture at Njala was not suitable for research in irrigated rice. The idea of establishing rice research in the Scarcies estuary where wetland rice production was already well established and from where Freetown obtained the bulk of it rice supplies became effective. Governor Wilkinson decided to bring two native agricultural instructors from India to train the protectorate natives in the technical details of rice production by simple irrigation methods (Wilkinson, 1920). A. C. Pillai, a senior agricultural instructor from the Department of Agriculture, Madras, was posted to the Scarcies area to investigate ways of improving local wetland cultivation practices. A Mr. Naik, also a Madras rice cultivator, assisted him. Pillai (1921) suggested the use of natural rainy season floodwater, a method already well-established by native and land-lords using slave labor in the late 19th century.

He also suggested that agricultural research should be conducted for long-term solutions and that the Scarcies method should be extended to farmers in other parts of Sierra Leone, using local expert farmers as trainers for immediate alleviation of the problem. By 1929, soon after the abolition of domestic slavery in the Sierra Leone hinterland, the method of wet land rice cultivation was being demonstrated in all districts of central Sierra Leone.

2.3.1.2 The indigenous alternative to technology transfer

From the time simple research on rice work started in Sierra Leone early in the century, the option of adapting indigenous knowledge of farmers to solving ecological and social problems has been viewed with some skepticism by both the colonial administration and by policy-making bodies in the post-independence era in Sierra Leone. There were, however, several instances where local knowledge was found to be highly successful. Glanville (1938) rightly concluded that local farmers' initiatives were highly responsive to the technological challenges posed by swamp development in the Scarcies area in the 19th century. The transfer of local rice production techniques from the Scarcies area to other wetlands between 1920 and 1930 further demonstrated the importance of the indigenous knowledge of native farmers. Glanville proposed assessing farmers' methods, before seeking to improve on local knowledge. A Rice Research Station (RRS) on the Great Scarcies at Rokupr was established in 1934 and researchers in the early years used local farmer's varieties for mass selections and multiplication. Researchers then distributed the pure seed to farmers through a seed exchange scheme. Farmers were advised to carry out purification of their varieties in their fields but they already had much local knowledge of the topic, especially in the Scarcies estuaries. One report described farmers as being enthusiastic to test any new variety (Richards, 1985).

2.3.2 The agricultural research base

In the 1920s and 1930s, research on Sierra Leone soils, insect pests and diseases was first developed on a sound footing. The socio-economic context within which local agricultural practices were carried out was discovered to be constrained by labor shortages. The farmers were, therefore, reluctant to adopt labor intensive methods in rice production, and this had been earlier interpreted as evidence of ignorance and indolence on the part of a backward population. The other major finding was the indebtedness of the farmers prior to harvest and importance of litigation after harvest (Mackie *et al* 1927). A report on this problem carefully stated local farmers' difficulties and cited the ecological and social problems that prevented Asian technologies from working in Sierra Leone. In the 1930s Glanville visited Madras and Ceylon where conditions were similar to those in the Scarcies area, and on his return recommended the importance of in-country rice research (Richards, 1986). He drew a conclusion that a vigorous rice improvement program along similar lines to those in India and Ceylon for Sierra Leone might yield good result. But in the interim, Glanville encouraged rice farmers to make mass selections on their farms. Some farmers already possessed good strains (Glanville, 1933, 1938). After the Rice Research Station (RRS) was finally opened a choice of developmental strategies for rice development in Sierra Leone, began to be available, though the research-based approach Glanville anticipated in the long term did not become a reality until the later 1940s. One problem was the variability of mangrove soils in the main research site. Within-plot variance was so high as to invalidate all trials results in the first ten years.

2.4 Research Work at the Rice Research Station (RRS) 1934 to 1994

The RRS at Rokupr was established in 1934 to increase the production of rice in the Scarcies area, in order to reduce the pressure on the uplands, to help saturate the local market with rice, and to produce surpluses for export.

2.4.1 The specific objectives of RRS in 1934

- The objectives were to
- select/develop high yielding rice varieties tolerant to saline water in the mangrove swamp,
- develop improved cultural practices to increase production in the mangrove swamps,
- study the physical and chemical properties of mangrove soil,; and
- improve on the milling quality and marketing of rice.

All work was initially geared towards the mangrove swamp rice production zone in the Scarcies area downstream of Rokupr.

2.4.2 History, research activities and achievement

The RRS has a somewhat checkered history since its establishment in 1934. Between 1934 and 1953, the main emphasis was to acquire and screen as much local and foreign germplasm as possible and multiply and distribute successful selections to farmers. Many local varieties were collected in all the rice growing ecologies (mangrove swamps, inland valley swamps, uplands, deep flooded areas, bolilands and riverine grasslands) (Map 2.1). The activities of the station stagnated because of the Second World War (1939 to 1945).

After the Second World War, RRS expanded in 1951 to cover the other British West African colonies (The Gambia, Gold Coast (Ghana) and Nigeria) It was retitled the West Africa Rice Research Station (WARRS). The mandate of the station was to conduct research in varietal improvement and to introduce swamp rice varieties with a view to increasing their distribution. Several important rice varieties were distributed to rice farmers in the region (WARRS, Annual Reports, 1953-1964). Other achievements included establishment of optimum time for seedling for transplanting after six weeks of nursing and a standard spacing of 20 x 15 cm for transplanting with 2 to 3 seedlings per hill, seed rate between 70 and 100 kg ha^{-1} in the bolilands and riverine grassland, timing and rates of fertilizer use, suitable pesticide, herbicide and insecticide application, date of harvesting after 100% flowering, and parboiling of rice to improve milling and nutritional quality during processing. The work on the chemistry of *Rhizophora* mangrove swamp soils was of path-breaking importance and established a global reputation for WARRS.

After the British West African colonies attained independence (between 1950 and 1964), WARRS ceased to exist. The name of the station remained, but the institution was integrated into the Faculty of Agriculture of the newly established Njala University College between 1964 to 1971. The station was made semi-autonomous in 1971, and was renamed the Rice Research Station (RRS). The mandate of the station was increased to cover rice research in the upland, inland valley swamps, bolilands, and riverine grasslands, in addition to the mangrove swamps. Research on other food crops was also included in the research responsibility of the Station.

Between 1974 and 1980, the United Nations Development Program (UNDP) supported the station in the area of Agronomy, Extension, Plant Pathology and training. The West African Rice Development Association (WARDA) also established a regional mangrove rice program at Rokupr to conduct research and development activities in mangrove rice (WARDA, Annual Reports, 1977-1988). The WARDA project was phased out in 1993 and was replaced by collaborative work under the Mangrove Swamp Taskforce Research Program. A European Union (EU)-supported project has also been conducting farming systems research, and research extension linkage activities, since the early 1990s.

Research undertaken especially between 1970 to 1985 was geared towards replicating an Asian-style Green Revolution with money from donor agencies tied down to specific research activities (RRS Annual Reports, 1934 - 1989). Several new rice varieties were introduced and hybridization work was carried out to introduce rare and valuable traits into well-established local varieties. Several high fertilizer-responsive varieties with resistance to diseases and pest were developed and released, to meet the need of the World Bank-supported Integrated Agricultural Development Programs (IADP) operating all over the country. In the uplands, drilling with a rolling injection planter at a seed rate of 80 to 100 kilograms per hectare was developed, and transplanting was recommended for the lowlands.

2.4.3 Sources and Uses of Rice Genetic Diversity RRS

The sources and management of plant genetic resources by RRS over the last 60 years of research has been through three phases:

During the first phase, germplasm collection, evaluation, and release of land races and introductions from other countries were the main activities. This went on from 1928, before the official opening of RRS, up to 1961. During this period several rice varieties were introduced from many rice growing countries in the World (Table 2.2).

In the second phase, the development of rice varieties for high input culture in line with the Green Revolution concept was emphasized.

The third phase was concerned to learn the lessons of the failure of the Green Revolution concept. Low-resource farmers in marginal areas in the country have not adopted Green Revolution varieties, as will be discussed later. Between 1971 and 1988, the station released 33 varieties intended for both high input and low input farming. Varieties ROK 3 (*Ngiema Yakei*) and ROK 16 (*Ngovie*) are both local upland varieties selected and released in 1973 and 1978 respectively and now the most common upland varieties adopted by farmers in the country. The varieties ROK 1 and ROK 2 released at the same time with ROK 3 in 1973, and ROK 15 released with ROK 16 in 1978, were foreign introductions selected by breeders but rejected by farmers.

Table 2.2: Dates and origin of foreign rice germplasm introduced via the Rice Research Station 1928 to 1956.

Year of rice germplasm introduction	Source of germplasm
1928	French Guinea
1934	Madras, British Guyana
1936	Burma, Hong Kong
1942	The Gambia, Ceylon, Peru
1945	Nigeria
1948	Portuguese Guinea
1949	Hungary, Eastern Pakistan, Portugal, Malaya
1950	Orissa, North Borneo
1951	Thailand
1952	Hyderabad, Nyasaland, French Sudan, Philippines
1953	South Africa
1954	Cameroon, Indonesia, Vietnam
1956	Zanzibar, Argentina, Tanganyika, Turkey, Java

Also a local variety Pa Wellington was successfully used with introduced variety SR 26 from Malaya in a hybridization program to develop ROK 4, 5, 8, 9 and BD2 for the lowland ecologies, especially the mangrove swamps. BD2 and ROK 5 are among the most widely adopted lowland varieties.

After 1971, most foreign introductions came from the International Rice Research Institute (IRRI) in the Philippines, The International Institute of tropical Agriculture (IITA), The West Africa Rice Development Association (WARDA), and other rice research program in the Consultative Group on International Agricultural Research (CGIAR) system. Some semi-dwarf varieties with IRRI parentage, such as ROK 11, 12 and 14, were developed for high external-input environments and required good water control, high rate of agro-chemicals and good cultural practices. These varieties were in line with the demands from IADPs at the time of their release in 1978. The IADPs were World Bank-funded vehicles to push the Green Revolution. By 1990 all had failed and had been closed.

From the earlier days RRS scientists have given at least some consideration to low-income farmers in varietal development program. This interest was continued somewhat against international policy advice, even during the period of the IADPs when the demand for high input varieties was at it height. As pure line selection from farmers' varieties, ROK 3 and ROK 16 are popular with low-income farmers. On-farm research over 65 years has emphasized the existence of large yield gaps between the on-station research results and what is obtained on the farmers' fields, especially for the fields of low-income farmers in degraded environments. To bridge this gap more attention is now being paid to understanding the indigenous knowledge of the farmer in terms of varietal selection and how farmers adapt varieties to varying environmental conditions. This resumes an emphasis strong in the early days and never entirely supplanted by the donor agencies even during the heyday of IRRI influence.

2.5 Government Efforts to increase Rice Production in Sierra Leone

With research results in place, the Government of Sierra Leone requested funds from several donor agencies to fund agricultural development in the country. From the early 1970s, several agricultural development programs were working in Sierra Leone to help farmers increase rice yield, especially in the lowlands. The government placed emphasis on rice self-sufficiency between 1961 and 1974. Despite government interventions the decline in rice production started at this time and continues till today. This owes much to the influence of mining on rural labor availability. Also, government wants more rice, but cheap rice, to feed mine laborers and political clients. The government used it control over foreign exchange rates to fund cheap rice imports, thus undermining the efforts of the farmers. Even so, between 1960 and now, considerable efforts were made to increase rice production through the use of improved rice varieties from Rokupr. The most important instances are discussed in the following sections.

2.5.1 Integrated Agricultural Development Programs (IAPDs)

These World Bank-funded projects were meant to assist small-scale farmers in developing countries to increase their productivity and income, and therefore improve rural livelihoods. The main features of the IAPDs in Sierra Leone were that they were scattered all over the country, covered limited geographical areas, and were financed mainly by foreign concessional loans and grants. They provided a high extension agent to farmer ratio; offered improved agro-chemicals on credit to farmers; provided low interest development and seasonal loans to finance farmers' operations, including hiring of labor; made provision for infrastructural items such as feeder roads and village wells, and utilized mainly expatriate personnel for senior management positions (Spencer, 1982).

The main focus of the IAPDs was the development and improvement of the cultivation of the inland valley swamps so that by 1986 over 12,000 hectares of inland valley swamps have been brought under improved cultivation in the various IAPDs all over the country. The IAPDs met their target in terms of area under improved rice cultivation. They failed however to meet their target in terms of yield increase and profitability of the investment to the farmers adopting the improved practices. They also did not provide for the sustenance of the practices after the projects phased out (Spencer, 1982). The demand for improved rice varieties increased in the 1970s and 1980s when the IAPDs were active in the country. When funding of projects was terminated, farmers who were working with projects were not able to purchase the high inputs formerly provided by the project. Water control, for example, in most inland valley swamps failed because design, layout and construction were of inadequate standard. Many swamps quickly dried out for lack of maintenance, leaving them worse than they were before they were developed. The promise of double cropping was unattainable (Richards, 1986).

Labour productivity in the developed swamps is often not better than in upland rice farming where farmers grow as many crops as possible on the same land and at the same time.

Table 2.3: Donor agencies, year of establishment, area of coverage and Activities of Integrated Agricultural Development Programs (IADP) in Sierra Leone Between 1992 and 1985

Project (HQ LOCATION)	Donor Agency	Years active	Area covered	Main activities
Eastern Project (KENEMA)	IDA	1972 – 82	Eastern Province	Tree crops and swamp development
Bo-Pujehun Project (BO)	GTZ	1980-85	Bo and Pujehun Districts	Swamp development
Magbosi Project (MILE 91)	IFAD	1980-85	Tonkolili and Kono Districts	Swamp development and upland crops
Moyamba Project (MOYAMBA)	ADB	1978-84	Moyamba District	Swamp development
Northern Area Project (MAKENI)	World Bank	1976-79	Bombali District	Swamp development
North-western Project (PORT LOKO)	EDF	1980-84	Port Loko District	Swamp development
North-western Project (KAMBIA)	EDF	1980-90	Kambia Distrct	Swamp development and tree crops
ACRE Project (NJALA)	USAID	1978-82	Njala and other areas	Adaptive Crop Research and Extension
Koinadugu Project (KABALA)	EDF	1981 - ?	Koinadugu District	Swamp development and vegetable production
ASSP I and II	World Bank	1985 +	MAFE	Re-organization programmme
SMP FREETOWN	GTZ	1975	Whole country	Seed Multiplication
Taiwanese & Rep. of China VARIOUS AREAS	Chinese governm ents	1960	Kenema, Bo, Mange, Makale, Ogoo Farm (Freetown)	Swamp Development
Work Oxen Project	ODA	1980-90	Njala	Swamp Development
Certificate Training Center (CTC), NJALA	ODA	1975-90	Whole country	Backup training in agricultural extension

The reasons for the failure of the Green Revolution in the country are various: lack of continuity of inputs for farmers, poor construction of the swamps, and the comparatively high labor inputs in water controlled swamps as compared to the uplands can all be cited. Farmers' health due to water borne disease was another hindrance in swamp rice production. But perhaps especially the Green Revolution failed because it made the false assumption that because Sierra Leone was a rice growing country with abundant wetland, that environmental and cultural conditions were equivalent to conditions in better favored and very densely populated South-east Asia.

2.5.2 Seed Multiplication Project (SMP)

Seed multiplication was organized around Green Revolution assumptions. The German government funded the national Seed Multiplication Project (SMP) to:

- contribute to the Sierra Leone's agricultural development and food security by ensuring dependable supplies of improved seeds for use by farmers
- improve the income and living condition of small-scale farmers by encouraging them to produce and sell seeds.
- develop an economically viable organizational base for the management of seed production.

The project started seed production and distribution in 1978 and attained an annual seed production and distribution of 950 metric tonnes of pure seed rice per year. In addition to rice seeds, the project also produced improved cassava and sweet potato cuttings, maize, groundnut and cowpeas. It also introduced a wide range of high quality vegetables especially for urban area vegetable growers. The SMP concentrated more on the production and sale of improved agrochemical-responsive varieties and supplied on average about 20% of the national annual seed requirement. Most of this is sold at subsidized rates. Little thought was given to multiplication of farmers local varieties until c. 1990 (some efforts were then instituted in response to persistent farmers' demand for locally adapted cultivars.

2.5.3 Green Revolution Project

A government initiative misleadingly entitled the Green Revolution Project (GRP, 1986) was basically a strategy for national food production and security using mechanization. It was meant to transform agricultural production and increase food self-sufficiency. Rice was the main focus of the program due to the unprecedented deficit in production in the 1980s which resulted in the importation of 180,000 metric tonnes of rice costing $41 millions per year

The main objective of the GRP was the mobilization of manpower and other resources, and effective utilization of available resources in areas with the greatest potential for the production of rice and other food crops. Rice self sufficiency was the primary focus so that importation would be minimized in three years (RRS and WARDA, 1987). Farmers were therefore provided with improved seeds, fertilizer, pesticides, and farm machinery. The other aspect of the GRP was to develop effective cropping systems and encourage improved cultural practices through intensive extension activities. The use of work oxen, improvement of range lands, and developments in fishery and forestry were also considered in the Green Revolution Project. The GRP was never fully executed because of lack of funds from the Sierra Leone government and skepticism of foreign donor agencies. Donors had long since despaired that the state could organize an agricultural revolution. The ending of the Cold War in Africa meant that Western donors no longer had to even pretend to keep up with the Soviet "collective" approach.

2.5.4 Internal war and new beginnings - the CBDC approach

The survey of Sierra Leone's recent agricultural history makes rather dismal reading. Confidence in any form of agricultural transformation had ebbed away by the start of a bruising civil war in 1991. From this point most farmers were concerned only with survival. This began to sort out sustainable from unsustainable innovations. Paradoxically, both farmers and researchers now have a very clear understanding at what works in the most difficult and degraded conditions. This suggests ways of making a new start around provision of seed for very adverse environments in which bandits may be as much a factor as birds or weeds. This is the context explored in later chapters.

A framework for this new (but old, and survival-oriented) approach was put in place when Rokupr Rice Research Station was included, in 1994, in the multi-national Community Biodiversity Development & Conservation project (CBDC). CBDC is a consortium of farmer-oriented (mainly NGO) agro-biodiversity conservation projects funded by the Dutch, Canadian and Swedish aid programmes. For CBDC-Sierra Leone Rokupr scientists collaborate, informally, with extension workers from ActionAid (AA). AA has a well-established community-participatory rural development project in Bramaia and Tonko Limba chiefdoms, but only rather limited agricultural activities. The present author, designated as the main Rokupr scientist for CBDC field activities, was able to build upon AA links to establish, rather quickly, networks of local farmers interested in becoming part of the CBDC initiative and familiar (via AA) with participatory approaches. The third chiefdom in this study - Magbema - is not covered by AA, but RRS is located in Magbema and activated its own network of local contacts in introducing the CBDC approach to this chiefdom.

2.6 Area and Percentage of Land Types within Chiefdoms in Kambia District

The use of rice genetic diversity is closely related to distribution of rice-growing ecologies, rice varieties selected by farmers (land races), and seed introductions made by scientists. In understanding the role of each of these players in the utilisation of rice genetic diversity in Kambia District, it is necessary to understand farmer and scientist knowledge concerning varietal selection and how farmers adapt varieties to the various rice growing ecologies. All the rice growing ecologies in Sierra Leone are in fact found in this area (Map 2.1) and this is clearly a stimulus to adaptive selection.

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Land facet groups for Kambia District are summarised in Table 2.4. Land in the three case-study chiefdoms mainly comprises inland valley swamps, terraces, interfluves and plateau. Magbema has some mangrove tidal land. The large percentage of terrace material and back swamps in Tonko, and of plateau land in Magbema should be noted.

2.7 Rice farming systems in Kambia District

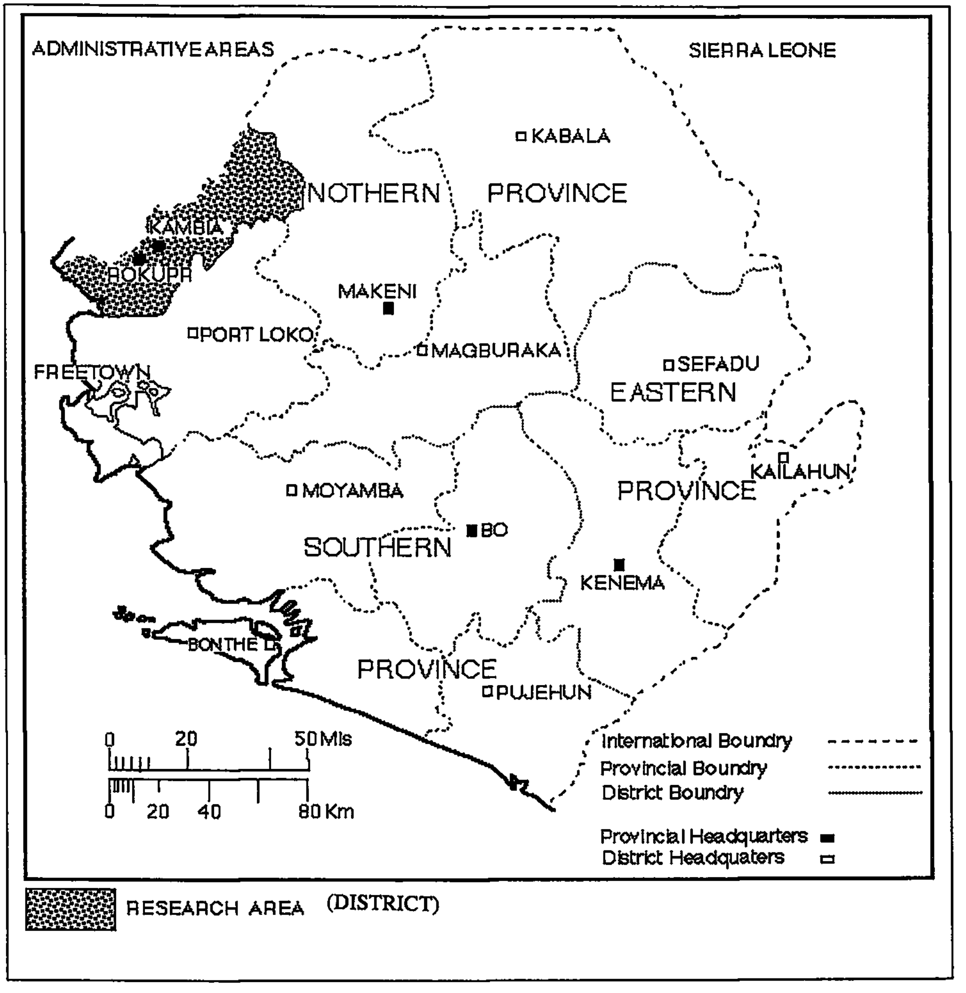
Kambia District is administratively divided into seven Chiefdoms; viz Gbinle Dixing, Bramaia, Magbema, Mambolo, Masumgbala, Samu and Tonko Limba (Map. 2.5 and 2.6). Each Chiefdoms, is ruled by a Paramount Chief elected by tribal elders.

Table 2.4. Area and percentage of facet groups within Chiefdoms in Kambia District

Chiefdom	Tidal flats		Acid sedges swamps &terraces		Drainage depression and back swamps		Minor flood plains and valley swamps		Beach ridges on swamps		Colluvial and alluvial terraces		Interfluves		Plateau	
	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%	km²	%
Gbinle Dixing	7	4	4	2	1	0.5	14	7	-	-	1	0.5	83	44	80	42
Bramaia *	-	-	-	-	39	6	33	5	-	-	24	4	467	76	57	9
Magbema*	21	6	11	3	6	1.5	28	7.5	-	-	4	1	174	47	126	34
Mambolo	91	32.5	46	16.5	-	-	46	16.6	-	-	15	5.5	82	29	-	-
Samu	232	43	51	9.5	-	-	55	10	22	4	23	4.5	157	29	-	-
Masumgbala	-	-	-	-	9	4.5	18	9	-	-	2	1	171	85.5	-	-
Tonko Limba *	-	-	-	-	103	12	37	4	-	-	162	20	528	64	-	-

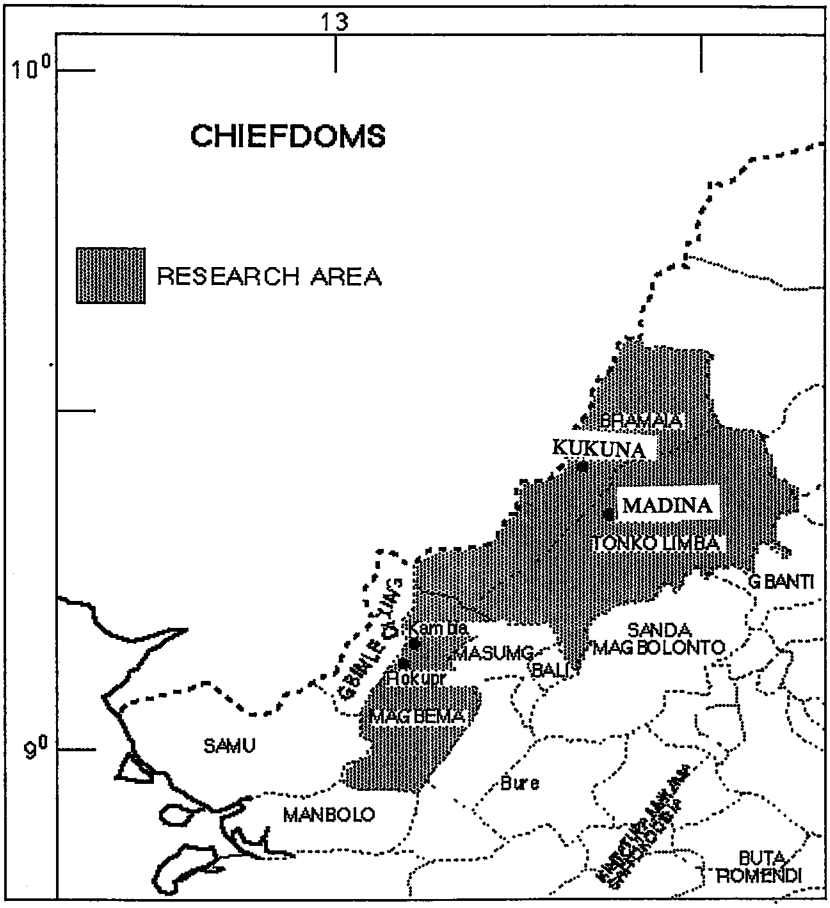
Adapted from *A preliminary land Evaluation of Kambia and Port Loko Districts for IADP - Land Resources survey Project FAO/UNDP-MANR, Freetown, Sierra Leone.* SL/73/002 Miscellaneous Report , (July, 1980) by C.J. Birchall , O.L.A. Gordon, A.S. Lamin and W.K. Alkire.

* Chiefdoms in which research was conducted.



Map 2.5: Map of Sierra Leone showing the research area (District)

The incidence of major landforms and vegetation types is presented in Table 2.4. In general the land rises from sea level to an average elevation of 300 m in the north of the district. The area is drained by the Little and Great Scarcies rivers which flow into the sea through broad estuaries.



Map 2.6: Map of Sierra Leone showing the research area (Chiefdoms)

Minor flood plains and inland valley swamps, colluvial and alluvial terraces, and interfluves occur in all seven Chiefdoms. The tidal flats, acid sedge swamps, and terraces occur in Samu, Gbinle Dixing, Mambolo and Magbema Chiefdoms which are close to the sea and within the tidal influence of the Scarcies rivers. There are, however, no drainage depression and back swamps in Samu and Mambolo chiefdoms (close to the sea) because there is negligible relief. Beach ridges are found only in Samu chiefdom where most of the fishing and salt mining is carried out.

2.7.1 Agricultural Production Systems and Farming Activities

Kambia District is considered quite viable for food crop production. Rice is the main crop in the district, and land suitability for rice production, is given in Table 2.5. Areas which are not suitable for rice production, are used for the production of tree and other arable crops. Bramaia and Tonko Limba chiefdoms have the most suitable lands for agricultural production (Table 2.5).

Rice is grown both rainfed and low-lying wetlands. In the upland, it is inter-cropped with several other crops but is a sole crop in the lowlands. The ecologies are diverse and inhabitants have adopted crops and techniques suited to the various ecologies. Vegetables, cereals, roots and tubers, tree crops and herbs are the main categories (Table 2.6). The ecologies and the agricultural activities in the area are briefly described below.

Table 2.5. Land suitability of chiefdoms in Kambia District for rice production

Chiefdoms	S1		S2		S3		N	
	Km^2	%	Km^2	%	Km^2	%	Km^2	%
Bramaia (620 Km^2)	50	8	20	3	-	-	550	89
Tonko Limba(830 Km^2)	50	6	90	3	-	-	690	83
Gbinle Dixing(190 Km^2)	10	5	10	5	-	-	170	90
Kambia Magbema (370 Km^2)	20	5	30	8	10	3	310	84
Masumgbala (200 Km^2)	20	10	-	-	-	-	180	90
Samu(540 Km^2)	40	75	260	48	40	75	200	37
Mambolo (280 Km^2)	30	11	150	53	-	-	100	36
Total	220	7	560	18	50	2	2200	73

Note:

Land Suitability Classes:

S1 = High to Moderate
S2 = Low
S3 = Very low
N = Nil

2.7.1.1 Upland ecology

The upland ecology is the most widely dispersed rice growing ecology in Sierra Leone. In Kambia District the uplands consist of colluvial and alluvial terraces, interfluves, and plateau and these account for up to 82.6% of the land area (Table 2.4). Depth of soil varies from 3 to 9 cm over freely drained ferralitic subsoil. The organic matter content is low varying from 1% to 3% and decreases with depth. Soils are acidic, with pH ranging from 4 to 5. The cation exchange capacity (averaging 0.7%) and base saturation (5.7%) are typically low. Mean nitrogen content varies from 0.06% in the north to 0.19% in the southern part of the district. Upland soils are high in aluminum and iron content (Odell *et al* 1974).

Rice farming practice in the uplands is bush-fallow rotational shifting cultivation. The bush is left fallow for four to eight years depending on the population pressure to conserve and restore soil fertility. Most authorities consider high population pressure has caused a shortening of fallow period to a point that this natural amelioration of the soil is no longer able to maintain stable yields for most arable crops in this ecology but historical research, e.g, by Richards (1985), suggests 4-8 years has been the standard interval since at least the 17th Century. After the fallow period, the bush is cleared using local farm implements (heavy cutlasses and axes), burnt, and the farm cleared of debris. The land is then broadcast with

rice as the main crop and other minor crops in a mixed-cropping pattern at the onset of the rains in May to June. This practice is common to all upland rice farming in the country but land preparation and planting depends on the onset on the rainy season. Local rice varieties are the main seed types and yields tend to be low, ranging from 1.5 to 2 tonnes $ha^{-1.}$

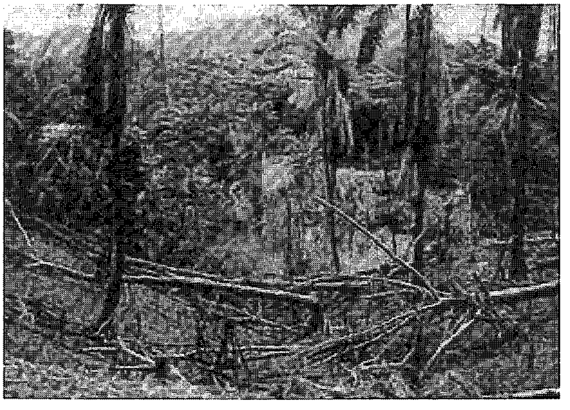


Photo 2.1: Burning of the rice farm to reduce biomass and fertilize the soil

Farms are usually divided into small blocks per family. In some areas of Kambia District many farmers from one or more villages in the area come together to clear a large piece of land for farming. Farmers plant more than one variety per farm (typically 2 to 5), and there is no line of demarcation between the varieties within farm blocks. Varieties on neighboring farms may be bounded by nothing but a line of sticks. In Bramaia chiefdom, in particular, the farmers clear large land areas and then divide it into small plots per family for cultivation. The line of demarcation between the varieties planted is only visible as a patchwork of slightly different colors as harvest approaches. Varieties with the same duration may be planted together, and out-crossing, although low in rice, a mainly self-pollinating crop, occurs. In hilly areas, erosion causes seed drift from the upper portion of the farm catenary to the farms in the lower slopes. This also causes varietal mixtures in farmers' field.

The rice crop in the first year is planted with a variety of minor crops such as benni (*Sesamum indicum),* Okra, *(Hisbiscus esculentus*), Maize (*Zea mays*), Pigeon peas (*Cajanus cajan*), Amaranth (*Amaranthus*), chilies and several other vegetables. These are normally referred to as women's crops, essential in the preparation of the sauces to accompany rice as the main diet for the family. The women are the custodians of the genetic diversity of these minor crops. They plant, process and store many varieties of these minor crops.

Crops such as sorghum and pearl millet are used when the rice has been depleted at the peak of the rainy season. This is the time when the farmers are awaiting the new rice harvest. Some households experience seasonal hunger. Other crops such as cassava (*Manihot esculenta*) and yams (*Dioscorea alata*) are also planted and used as staple substitute on various occasions.

In the second year of cultivation of one clean plot of land, cassava, sweet potatoes (*Ipomoea batatas*), groundnut (*Arachis hypogaea)* and several vegetables are planted.

Digitaria exilis ("hungry rice" or *fundi*) is a special crop farmers exploit to avoid the hungry season. Farmers have selected three varieties that matures at three stages during the peak hungry season, viz. an early type that matures in two and half months, a medium type that matures in three months, and a late type that mature in three and half months. The farmers seed these *Digitaria* varieties before the rice is sown in preparation for the hungry season, sometimes using an old rice plot in its second year.

Tree crops are cultivated in front of houses, in the back yard and on a small scale in back yard gardens. They are used as shade trees and for the fruits. Tree crops such as guava (*Psidium guajava),* paw or papaya *(Carica papaya),* Cashew (*Anacardium occidentale*), bananas and plantains are grown. Locally adapted tree crops such as *Tombi* and *Tola* are also cultivated. Locust bean is wildly grown and is harvested for the preparation of *Keinda*, a recipe that, as an ingredient, adds flavor to sauces. Very little research has been done on these crops but they are well known through the country and have high market value.

Tree crop plantations for commercial production are established in small patches in the district. Plantations of citrus species such as lime *(Citrus aurantium),* lemon (*C. limonum*), grapefruit (*C. decumana*) and sweet oranges (*C. sinensis*), mangoes and oil palm plantations are found in many chiefdoms nowadays. Plantains and banana are grown near villages and also in newly established plantations.

Farmers have exploited the soil variability in the uplands in several ways. The main one is upland rice cultivation where many annual crops are inter-cropped with rice. Cash crops are also planted in this ecology. The inter-cropping practices in rice in this ecology have hindered the movement of farmers from the upland to lowland rice cultivation. The advantage of the upland is that farmers can grow many crops on the same piece of land at the same time and harvest them over time. Land preparation is done for several crops at the same time, reducing labor input in the cultivation of these various crops. The hazards of cultivating lowlands, including health hazards such as river blindness, are not found in uplands

2.7.1.2 Inland Valley Swamps (IVS)

The Inland Valley Swamps (IVS) are upstream valley depressions. The IVS develop in the headwaters of major rivers and their tributaries. They are associated with streams that spread out over narrow valley bottoms to form winding swamps. The vegetation comprises sedges, grasses, raffia palm, and some broad leaf plants that are adapted to the ecology. The soils are rich in organic matter and have relatively thick fertile topsoil high in iron and aluminum content. The subsoil is relatively infertile with textures varying from sandy loam to sand with quartz gravel mostly from adjacent uplands. The major problems are heavy weed infestation, poor water control and iron toxicity (Hoque, 1974). Low pH and high organic matter content cause iron toxicity. This results in the yellowing and bronzing of leaves. Stunting of the rice plant, poor tillering and poor root development are common symptoms in susceptible rice varieties in the IVS.

Rice cultivation in the IVS is variable and depends on the availability of water in the rainy and dry season. Some IVS are perennial swamps with streams that do not dry out throughout the year. Rice can be cultivated in both the dry and rainy season. Some are seasonal swamps and flooded for only part of the rainy season. Rice can be grown in seasonal IVS during the rainy season. In the dry season artificial irrigation is required for the production of a second crop of rice.

The method of cultivation is variable. In Kambia District, swamp rice production has been practiced longer than in other parts of the country and farmers are highly experienced. Rice seeds are nursed in June and five to six weeks old seedlings transplanted in July and August after the land has been brushed, cleared, dug and puddled to a fine tilth using rudimentary local tools such as cutlasses and hoes. Harvesting is done from October to January depending on the duration of the variety.

A wide array of low yielding varieties selected and adapted to this ecology by farmers, are cultivated. The yields are generally low, ranging from 2 to 3 tones ha^{-1} under farmers' condition.

During the dry season, crops such as cassava, sweet potatoes, maize, cowpeas and a variety of vegetables are grown. Short duration cassava and sweet potatoes varieties, which mature before the flooding of the swamps, are planted. Vegetable production is becoming a very important practice near larger settlement such as Kambia, Rokupr, Madina, Mambolo and Kukuna. Some of the vegetables, especially chili, are exported to the neighboring Republic of Guinea, and others are sold to traders from Freetown.

2.7.1.3 Mangrove Swamp ecology

Mangrove swamps form through inundation by seawater or tidally pumped brackish waters into the estuaries along the rivers. They occur along the coastal region in the south of the district and extend inland along the Great and Little Scarcies rivers from their estuaries up to the tidal limit, the extent of which ranges from 20 to 60 km from the sea. They are quite extensive and most have been cleared of the mangrove vegetation for swamp rice production. Mangrove rice production has been going on in this area for about 120 years. The swamps are highly variable depending on their distance from the sea and the nature of tidal influence (WARRS, 1953 - 1964).

In the mangrove swamp rice production, the rice seeds are nursed at the beginning of the raining season from May to June in the uplands. Six weeks old seedlings are transplanted when the land has been cleared of sedges and grasses dug and puddle to a fine tilth. Transplanting is done by hand between July and October when the amount of salt in the water is low enough for rice growth. The salt is washed from the soils by the direct rainfall on the soils, overflow from the rivers and creeks and from adjacent uplands. Land preparation is by rudimentary tools such as cutlasses, machets and hoes. Harvesting is done between November and February depending on class of the swamp and the duration of the variety. Rice yields (1.0 to 4.0 ton ha^{-1}) are higher than those in the uplands (1.5 to 2 ton ha) under farmers practice.

The Great and Little Scarcies area is one of the main rice bowls in Sierra Leone. Government intervention in providing an irrigation and mechanization facility, especially in the associated mangrove swamps has been attempted in the past, but resulted in the acidification of soils. Several techniques, both local, and by researchers at RRS, have increased production per unit area.

Vegetables, cassava, sweet potatoes are grown as off-season crops during the dry season in the associated swamps using artificial irrigation. Most of the vegetables produced are sold to other farmers and fishermen near the sea, and some transported to the big towns. Cassava and sweet potato tubers are used as food during land preparation in June through August.

2.7.1.4 Bolilands

Bolilands are extensive, low-lying, undulating and saucer-shaped and poorly drained grasslands. They are flooded during the rainy season and can hold about 50 to 120 cm of standing water for 3 to 5 months depending on the area and the length of the rainy season.

The soils are low in phosphorus, high in acidity (pH 3 to 5), low in available nutrient, poor in base exchange capacity and have low response to nitrogen (Odell *et al*, 1974). They are sandy loam to sandy clay loam soils with high salt content and varying amounts of iron, aluminum stone and gravel.

The normal farmers' practice involves the clearing, digging, and puddling and direct seeding of rice before the onset of the rains in June. In such a practice, the land preparation is poor, and the seeds are not properly covered by the soil, resulting in low plant populations and heavy weed infestation.

A second method involves the preparation of ridges to cover the weeds and rice straw in the dry season. Some farmers nurse the rice seeds on these ridges. Some plant groundnut, cassava, sweet potatoes and vegetables and use artificial irrigation in the dry season. In July and August when the bolilands are about to be flooded the rice seedlings are uprooted, the ridges leveled and the seedlings transplanted. This method of cultivation requires a lot of labor input and very few farmers have adopted it. Harvesting is done in December and January when the floodwater has receded after the rains decline in November and December. Local varieties selected by farmers are grown. Improved long duration varieties such as CP4 and ROK 10 released by RRS in 1978 (170 to 180 days from seeding to harvest) are also planted. Yields are generally low due to the heavy weed infestation, soil problems such as iron toxicity, intermittent flooding and diseases and pests. Rice yields range from 1.0 to 2.0 ton $ha^{-1.}$

In the three case study chiefdoms farmers mainly cultivate upland and IVS, sometimes in catenary sequence. There is some mangrove cultivation in Magbema Chiefdom. Farmers are included in the survey of crop varieties (below), but the detailed field investigation concentrated on farmers cultivating the upland swamp/continuum.

2.8 Crop Diversity in the Kambia District

A survey of genetic diversity in the three Chiefdoms of the research area was carried out in the 1995/96 growing season to record the different type of crops grown by farmers. The research was conducted in the south (Magbema), on the border of the Republic of Guinea (Bramaia) and in the North-east (Tonko Limba). Each Chiefdom has its dominant ethnic group with its own varying cultural and agricultural practices. Several rice varieties are grown in the uplands, mainly farmer's local *O. sativa* varieties. They also plant a number of *O. glaberrima* varieties and "hungry rice"(Digitaria exilis). Despite the name *D. exilis* is not a rice variety but a small grained millet. It replaces rice in the diet in the hungry season.

To ensure good representation, farmers were selected at random in villages both close to Rokupr in Magbema, Madina in Tonko Limba, and Kukuna in Bramaia chiefdoms and in villages up to 20 kilometer from these chiefdom Head quarters (Map 2.6)

Ten villages per Chiefdom were selected, and in each village ten farmers were requested to list the number of crops, and varieties of each crop they grew. The number of cereals, roots and tubers, tree crops, legumes and vegetables was recorded. The results from the 300 farmers interviewed are summarized in Table 2.6. Rice is as expected the main food crop. The root and tuber crops and other foodstuffs are secondary to rice. Vegetables are eaten with rice in all recipes. Tree crops, groundnuts, chilli and maize are planted mainly as cash crops.

The number of rice varieties recorded for the three chiefdoms was related to distribution of the rice growing ecologies and the suitability of the area for rice production. In the upland ecology, 14, 21 and 19 distinct varieties were recorded for the Magbema, Tonko Limba and Bramaia chiefdoms respectively. The common varieties across all Chiefdoms were Dissi Kono, Damba and Pa Three-month. In Bramaia and Tonko Limba chiefdoms the rice varieties that were recorded were Samba Konkon, Saliforeh and Bundu Yaka were the main varieties recorded in Tonko Limba and Bramaia not in Magbema.

In the lowlands, 39, 29 and 27 varieties were recorded for Magbema, Tonko Limba and Bramaia chiefdoms respectively. Varieties included Pa Muslim, Pa Kolma and ROK 3. The varieties Gbassin, Kuatik Kundur, Yan Gbassay, Pa Sorro, ROK 10 and CP4 were grown by farmers in Magbema and Tonko Limba, and not recorded in Bramaia chiefdom. These varieties are salt tolerant varieties adapted mostly to the mangrove swamps found only in Magbema chiefdom. The same varieties were also used in the lowlands in Tonko Limba chiefdom. The varieties Kaulaka, Lansana Conteh and Pa

Three Month were recorded in the lowlands only in Bramaia and Magbema chiefdoms and were not recorded in the lowlands in Tonko Limba chiefdom. In Tonko Limba and Bramaia chiefdoms the varieties Sapakai and Kori Kori were only recorded wetlands in these two chiefdoms and not in Magbema chiefdom.

The results showed that there are more rice varieties in the lowlands than in the upland in the case study area. There were more upland varieties in Tonko Limba and Bramaia chiefdoms than in the Magbema chiefdom. Magbema farmers indicated that their source of the upland varieties was from Tonko Limba and Bramaia chiefdoms. There were also more lowland varieties recorded in Magbema chiefdom than in the Tonko Limba and Bramaia chiefdoms. Susu and Limba farmers also indicated that they obtain new lowland varieties from Temne farmers. All the farmers in the three chiefdoms acquire new varieties from outside sources, as will be illustrated later in this thesis. None is dependent solely on indigenous land localized planting material.

Table 2.6 : Crops cultivated by farmers in the Kambia District in Northwest Sierra Leone

Number	Common Name	Scientific Name
1	Rice	*Oryza spp*
2	Maize	*Zea mays*
3	Sorghum	*Sorghum bicolor*
4	Pearl millet	*Pennisetum americanum*
5	Potatoes (sweet)	*Ipomoea batatas*
6	Cassava	*Manihot esculenta*
7	Yams	*Dioscorea rotundata*
8	Ginger	*Zingiber officinale*
9	Okra	*Hibicus esculentus*
10	Garden eggs (egg plant)	*Solanum melongena*
11	Krein kre	*Corchorus olitorius*
12	Pepper (hot chilies)	*Capsicum frutescens, C. annum*
13	Chilli	*Capsicum spp*
13	Tomatoes	*Lycopersicon spp.*
14	Equsi	*Colocynthis citrullus*
15	Cucumber	*Cucumis sativus*
16	Onions	*Allium ascalonicum, A. cepa*
17	Pineapple	*Ananas comosus*
18	Pawpaw	*Carica papaya*
19	Pumpkin	*Cucurbita pepo*
20	Sugar cane	*Saccharum officinarum*
21	Common bean	*Phaseolus vulgaris*
21	Faba bean	*Vicia faba*
22	Benni seed	*Sesamum indicum*
23	Groundnut	*Arachis hypogaea*
24	Pigeon pea	*Cajanus cajan*
25	Allegata pepper	*Aframomum melegueta*
26	Coco yams	*Colocasia, Xanthosoma spp.*
27	Bitter cola	*Garcinia kola*
28	Coconut	*Cocos nucifera*
29	Oil palm	*Elaesis guineensis*
30	Sweet oranges	*Citrus sinensis*
31	Grape fruit	*Citrus paradisi*
32	Tangerine	*Citrus reticulata*
33	Lemons	*Citrus limon*
34	Kolanut	*Cola anomela & C. acuminata*
35	Cashew nut	*Anacarduim occidentale*
37	Avocado	*Persea americana*
38	Tola	*Beilshmiedia mannii*
39	Tombi	*Tamarindus indica*
40	Banana	*Musa spp*
41	Mangoes	*Mangifera indica*
42	Sweet sop	*Annona squamosa*
43	Coffee	*Coffea arabica*
44	Bread fruit	*Artocarpus communis*
45	Calabash (gourd)	*Lagenaria sicerania*
46	Monkey apple	*Anisophyllea laurina*
47	Jack fruit	*Artocarpus heterophyllus*
48	Plum (wild)	*Spondias mombin*
49	Pea	*Persea americana*
50	Fundi	*Digitaria exilis*
51	Amaranth	*Amaranthus species*
52	Lime	*Citrus aurantifolia*
53	Locust tree (for Kainda production)	*Parkia biglobosa*
54	Cucumber	*Cucumis sativus*
55	Groundnut	*Arachis hypogaea*
56	Guava	*Psidium guayava*
57	Hemp (Jamba)	*Canabis sativus*
58	Passion fruit	*Passiflora edulis*
59	Bitter-leaf	*Vernonia amygdalina yg*
60	Bologi	*Crasscocephalum biafrae*
61	Cow pea	*Vigna unguiculata*
62	Soya bean	*Glycine max*

In addition to rice as the main crop, other cereals include maize, sorghum, *Digitaria exilis* and pearl millet. The most common maize varieties were local late duration varieties that produced two cobs per stand on average. Farmers preferred these varieties because they were resistant to local diseases and pests and did not require fertilizer to produce a crop. Early types were materials introduced by agricultural development projects in recent years. These varieties were high yielding but susceptible to the local diseases and pests and required high fertilizer input, beyond the reach of most farmers. These early types were common in Magbema and Tonko Limba chiefdoms, with greater exposure to agricultural projects than farmers in Bramaia chiefdom.

Sorghum was grown with rice as the second most important cereal. Farmers classed the varieties according to color of the seed coat. The commonest types were white seed coat varieties, which according to women were easier to process. Few farmers grew red types. More farmers grew sorghum in Tonko Limba and Bramaia chiefdoms than in Magbema chiefdom.

Digitaria exilis was commonest among farmers in Tonko Limba chiefdom. The crop was grown to avoid food shortages at the peak of the rainy season. Pearl millet was not very common among farmers in any Chiefdom.

Root and tuber crops included sweet potatoes, cassava, yams and ginger. Sweet potato varieties included local varieties such as Sorieya and Nukuola. The improved varieties included Facole, Raymondo, Njala White and Two-Leaf potato. The number of local varieties was very small among farmers in area. Farmers in Magbema were able to distinguish these varieties, but farmers in Bramaia and Tonko Limba chiefdoms could not easily do this. Many potato varieties have been released in Magbema chiefdom by workers at RRS and from the Institute of Agricultural Research at Njala (IAR). Raymondo was introduced by an IITA scientist of that name on secomdment to RRS in the 1970s.

The case of cassava was similar to that of sweet potato. Cassava varieties included "local" varieties such as Gbani and Warema and the improved varieties such as Milikit, ROCAS, and Two-Leaf cassava. Gbani bears the name of an Njala/IAR scientist. This survey showed that cassava and sweet potato production was not very common in the area before the introduction of improved varieties by RRS and IAR in the past 20 years. Yam production, based on the number of farmers growing the crop, was higher in Magbema chiefdom than in Bramaia and Tonko Limba chiefdoms. The local yam species grown included the variety Mawum. This type has been grown in the research area for centuries and some of the local types have been domesticated from the wild. Bush yams are still collected in the rainy season. These were long duration, however, and can remain in the ground for two years before they are harvested. These local varieties are high yielding and one stand can produce up to 20 kg of tubers. Farmers plant the tubers close to plantation trees such as mango and the yam climbs on the branches. Introduced types included Chinese yams, Cocoyams, Sweet yams and Two-Leaf yams. Ginger is still grown in Bramaia and Tonko Limba chiefdoms in small plot. These chiefdoms used to be the main ginger producing areas in the district.

Vegetables and other crops are also cultivated. According to the variety survey, pepper was the most common vegetable crop in the research area. Production has increased in recent years, particularly in the Bramaia chiefdom where it has become an important cash crop. Groundnut varieties included Marris, Bakuku, Yakumba and Mayakumba. These count as local varieties, but Marris is a colonial introduction. The high demand for pepper in Conakry, the capital city of the Republic of Guinea, and in Freetown, and low groundnut production in recent years, were some of the reasons why many of the farmers had increased their pepper production. Okra and garden eggs were cultivated by women for sale in Rokupr, Kambia and Mambolo.

Most tree crops (mangoes, banana, plantain and oranges) were found in Magbema chiefdom. These were planted as single trees within residential compounds of village settlements, and in larger stands as plantation crops. Other tree crops were mainly planted in backyard gardens.

2.9 Summary of results of variety survey

A number of points stand out from the variety survey.

- farmers in the three case study chiefdoms mainly produce annual crops. Only farmers in Magbema Chiefdom have significant holdings of cash crops. Bramaia farmers, in particular, earn cash from pepper and groundnuts.
- rice remains by far the most important food crop, and this is reflected in the level of varietal diversity. Traditional grains (sorghum and Digitaria) continue to supplement rice, but there has been a significant spread of introduced roots and tubers (cassava and sweet potato) varieties in recent years. Science has had more impact on roots and tubers than on rices, a crop grown for millennia.
- farmers in the three Chiefdoms mainly grow rice on the upland-swamp continuum. Unlike the wetter, forested districts in the southern and eastern Sierra Leone, farmers have more lowland than upland varieties.
- Farmers in all three Chiefdoms report dependence on the wider regional system for rice germplasm. Magbema farmers tend to get new local upland rice varieties from Tonko Limba and Bramaia. Tonko Limba and Bramaia farmers tend to get new wetland varieties from Magbema, an area with a long history of wetland cultivation (in mangrove brackish water and associated fresh water swamps).
- Rices from the species *O. glaberrima* remain important in the region. The proposed "intermediate" (farmer selected inter-specific hybrid) rice, Pa Three Month is one of these varieties, and planted quite widely, especially Magbema Chiefdom.

3 FARMERS' RICE SEED MANAGEMENT PRACTICES FROM HARVESTING TO SEEDING IN SIERRA LEONE

3.1 Introduction

Seed is a major input in any agricultural production system and the management of seeds and adaptation of varieties to the various rice growing ecologies are key aspects of rice farming in Sierra Leone. This includes traditional varietal selection and development, varietal adaptation to the various rice growing ecologies and seed processing techniques. Local knowledge on selecting and developing new varieties, and the processing and management of rice seeds from season to season and in matching varieties to soil type is very important among farmers in Sierra Leone. Richards (1996) reviews evidence to suggest this adaptation dates back as least as far as the 17^{th} century. Variety names today offer some clue to farmers' adaptive knowledge. For instance Mbeibeihun is Mende for a variety selected from within a variety, i.e. material selected by farmers from spontaneous crossing. The variety *Helekpoi* is Mende for a variety selected from elephant dung i e rice plants that germinate from undigested seed in elephant dung along tracks in the forest. In the research area, the lowland variety Thonsokerenyi, a Susu word for "one panicle" was developed from single panicle selected in a farmers' field and developed into a variety (Longley, 1999).

These names suggest Sierra Leone farmers are always experimenting to develop new varieties of rice. This knowledge of the farmer in rice development is not always recognized as an important resource. Therefore co-operation between researchers in formal institutions like the Rice Research Station (RRS) and farmers is often limited, due to institutional cultural arrangements and the availability of resources. Farmers' knowledge is gaining international recognition, however, e.g. in the Convention on Biological Diversity, and in Chapters 14 (Agriculture and Rural Development) and 15 (Convention and Biological Resources) of Agenda 21 (In Friis-Hansen, 1995). The Community Biodiversity Development and Conservation project has been very instrumental in this area in recent years.

The research reported below covers the various ways rice seed is selected by farmers on-farm, processing and storage, the gender dimensions involved, and the major players in activities from the harvesting of the crops to the next round of seeding.

The chapter is divided into five parts. The first part is concerned with the background of the farmers. The second is about the farmers' varietal management activities between the time rice varieties are matured in the field to the time they are stored for next planting. The third part examines the role of gender in the processing of seed from harvesting to storage, and the fourth part reports farmers' knowledge about matching varieties to different soil types on their farms. The fifth part reports on farmers' seed sources in and outside the farming community and the genotype, environment and social interactions.

3.2 Materials and methods

The present study was carried out with support from the Sierra Leone component of the Community Biodiversity and Development project, based at Rokupr Rice Research Station under the leadership of station director, Dr Sama Monde. The CBDC objective was to build a platform for interaction of scientists and local farmers on issues of seed management.

The research reported in this thesis was seen as a major first step in such a process. To that end we approached farmers in a number of villages interested in the CBDC idea. As much as possible we decided to co-operate with existing agencies in the field. Farmers become very confused by an endless stream of new projects, all with differing aims and many disappearing as quickly as they come. The main rural development activity in Tonko Limba and Bramaia chiefdoms is a well-established long-term participatory program run by the international non-governmental agency ActionAid. ActionAid in Sierra Leone had rather few agricultural activities at the time so the management was keen to co-operate with CBDC, thinking it might eventually adopt its philosophy if research results proved convincing.

To sample farmers for the present study we used the list of ActionAid villages as the frame. Ten villages from the ActionAid list were chosen in both Tonko and Bramaia chiefdoms, some close to the main settlements and others up to 20 km from chiefdom headquarters (to ensure representation of more remote areas). Villages were contacted and the CBDC idea explained to farmers. But CBDC wanted to include Magbema chiefdom in the study. ActionAid does not operate in Magbema. So instead we turned to villages and farmers registered under the Ministry of Agriculture Farmer Association Support Program (FASP) and selected a further ten villages (including some more remote settlements).

Prior to the main research we made a pass through the villages to monitor seed purity in farmers' fields and to make a representative collection of local germplasm, for rice and other main crop types. This work was done during the main rice harvest season (September to November) in 1994. The varieties were harvested from one-meter square quadrants per farm and taken to the Breeding Department of the Rice Research Station and processed and dried. The samples were separated into varieties, and the International Rice Research Institute Standard Evaluation System for rice (IRRI SES 1996) was used to classify samples morphologically, to determine varietal purity of each sample. The panicle and grain characteristics were also used to classify the varieties. It was found that Temne and Limba farmers (from Magbema and Tonko, respectively) maintain higher varietal purity than Susu farmers (from Bramaia). That varietal purity varied by ethnicity was a surprise. Clearly, we needed to investigate more systematically farmers' ideas about varieties, rogueing and selection.

To do so, we first carried out an informal survey of farmer seed management practices for the thirty selected villages in the three chiefdoms (using open-ended interviewing). Seed activities were monitored from October 1995 to July 1996, and again from October 1996 to July 1997. The informal surveys were carried out as opportunity arose, resulting in unequal sample sizes (65 farmers in Magbema villages, and 46 and 31 farmers in Tonko and Bramaia villages, respectively). Farmers were visited in their fields when the seed for the next planting on the new farm was being stored.

From the experience of the 1996 harvest season, we then developed structured questionnaires for systematic investigation of activities identified in the informal survey. For the formal surveys we sampled six farmers/farm households per village in each of the ten villages per three chiefdoms, resulting in a random sample of 180 farmers in all. This formal survey, using a structured questionnaire, was undertaken in 1997 (and is referred to as "the 1997 sample").

But in addition to the 1997 sample, we also sampled a larger group of CBDC registered farmers in the thirty villages specifically about the ways in which they acquire new rice materials to add to their familiar selections. Since seed acquisition tends to depend on a large number of distinctive but rather low frequency events we were anxious to widen the sample net for this kind of information. Accordingly, information was collected from 170 farmers from Magbema, 108 from Tonko and 147 from Bramaia chiefdoms. It is where we have drawn upon these data, and from the earlier 1994 and 1996 informal surveys and direct (participant) observation in farmers' fields. But the greater part of the data analyzed in the current chapter is in fact from the data set we refer to as "the 1997 sample" (i.e. the set of 180 farm households chosen at random in 30 villages in the three chiefdoms).

It should be noted that "farmer" is here defined as "head of a farming household" (on occasion data collection

3.3 Results and discussion

3.3.1 Farm labor force

In the study area, the main labor force in the upland rice production system is the farm family. According to Finnegan (1965) the Limba household comprises of a group of patrilineal kin actually or functionally related, living together in one household and co-operating economically, socially and religiously. This definition is commonly applied to the three groups of farmers in the case study area. The household comprises co-residents, generally eating from the same pot and recognizing one head. The head is responsible for all major decision making and bearing the risk of such decisions. The head is normally a man with one or several wives, sons and daughters, mothers, uncles and aunts under his control. All of these make up the labor force on the farm and form the backbone of agricultural production in a country where more than 90% of the land is tilled by rudimentary tools. The family head decides on the farmland to be cultivated and the main crops to be grown. The selection of crop varieties to be cultivated is a crucial decision and requires a lot of expertise. Children schooled in tradition acquire this knowledge over the years. Boys learn from their fathers and girls from their mothers. Women tend to play a limited role in decision making relating to cultivation of commercial and main food crops. When a crop becomes commercial, men gradually displace women from its cultivation by denying them access to farmland, since land ownership is patrilineal and women have little right to the land. This was reported by women as a problem for groundnut, maize and chili production in Bramaia and Tonko Limba chiefdoms. Rice seed production is also becoming an enterprise in Tonko Limba and Magbema chiefdoms in recent years and this will continue to increase the pressure on land. Very few women become heads of households. Typically this happens only when the husband is sick or dies and the elder son has left to start his own household. Each member of the family has a role in the farming system.

The data presented are a combination of the 1994 variety purity survey, informal information gathered in the 1996 harvest season during farm visits, and results of the structured questionnaire administered in 1997 to 180 farmers. Results on the different sources from which farmers acquired new seeds are also presented.

3.3.2 Background of sample farmers

The background of the sample farmers in terms of ethnicity, citizenship, and religion are given in Table 3.1a and in terms of gender and land tenure in the three farming communities in Table 3.1b. The Temne, Limba and Susu ethnic groups were the dominant farmers in the Magbema, Tonko Limba and Bramaia chiefdoms respectively. A majority of farmers in the three chiefdoms were Muslim. The household heads were mainly male farmers who inherited farmland from their parents.

Results show that Temne and Susu farmers normally farmed their own land allowing no other ethnic group to own and farm in these chiefdoms. The Limba on the other hand gave farmland to both Temne and Susu farmers. This could be partly due to their position in the research area and the inter-marriages between Limba women and the other ethnic groups. The Tonko Limba chiefdom is also historically known to encourage farmers from other areas to come and farm. Prior to the 19^{th} century Tonko Limba served as a refuge for harassed warriors and displaced people seeking fertile lands on which to hunt and farm (Moore-Sieray, 1983).

Susu and Temne women hardly married outside their ethnic groups because of strong Muslim beliefs, and their great pride in abstinence from alcohol. Among the Temne men and women hardly married the Susu and Limba ethnic groups because of cultural and religious differences. Susu and Temne Muslims looked down on Limba as people who drink palm wine from dawn till dusk (Monde et al, 1997). The Limba are more flexible in their religious activities (religion was not a barrier to any relationship) and marriage alliances. They travel widely tapping palm wine from one place to the other and working in government offices. The Tonko Limba, (speaking one out of the 13 different Limba dialects in the country) consider themselves as the most civilized, enlightened and educated Limba. The Susu are also well traveled as Arabic teachers and traders.

The Temne were also traders but mostly married within their own ethnic groups. The movement of the three groups plays an important role in rice germplasm exchange and formation of farming knowledge, as illustrated by Catherine Longley (1999) and Monde et al (1997). Wherever marriages occur, there were high chances of land and germplasm exchange.

Table 3.1a: Ethnicity, citizenship and religion of farmers in the three chiefdoms given as percentages (1997 samples)

Farmers	Ethnicity			Citizenship		Religion	
	Temne	Limba	Susu	Citizen	Non-Citizen	Muslim	Christian
Temne	100	Nil	Nil	96.7	3.3	96.7	3.3
Limba	6.7	81.6	11.7	98.3	1.7	80	20.0
Susu	Nil	Nil	100	96.7	3.3	98.3	1.7

Table 3.1b: Gender and land tenure of heads of households in the three chiefdoms as percentages (1997 samples)

Farmers	Gender		Land Tenure			
	Male	Female	Bought	Inherited	Exchanged	Rented
Temne	96.7	3.3	Nil	98.3	Nil	1.7
Limba	95	5.0	5.0	91.7	3.3	Nil
Susu	95	5.0	Nil	95.0	5.0	Nil

3.3.3.1 Age of farmers

There was a big difference in the age distribution of the sample heads of farming households as shown in Table 3.2. In all the three chiefdoms, very few respondents started their own farms below the age of 30 years. They worked on their father's farm in the same household until they were 30 years or more. Many Temne farmers started their own farms early and retired soon after 50 years of age. The Limba and the Susu on the other hand started early but retire from farming very late, some even after 70 years of age. The level of formal education in Tonko Limba and Bramaia was comparatively lower than in Magbema. Farming was therefore the main employment in the area. Palm wine tapping by the Limba farmers and buying and selling of groundnut and pepper (chili) by Susu farmers was done as off farming season commercial activity. As farmers get older their role was taken over by their sons. Seed and farming knowledge was therefore passed down from generation to generation.

Table 3.2. Age distribution of sample farmers in the three chiefdoms as percentages (1997 samples)

Farmers	Age distribution of farmers					
	20 - 30	31 - 40	41 - 50	51 - 60	61 - 70	71 - 80
Temne	8	57	30	5	Nil	Nil
Limba	5	26.7	35	16.6	11.7	5
Susu	15	31	20	20	12	2

3.3.3 Farmers' Varietal Development Activities.

Results from the rice purity assessment in 1994 showed up to 18 different genotypes per variety identified in samples collected from Susu rice fields. It was later discovered that the samples with the highest number of different varieties were collected from farmers who "intentionally" mixed their varieties before seeding (see chapter 6). The number of different genotypes per field found in the samples collected from the Temne and Limba rice fields varied from 1 to 4 different genotypes. In short, the rice varieties cultivated by Susu farmers were highly mixed, compared to varieties from the Temne and Limba farmers.

Rogueing was identified as one of the ways in which the farmers maintained the varietal purity of their varieties. Rogueing is the removal of off types from the main variety to maintain the purity of the variety for next planting. Rogueing was done at various stages from flowering to the time the seed was stored. Plants that did not flower and mature at the same time were removed. Plants with different morphological characteristics were also removed as rogues. Farmers knew their varieties and the presence of new types were easily recognized in the field and removed.

Table 3.3a gives the portion of farmers rogueing their rice varieties among the three ethnic groups. The results of this survey showed that Temne and Limba farmers carry out more rogueing than the Susu (Table 3a). This might reflect greater interest in the rice crop by the Temne and Limba farmers than by Susu farmers. Susu farmers depend more on trading and groundnut farming, than on rice farming. When their rice varieties became too badly mixed, they would prefer to acquire pure seeds from their Limba or Temne neighbors.

Magbema chiefdom is closer to RRS than the two other chiefdoms in the research area. Temne farmers were, therefore, more exposed to new agricultural technologies than Susu and Limba farmers in the area (see chapter 2).

Table 3.3a: Rogueing activity of Temne, Limba and Susu farmers in the 1997 harvest season (1997 samples)

Farmers	Rogueing activity of farmers (%)	
	Yes	No
Temne	61.7	38.3
Limba	41.7	58.3
Susu	13.3	86.7

The time of rogueing among Temne farmers in Magbema chiefdom was more variable than among Limba and Susu farmers in Tonko Limba and Bramaia chiefdoms respectively. Most farmers carried out rogueing before the seed was harvested. During the farmers' field visit in 1996 to monitor the farmers crop management activities, it was observed that some farmers started removing off-types from their fields from flowering to the time the seed was processed for storage. A majority of farmers, however, carried out rogueing when varieties were about to be harvested. In Bramaia chiefdom, the few farmers who carried out rogueing did it mostly before harvest (Table 3.3b). Rogueing before harvest took place in different forms. When the variety was really mixed, experienced members of the family harvested all the panicles of the original variety leaving the panicles of the other varieties to be harvested by the harvesters. This type of rogueing was done to keep the distinctness of the original variety. The panicles of the varieties with the same phenotypic appearances were harvested leaving the panicles of other varieties in the field. Varieties with the same height, grain color and maturity were harvested as the original variety and processed for seed.

In some instances, rogueing was carried out just after harvest, before the seed was threshed. The panicles of the original variety were removed, threshed and processed separately for seed. The panicles of other varieties were also removed leaving the panicles of the original variety for processing as seed. In both cases, the method of rogueing depended on the level of mixtures found in the variety.

In terms of gender involvement, rogueing was done totally by men among the sample farmers in Magbema, and in most cases by the whole family in Tonko Limba and Bramaia chiefdoms (Table 3.3c).

Table 3.3b: Time of rogueing by Temne, Limba and Susu farmers in the 1997 harvest Season (%)(1997 samples)

Farmers	Rogueing activity of the farmers (%)		
	Before Harvest	At Harvest	After Harvest
Temne	36.7	45.0	18.3
Limba	41.7	58.3	0.0
Susu	86.7	11.6	1.7

Table3.3c: Percent gender distribution in rogueing, Temne, Limba and Susu farmers in 1997 harvest Season (1997 samples)

Chiefdom	Gender Groups			
	Men	Women	Men+Boys	Whole Family
Temne	100	Nil	Nil	Nil
Limba	Nil	8.0	4.0	88.0
Susu	23.0	Nil	13.5	63.5

The farmers who carried out rogueing were the main suppliers of clean seed in the community. When the varieties of other farmers were totally mixed they went to their neighbors for seed exchange. Some farmers may have learnt rogueing from working at the Rice Research Station at Rokupr, or as contract farmers with the Seed Multiplication Project (SMP), or were taught by the FASP and Action Aid extension workers. These agricultural organizations teach farmers how to purify seeds because they want to buy pure seeds from them to supply other farmers in other parts of the country. But farmers' knowledge in the maintenance of varietal purity is not new in the research area. It was recognized as early as 1938 when Glanville (1938) recommended the same practice in the Scarcies area should be taught to other farmers in the country. This suggests it is mainly traditional activity.

Kambia District has been a relatively stable area as compared to other parts of the country, for agricultural activities, since the start of the civil war in 1991, and farmers in the District have been given high price incentives to produce pure seeds to supply to seed agencies rehabilitating war affected farmers in other zones.

The results from this study indicate that Temne men are solely responsible for maintaining the purity of rice seeds. Since rice has become a commercial commodity in recent years, men (in most cases the head of the farm family household) exercise a complete control over the handling and sale of seed rice. It also implies that since seed is an important input in farming, the control of the seed for next planting must be under the control of the heads (mainly, male) of the household. Among the Limba and Susu, responsibility for seed maintenance was shared in some cases (Table 3.3c) by the rest of the family. Some Limba and Susu farmers teach their boys the technique of rogueing before they come of age. Seed has also gradually become a commercial commodity in Tonko Limba and Bramaia chiefdoms in recent years and it would be interesting to see what role the other members of the farm family will play in seed management in these chiefdoms in the future.

Results from the 1997 sample survey also confirmed our earlier finding that the Limba maintained a higher seed purity than the Susu because they carried out more rogueing. Generally Susu rice fields consisted of many different varieties all coming to maturity at about the same time. In some cases, Susu farmers intentionally mixed seeds of two or more different varieties before seeding in the uplands (Longley, 1999). Some Susu farmers cannot easily differentiate between different rice varieties in the field. Longley (1999) confirmed that Susu rice varieties contained higher varietal mixtures than Limba varieties in the field. To some Susu farmers rice mixtures are highly appreciated and it was totally prohibited to rogue on their farms (Momoh Bangura, pers. comm.).

The type of variety rogueing undertaken by farmers in the research area is similar to the mass selection technique practiced in plant breeding, but to a less systematic degree. Mass selection is the identification of superior plants from a population and the bulking of seed to form the next generation (Welsh, 1990). If this is practiced season after season with the same seed stock, mass selection can improve such characters as plant height and duration. In plant breeding the panicles of the desirable variety are selected and multiplied with continuous removal of off-types until a good quantity of seed of the selected variety is obtained. The next generation is propagated from the aggregate of the seeds from the previous generations. This may take several generations before a good quantity of breeder's seed of the selected variety is obtained.

This study investigated the ways farmers use mass selection in the research area to produce seeds for next planting. Farmers removed unwanted off-types from their varieties leaving other panicles of similar morphological characteristics, duration and height. The variation in some farmers' varieties is difficult to see in the field because the varieties appear phenotypically similar. Small differences such as differences in grain apiculus color, ligule length and shape are not important to farmers and are not considered during rogueing.

The farmers therefore carried out negative and positive mass selections. When the varieties were highly mixed, the farmers carried out negative mass selection by removing the panicles of the unwanted plants and retaining the panicles of the original variety that were phenotypically similar. Farmers using this technique cannot easily change the agronomic characteristics of the variety. Varieties may be mixed with other varieties or progenies generated by mutation or outcrossing. The farmer removes only the plants that are not phenotypically similar to the original variety or that are not adapted to the farmers' condition. Farmers cannot easily change the original variety by only continuously removing what is not favorable to the environment. By this technique, many favorable genes are retained in the population. This technique therefore has little consequences in terms of loss of useful genetic diversity.

Most farmers' varieties are in fact multilines made up of several genotypes with similar morphological traits. Pa Konkon and Samba Konkon (released as ROK 3, and adopted by farmers who changed the name to Samba Konkon), for example, are similar in plant height and duration, but the grain color of Pa Konkon is red, and farmers can only distinguish between the two by comparing the hull of the two varieties. Seed agencies in the past have bought Pa Konkon for Samba Konkon (ROK 3) because they are similar and only discovered the difference when processing the seeds for sale, or when the seed is distributed to the farmers for planting.

The causes of some sources of varietal mixtures were identified as 1) mixing of varieties during "plowing" (hoeing in of broadcast rice) especially along the borders of two different varieties and 2) heavy rains during which varieties from the upper part of a farm drift to the lower areas. The mixing of varieties was also common during processing and storage if the processing floors and storage containers were not thoroughly cleaned of old seeds. The mixing of the varieties occurred at various stages during gathering and stalking. Some farmers stalked more than one variety on the same processing floor. These floors had cracks with seeds from other varieties, which could easily contaminate the new variety. Mixing of varieties occurred when the containers farmers use to process seeds were not properly cleaned between the processing of different varieties

These mixed varieties, mutants, and any progeny from outcrossing in farmers' fields were continuously removed from the farmers' varieties by rogueing or were naturally selected against by duration, height, and susceptibility to biotic and abiotic factors.

Table 3.3d: Use of the rogue panicles by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples)

	Use of rogue panicles (%)	
Farmers	Food	New varieties
Temne	70	30
Limba	52	48
Susu	50	50

In addition to the farmers' practices of mass selection or purifying the seed lot for next planting, some farmers also carried out rogueing for the development of new varieties. The appearance of new plants in a field tempted some experienced farmers to further test their performance in the following year. By this practice, farmers carried out positive mass selection by selecting and maintaining panicles of desirable plants and developing them into a new variety. The majority of the panicles of the original variety were discarded. The adverse characteristic of the original variety was hence discarded in favor of the positive characteristics of a variety better adapted to the environmental condition. In this technique desirable genotypes generated by outcrossing (recombination) and mutation were selected from the population and developed into new varieties.

Respondents in the research area who carried out rogueing were found to use most rogue panicles for further testing or for food. Among Temne farmers, 30% of rogue panicles were used for further testing for the development of new varieties (Table 3.3d). The figures were higher for the Limba and Susu farmers (48% and 50% respectively). The Susu farmers did more experimentation (positive mass selection) than Limba and Temne farmers, who mostly carry out negative mass selection for seed production for seed agencies and for other farmers in the community. The Temne and Limba farmers hence were more interested in varietal purity than in developing new varieties largely because they were more in the seed trade than Susu farmers (despite the greater historical involvement of the Susu in commerce more generally).

3.3.4 Seed reservation and gender factors

3.3.4.1 Time of seed harvest for next planting

Seed rice for next planting was harvested from the field before the bulk of the crop was harvested from the farm. Seed was also removed from the main harvest at various stages during seed processing. In Magbema chiefdom, most of the farmers selected a certain portion of the field, containing the best performing panicles of the variety for seed. The panicles were harvested separately and processed and kept as seed for next planting by the head of the family. In Tonko Limba and Bramaia chiefdoms a majority of farmers interviewed reserve their seeds after drying. A large number of the respondents in Tonko Limba removed their seed after harvest but before threshing. In this case the farmers selected the best panicles and these were then processed and kept as seed for next planting.

Table 3.4: Seed rice reservation by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples)

Farmers	Time of seed removal (%)					
	BH	BT	AW	BD	AD	AS
Temne	61.7	6.7	Nil	Nil	31.6	Nil
Limba	Nil	31.7	8.3	5.0	51.7	3.3
Susu	3.3	25.0	20.0	1.7	45.0	5.0

Note: BH = before harvest, BT = before threshing; AW = after winnowing; BD = before drying; AD = after drying; AS = after storage

In Bramaia chiefdom, some farmers removed their seeds after winnowing. The selected seeds were dried separately and stored for next planting.

The majority of Temne farmers removed their seed rice for the next planting season before the main harvest and a minority after drying. Limba and Susu farmers removed their seeds at harvest and after drying (Table 3.4). We can infer that farmers who reserve their seeds after drying the harvest are not much interested in varietal purity and development of new varieties.

3.3.4.2 Harvesting

Two types of harvesting method are used in Sierra Leone, each of which is specific to a region, and has important implications for rice genetic resource management and conservation.

3.3.4.2.1 Bulk harvesting

This is a practice wherein the matured rice panicles are gathered in one hand and the sickle held in the other hand to cut the panicle 40 to 60 cm below the tip. The harvested rice encompasses the panicle, flag leaf and other tall leaves below the panicles. The tillers that fall on the ground are left for gleaners to pick thereafter. Grain loss was high. The bulk harvesting technique is common in the north, but is practiced in the east and south of the country by immigrant northern farmers.

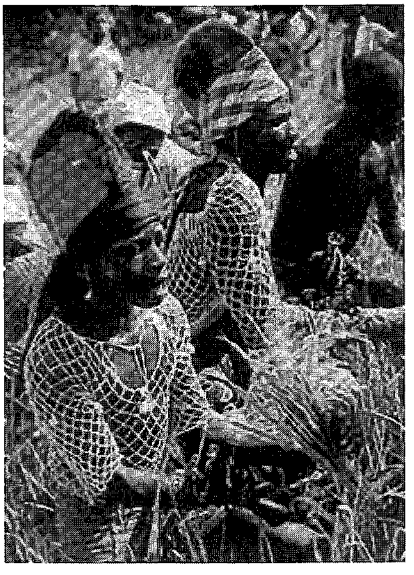


Photo 3.1: Bulk rice harvesting in Sierra Leone

3.3.4.2.2 Panicle harvesting

This is a practice wherein every individual panicle of a matured rice plant is harvested, with either a finger, sharpened bamboo cane, or a small knife, just below the flag leaf, usually 30 cm below the tip of the panicle. Harvesting is done by one hand, the panicle is transferred to the other hand and the thumb of the second hand separates the flag leaf and other leaves from the panicle. The harvested panicles are clean with less straw and leaves. Even the panicles that fell on the ground are harvested but other varieties not wanted by the farmer are left on the stalk for gleaners to cut thereafter.

Panicle harvesting enhances variety selection because each panicle harvested by the farmer is observed with keen interest. The best panicles are easily selected and preserved for next planting. However it is a slow process, and requires a high labor input compared to bulk harvesting. It remains the common harvesting technique in the east and south of the country. In the research area bulk harvesting prevails, but panicle harvesting is done by farmers who wanted to purify their varieties before harvest, as indicated earlier. Variety purification is not just something that happens. It involves a laborious decision.

The harvesting for household food consumption was done by women and girls and by the mother on small farms owned by a boy who was old enough to start his own household with his wife and children. In some cases the boy and his family continued to stay in the father's household and learn all the techniques of farming.

In the research area, men normally harvest in bulk with a large knife (equivalent to a sickle), but women and children use the panicle method. Panicle harvesting differs from the one carried out in the south and east in that the leaves are not removed from the pure panicles during harvesting.

Men did most of the harvesting in Magbema (Table 3.5). Among the Limba farmers in Tonko Limba, harvesting was done by men (81.7 %), men and women (3.3 %) and the whole family (15.0 %). The Susu worked more in groups in their farming activities. Harvesting was done by men (60.0 %), men and boys (1.7 %) and the whole family (38.3 %) (Table 3.5).

Table 3.5: Gender distribution in harvesting, Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples)

	Gender Groups (%)			
Farmers	Me	Me+Wo	Me+Bo	W Fam
Temne	86.7	Nil	13.3	Nil
Limba	81.7	3.3	Nil	15.0
Susu	60.0	Nil	1.7	38.3

Note: Me = men; Wo = women; Bo = boys; W Fam = whole family

3.3.4.3 Gathering

The harvested rice was usually left in the field to dry before bundles were gathered and stacked in one place. Some farmers left the harvested rice on the ground but others stalked it on stumps to dry before gathering. This depended on weather conditions and the commitment of the farmer. Most farmers completed gathering within one week, although some Limba farmers still left their rice on the farm for more days to dry (Table 3.6).

During field visits in the 1996 growing season, it was observed that removing the harvested rice from the field to the processing area caused great losses to the farmer in terms of seed purity and quantity. These losses were caused by the farmers themselves and vary from chiefdom to chiefdom according to gender (Table 3.6). In Magbema chiefdom women and girls gathered the harvested rice. The men and the boys did the more muscular operations in harvesting, leaving the gathering to the women. In Tonko

Limba and Bramaia chiefdoms all the members of the family were involved in gathering the harvested rice from the field (Table3.6).

Table 3.6 : Gender distribution in gathering of the harvested rice by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples).

Farmers	Gender Groups (%)				
	Me	Me+Bo	Me+Wo	Wo+Gi	Family
Temne	5.0	10.0	Nil	70.0	15.0
Limba	Nil	Nil	5.0	Nil	95.0
Susu	1.7	6.7	Nil	Nil	91.6

Note: Me = men; Wo = women; Bo = boys; W Fam = whole family

The time the harvested rice took in the field before it was gathered also varied in the three chiefdoms. Some farmers started gathering the rice from the field even on the day of the harvesting operation. With some farmers this operation was completed within one week, in Magbema and Bramaia chiefdoms. In Tonko Limba chiefdom gathering was found to go on for more than one week. Most of the gathering was done between the first and third week after harvesting (Table 3.7). After gathering, the food for family consumption was taken from the harvest everyday and processed before the main threshing. The site was used as storage ground for both seed and grain. The seed was removed from the harvest before or after threshing.

Table 3.7: Period between harvesting and gathering of the harvested rice by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples)

Farmers	Duration in days, weeks and months (%)								
	1d	2d	1wk	2wk	3wk	1month	2month	3month	4month
Temne	11.7	1.7	26.6	18.3	30.0	11.7	Nil	Nil	Nil
Limba	1.7	3.3	30.0	45.0	5.0	6.6	5.0	1.7	1.7
Susu	10.0	16.7	20.0	26.7	21.6	3.3	1.7	Nil	Nil

Note: 1d = first day; 2d = second day; WK = week

The women and children gathered the harvested rice on small farms. On large farms, hired male labor, or working groups to which the farmer or a member of the household belonges, assisted in the gathering of the harvested rice. After gathering, the rice was packed at a prepared place near the farm hut, which was also used as a residence by the household for most of the dry season, especially in Tonko Limba chiefdom. The farmers stay at this old farm site after harvesting of the upland varieties in September and October until new farmlands are brushed, burnt, cleared and new farm huts constructed. It is May before they relinquish the old site. This was usually the time when some farmers processed their harvest and removed seed rice for seeding on the new farm.

The period between gathering and threshing varied from one ethnic group to the other. A majority of farmers gathered the harvested rice between the first and third weeks after harvest. (Table 3.7)

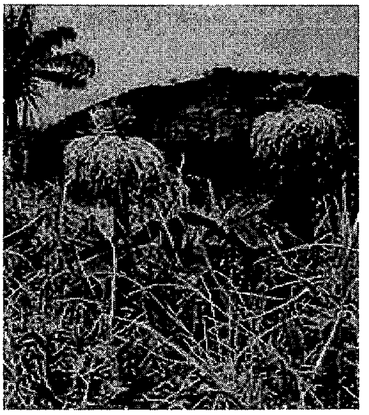


Photo 3.2: Panicle harvested rice stored on stump.

Some Limba farmers kept their rice stacked at the farm hut even after four months. Among the Limba superstitious beliefs in the power of various thunder and *"juju"* evil spirits tended to prevent pilfering by family members and stealing by outsiders. Stealing of harvested rice was rare, and where it occurred was mainly by outsiders. But the stealing of harvested rice from farms is increasing, possibly because of the increased immigration of non-Limba farmers in the chiefdom.

With the present economic situation, the farmer is burdened with financial obligations such as feeding, medical bills, school fees, marriages, funerals and money loans taken during the hungry season. Traders give loans to farmers for any of the above financial obligations and this is usually paid for in kind with farm produce after harvest. All these commitments force the farmers to thresh and process their harvest in time.

The culture of the farmers in the research area is gradually changing because of prevailing circumstances. In Magbema chiefdom farmers now have to sleep on the farm to protect their harvested rice from thieves before gathering. Stealing of harvested rice from the farm remains relatively uncommon in Tonko Limba and Bramaia chiefdoms because most villages are far removed from motorable roads and market centers.

The situation has also been aggravated by the present war in the country, wherein many displaced people have moved into the area in search of refuge and fertile land for cultivation (see chapter 2). The rebels have also been on the rampage and attack seed and grain stores for food. Farmers in more accessible areas have been forced, therefore, to remove their produce from the farm on the same day the rice is harvested.

Table 3.8: Gender distribution in rice threshing by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples).

Farmers	Gender Groups (%)					
	Me	Wo	Me+Wo	Me+Bo	Wo+Bo	Family
Temne	81.7	Nil	Nil	18.3	Nil	Nil
Limba	6.6	1.7	1.7	Nil	13.3	76.7
Susu	6.6	1.7	Nil	Nil	Nil	91.7

Note: Me = men; Wo = women; Bo = boys; Gi = girls; W Fam = whole family

3.3.4.4 Threshing

Threshing was done by men (81.7 %) in Magbema chiefdom and by the whole family in Tonko Limba (76.7) and Bramaia (91.7%) chiefdoms (Table 3.8). In the three chiefdoms, women, boys and girls alone were not allowed to do threshing because it was household rice and the head of the family needed to be present during threshing to control the produce. The activity started on the same day as the harvest with some farmers in all the chiefdoms, but continues up to one month in Magbema, two months in Bramaia and four months in Tonko Limba.

Threshing is the removal of kernels of rice from the panicle. In the research area, threshing is done by trampling on the harvested rice with the feet by women and boys, or flailing with sticks by men. Women and children usually tramp with their feet (cover photograph). A bundle of bulk or panicle harvested rice is placed on a threshing floor and trampled upon by the feet. The practice is common with panicle harvested rice because the bundles are smaller in size. Threshing with the feet reduces wastage when seed processing is involved and reduces varietal mixture. Flailing is done by men and women, and rarely by children. The rice is placed on the threshing floor in large quantities and is beaten by or against sticks. The practice is common with bulk harvested rice because the bundles are very bulky and heavy with lot of straw. Flailing is faster than trampling and is more common in Magbema chiefdom where a large quantity of mangrove rice is produced and threshing by trampling takes too much time to finish. Flailing results in high varietal mixtures. The methods of threshing, especially flailing to remove the kernel from the straw, causes rice seeds to move long distances from the threshing area. Where there is more than one variety stacked on a single processing floor, mixing can easily occur. Seed rice removed before threshing is usually processed by trampling by the foot to maintain purity.

Threshing floors are prepared near the farm hut. The area is cleared of grasses, debris and stones. They are dug over and the soils beaten by heavy logs to compact the surface. In some cases, soil from anthills high in clay content is transported to the site, spread on the surface of the site are then beaten to smooth the surface. The area is then left to dry before the rice is transported to the site for packing and processing. Some rich farmers used large mats (coota), or tarpaulins for packing and processing their harvest. Some farmers in Magbema and Bramaia thresh the rice in the field and carry out winnowing and drying in the village.

3.3.4.5 Winnowing

Most farmers started winnowing on the same day as the harvest . A few farmers in Tonko Limba took as long as six days to start (Table 3.8).

Table 3.9: Period between threshing and winnowing of the harvested rice by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples).

Farmers	Number of days (%)					
	1D	2D	3D	4D	5D	6D
Temne	93.3	5.0	Nil	Nil	1.7	Nil
Limba	51.6	3.3	1.7	1.7	1.7	40.0
Susu	73.3	11.7	Nil	Nil	Nil	15.0

Note: D = Days

Winnowing is done by women in Tonko Limba (98.3) and by the whole family in Magbema (78.3 %) and Bramaia (98.3 %). This is the separation of the seed or grain from the chaff and impurities by the use of air currents. Two methods are used. In the first method the harvested rice is loaded into winnowers, raised above the head and the material released slowly while the wind blows through the material as it drops, hence separating the chaff and other impurities from the pure seed. In the second method, local winnowers are used into which the material was loaded and simultaneously raised up and down in a harmonic motion to allow the breeze to pass through and separate the chaff and the impurities from the seed. In both methods heavier impurities such as stones, clods of earth and seeds of other crop species remained in the produce and are removed after winnowing. These are separated by sieving or hand picking. Women usually use the second method because it requires less energy.

Among Temne Farmers, men participate in winnowing operations because women and children cannot handle all harvest. Rice is a cash crop in this area and the men, who are usually heads are anxious to control the produce.

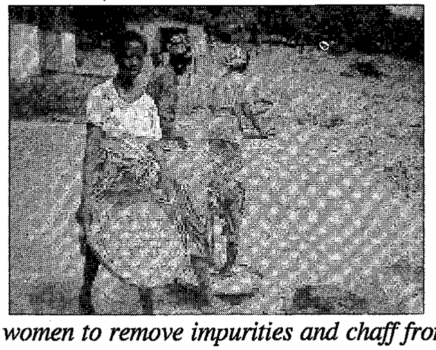


Photo 3.3 : Winnowing by women to remove impurities and chaff from the seed rice.

3.3.4.6 Drying

Duration of drying of seed rice that has been selected for planting depends on the number of sunny days. Short duration varieties that mature in September take more days to dry than the medium and long duration varieties harvested in October when there were few rainy days.

In Magbema chiefdom men mostly supervised and participated in drying the seed but women in Tonko Limba and Bramaia chiefdoms organized the drying operations. Heads of households (men and few women) normally carry out the drying of the seed to secure the seed for the next planting season (result not presented).

3.3.4.7 Seed storage

The men stored the seed in Magbema, Tonko Limba and Bramaia chiefdoms (Table 3.10). Seed for next planting was stored by the head of the family, or the most reliable person's in the household. It is this person's task to make sure that the seed is available and viable at next planting.

Table 3.10: Gender distribution in rice seed storage by Temne, Limba and Susu farmers in 1997, after rogueing (%) (1997 samples).

Farmers	Gender Groups (%)		
	Me	Wo	Me+Wo
Temne	86.6	6.7	6.7
Limba	100.0	Nil	Nil
Susu	80.0	1.7	18.3

Note: Me = men; Wo = women.

3.3.4.8 Seed storage containers

Farmers in the case study area store their seed mostly in baskets and jute bags. Farmers in Tonko Limba and Bramaia chiefdoms (Table 3.11) use a number of other containers. Jute bags are used for the storage of seeds of groundnuts, chilies and maize, and for marketing.

Table 3.11: Storage containers among Temne, Limba and Susu, 1997 harvest season.(%) (1997 samples).

	Containers (%)		
Farmers	Baskets	Jute bags	Others
Farmers	53.3	46.7	Nil
Limba	8.3	63.3	28.4
Susu	11.7	83.3	5.0

The baskets are made from local materials and can store seeds from a few kilograms to hundreds of kilograms. Farmers with large quantities of seed prefer baskets from which they can fill jute bags for transportation. The seeds are also stored in jute bags kept in rodent-proof stores for next planting. Mixing of varieties occurs if the baskets and jute bags are not properly cleaned of old seeds before storage of new seeds. In addition to jute bags and baskets, some farmers in Tonko Limba and Bramaia chiefdom store their seeds on the panicle, and seed is only processed when a new farm is cleared and ready for planting. Some farmers also store their seeds in locked boxes (often on a house veranda). This was more prominent among Limba and Susu farmers in Tonko Limba and Bramaia chiefdoms than in Magbema Chiefdom.

3.3.5 Farmers' knowledge: varieties and soil type

Farmers have a very detailed and valuable knowledge about cultivation of crops, and desirable characteristics of crops and farmlands. This is apparent in the knowledge they use to determine the type of variety to plant on different soil types in their farms. Farmers in the research area were interviewed using structured questionnaires (1997 sample) on criteria they use to determine the type of varieties they should cultivate on a particular part of the farm in terms of soil suitability, fallow period and water regime. Three criteria were identified among farmers in three chiefdoms.

In Magbema chiefdom, the farmers used the following criteria to determine the type of varieties they planted on their farms:

- After growing different type of varieties on different soil and plots over the years farmers know the right spot where each of their varieties will perform best. This knowledge take years to acquire but it an important part of the indigenous knowledge system of the community: 18.4 % of respondents said they used this method to determine the type of variety they should cultivate on any farms. Farmers clear farms each on a rotational cycle

- The age of the farm bush: only 3.4% of the respondents used this criterion to determine the variety to be cultivated on their farms

- Information from other farmers in the community: some farmers (13.4%) relied on the knowledge of other farmers about varieties suited to their land. These were mainly young farmers starting to farm or farmers who had never planted on that particular land type before.

- Some respondents (13.4 %) combined varietal testing and age of the bush to determine the varieties to be cultivated on their farms: 35% said they combined the knowledge of varietal testing and information from other farmers to determine the type of varieties to be grown. A few depended on the age of the bush and information from other farmers (10 %). Some farmers also relied on a combination of varietal testing, age of the bush and information from other farmers to make appropriate seed choices for their farms (6.4%)

In Tonko Limba Chiefdom the situation is slightly different. A majority of respondent (88.4%) depends on soil type to determine the type of variety to be cultivated. Very few farmers relied on the age of the bush (8.3 %), or the past history of varietal performance on a given land type (3.3 %).

The Susu determine the seed to be planted by soil type (84%), by age of bush (10 %), and through a combination of age of bush and soil type (6 %).

Results indicate that farmers have considerable knowledge about the type of varieties to grow on their farmland. Key informants revealed that Dissi Kono and Saliforeh (both *O. glaberrima* varieties) perform better on gravelly soils, sloping land, and in short-fallow bush. As distinct from *O. glaberrima* varieties, the *O. sativa* variety Samba Konkon (ROK

3; released by RRS in 1972 adopted and renamed by farmers as *Samba Konkon*) performed better in long fallow bush, on sandy loam soils, on clayey soils, on flat lands, especially those close to the swamps, on soils with high organic matter content, and on farms where burning was only partial (Richards, 1986).

The soil type was, therefore, the main factor that farmers used to determine varieties to be planted on a new farm. They might save seeds for the next planting season but the actual variety planted would depend on the extent of their former knowledge of the farm land in question. This was even one of the main reason why farmers did a lot of varietal exchange, so that the right type of variety was planted in the right soil, taking into account the age of the bush, past history of the land, and information sharing among farmers in the community.

Researchers and development workers in rural areas usually have limited local knowledge as compared with the knowledge of the farmer as apparent above. The failure of many agricultural development schemes reflects lack of understanding and appreciation of farmers' knowledge about the environment, including knowledge of plant genotypes x environmental interaction.

Since the beginning of agriculture, perhaps 10,000 years ago, women and men farmers have molded consciously, or through practice, the phenotype of hundreds of plant and animal species, as one of their many routine activities in the normal course in making a living (Harlan, 1992). These traditional methods of plant shaping by farmers are still operative the research area and still continue to produce distinctive varieties adapted to various land types and social conditions of farmers. In recent years, scientists have developed participatory approaches to crop development. The method is sometimes referred to as Participatory Varietal Selection (PVS), and is where farmers make their choices among the final products of a crop improvement program (Witcombe *et al*, 1996). This method is becoming a valuable tool in reinforcing conventional crop improvement activities throughout the world. To most resource-poor farmers in degraded areas, nothing has changed. The changes taking place in the science of high yielding varieties and the provision of facilities for high input environments have often passed by these low resource areas. Farmers still maintain established local selection strategies in adapting varieties to varying environmental conditions. Where recent innovations by scientists are considered, they are absorbed in an on-going process by farmers. As illustrated by the locally varied results in this chapter, scientists must first know what farmers are doing, so that they can use scientific knowledge to reinforce appropriate technologies for alleviating food production problems. It may make sense for researchers to release new varieties to farmers not as "innovations" but as ways of giving local selection new materials with which to work.

3.3.6 Original sources of rice varieties among farmers

It is thus important to know where farmers in the research area acquire new seeds.
The eight different sources through which farmers in the three chiefdoms acquire new seeds are listed in Table 3.12. Farmer saved seed was planted on the new farm only if the variety matched with the soil type on the farm. If, however, the soil on the new farm and the variety do not match, the farmer will look out for other sources. Farmers had a detailed agro-ecological knowledge of their farmlands. They have learnt over the years to match rice varieties to the land niches where they were known to perform best. At

seeding they look out for varieties that suit their newly cleared farmland and hope to obtain a suitable variety often by exchange with kin or friends.

The main source of new seed was by seed exchange among the farmers, and accounted for 38% of their seed acquisition. Farmers search in the community for other farmers who might want to exchange their seed, according to the suitability of seed to the soil (Table 3.12).

In addition to seed exchange, farmers also acquire new seeds as gifts from family members, especially via wives and in-laws, and as tithe to head of the family for land. Muslims also normally give, as a sacrifice, one out of every ten bundles of harvested rice to an Arabic teacher (karamoko) who provides koranic education in the village or leads prayers in the Muslim congregation in the mosque. The elderly members of the family in the village receive seed from their sons for land use. This accounted for 16% of new seed planted by the farmers.

Farmers also bought seeds from traders and itinerant craftsmen and healers in the community, who acquired more seeds than they required during the harvest season. These members of the community loaned seed for payment in kind after harvest. New seed was also acquired through migrants to diamond areas or from workers in agricultural institutions such as RRS who regularly travel back home to visit their relatives.

Within the farmer seed system, only 5% on average of new seeds were improved varieties. Most seed comes from within the community, with less than 20% of seed stock from outside the community, including improved varieties and "local" varieties supplied by projects.

Table 3.12: Original source of rice varieties among Temne, Limba and Susu Farmers (%)

	Number and percentage of farmers			
Source of new seed	Temne	Limba	Susu	Totals
Bought	18 (10.6)	18 (17)	36 (25)	72 (17)
Exchange	58 (34.1)	48 (44)	55 (37)	161 (37,9)
Gift	15 (8.8)	28 (26)	23 (16)	66 (15.5)
Loan	23 (13.5)	4 (4)	2 (1)	29 (6.8)
Improved seed	19 (11.2)	Nil	1 (0.7)	20 (4.7)
Payment for work	5 (3.0)	Nil	4 (3.7)	9 (3.1)
Source not known	Nil	6 (5)	6 (4)	12 (3.8)
Project sources				
(Total)	32(18.8)	4 (4)	20 (13.6)	56 (13.2)
Action Aid	Nil	4	17	21
IADP	7	Nil	2	9
NAPCO	5	Nil	Nil	5
SMP	9	Nil	Nil	9
RRS	11	Nil	Nil	11
Total no. of farmers	170 (100%)	108(100%)	147(100%)	425(100%)

Note: Numbers in bracket indicate the percentage per group of farmers

Improved seed accounted for only 5 percent of the farmers' seed sources averaged across the three ethnic groups, the highest percentage (11.2) being among the Temne (living closest to RRS). Limba farmers in Tonko, according to this survey had least access to or interest in improved seeds. Farmers in Magbema chiefdom had greater proximity to agricultural development agencies in the district. Improved seed is usually acquired from agricultural agencies and from relatives who work in research institutions. The cost of much project seed is subsidized, and seeds are available when prices are high. Farmers take project seed on price and availability, and not necessarily because they prefer modern varieties.

ActionAid or the Farmers' Association Support Program (FASP) of the Ministry of Agriculture are the main suppliers of project seeds. Farmers also obtained new seeds from research institution during on-farm trials. (Note: the results from this study do not indicate the area of local or improved seeds in on-farm planting in the research area, but give only an indication of where farmers get their new seeds from for planting).

3.7 Genotype x Natural environment x Social environment

Rice breeders are familiar with the idea of genotype x environment interaction (G x E) - that a variety will behave differently in different environments. More broadly, evolutionary biologists know that environmental pressure "selects" among life forms with different "fitness" (or genetic make-up). This chapter has shown clear evidence that the pressures of the environment acting on rice varieties in North-west Sierra Leone include the actions farmers take as part of their seed management activity. The "E" term, as it were, is made up of two components - E_1, the bio-environment, and E_2, the social context. But can we usefully separate the two terms?

The present study was conceived in parallel with a study by anthropologist Catherine Longley working closely with Susu and Limba farms at the border of Bramaia and Tonko chiefdoms, and results of this thesis combined with Longley's findings (Longley 1999) help answer this question.

The present chapter confirms a perhaps surprising degree of variation in seed management practice, and approach to selection, among three different ethnic groups living in contact over a long time period in a limited area.

Some of this variation may reflect E_1 factors. There is a shallow environmental gradient as we pass from the Temne area (Magbema) chiefdom to the Susu (Bramaia) and Limba (Tonko) chiefdoms (rainfall reduces slightly, the rainy season is slightly shorter, cf. Map 3.1, and there are minor soils differences passing from the rocks of the Kasila series around Kambia to the acid gneisses of Bramaia and Tonko). This gradient may account for some of the differences between the Temne farmers of Magbema and the Susu and Limba farmers of Bramaia and Tonko, in the way they select rices and manage seeds.

But what is more striking, and less easy to explain in terms of E_1 factors, is the very clear contrast between Susu and Limba farmers. Susu farmers encourage or tolerate within-farm diversity of rice types, Limba farmers discourage it.

Longley narrowed this down by studying closely Limba and Susu farmers working, in effect, in the same environment (opposite sides of a valley, with the stream marking the boundary between the two ethnic groups). The differences in selection strategies and seed management persist. They are clearly in the culture (E_2), and not the natural environment. Longley (1999) suggests it may be a different experience of slavery, and different attitudes to, and involvement in, inter-regional commerce that helps explain these cultural differences between the two groups. She warns that we must not see these differences in over-concrete terms (or, as social scientists prefer to put it, we should not "reify" ethnic differences). But even so, the difference remains, and it is clear that breeders must begin to take account of G x (E_1 + E_2).

In chapter 6 this thesis will try and pin down some of the consequences for the rice plant and rice agronomy of Susu preference for "mixed" seed and "mixed" planting strategies.

3.8 Summary

The main labor force is the farm household labor consisting of all members of the family headed by males in most cases. Ethnic group is specific to chiefdom i.e. Temne, Limba, and Susu farmers are found in Magbema, Tonko Limba and Bramaia chiefdoms respectively. Farmland is inherited but the Limba are more liberal in giving farm land to strangers than the Temne and the Susu. The age of the farmers in the sample ranges from 20 to above 70 years.

Varietal impurity fluctuated by ethnic group with the highest percent of admixtures among seed planted by the Susu. Farmers carry out negative and positive mass selection and develop varieties from off-types selected before or at harvest.

Men play an important role in rice seed management, especially among the Temne. Among Limba and Susu farmers, the whole family participates in seed management practices. Men, or head of the household, store rice seed.

The matching of rice varieties to different farmland types is based on past experience, age of bush, soil type, or a combination of these different factors.

Seed source is mainly from seed exchange, followed by gift and purchase from members of the community. Improved seed from research institutions and seed from project supplies accounted for only 29.8 percent of farmers' sources of new seeds.

4 RICE VARIETAL SELECTION IN NORTH WEST SIERRA LEONE: FARMERS' AND SCIENTISTS' PERSPECTIVES

4.1 Introduction

Institutional crop development has failed adequately to meet the needs of poor farmers in unfavorable environments because formal breeding objectives are mainly directed at increasing yields in more favorable environments. Farmers in unfavorable environments often reject varieties developed in research institutions because they are not well adapted to the physical and socio-economic environment of the farmers. The new trend from the view point of the formal sector is the involvement of farmers and professional plant breeders in varietal development at the early stages of selection, using a method referred to as Participatory Crop Improvement (PCI). Witcombe and Joshi (1996) subdivide PCI into two types of activities. In the first activity, referred to as Participatory Varietal Selection (PVS), farmers evaluate varieties in demonstration plots or in their own fields choosing from 'finished' varieties offered by plant breeders' programs. In the second activity, referred to as Participatory Plant Breeding (PPB), farmers are involved in the early stages of varietal development including the choice of plant characteristics to improve crop populations and breeding technique (Rice *et al*, 1998).

There are two most frequently cited breeding goals in PCI. The first goal is the selection for specific adaptation in adverse conditions, so that the breeder may better meet the need of these farmers who have not benefited from the improved techniques in modern plant breeding (Ceccarelii *et al,* 1996). The second goal is concerned with increasing the effectiveness of plant breeding programs by ensuring appropriate selection criteria for the development of varieties in the right environment (Weltzien *et al* 1996; Kamara *et al,* 1996). PCI has also been viewed as a means of linking agricultural development and conservation of crop genetic resources (Eyzaguirre and Iwanaga 1996; Riley, 1996). The proponents of PCI approaches argue that while professional plant breeding aims at producing a few varieties that are adapted to a wide range of environmental conditions, PCI supports the development and maintenance of more diverse, locally adapted populations (Biggs, 1989; Witcombe and Joshi, 1995).

Some of the problems with the involvement of breeders in PCI include institutional implications of the crop improvement strategies in both national and international centres (Ashby *et al*, 1995), the effectiveness of farmers' methods of seed selection and management (Friis-Hansen, 1996), and the nature of informal seed supply systems among farmers (Ceccarelli *et al* , 1996).

Several research organisations and projects are now aware of the importance of farmer participation in variety development, especially for resource-poor farmers in degraded environments. One of these projects is the Community Biodiversity Development and Conservation (CBDC) Program, which works with farmers and scientists in developing countries in Africa, South East Asia and Latin America. In Sierra Leone the Program had its preparatory phase from 1992 to 1994. During that period the extremely low adoption by farmers of improved technologies from the Rice Research Station (RRS) at Rokupr and from other research institutions was identified as a major problem.

In the research area, (Chapter 2, Map 2.6) only a few modern varieties had become established with farmers. During the early stages of this work, field days were organized between farmers in the Bramaia chiefdom and researchers at the RRS to develop researcher-farmer linkages. The researchers at RRS spent some times observing farmers' rice fields in Bramaia chiefdom, and at the end of the tour a meeting was held where farmers and scientists exchanged ideas about problems that farmers encounter with their rice farming. Results from this meeting revealed that over 70% of the farmers in a Chiefdom located only about 75 kilometres from RRS did know about the existence of RRS. Farmers did not much utilise the varieties released by RRS. In fact, only one variety, ROK 3 (renamed by farmers as *Samba Konkon,* Jusu and Longley, unpublished data) had been adopted. The farmers were later invited to visit RRS during a field day to see the research conducted at the station. The farmers were amazed to see so many varieties displayed by the station in the breeding laboratory and also in the fields. The farmers requested some of the varieties to be tested in their field and to be allowed to participate in variety selection. This resulted in the work reported in this thesis.

As part of this study, a Farmers Participatory Research Proposal for the upland rice ecology in Sierra Leone was developed at the departments of Technology and Agrarian Development, and Plant Breeding and Crop Protection of the Wageningen Agricultural University (WAU) and the Centre for Genetic Resources, the Netherlands (CGN) at CPRO-DLO. The proposal was to bring farmers and scientists together to participate actively in the selection of varieties farmers might eventually adopt. The activity was conducted under the umbrella of the CBDC project in Sierra Leone.

This work was intended to help understand farmers' selection and how farmers' selection can be utilised in farmers' plant improvement activities. Several researchers (Ceccarelli *et al* 1996; Biggs, 1989) have shown that where resource poor farmers are the target group, it is advantageous to select under farmers' conditions, and if possible to involve farmers directly in the selection process. The overall argument for this activity is that high and low performing selections in good environments often change ranks in poor environments, i.e. there is G x E interaction. The objectives of the work were to establish trials in collaboration with farmers in order to:

- identify the characteristics that farmers prefer in their varieties,
- evaluate the yield performance of varieties at RRS and on farmers' fields
- find out whether the varietal characteristics and preferences differ between ethnic groups/Chiefdoms
- find out whether selection criteria differed between farmers and scientists.

4.2 Materials and methods

4.2.1 Formation of CBDC farmers association

The project area consisted of three chiefdoms in Kambia District, viz. Magbema, Tonko Limba and Bramaia chiefdoms. Ten villages were selected in each of these chiefdoms and in each village 6 farmers were identified as participating farmers representing the village farming community. The farmers were selected in collaboration with Farmers Association Support Project (FASP) in Magbema chiefdom and ActionAid (AA) in Tonko Limba and Bramaia chiefdoms.

4. 2.2.1 Set of trials

Two types of trials were conducted. Farmers' evaluation of varieties in Participatory Varietal selection (PVS) and farmers' evaluation of varieties using Informal Research and Development (IRD). In each of the trials varieties were planted in farmer' fields with the objective that, at crop maturity, the farmers would be able to select the varieties they would like to grow in the following seasons. These selections would be based on criteria determined by the farmers themselves. PVS was also planned at the Rice Research Station (RRS) under researcher-managed conditions.

4.2.2.2 Farmers' evaluation of varieties in Participatory Varietal Selection (PVS)

4.2.2.2.1 Acquisition of planting materials

At harvest of upland rice farms in the 1995 cropping season (September to October) an inventory of the crops grown by farmers in the research area was made to determine crop diversity (crop types grown by farmers) in the project area (Chapter 2).

Once the crop inventory was analyzed, the most popular upland rice varieties were then collected from the three chiefdoms. Promising rices from International Network for the Genetic Evaluation of Rice for Africa (INGER-Africa) based at the West Africa Rice Development Association (WARDA) were also requested and included. The other materials were obtained from the Breeding Division of RRS. The trial consisted of 100 varieties plus a local check at each location (Table 4.1). The sources of the varieties are as indicated below.

Table 4 1: List of varieties, species and sources of Oryza materials used in the farmers' selection trial in 1996 cropping season

#	NAME OF VARIETY	SPECIES	SOURCE
1	Kebleh	O. glaberrima	Farmer's var. (Tonko Limba)
2	Black Sallay	O. glaberrima	Farmer's var. (Tonko Limba)
3	Daimaru Bali	O. sativa	Farmer's Var. (Bramaia)
4	Bayiba	O. sativa	Farmer's var. (Tonko Limba)
5	Joe Wanjei	O. sativa	RRS Selection (Magbema)
6	Ngolo Yumboi	O. sativa	RRS Selection (Magbema)
7	Damba	O. glaberrima	Farmer's Var. (Tonko Limba)
8	Pa Damba	O. glaberrima	Farmer's var. (Bramaia)
9	Khorry Kindeh	O. glaberrima	Farmer's Var. (Bramaia)
10	Bensali	O. sativa	Farmer's var.(Bramaia)
11	Nylon	O. sativa	Farmer's var.(Bramaia)
12	Thabunsu	O. sativa	Farmer's var.(Bramaia)
13	Sumaila	O. sativa	Farmer's var.(Bramaia)
14	Isatu	O. sativa	Farmer's var. (Tonko Limba)
15	Rok 5	O. sativa	Farmer's Var. (Bramaia)
16	Rok 16	O. sativa	Farmer's Var. (Magbema)
17	Janet	O. glaberrima	Farmer's var. (Tonko Limba)
18	Nyarie Bomboi(White)	O. sativa	Farmer's var.(Bramaia)
19	Nyarie Bomboi(Red)	O. sativa	Farmer's var.(Bramaia)
20	Pa Three month	O. sativa/glab	Farmer's var. (Magbema)
21	Pa Three month	O. sativa/glab	Farmer's var. (Magbema)
22	Salifaigai	O. glaberrima	Farmer's var.(Bramaia)
23	Salifaigai	O. glaberrima	Farmer's var.(Bramaia)
24	Sorie Kunde	O. glaberrima	Farmer's var.(Bramaia)

25	Dissi Kunke	O. glaberrima	Farmer's var.(Bramaia)
26	Pa Temne	O. glaberrima	Farmer's var.(Bramaia)
27	Pa Temne	O. glaberrima	Farmer's var.(Magbema)
28	Dissi Temne	O. glaberrima	Farmer's var.(Magbema)
29	Dissi Forie	O. glaberrima	Farmer's var.(Bramaia)
30	Dissi Forie	O. glaberrima	Farmer's var.(Bramaia)
31	Dissi Forie	O. glaberrima	Farmer's var.(Bramaia)
32	DISSI Forie	O. glaberrima	Farmer's var.(Bramaia)
33	ROK 3 1	O. sativa	Farmer's var.(Magbema)
34	ROK 3 2	O. sativa	Farmer's var.(Magbema)
35	Pa Dissi Temne	O. glaberrima	Farmer's var.(Magbema)
36	Dissi Kono	O. glaberrima	Farmer's var.(Magbema)
37	Saliforeh	O. glaberrima	Farmer's var.(Bramaia)
38	Saliforeh	O. glaberrima	Farmer's var.(Bramaia)
39	Yak Gassy	O. sativa	Farmer's var.(Magbema)
40	No Name	O. sativa	Farmer's var.(Bramaia)
41	Pa Three month	O. sativa/glab	Farmer's var. (Tonko Limba)
42	Pa Bop	O. sativa	Farmer's var.(Magbema)
43	Pa Three month	O. sativa	Farmer's var. (Bramaia)
44	Dissi Temne	O. glaberrima	Farmer's var.(Magbema)
45	Dissi Kono	O. glaberrima	Farmer's var.(Magbema)
46	Dissi Kono	O. glaberrima	Farmer's var.Tonko Limba
47	Pa Konkon	O. sativa	Farmer's var.(Tonko Limba)
48	Samba Konkon	O. sativa	Farmer's var.(Magbema)
49	Samba Konkon	O. sativa	Farmer's var.(Bramaia)
50	Samba Konkon	O. sativa	Farmer's var.(Bramaia)
51	IRAT 168	O. sativa	INGER-AFRICA(AURAT-E)
52	IR 55549-1-2	O. sativa	INGER-AFRICA(AURAT-E)
53	ITA323 (TOX1780-7-1-201-1	O. sativa	INGER-AFRICA(AURAT-E)
54	TGR 68	O. sativa	INGER-AFRICA(AURAT-E)
55	TRIUNFO (CNA 4141)	O. sativa	INGER-AFRICA(AURAT-E)
56	WAB 181-18	O. sativa	INGER-AFRICA(AURAT-E)
57	WAB 32-46	O. sativa	INGER-AFRICA(AURAT-E)
58	WAB 33-17	O. sativa	INGER-AFRICA(AURAT-E)
59	WAB 56-50	O. sativa	INGER-AFRICA(AURAT-E)
60	FARO 40	O. sativa	INGER-AFRICA(AURAT-M)
61	IR 47686-15-1-1	O. sativa	INGER-AFRICA(AURAT-M)
62	IR 47686-18-6-1	O. sativa	INGER-AFRICA(AURAT-M)
63	IR 57924-1	O. sativa	INGER-AFRICA(AURAT-M)
64 .	ITA 216	O. sativa	INGER-AFRICA(AURAT-M)
65	ITA337(TOX1889-15-1040101)	O. sativa	INGER-AFRICA(AURAT-M)
66	RY 1	O. sativa	INGER-AFRICA(AURAT-M)
67	TOX1010-6-9-3-201	O. sativa	INGER-AFRICA(AURAT-M)
68	WAB 32-55	O. sativa	INGER-AFRICA(AURAT-M)
69	WAB 96-1-1	O. sativa	INGER-AFRICA(AURAT-M)
70	WAB 99-1-1	O. sativa	INGER-AFRICA(AURAT-M)
71	B-2151C-MR-57-1-3-1	O. sativa	RRS advanced line
72	BR153-2B-10-1-3	O. sativa	RRS advanced line
73	BR 31615-4-1	O. sativa	RRS advanced line
74	GUINEA	O. sativa	RRS advanced line (Farmer's Var.)
75	IR 9884-54-3-1E-P1	O. sativa	RRS advanced line
76	IR 2282-41-2	O. sativa	RRS advanced line
77	ITA 123	O. sativa	RRS advanced line
78	ITA 302	O. sativa	RRS advanced line
79	ITA 306	O. sativa	RRS advanced line
80	NO 1 BP 148	O. sativa	RRS advanced line
81	TOX 3052-46-E2-2-2-4-3	O. sativa	RRS advanced line

82	TOX 3211-14-1-2-1-2	O. sativa	RRS advanced line
83	TOX 3553-36-2-2-2	O. sativa	RRS advanced line
84	TOX 3440-176-1-2-1	O. sativa	RRS advanced line
85	ROK 11	O. sativa	RRS release
86	ITA 212	O. sativa	RRS advanced line
87	ROK 3 3	O. sativa	RRS release
88	ROK 16	O. sativa	RRS release
89	ROK 19	O. sativa	RRS Released
90	ROK 20	O. sativa	RRS release
91	Pa Konkon/Samba Konkon	MIXED	Combination
92	Saliforeh/Samba Konkon	MIXED	Combination
93	Bensali/Samba Konkon	MIXED	Combination
94	Daimbaia Bali/Samba Konkon	MIXED	Combination
95	Sorie Dunke/Samba Konkon	MIXED	Combination
96	Janet/Samba Konkon	MIXED	Combination
97	Dissi Konkon/Samba Konkon	MIXED	Combination
98	Nylon/Nylon	O. sativa	Combination
99	Daimba/Daimba	O. sativa	Combination
100	Dissi Dunke/Dissi Dunke	O. sativa	Combination

50 varieties (*24 Oryza glaberrima* and 26 *O. sativa*) came from farmers in Magbema, Tonko Limba and Bramaia chiefdoms of Kambia District in North-western Sierra Leone. 20 varieties were supplied by the INGER-Africa nurseries at WARDA in Cote D'Ivoire 15 varieties were selected from among advanced breeding (upland) lines from the Breeding Division at RRS. 5 varieties were released RRS upland varieties. Ten local varieties were physically mixed in the laboratory before weighing, replicating the practice of some farmers in Bramaia chiefdom.

Not all randomly selected farmers actually participated in the trials. Actual numbers were as as follows 53 in Magbema, 39 in Tonko Limba and 41 in Bramaia (on details of sampling, see chapter 3).

4.2.2.2.2 RRS - Masorie trial

The trial at the RRS experimental site was conducted to compare the performance of the varieties under research conditions and farmers' conditions. The area was brushed, burnt to remove biomass, stumped and dug using native cutlasses and hoes. The varieties were drill-sown. Each variety was sown in 3 rows per plots each 3 meters long with a row spacing of 20 cm between varieties and 40 cm between the plots. The trial was planted in 5 blocks, each block consisting of 20 plots of varieties plus three plots of the check variety sown in plots at the start of the block, after every 10 varieties and at the end of the block. A seed rate of 100 kg ha^{-1} was used. An RRS released variety, ROK 19, was used as a check. The trial was sown on the 28 June 1996

A fertiliser rate of 80 kg N ha^{-1} as urea, 40 kg P_2O_5 ha^{-1} as Single Super Phosphate (SSP) and 40 kg K20 ha^{-1} as Muriate of Potash (MOP) was applied. Phosphorus was applied at seeding and nitrogen and potassium at 14 and 42 days after sowing to coincide with the vegetative and reproductive stages of the varieties. Weeding was done before second and third fertiliser application and whenever necessary.

4.2.2.2.3 Farmers field trial

The trials in the farmers' fields were conducted under farmers' condition where the stumps were not removed and agro-chemicals were used. Land preparation was done as described in chapter 2. Each variety was seeded separately in rectangular plots to avoid mixing of varieties. Samba Konkon was used as a check at the locations and was planted after every 10 varieties. Seed was broadcast at a rate of 80 kg ha $^{-1}$ in plots 60 cm wide and 3 meters long. The varieties were seeded in 5 blocks, each block consisting of 20 varieties. The trials were seeded at the Masorie on-farm site on the 28 June, at Kawonsor on the 11 July and at Kambi Kabaia on the 12 July. All other cultivation was according to farmers' practices.

Forty-nine varieties selected by farmers from the 1996 trials were then grown in the 1997 cropping season at RRS on the 21 June, Rokupr Junction, 22 June, Baghonyi Junction, 25 June, and Sela Kafta, 27 June 1997. The same methodology used in 1996 was adopted. Some of the varieties selected were not enough to be planted at all the sites. The main aim of the 1997 trial was to test the performance of the selected varieties during the second season at RRS, and on farmers' fields.

4.2.3 Site selection for the PVS trials

The sites for the on-farm trials were acquired from the farming communities at the various villages in the three chiefdoms. The trial plots and varieties were acquired by a joint decision of the community participating in the evaluation of the trials. Before the acquisition of the trial sites and varieties, we held a meeting with the farmers to discuss the objectives of the trials and how the trials were to be conducted to achieve these objectives. The farmers then held a meeting to decide on the type of varieties and land to be used for the trials at the various locations.

4.2.4 Description of trial sites

The research area is characterised by a growing season from June to November (180 days) with an annual rainfall between 2000 and 3000 mm per annum. The soil and vegetation varied from location to location as indicated below, for a total of eight sites where trials were conducted.

4.2.4.1 Rice Research Station (RRS) experimental site at Masorie upland (1996 and 1997)

The trial plots at this site were acquired from the Breeding Division of RRS. Shrubs and trees characterised the vegetation. The land had been left fallow for five years before clearing for experimentation. The low fertility status of the soil resulted in high weed, pest and disease infestation. The soil was sandy loam with very little gravel on the surface.

4.2.4.2 Masorie on-farm trial (1996) in Magbema chiefdom

The vegetation was mainly of trees and shrubs. The trees were mainly mahogany forest trees planted for timber production. The land had been left to fallow for twenty-one years before clearing. The trial was conducted during the second year of cultivation. The soil was loamy with few stones.

4.2.4.3 Kambi Kabaia on-farm trial (1996) in Tonko Limba chiefdom
The site was secondary bush with a fallow period of six years. The vegetation consisted of shrubs, sedges and grasses. The soil was sandy loam with a lot of stones and gravel.

4.2.4.4 Kawonsor on-farm trial (1996) in Bramaia chiefdom
The site was also secondary bush, with a fallow period of five years. The vegetation consisted of trees, sedges and *Calapogonium mucunoides* weeds, dominant in areas where there were few trees. The soil was sandy loam with many stones and much gravel at the surface.

4.2.4.5 Rokupr Junction on-farm trial (1997) in Magbema chiefdom
The site was in a former "forest reserve" left fallow for the past 40 years. The land was cleared in 1996 for upland rice production and used again in 1997 for the same purpose. The faster growth of the mahogany forest trees caused a lot of shading of the crop. The soil was also loamy with high organic matter content with very few stones on the surface.

4.2.4 .6 Sela Kafta on-farm trial (1997) in Tonko Limba chiefdom
The site was a five-year-old fallow bush with dominant tree cover used by the farmer for the first cropping. The organic matter content of the soil was very high with few stones on the surface. The trial was seeded late on 20 July 1997. The late seeding reduced the yield drastically because the rains had ended by early November. Most of the farmers in the area had seeded their own fields before the trial was executed.

4.2.4 .7 Baghonyi Junction on-farm trial (1997) in Bramaia chiefdom
The site was a secondary bush with nine years of fallow. There were few grasses and sedges at this site. The soil was sandy loam with few stones on the surface. The organic matter content was very high. The trial was sown late, on the 21 July 1997. Most farmers had seeded their own farms by the time the trial was seeded.

Organic matter status of soils at all trial locations was assigned a rating, as judged by the researcher.

4.2.5 Farmers Evaluation of Varieties using Informal Research and Development (IRD) Protocol
Fifteen farmers (heads of households), five per chiefdom, were given 5 kg each of two RRS released varieties (ROK 16 and ROK 20) to evaluate on their farms along with their local varieties. ROK 16 (Ngovie) released in 1978 is still not very popular among farmers in the project area. ROK 20 was released in 1988. The farmers selected for the trials were key collaborators working with the CBDC project in the selected villages. They were all heads of farm family households, male, and citizens of the area.

These farmers were asked to invite as many farmers as possible to evaluate the varieties and to give reasons for selecting or rejecting the varieties. During the first part of this work, farmers' fields were demarcated and farmers and scientists planted the varieties together. At the end of the two years, the farmers and scientists met at the trial sites and the farmers' reaction on the performance of the varieties during cultivation, palatability and whether they would like to continue growing the varieties were recorded. Participating farmers invited as many farmers as possible in the locality to evaluate and give reasons for selecting or rejecting the varieties. This facilitated the evaluation of the varieties in the IRD trial.

In both PVS and IRD the farmers took care of the trial from seeding to harvest.

4.2.6 Investigating how scientists think about institutional and farmer "ideotypes"

A list of 19 characters from IRRI rice model (IRRI ideotype) for rice scientists was developed in a form of a questionnaire (Appendix 4.1). The IRRI rice model is a rice prototype developed at IRRI and used widely by rice scientists around the world for developing acceptable rice varieties for all rice growing ecologies. From the rice characteristics identified by farmers during the farmers' selection trial, 19 of the most frequently occurring characters were listed in order, to develop the farmers' rice model (ideotype) (Appendix 4.2)

The scientists (both junior and senior technical staff) of RRS were then requested to rank the characters in descending order of preference for both the farmers' ideotype (Appendix 4.2) and the IRRI ideotype (Appendix 4.1). The list of the 19 farmer model characters (ideotype) was then compared with the IRRI characters as ranked by scientists, as a measure of agreement/disagreement between farmer and scientist selection approaches. This measure was constructed to assess.

- convergence or divergence in the opinion of scientists concerning the IRRI model and the farmers' rice model as developed during this study.
- whether scientists and farmers view varieties the same way during selection or to find out where opinions converged and diverged.

The two models (ideotypes) were then used as probes to find out whether the workers in the various research divisions in the four main disciplines at RRS (Plant Breeding, Agronomy, Plant Health and Farming Systems Research) had the same visions, expectations and requirements in developing rice varieties for farmers. Data from the ranking of the two models were analysed using the Spearman's Rank Correlation Coefficient (Steel and Torrie, 1980) as a measure of degree of similarity in the assessment of various groups involved in rice development, including farmers.

4.2.7 Problems in trial management

Farmers paid more attention to their own rice fields, and this resulted in heavy weed and bird damage on most trial sites. The tight farming calendar could not easily be compromised. The only option of most of the farmers was to send young children to take care of the trials. We learnt that most farmers were only at the trial site when the scientists were there; otherwise they went to work on their farms.

In addition to the above problems, the rainfall pattern in the area was very erratic. Magbema had a higher rainfall followed by Bramaia chiefdom and then Tonko Limba. The rains stopped in Magbema in late October, in Bramaia in the middle of October, and in Tonko Limba Chiefdom in late October.

Differences in household composition and variation in farming practices also had an impact on the trial. Temne and Limba farmers cultivated approximately 0.5 to 1 ha per farm family. Farm size, however, depended on the size of the household, which ranged from 2 to 30 members. The Susu worked communally and cleared extensive areas, which were subdivided per household for cultivation. With the Susu system it was easier to bring farmers together, since over fifty farms families were found at one location.

Farmers practice shifting cultivation and normally cultivated rice at one farm site only for one cropping season. They then moved to another site in the following year leaving the old site for the cultivation of less nutrient-demanding crops such as sorghum and pearl millet, groundnuts, chillies, *Digitaria exilis* etc. This farming activity prevented the establishment of trials at one location for more than one year. Therefore the scientists and farmers moved to another site during the second year. Data analysis for the PVS was intended to evaluate the varietal adaptation to the farmers production systems within the research area where farmers were changing farmlands every year and returning to the land after the soil fertility had been restored after several years of fallow. It was not possible, therefore, to study the stability of the varieties at one location over two years.

4.2.8 Data collection and analysis

4.2.8.1 Participatory Varietal Selection (PVS)

Two types of data were collected. Farmers were invited to the trials individually at their leisure, and as a group during farmers' field days, to select. In total, 289 farmers carried out selection (Table 4.2). They were individually asked to make a guided tour along the 100 varieties including the checks (ROK 19 at RRS and Samba Konkon at village sites) to select the varieties they preferred most for cultivation. When a variety was selected, the accompanying scientist then recorded the reasons for which the farmer selected that variety.

In addition to characters recorded and varieties selected by farmers, data were also recorded on the performance of varieties at the various locations, to compare yield performance of varieties at RRS and on the farmers' fields. The data were also used to compare the relationship between yield and farmer choices in varietal selection. At maturity the following traits were recorded at RRS and on the farmers' fields:

- grain yield (kg/ha)
- days to maturity (days)
- culm number
- planted height (centimetres)
- lodging (scores, from 1 = best, to 9 = worst)

4.2.8.2 Informal Research and Development

Data for Informal Research and Development (IRD) were collected by recording farmers' perceptions about the varieties they evaluated at the end of the two years.

Data were analyzed using Excel and Genstat 5. Spearman's rank correlation coefficients (rs) were calculated to compare preferences of farmers and scientists as well as to assess agreement between yield performance of varieties and the frequencies with which they were selected by farmers. ANOVA was used to compare the performance of the varieties in the two years at the 8 locations.

4.3 Results and discussion

4.3.1 Varieties

The 100 varieties used in the various farmer selection trials in (PVS) 1996 and 1997 are listed in Table 4.1. They comprise farmer varieties of *O. sativa* and *O. glaberrima* (24 each), 15 RRS advanced lines, 5 RRS releases, 2 RRS farmer selections, 20 international advanced lines (including 7 WARDA inter-specific hybrids), 7 mixtures, and 3 samplings of the farmer inter-specific hybrid *Pa Three Month*. In Table 4.1 the seven WARDA inter-specific advanced lines are listed with the prefix WAB.

In the selection trials farmers chose 49 varieties (49%) a total of 289 times. Varieties chosen are shown in Table 4.2 by chiefdom and times chosen. The material is grouped by category and chiefdom in Table 3.3. The categories are farmer sativa, farmer glaberrima, RRS sativa, international sativa, and WARDA inter-specifics (plus *Pa Three Month*).

A number of patterns are clear from Tables. 4.2 and 4.3:

- international sativa material was chosen most often (11 out of 13 varieties tested and 34% of all choices) but quite closely followed by farmer sativa material (15 out of 24 varieties tested and 27% of all choices), thus indicating that international germplasm <u>is</u> relevant to farmer interest, contrary to the cherished beliefs of some ardent proponents of a farmer-first approach to plant improvement, but also confirming the continued importance of local germplasm in upland rice farming.

- RRS material was relatively unpopular for the number of varieties available for selection (only 6 out of 22 varieties tested, and 19 per cent of all choices). Most of the choices (32/54) were accounted by two well-known selections from farmer upland varieties released in the 1970s (ROK 3 and ROK 16). It is definitely worrying that the material currently in the RRS "pipe" was chosen so infrequently (2 out of 15 advanced lines tested, chosen only 5 times, in a total of 54 choices of RRS material).

- farmers selected a greater proportion of local *O. glaberrima* varieties included in the trial than RRS sativa varieties (11 out of 24 varieties, compared to 6 out of 22) but the glaberrima materials accounted for only 10 per cent of choices overall (choices among *glaberrimas* tended to be restricted to only small numbers of farmers per variety, scattered among the chiefdoms, suggesting local or personal considerations may weigh heavily in the selection of this class of material).

- *O. glaberrima x O. sativa* inter-specific material was chosen more often than *O. glaberrima* material (taking *Pa Three Month* and WARDA material together, the relevant figures are 6 out of 10 varieties tested, and 12% of all choices).

- if the glaberrima and inter-specific material is treated as a single group then 17 out of 34 varieties tested were selected, with material of glaberrima parentage accounting for 22% of all farmer choices. This would place such material third behind international and farmer sativa material in terms of farmer popularity, but in front of RRS sativa material, suggesting there is still a definite place for material with glaberrima characteristics in farmers' thinking, and that testing and developing varieties with glaberrima parentage should become part of RRS research plans for low-resource upland farmers.

- -interest in *O. glaberrima* varieties or material with glaberrima parentage was greatest in Bramaia chiefdom, but least in neighbouring Tonko, despite a similar harsh environment for upland rice. (The chiefdom pattern reverses for interest in international sativa material.) Interest in the WARDA interspecific hybrids was restricted to Magbema and Bramaia chiefdoms. Interest in the local inter-specific *Pa Three Month* was greatest in Magbema chiefdom, the region in which it was first adopted.

- per category the most popular individual rices were RY-1 (international sativa, chosen 38 times), white Nyarie Bomboi (farmer sativa, 26 choices) and ROK 3 & ROK 16 (RRS sativa, chosen 16 times each). Among interspecifics, the WARDA hybrid WAB 96-1-1 was chosen 13 times, ahead of Pa Three Month (chosen 11 times), but both ahead of the single most popular pure *O. glaberrima* variety, Dissi Kono, chosen 9 times.

- No farmer chose any material presented as mixtures, even though some farmers plant material in mixtures. This is perhaps not surprising. Farmers were asked to chose varieties. Mixing is something farmers do - where they do it - to induce changes in known varieties. Farmers usually plant small plots of *O. glaberrima* varieties as a hungry season crop, which they harvest for food while awaiting the main harvest. The high rate of selection of new materials (80% selected) confirms that farmers are always very inquiring about new materials from out side the community to test on their farms.

- For varieties selected at least once, the varieties were ranked by the frequency with which were chosen by each of the ethnic groups and Spearman's rank correlation coefficients (rs) between these groups were calculated. These were -0.03, 0.449 and 0.233 for Magbema/Tonko Limba, Magbema/Bramaia and Tonko Limba/Bramaia Chiefdoms respectively. Only, the Magbema/Bramaia choices showed any degree of correlation. Lack of correlation suggests that farmers' rankings are specific to local environments or that farmers make idiosyncratic choices.

- When the actual varieties selected by farmers are compared between the chiefdoms some striking differences emerge. The most popular varieties among the three ethnic groups were RY1 and Nyarie Bomboi white and red, TOX1010-6-9-3-201, ROK 3 from RRS, ROK 16 and Bensali. Some varieties were preferred more by certain ethnic groups than others. In the Magbema chiefdom farmers did not select TOX1010-6-9-3-201, which ranked first in Tonko Limba and Bramaia chiefdoms. Nyarie Bomboi white and red, ROK 3 and ROK 20 from RRS were also preferred. Similarly, in the Tonko Limba chiefdom ITA 216 was the most preferred variety but was not selected by farmers in Magbema and Bramaia chiefdoms. Other varieties selected in Tonko Limba were RY1, Nyarie white, FARO 40, IRR55549-1-2, ITA306 and Pa Konkon while in Bramaia chiefdom RY1, Nyarie Bomboi white and red, WAB96-1-1, Dissi Kono and ROK 19 were preferred. The total number of varieties selected per farmer varies from.

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Table 4.2: Farmer choices (varieties and times chosen), by category of rice variety and chiefdom

	Varieties chosen per category	MAGBEMA varieties chosen	MAGBEMA farmers selecting variety	TONKO varieties chosen	TONKO farmers selecting variety	BRAMAIA varieties chosen	BRAMAIA farmers selecting variety	TOTAL farmers selecting variety	PERCENT farmers selecting variety
Farmer sativa	15/24	6	30	11	26	6	21	77	27%
Farmer glaberrima	11/24	4	12	3	3	6	11	26	10%
Pa three month	2/3	2	10	1	1	0	0	11	4%
RRS sativa	6/22	4	35	2	4	5	15	54	19%
Inter-national sativa	11/13	8	38	8	42	2	19	99	34%
WARDA inter-specifics	4/7	3	6	0	0	4	16	22	8%
RRS mixtures	0/7	0	0	0	0	0	0	0	0%
TOTAL	49/100							289	102% rounding error

TABLE 4. 3: List of Varieties Selected By Farmers Out of the 100 Varieties Tested Among the Temne, Limba, and Susu Ethnic Groups in Northwest Sierra Leone in the 1996 Cropping Season

VARIETIES	MAGBEMA FARMERS (53)	TONKO LIMBA FARMERS (39)	BRAMAIA FARMERS (41)	TOTAL FARMERS (133)
1. RY1 (INT, OS)	5	16	17	38
2. NYARIE BOMBOI WHITE (FAR, OS)	12	8	6	26
3. TOX 1010-6-9-3-201 (INT, OS)	20	-	-	20
4. ROK 3 3 (RRS,OS)	14	1	1	16
5. ROK 16 (RRS,OS)	8	-	8	16
6. BENSALI (FAR, OS)	3	4	7	14
7. NYARIE BOMBOI RED (FAR, OS)	6	3	5	14
8. WAB 96-1-1(INT, OS)	2	-	11	13
9. ITA 216 (INT, OS)	-	13	-	13
10. ROK 20 (RRS,OS)	11	-	1	12
11. DISSI KONO (FAR, OG)	6	-	3	9
12. PA 3 MONTH 1 (FAR, ?)	7	1	-	8
13. FARO 40 (INT, OS)	1	7	-	8
14. PA BOP (FAR, OS)	5	-	1	6
15. IR 47686 (INT, OS)	5	1	-	6
16. ROK 19 (RRS,OS)	2	-	3	5
17. DAMBA(FAR, OG)	4	-	1	5
18. IR55549-1-2 (INT, OS)	1	3	-	4
19. WAB32-46 (INT, OS)	2	-	2	4
20. BLACK SALLY (FAR, OS)	1	1	1	3
21. JANET (FAR, OS)	3	-	-	3
22. TRIUNFO (CN4141) (INT, OS)	3	-	-	3
23.ITA 323 (TOX....) (INT, OS)	1	2	-	3
24. PA 3 MONTH 2 (FAR,?)	3	-	-	3
25. ITA 306 (RRS,OS)	-	3	-	3
26. PA KONKON(FAR, OS	-	3	-	3
27. IR57924-1(INT, OS)	-	-	2	2
28. SALIFOREH 1(FAR, OG)	-	-	2	2
29. DISSI FORIE(FAR, OG)	-	-	2	2
30. SORIE DUNKE (FAR, OG)	-	-	2	2
31. TOX3211-14 (RRS,OS)	-	-	2	2
32. WAB32-55 (INT, OS)	2	-	2	2
33. ITA 232 (TOX..) (INT, OS)	2	-	-	2
34. THABUNSU (FAR, OS)	-	2	-	2
35. DISSI FORIE (FAR, OG)	-	-	1	1
36. KEBLEH (FAR, OS	-	-	1	1
37. WAB56-50 (INT, OS)	-	-	1	1
38. PA. TEMNE (FAR, OG)	1	-	-	1
39. SALIFOREH 1 (FAR, OG)	1	-	-	1
40. DAMBARA BALLI (FAR, OS)	-	1	-	1
41. ITA337 (INT, OS)	-	1	-	1
42. JOE WANJEI (FAR, OS	-	1	-	1
43. KHORRY KINDE (FAR, OG)	-	1	-	1
44. No.1 BP(INT, OS)	-	1	-	1
45. PA DAMBA (FAR, OG)	-	1	-	1
46. SAMBA KONKON 1 (FAR, OS	-	1	-	1
47. SAMBA KONKON 2 (FAR, OS	-	1	-	1
48. SAMBA KONKON 3 (FAR, OS	-	1	-	1
49. SORIE DUNDE (FAR. OG)	-	1	-	1

Note FAR, OS = Farmers variety that is O. sativa; FAR, OG = Farmers variety that is O. glaberrima; INT,OS= Introduction that is O. sativa; RRS , OS = Rice Research Station Variety that is O. sativa and ?farmers variety that cannot be assigned to any group

Photo 4.1 : A farmer selecting a variety during farmers field day

chiefdom to chiefdom and ranges from 1 to 7 in Magbema, 1 to 4 in Tonko Limba and 1 to 6 in Bramaia chiefdoms In order to assess farmers' preferences by yield performance, the varieties were ranked for their yield obtained at the various locations and their frequency of being selected by the farmers. This was done separately for each chiefdom. The Spearman's rank correlation coefficients (rs) obtained for each chiefdom were 0.871 ($p < 0.05$), 0.007 ($P < 0.05$) and 0.317 ($p < 0.05$) for Magbema, Tonko Limba and Bramaia respectively. The correlation between yield and farmers choices in Magbema is notable, as is the complete absence of any such relationship in Tonko Limba.

4.4.2 Characters

The characteristics of rice varieties selected by farmers in the different ethnic groups are shown in Table 4.4. These are broadly divided into agronomic, yield, duration, panicle and grain characteristics, eating qualities, tolerance to biotic and abiotic factors and performance during cultivation. Across the three ethnic groups bold grain was the most preferred character followed by grain yield, high tillering ability, grain colour, plant height, panicle length, panicle size, ease of milling, grain filling capacity, lodging resistance, and duration. The most important characteristics preferred by Temne farmers were bold grains, high tillering, yield and tall plant, lodging and grain colour. Limba farmers preferred clean and attractive grains, grain yield, ease of milling (specifically required by women to minimise labour in milling), duration, bold grain, and good adaptation to poor soil conditions. Susu farmers preferred varieties with bold grain, good adaptation to poor soils, ease of milling, big panicles, medium plant height and high grain filling capacity. The reaction of varieties to both biotic and abiotic factors was emphasised more by Limba and Susu farmers, where the soils are generally poorer and the rain ceases earlier, than by Temne farmers in the better favoured Magbema chiefdom.

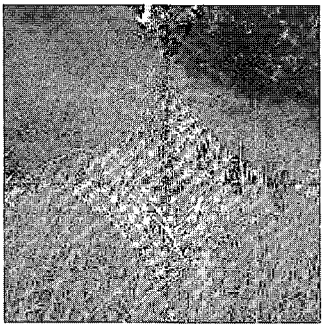


Photo 4.2 : A local variety Samba Konkon selected by most of the farmers

Similarly to ranking varieties, the characters the farmers used in selecting varieties were ranked (Table 4. 4) and these were compared between the farmers in the three chiefdoms. The Spearman's rank correlation coefficients (rs) were 0.55, 0.40 and 0.43 for Magbema/Tonko Limba, Magbema/ Bramaia and Tonko Limba/Bramaia respectively. These values indicate a statistically significant degree of agreement among farmers in selecting the same varieties using the same characters only in the Magbema/Tonko Limba case..

The list of varieties that farmers selected for particular characters is given in Table 4.5. Over 50 % of the farmers considered grain shape (75%) and colour (58 %) as the most important characters in selecting new varieties. The other characters that were also considered were high tillering, plant height, and panicle length. Grain yield and duration were considered but were not the most important characters in farmers' choices of varieties.

For the evaluation of varietal choices and the characters farmers prefer in their varieties, the farmers were invited at the time when the varieties were between half dough stage and maturity. Their judgement was therefore only based on the appearance of the varieties in the later stages of reproduction and maturity. It was initially intended to bring them to the trial site during the vegetative, reproductive and post harvest stages to evaluate the varieties. Security considerations and other logistical difficulties made this impossible. It is expected that the above results would have been different if farmers had evaluated the varieties at all growth stages.

Table 4.4: Characteristics of rice varieties Farmers Used in Selecting New Rice Varieties in the Magbema, Tonko Limba and Bramaia Chiefdoms in Northwest Sierra Leone.

Characters	Magbema	Tonko Limba	Bramaia
A. AGRONOMIC			
1. PLANT HEIGHT			
- medium	34	8	11
- tall	-	4	3
- short	-	1	4
2. PLANT TYPE			
- erect	1	-	-
3. TILLERING ABILITY			
- high	47	13	8
4.LODGING			
- tolerance	28	-	1
5. RATOONING			
- high	-	1	-
6. LEAFINESS			
- many	-	-	1
- less	6	-	3
7. LEAF SHAPE	2	-	-
B. YIELD	39	30	12
C. DURATION			
- short	6	20	-
- medium	-	10	-
- long	-	1	-
D. PANICLE			
1. THRESHABILITY			
- easy	3	12	7
2. SIZE			
- big	31	-	14
3. COLOUR			
- clean	1	1	13
4. SHATTERING			
- low	39	-	14
E. GRAIN			
1. SHAPE			
- bold			
- slender	48	18	29
- big	-	2	4
- medium	1	-	-
2. COLOR	1	-	-
- attractive			
- clean	22	30	4
- straw	-	-	2
- gold	-	-	1
- white	6	-	-
3. FERTILITY	2	-	-
4. MILLING QUALITY	14	2	13
5. WEIGHT	1	21	14
- heavy			

Table 4.4 cont.

Characters	Magbema	Tonko Limba	Bramaia
6. LENGTH			
- slender	2	2	2
7. AWNING			
1. PALATABILITY			
2. AROMA	8	3	7
3. KEEPING QUALITY	31	5	12
4. WHEN EATEN	9	-	-
- Last longer in the stomach			
- Easily fed	4	1	-
G. ABIOTIC FACTORS	4	2	6
- adaptation to poor soils			
- adaptation to lowlands	2	18	11
- tolerant to drought	1	-	18
H. BIOTIC FACTORS	1	3	2
- weed suppressing ability			
- tolerant to rodent damage	4	1	1
- resistant to seedling blast	-	-	1
- insect pest	4	2	10
- birds damage	-	1	10
- tiller development after rodent damage	2	3	9
- adaptation to short fallow period	-	4	-
I. CULTIVATION			
- good for mixing			
- low seed rate needed	-	1	1

Table 4.5: List of rice Varieties farmers selected for particular characters in the Magbema, Tonko Limba and Bramaia Chiefdoms, in Northwest Sierra Leone.

Characteristics	No. of farmers	Varieties associated with the characters
Grain shape	100	Nyarie Bomboi (21), RY1 (20), TOX1010-6-9-3-201 (13), ROK 20 (8), WAB32-55 (6), ROK5 (5), Bensali (5), Pa Bop (4), Faro 40 (4), IR55549-1-2 (3),ITA 323 (3), ROK3 (2), DC Kono (1), Janet (1), IR47686-15-1-1 (1), ITA 337 (1), WAB96-1-1 (1), WAB56-50 (1)
Color	77	Nyarie Bomboi (18), RY1 (17), ITA216 (10), WAB96- 1-1 (5), Bensali (3), ROK19 (3), TOX1010-6-9-3-201(3), Trinfo(CN4141) (3), Faro 40 (2), ITA 323 (TOX1780-15-1-1 (2), IR55549-1-2 (1), Pa Bop (1), Pa 3 Month 2 (1), Pa Konkon (1), ROK 16 (1), ROK 20 (1), Thabunsu (1), ROK 3 (8), ROK 3 (8), DC Kono (5), TOX10-6-9-3-201 (5), RY1 (4)
High tillering	65	Pa 3 Month (4), Ben Sali (3), Nyarie Bomboi (3), Pa Damba (3), ITA 306 (2), WAB96-1-1 (2), WAB32-55 (2), IR47686-15-1-2 (2), ROK 20 (1), Bensali (1), Dambara Balli (1), ITA323(TOX1780-7-1--) (1), Janet (1), IR55549-1-2 (1), Pa 3 Month 2 (1), Thabunsu (1), Black Salli (1), DC Forie 4 (1), Khorry Kinde (1), TOX 3211 (1), Sorie Kinde (1), Triunfo (CN4141 (1) Nyarie Bomboi (10), Bensali (7), TOX1010-6-9-3-201 (6),RY1 (5), WAB96-1-1 (5), DC Kono (3)
Plant height	64	Pa Bop (3), Janet (2), ROK 16 (2), ROK 19 (2), ROK 3 (2), ROK 20 (2), WAB32-55 (2), Black Sali (1), Daimbara Balli (1), ITA306 (1), IR47686-15-1-2 (1), Kebleh (1), Pa 3 Month 1 (1), WAB32-55 (1), Pa Konkon (1), Sorie Kunde (1), Pa 3 Month 2 (1), Triunfo(CN4141) (1), Nyarie Bomboi (9),ROK 3 (9) RY 1 (9), ITA 216 (8), ROK 16 (5), DC Kono (5), PA 3 Month (4), ROK 19 (3), ROK 20 (3), Faro 40 (3), Pa Damba (3), Ben Salli (2), ITA 306 (2), IR4757924-1
Panicle length	64	Nyarie Bomboi (8), ROK 16 (8), RY1 (8), TOX1010-6-9-3-201 (8), ROK 20 (4),Bensali (4), ROK 3 (4), WAB96-1-1 (4), IR47686.15.12-1 (4), IR55549-1-2 (2), Triunfo(CN4141) (2), Pa Bop (2),WAB32 55 (2),ITA 323 (1), Joe Wanjei (1), Pa 3 Month (1), ROK 19 (1),
Duration	58	RY1 (11), Faro 40 (7), Nyarie Bomboi (7), ITA 216 (4), Pa 3 Month (4), IR55549-1-2 (3), Bensali (2), ITA 323 (2), ROK 20 (2), WAB96-1-1 (2),Black Sally (1), Dambara Balli (1), ITA 337 (1), Joe Wanjei (1), Pa 3 Month 1 (1), Pa 3 Month 2 (1),ROK 16 (1), Pa Damba (1),Samba Konkon 1 (1), Samba Konkon 2 (1), Samba Konkon3 (1) Sorie Kunde (1), WAB 32-55 (1), WAB 56-50 (1)
High yielding capacity	56	Black Sallay (1), ITA 337 (1) WAB 96-1-1 (1), Joe Wnjei (1), No.1 BP (1), Janet (1), Pa Temne (1), Pa Konkon (1), Nyarie Bomboi (6), Pa Damba (6), ROK 3 (6), DC Kono (5), Pa 3 Month 1 (5), RY 1 (4), Pa 3 Month 2 (2), ROK 16 (2), WAB 96-1-1 (2), Benalli (1), DC Forie (1),Faro 4 (1), IR47686-6-1 (1), Janet (1)
Swelling capacity	47	Pa Bop (1), Pa Temne (1), Triunfo (CN4141) (1), TOX1010-6-9-3-201
Panicle Shape	36	Nyarie Bomboi (7), TOX1010-6-9-3-201 (6), ROK 20 (5), RY1 (5), WAB96 (5), ROK 3 (4), ROK16 (3), Bensali (3), ROK 19 (2), IR47686-15-1-1 (1), Janet (1), Pa Bop (1), WAB96-1-1 (1), WAB56-50 (1), WAB32-55
Performance in poor soils	31	Nyarie Bomboi (10), RY1 (3), ROK16 (2), ITA216 (2), ITA306 (2), Pa Konkon (2),Bensali (1), Dambara Balli (1), Faro 40 (1), ROK20 (1), Khory Kinde (1), No.1 BP (1), ROK3 (1), TOX32111-14-1-2-1-2 (1), WAB96-1-1 (1), WAB56-50 (1)
Ease of milling	30	Nyarie Bomboi (8), WAB96-1-1 (6), Faro 40 (4), ROK16 (3), IR55549-1-1 (3), Bensali (2), ITA216 (2), ITA306 (2), RY1 (2),ITA323 (1), Joe Wanjei (1), Pa Bop (1), WAB56-50 (1)

NOTE : Numbers in bracket after each variety denote the number of farmers who selected the variety for that character.

4.4.3 Multi-location Evaluation

The performance of the selected varieties at the four sites in 1996 and in 1997 cropping season is given in Tables 4.5 and 4.6.

The results of the average performance of the varieties at RRS under research managed trial and at the various locations in the farmers managed on-farm conditions are presented in Table 4. 6.

Table 4.6 Mean performance of selected varieties at 8 locations in the 1996 and 1997 cropping season

Location	Years	Yield kg ha^{-1}	Maturity (days)	Plant Ht at Maturity (cm)	Panicle length (cm)	Culm number	Lodging
RRS	1996	1511.1	114.6	112.0	24.0	4.3	2.6
masorie	1996	349.4	122.7	84.9	20.1	1.9	4.2
Kawonsor	1996	358.9	118.4	96.6	21.1	2.1	2.5
Kambikabaia	1996	756.7	121.5	101.2	21.9	2.3	4.0
RRS	1997	1364.3	118.7	107.6	24.4	4.2	2.2
Rokupr Junction	1997	686.1	118.5	98.9	21.3	2.2	2.2
Sela Kafta	1997	600.0	120.2	100.0	21.8	2.2	2.6
Baghonyi	1997	489.0	119.9	101.9	21.5	2.2	2.4
Minimum	Year x site	56.7	91.0	57.0	12.2	1.0	1.0
Mean	Year x site	764.4	119.3	100.4	21.8	2.4	2.6
Maximum	Year x site	4138.9	154.0	144.0	29.0	8.0	9.0
SS		1985080	1891.2	20144.1	347.239	91.8194	34.311
MS		283583	270.2	2877.7	49.606	14.1171	4.902
RMS		6270	177.6	246.6	5.126	0.8365	7.834
V-ratio		45.23	1.52	11.67	9.68	15.68	0.63
F-probability		<.001	0.159	<.001	<.001	<.001	0.735
SED		16.69	2.81	4.311	0.477	0.1928	0.59

There were large differences in average grain yield, plant height, panicle length and tillering ability of the varieties between the two research station trials and the six farmer's field trials (Table 4. 6). The highest yields were obtained from the research station trials in the two years. This reflects fertilizer application and weeding and other cultural practices that were carried out on research managed trials.

The low yield of the varieties at Masorie in the Magbema chiefdom and Kawonsor in Tonko Limba chiefdom is attributable to the second year farming at Masorie and the poor soil condition at Kawonsor in the Tonko Limba chiefdom. The low yield at Baghonyi was due to the farmer paying little attention to the trial. He was a refugee and had two farms, one in Guinea and the other in Sierra Leone. Because of security considerations, he was spending more of his time with the farm across the border in Guinea than the one in Sierra Leone. The farm in Sierra Leone was planted only to save his varieties from being lost, which would have occurred if they were not planted for two years.

The average performance of the varieties over the two years is presented in Table 4. 7. The widest variation was recorded for grain yield followed by culm number and lodging. The grain yield per plot ranged from 56.7 to 4138.9 kg ha^{-1} and duration from 91 to 153 days with the highest yields obtained from the research plots. The mean plant height was 100 centimeters, which is typical of farmer's varieties in the research area. Farmers use sickle harvesting and prefer varieties that do not force to them to bend down during harvesting. Because of the short stature farmers rejected some of the RRS varieties. Of the 45 varieties grown in the two years, only 13 % (n = 6) were found to lodge (Table 4. 7).

When averaged over locations and years there were large differences between the varieties, the average yield varying by a factor of 4.9 (ratio of highest/lowest yield).

However, due to the large error of these means, the only two varieties that were out-yielded by the highest yielding check (ROK 20) were No. 1 BP and TOX 3211-14-1-2.

Although the error of the mean yield of the varieties is large, this result indirectly indicated that grain yield was not the major criterion in farmers' selection, as confirmed by the results of the evaluation of farmers' selection criteria presented earlier in this chapter.

The local varieties Bayiba and Ba Isatu and the RRS selections Joe Wanjei and ROK 3 3 were significantly ($p<0.05$) later than the improved check (ROK 20) and similar to the local check (Samba Konkon). The duration of more than 50 % of the test varieties was below ($p<0.05$) that of the local check. The maturity of most of the test varieties was similar to ROK 20, however.

Table 4. 7 Performance of varieties tested in Participatory Varietal Selection (PVS) at the Rice Research Station experimental site at Masorie upland site and on-farmers fields in the 1996 and 1997 cropping seasons

Variety	Yield (kg ha^{-1})	Maturity (days)	Plant height (cm)	Panicle length (cm)	Culm number	Lodging
1 ROK 16	914.9	118.0	116.4	26.01	2	1
2 KEBLEH	851.1	100.0	94.0	21.1	2	3
3 IR57924-1	1049.4	114.0	96.8	20.4	2	1
4.TRIUNFO (Cn4141)	698.3	110.0	95.4	19.9	2	1
5.FARO 40	711.7	118.0	94.6	22.1	2	1
6.SAMBO KONKON	**8.4.9**	**137.0**	**120.0**	**22.6**	**3**	**3**
7.NYARIE BOMBOI (white)	777.2	114.0	100.5	20.7	2	1
8.DC FORIE	714.4	124.0	79.9	21.6	2	9
9.WAB 96-1-1	749.2	116.0	95.5	21.9	3	1
10.PA BOP	1246.11	109.0	98.9	20.9	3	3
11.WAB 32-55	410.0	107.0	88.3	22.6	2	1
12.DC KONO	746.7	119.0	109.4	24.5	2	9
14.IR 55549-1-2	234.6	112.0	84.5	21.7	2	1
14.BAYIBA	739.4	138.0	115.0	24.3	3	3
15.ROK 20	**978.9**	**117.0**	**87.9**	**22.7**	**3**	**1**
16.TOX 1010-6-9-3	1064.6	116.0	109.0	24.8	2	1
17.IR 153-213-10	479.4	126.0	92.5	25.9	3	3
18.PA THREE MONTH	548.3	104.0	101.9	18.6	2	9
19.PA TEMNE	741.7	124.0	97.9	24.0	2	9
20. WAB 99-1-1	877.2	104.0	79.4	19.2	2	1
21.PA KONKON	882.8	120.0	101.8	22.5	2	3
22.KHORY KINDE	501.7	150.0	110.4	20.2	3	1
24.PA NYLON	1145.0	132.0	112.0	24.0	2	1
24.No.1 BP	326.7	102.0	79.4	18.6	4	3
25.KABUNSU	444.3	147.0	116.4	21.6	3	1
26.RY1	866.7	115.0	101.0	21.3	2	3
27.ITA 216	886.1	104.0	84.3	20.5	2	1
28.NYARIE BOMBOI (RED)	912.2	117.0	105.3	19.9	2	1
29.IR 4797-15-1-1	686.1	110.0	96.5	21.8	2	1
30.1TA 212	857.8	99.0	89.8	19.4	2	1
31.PA DAMBA	630.6	114.0	108.6	21.2	2	9
32.ITA 337 (TOX1780-7-1-201-1	832.2	115.0	81.9	21.6	3	1
34.SALIFOREH	725.0	127.0	115.8	24.9	3	9
34.PA THREE MONTH 2	658.3	106.0	95.0	19.4	3	9
35.SORIE DUNKE	732.8	130.0	112.9	20.7	3	1
36.ROK 19	634.9	121.0	82.8	22.0	3	1
37.PA JANET	875.0	124.0	116.1	24.0	3	7
38.ROK 33	1047.2	138.0	127.6	24.6	3	1
39.WAB 96-1-1	749.4	126.0	120.5	24.1	3	1
40.PA ISATU	962.2	139.0	119.4	24.4	3	1
41. BENSALI	406.7	116.0	108.3	22.1	2	1
42.WAB 56-50	578.3	101.0	89.5	20.1	2	1
44.TOX 3211-14-2	296.7	131.0	69.3	20.7	3	1
44.ITA 306	521.1	128.0	78.5	21.2	3	1
45.JOE WANJEI	830.0	137.0	119.6	24.4	3	1
CV	78.6	4.0	11.0	9.0	42.7	28.4
SED	54.01	6.71	8.6	1.22	0.52	1.39
LSD (0.05)	106.0	14.2	16.9	2.4	1.0	2.7
LSD (0.01)	139.0	17.3	22.1	4.1	1.3	4.6

Samba Konkon (ROK 3) was adopted by most farmers in the research area. However it is very long in duration in Bramaia and Tonko Limba chiefdoms, where the rainy season is shorter than in the Magbema chiefdom. Susu and Limba farmers normally complained about the sterility of Samba Konkon even though it out-yielded most of their local varieties. It is cultivated for the seed companies and for sale in the local market in Madina, the administrative headquarters of Tonko Limba chiefdom, where all the farmers in the area bring farm produce to sell to traders from the Republic of Guinea and Freetown. Farmers also had other considerations than duration for selecting varieties.. Each variety had its place in the diverse farming system. Long, medium and short duration varieties are used up and down the upland-wetland continuum to spread and prolong the harvest period.

None of the test varieties were significantly taller than the local check but over 50% were significantly shorter ($p < 0.05$) (Table 4. 7). When the varieties were compared with the improved check (ROK 20), only TOX 3211-14-1-2 was significantly shorter in height ($p = 0.05$). Although the farmers selected these varieties for further testing, their short height may militate against wider adoption.

Tillering was generally low for all varieties and only seven of the selected varieties completely fell to the ground at maturity. Once varieties had flowered and the grain filling was completed, lodging is not very crucial in varietal adoption. Most farmers even considered lodging an indicator of high yield. The variety that lodges is considered a good variety since it must have a heavy panicle.

4.4.4 Farmers evaluation of varieties in Informal Research and Development (IRD).
Results showing the reaction of farmers in each village where the 5 kg packets of the RRS released varieties were given and evaluated in 1996 and 1997 are shown in Table 4. 8.

All farmers in Magbema chiefdom rejected ROK 20 because of low tillering ability under farmers' condition. The farmers ate the seed during the 1997 rebel attack on the chiefdom. ROK 16 was selected because of its attractive long panicles, bold grains and awning, which, according to some farmers, reduced bird damage.

In Tonko Limba chiefdom only, some farmers rejected ROK 20 because of its low tillering. The majority however selected the variety because of its attractive husk and kernel colour.

In Bramaia chiefdom most farmers selected ROK 20 because of its attractive panicles, grains and kernel colour, high yielding capacity and good taste. One group of farmers rejected the variety because of its low viability at seeding. Some farmers in Bramaia chiefdom rejected both ROK 16 and 20 because of poor tillering ability.

TABLE 4.8. Some farmer reactions to RRS releases

CHIEFDOM	VARIETY	FARMERS REACTION
Magbema	ROK 20	-low tillering, attractive grains. (Variety rejected and eaten during rebel attac).
	2. ROK 20	- low tillering, (Variety rejected and eaten during rebel attack.)
	3. ROK 20	- low tillering. (Variety rejected and eaten during rebel attack.)
	4. ROK 16	- Low tillering, big panicles, tolerant to bird damage. (Variety selected.)
	5. ROK 16	(Variety selected, stolen, and farmer requested replavement of seed.)
Tonko Limba	1. ROK 20	- high yielding, attractive grains. (Variety selected).
	2. ROK 20	- high yielding, good taste, low tillering. (Variety selected.)
	3. ROK 20	- good vegetative growth, high yielding, attractive panicles, attractive grains, adapted to the environment. (Variety selected.)
	4. ROK 20	- high yielding, attractive grains, to be tested in the lowland. (Variety selected.)
	5. ROK 20	- low viability, attractive grains. (Variety rejected.)
Bramaia	1. ROK 20	- early duration, attractive grains, high yielding. (Variety selected.)
	2.ROK 20	- poor vegetative growth. (Variety rejected.)
	3 ROK 16	- poor tillering.(Variety rejected)
	4 ROK 16	- good vegetative growth, good aroma, high yielding, attractive grains and panicles. (Variety selected.)
	5 ROK 16	- Attractive grains and panicles, high yielding, tolerant to bird damage.(Variety selected.)

4.4.5 Proving a Comparison of scientists, and farmers, selection criteria

When the research was first designed it was hoped to get breeders to make their own selections in the farm trials, to match against farmers' selections. For a variety of reasons, including transport and security, this proved impossible. The researcher then fell back on his many years experience as a Rokupr rice breeder, where he has repeatedly observed his colleagues make systematic use of the IRRI "ideotype", as specified in (IRRI-SES 1996) to guide their selection work. This ideotype has normative force among breeders, and guarantees that material with *O. glaberrima* characteristics is rejected in selection work. This might have made breeder field selection something of a foregone conclusion. But it was still hoped to compare the IRRI-guided selection "model" with what farmers actually did. The test described below was devised, based on inferring a "farmer ideotype" from the actual selection decisions farmers made in the field sites and the reasons they gave for making such decisions. By looking at what farmers considered important and asking breeders to rank the components in the IRRI ideotype, it was possible to measure degrees of agreement/disagreement using rank correlation coefficients.

In this activity we were interested in the degree of internal agreement among the scientists and between scientists and farmers about what constituted the most important or acceptable characters in a genotype. (The list of the 19 characters used by scientists to evaluate the IRRI rice ideotype in the four Divisions at RRS is presented in Appendix 4.1).

Table 4.9: Spearman's rank correlation coefficients (rs) of characters between workers in the various research Divisions at the Rice Research Station at Rokupr and farmers in the study area (IRRI ideotype)

Divisions	Agronomy	Breeding	Farming System	Plant Health
Breeding	0.671**			
Farming System	0.747**	0.667**		
Plant Health	0.675**	0.632**	0.957**	
Farmers	-0.01 ns	0.573**	0.033 ns	-0.10 ns

*** = Significant at p < 0.01*

There was considerable agreement, as measured by Spearman's rank correlation coefficient , among scientists in the four divisions. This might be interpreted as evidence of interdisciplinary consensus between the Divisions at RRS on the IRRI characters. But in order to investigate this further, we "induced" a farmer "ideotype from information on the frequency with which farmers cited various factors in explaining their own selection decisions. We then looked at the correlation between the elements in this "farmer ideotype" as ranked by farmers' explanations of selection decision, and the ordering of elements in the IRRI ideotype according to different scientists. Strikingly, the only sizeable and significant correlation ($r = 0.0573$, $p < 0.01$) was between breeders and farmers. Perhaps because of their specialist concerns, agreement between agronomy and farmers and plant health specialists and farmers was no better than random. Plant health is involved in the early selection and screening of new materials, so any persistent lack of correlation between farmers' concern and plant health specialist might have major implications for the kinds of materials taken forward. It is a gap in need of closure The lack of significant correlation between the priorities of farming systems researchers and farmers is also something to be probed further.

The scientists in the four Divisions at RRS were then asked to apply their own ranking to the elements in the farmers' ideotype. The results (Table 4. 10) show a very low correlation between the farmers ranking and those of the scientists. The list of the ranking of the 19 characters (Appendix 4.2) from the farmers rice ideotype by scientists in the four Divisions at RRS is presented in Table 4. 10.

Table 4.10: Spearman's rank correlation coefficients (rs) of characters as ranked by workers in the various research divisions at the Rice Research Station at Rokupr and farmers in the study area (farmers ideotype)

Divisions	Agronomy	Breeding	Farming System	Plant Health
Breeding	0.37 ns			
Farming System	0.59**	0.49*		
Plant Health	0.45*	0.89**	0.50*	
Farmers	0.002 ns	0.29 ns	0.24 ns	-0.24 ns

*= $p < 0.05$
**$p < 0.01$

Scientists were sometimes in quite close agreement about the order of priorities among elements in the farmers list (e.g. an $r = 0.89$, $p < 0.01$ between the ranking of breeders and plant health). But strikingly, there was no significant correlation between the actual order imposed by farmers' choices and rationalizations and what scientists thought the ranking ought to be. This is clear evidence that even when scientists and farmers are faced with the same materials or situations they react in different ways.

A further general point can be made. Normally breeding research reports how breeders select for varieties and with what consequences. But there seems no reason why in principle we should not from time to time reverse the analysis, and consider how particular plant types "select" for breeders' (and farmers') attitudes and values.

4.4 General Discussion and Conclusions

Between approximately 1970 and 1990 Rokupr Rice Research Station released 33 improved rice varieties. Less than ten of these have found any acceptance among farmers. Only one - ROK 3, released c. 1972 - is at all widely used in the case study area, and even then only on the best land. Also, many farmers think ROK 3 is too long-duration a variety for the increasingly uncertain rainfall conditions in the northern part of Kambia District.

Where Green Revolution varieties, such as the semi-dwarf ROK 14 developed with IRRI parentage for intensively managed wetlands, have been taken up under the influence of the Integrated Agricultural Development Projects such adoptions have proven unsustainable because farmers have been unable to pay for the necessary inputs once subsidies were withdrawn.

As the country collapsed into the economic chaos associated with a long-drawn-out internal war basic inputs such as fertilizer were impossible to find, even for farmers with money. A focus on high-yielding rices under high-quality management that find no acceptance has, in the event, proved to be a misdirection of research time and waste of money.

As the war was starting (in 1991) the present writer was involved in a proposal to the European Union to fund a farmer participatory research program, in co-operation with colleagues in the neighboring Republic of Guinea, to quickly rescue, screen and select, through the kind of action with farmers discussed in this chapter, rice varieties that farmers might favour in adverse conditions. That proposal was rejected as being of no development interest. It is interesting to speculate eight year's later, with the rice economies of the region in ruins through internal conflicts not yet ended, in how much better a position the relief agencies might have found themselves if such a program had been pursued.

Effectively, the research reported in this chapter suggests that such a program would have worked, and why.

There has been little impact from RRS on the low-resource farmers in the three-case study chiefdoms over 75 years since 1934. But this is not because farmers have no interest in research.

The farmer trials program shows that with a small organizational input trial sites can be maintained, even if farmers with very little labor to spare tend only to invest limited time in such activities. There was rebel activity in Kambia District in 1996-7, but even so it was possible - with limitations - to organize the necessary sites and selection days. Farmers co-operated in selection trials themselves, and much could be learnt from the selections they made, and by contrasting farmer selections, and reasons for making selections, with the ideotype guiding professional selection.

First among lessons learnt is that not all farmers select for yield. The results above show that in the two chiefdoms with poorer soils and more adverse climate farmers are interested in plant performance under difficult conditions.

Breeders tend to assume that high yield under good management will correlate with better yield under adverse conditions. This is probably true for research station successes such as ROK 3, responsive to fertilizer but (as a local selection) a satisfactory performer in moderately harsh conditions also . But often the assumption remains to be rigorously tested, and as work by Ceccarelli and others (1996) shows may be incorrect, at least in some cases.

A concern to pick to better performers in adversity is clear in farmers making choices from the African Rice species *O. glaberrima* or supposed intermediates (Pa Three Month was frequently selected as of interest to farmers).

Belief that a good high input performer is also a good low input performer is in effect, in the language of institutional theorists such as Mary Douglas (1987) a "cultural bias" (a bias built into the social organization and working practices, including information handling practices, of members of a social collectivity, in this case the rice research community).

This point was demonstrated through looking not at how researchers select plants but how plants "select" researchers, through investigating how researchers rank ideotype elements.

The degree of consistency among professionals in terms of what aspects they thought most important in the IRRI ideotype is as expected. What was striking was that the rankings of only one group of researchers approached those implicit in the "ideotype" outlined by farmers' actual selection choices. Encouragingly, however, the members of this group were breeders! But when the set of elements in the farmer "ideotype" was ranked independently by the researchers and compared with farmer "rankings" as given in selection decisions even this "correlation" between breeders and farmers disappeared.

This is not say that scientists are "wrong". Plant health experts, for example, have sound reasons for emphasizing elements relating to their speciality. But the point of the exercise is to show that there is a large conceptual gap between what farmers and breeders think important when both are selecting on the same range of material.

The point comes better into focus when we understand that farmers are very interested in experimentation, but their idea of a "good experiment" is quite different from that of the scientists. Scientists lavish care and fertilizer on experimental plots because they think high conditions are equivalent to control - i.e. a no expense spared approach to experimental site management is the best way to separate out the genetic component in plant performance.

Farmers have a different approach (and we see it most perhaps clearly in the responses of Limba and Susu farmers in the above data set). They see plant performance in a particular environment as a single indivisible issue. The best way to identify a good plant is simply to experiment on a poor or problematic piece of land, and maybe to usefully stress the trial by neglecting it. Adam (1985) similarly reports that farmers in the mangrove zone were always allocating the poorest land for research trials.

But such neglect is not evidence that farmers pay no attention to results. As the above data make clear they are in fact keen observers of outcomes. But it does mean they are looking at the bottom of the range, where scientists are looking at the top. This is why it is not sufficient simply to bring farmers and scientists together in joint selection exercises.

The simple solution proposed by proponents of participatory plant improvement of looking at both ends of the spectrum - at high performance in good conditions and better performance in low environments (Simmonds 1991) is a bit more complicated than it seems.

Farmers and breeders both need to understand the practical as well as conceptual reasons why each group tends to focus on opposite ends of the spectrum. Farmers will have to educate scientists about why low-end performance is often so vital to them. Scientists in turn will have to show why simply concentrating on the best performers in adverse local conditions does not always yield the best and most consistent longer-term results, even according to farmers' "low-end biased" criteria.

Devising the right kind of trials to make such points will require an extension in time and space of the kind of on-farm methodology used in the research here reported, to get beyond localised selection amounting to personal preference. It also implies building an institutional framework for experimenting farmers - some kind of network of farmers devoting time to experimental activities of the kind envisaged in the Community Biodiversity Development and Conservation initiative.

Further discussion of such a network is beyond the scope of the present chapter, which has devoted itself to proving three simple points:

- farmers select;
- farmers and breeders think differently about selection;
- even so, there is scope to bring together the perspectives of farmers and breeders. Farmers are interested in high performing international varieties, even if they still keep an eye open for rugged local material.

4.5 Conclusion

Joint farmer-scientist selections exercises are feasible for rice, even in very adverse circumstances. Well handled, joint selection exercises could be a useful instrument for mutual learning, as well as for identifying material with neglected but useful characteristics. Certainly the exercises here described were well received by farmers, and continued despite the appalling problems posed by the rebel war. But farmers in North-western Sierra Leone still move farm sites from year to year, and local and immediate results will not be sufficient to fulfil their interest in low-end adaptation. So we conclude any such joint selection activity must be long-term, subject to institutional consolidation, and capable of yielding farmers a more than local and personal perspective on material of interest.

5 MORPHOLOGICAL CHARACTERISATION OF LOCAL RICE GERMPLASM.

5.1 Introduction

Genetic diversity is a key resource for crop improvement and results from evolution, domestication, mutation, recombination, adaptation, and natural and human selection. In West Africa, African Rice (*Oryza glaberrima*) has been grown for millennia (Porteres, 1976). In this region the cultivated *Oryza sativa* and *O. glaberrima* are grown as a monoculture or in mixtures in farmers' fields (Ng *et al*, 1988). In addition to these two species, six of the 21 *Oryza* species are found in Africa and two of these, *O. barthii* and *O. longistaminata*, are found in farmers' rice fields as weeds (Ng. *et al*,1988). The co-existence of the cultivated and wild species has, over the centuries, resulted in an array of genetic material that has been selected under local farming and environmental conditions. These selections are low yielding but stable over time and well-adapted to local conditions, with valuable attributes such as resistance to diseases and pests, weed suppression ability, tolerance of drought and harsh soil conditions and good consumer acceptability in terms of cooking, eating quality and keeping quality after cooking. The common farmers' varieties grown in the research area are briefly described below (WARDA,1996).

5.1.1 African Rice (O. glaberrima Steud)

O. glaberrima is indigenous to West Africa and is thought to have originated in the Inland Delta of the Upper Niger (Porteres, 1976). It is therefore appropriately called "African Rice". The primary center of diversity appears to be the swampy basin of the Upper Niger River, with two secondary centers of diversity in the South-west of West Africa along the Upper Guinea coast. Earliest occurrence in the primary center is estimated at 1500 BC and the secondary centers 500 years later (Carpenter, 1978; Jacquot, 1977). African Rice is grown only on limited scale and is not grown at all outside Africa (Chang, 1976; Richards, 1996; Khush, 1997; Porteres, 1976). The species exhibits less diversity when compared with the Asian *O. sativa* species (Miezan and Ghesquiere, 1985). The morphological characteristics of African Rice differ from the Asian types only in minor respects. Secondary branching of the panicle is simple, and panicles are erect. Grains are smaller, with red bran and a tough seed coat (Jusu and Monde, 1990). The ligule is rounded rather than pointed, and tillering is vigorous early in vegetative growth. Most varieties generally possess adaptive traits for shifting cultivation as traditionally practiced (Jones *et al*, 1997). The main landraces tend to have rapid and profuse vegetative growth and droopy lower leaves that suppress weeds by quickly outgrowing and shading them (Jennings *et al*, 1979). Many *O. glaberrima* varieties are known to possess resistance to diseases and pest (IRRI, 1976; 1977; Chang, 1976), resistance to drought (Maji and Singh, 1993) and tolerance to low phosphorus availability in the uplands (Monde *et al*, 1991). They also have a low yield potential due to a limited number of spikelets per panicle, which is caused by the lack of secondary branches, high grain shattering, and poor lodging tolerance (Koffi, 1980; Dingkuhn *et al.*, 1997). The sterility barrier in F_1 hybrids with *O. sativa* has been overcome in recent years (Jones *at al*, 1997).

O. glaberrima can be cultivated in all rice ecologies in the lowlands and uplands in West Africa, but is predominantly grown as deep-flooded rice in the river valleys of the Sahelian and Sudan savanna zone, which stretches from Senegal and The Gambia in the West to Lake Chad in Central Africa. It is also cultivated in rain-fed uplands and upper fringes of the lowlands in the rain forest and forest transition zone, stretching from the Republic of Guinea to Cote d'Ivoire, with a small outlier on the Ghana/Togo borders. In this region there is no clear distinction between upland and lowland types, since some varieties do well in both dry and wet-land conditions. The main distinction is the degree to which farmers at each locality have been able to adapt the varieties to the local ecology. It is therefore common practice to see a particular variety being grown in one area in the lowland and the same variety in the upland in another area (Richards, 1996).

In the research area, and in much of Guinea and Sierra Leone, *O. glaberrima* is retained a as a crop associated with poor soils that cannot support higher nutrient demanding *O. sativa* rice varieties (see chapter 3).

5.1.2 Asian Rice (O. sativa).
The *Oryza* genus probably originated at least 130 millions years ago in Gondwanaland, the super-continent that broke apart to form Asia, Africa, the Americas, Australia and Antarctica (Chang, 1976). Domestication probably started 9000 years ago (Khush, 1997), and Asian Rice was introduced to East Africa from India about 500 years ago and to West Africa along the African coast by the Europeans from the mid fifteenth century onwards (Carpenter, 1978; Jacquot, 1977; Khush, 1997). It is also speculated that *O. sativa* might have reached West Africa at an earlier stage overland via the trans-Sahara trade routes (Carpenter, 1978). *O. sativa* exhibits a wide genetic and ecological diversity and is grown in all rice growing areas in the world. It is gradually replacing the *O. glaberrima* varieties in West Africa. The process of replacement has been accelerated by the establishment of rice research institutions in the region with mandates to develop high-yielding varieties for West African farmers in all rice growing-ecologies. Today many farmers continue to grow both rice species in their fields and select what is suitable to their land.

5.1.3 Spontaneous hybridization between O. glaberrima and O. sativa and/or wild relatives.
Farmers in the research area also have access to what might be called neo-traditional varieties. An example is Pa Three Month which appeared in the research area in the last 15 years and was first reported during a germplasm collection mission in 1987. Given that farmers practice selection from spontaneous crosses some of the neo-traditional rices may be hybrids between the two cultivated *Oryza* species. The possibility was raised in chapter 3, and will now be considered in closer details in this chapter.

The approach of the chapter is to carry out a quantitative examination of the morphology of traditional farmers' varieties grown by Temne, Limba and Susu farmers in North-west of Sierra Leone, in order to differentiate *O. glaberrima* and, *O. sativa* types under local management. One purpose is to assess, indirectly, whether the local gene pool has sufficient diversity for further development through breeder co-operation. We are interested in whether the two species groups can be clearly differentiated on morphological grounds, whether there are "intermediate" types, and (if so) what are the morphological characteristics of any such intermediates. We included the neo-traditional (farmer innovated) Pa Three Month rice in the sample as perhaps the clearest candidate for intermediate status. A rather obvious analytical opportunity was missed in not extending the morphological analysis to the WARDA *O. sativa x O. glaberrima* hybrids. In future work it is planned to test whether Pa Three Month clusters with these known interspecific hybrids. We also hope to pursue the topic using molecular marker analysis.

5.2 Materials and methods

Forty-seven upland rice cultivars (Table 5. 1) collected from small-scale farmers in the Magbema, Tonko Limba and Bramaia Chiefdoms of the Kambia Districts of North-western Sierra Leone were collected in late 1995. These farmers' varieties comprise *Oryza sativa* and *O. glaberrima* species as the well as the Pa Three Month variety of intermediate status.

Table 5.1: Species and origin of farmers' varieties used in morphological characterization, 1996 and 1997 growing seasons

Variety number	Name of cultivar	Species	Origin
1	Kebleh	*O. sativa*	Tonko Limba Chiefdom
2	Black Sallay	*O. glaberrima*	Tonko Limba Chiefdom
3	Bayiba	*O. sativa*	Tonko Limba Chiefdom
4	Joe wanjei	*O. sativa*	Magbema Chiefdom
5	Ngolo Yomboi	*O. sativa*	Magbema Chiefdom
6	Damba	O. sativa	Tonko Limba Chiefdom
7	Pa Damba	*O. glaberrima*	Bramaia Chiefdom
8	Khorry Kindeh	*O. sativa*	Bramaia Chiefdom
9	Bensali	*O. sativa*	Bramaia Chiefdom
10	Nylon	*O. sativa*	Bramaia Chiefdom
11	Thabunsu	*O. sativa*	Bramaia Chiefdom
12	Sumaila	*O. sativa*	Bramaia Chiefdom
13	Isatu	*O. sativa*	Tonko Limba Chiefdom
14	ROK 5	*O. sativa*	Magbema Chiefdom
15	ROK 16	*O. sativa*	Magbema Chiefdom
16	Janet	*O. sativa*	Tonko Limba Chiefdom
17	Nyarie Bomboi(White)	*O. sativa*	Bramaia Chiefdom
18	Nyarie Bomboi(Red)	*O. sativa*	Bramaia Chiefdom
19	Pa Three Month 1	*O. sativa/glab.*(Proposed)	Magbema Chiefdom
20	Salifaigai 1	*O. glaberrima*	Bramaia Chiefdom
21	Salifaigai 2	*O. glaberrima*	Bramaia Chiefdom
22	Sorie Kunde	*O. glaberrima*	Bramaia Chiefdom
23	Dissi Kunke	*O. glaberrima*	Bramaia Chiefdom
24	Pa Temne	*O. glaberrima*	Magbema Chiefdom
25	Pa Temne	*O. glaberrima*	Magbema Chiefdom
26	Dissi Temne	*O. glaberrima*	Magbema Chiefdom
27	Dissi Forie 1	*O. glaberrima*	Bramaia Chiefdom
28	Dissi Forie 2	*O. glaberrima*	Bramaia Chiefdom
29	Dissi Forie 3	*O. glaberrima*	Bramaia Chiefdom
30	Dissi Forie 4	*O. glaberrima*	Bramaia Chiefdom
31	ROK 3 1	*O. sativa*	Magbema Chiefdom
32	ROK 3 2	*O. sativa*	Magbema Chiefdom
33	Pa Dissi Temne	*O. glaberrima*	Magbema Chiefdom
34	Dissi Kono	*O. glaberrima*	Bramaia Chiefdom
35	Saliforeh	*O. glaberrima*	Bramaia Chiefdom)
36	Saliforeh	*O. glaberrima*	Bramaia Chiefdom
37	No Name	*O. sativa*	Magbema Chiefdom
38	Pa three month 2	*O. sativa/glab* (Proposed)	Tonko Limba Chiefdom
39	Pa Bop	*O. sativa*	Magbema Chiefdom
40	Pa Three month 3	*O. sativa/glab* (Proposed)	Bramaia Chiefdom
41	Dissi.Temne	*O. glaberrima*	Magbema Chiefdom
42	Dissi Kono 1	*O. glaberrima*	Magbema Chiefdom
43	Dissi Kono 2	*O. glaberrima*	Tonko Limba Chiefdom
44	Pa Konkon	O. sativa	Tonko Limba Chiefdom
45	Samba Konkon 1	*O. sativa*	Magbema Chiefdom
46	Samba Konkon 2	*O. sativa*	Bramaia Chiefdom
47	Samba Konkon 3	*O. sativa*	Bramaia Chiefdom

Note : glab = O. glaberrima

Sixteen samples were collected in Magbema Chiefdom (6 *O. glaberrima*, 9 *O. sativa* and one Pa Three Month) from the Temne ethnic group, 9 in Tonko Limba Chiefdom (2 *O. glaberrima*, 6 *O. sativa* and one Pa Three Month) from the Limba ethnic group and 22 in Bramaia Chiefdom (12 *O. glaberrima*, 9 *O. sativa* and one Pa Three Month) from the Susu ethnic group. Sample size and species distribution from each Chiefdom was determined by the availability of farmers' planting material during the germplasm collection. For the purpose of this study the collected materials were considered representative of rice cultivars in each Chiefdom. The grouping of varieties into the three categories was based on our experience in rice morphology gathered over the past six years in this area prior to the start of the field study. It was difficult to allocate Pa Three Month to either of the rice species on morphological grounds. The varieties used were (with a few omissions) the farmers' varieties used in the studies on varietal selection by farmers and scientists (chapter 4). The samples included some RRS releases in the ROK series under farmer management. It should be noted that ROK 3 and ROK 16 are selections from native varieties, and that ROK 5 contains native parentage (Pa Wellington).

In the 1996 rainy season, the upland experimental site of the Rice Research Station (RRS) was brushed and dug using cutlasses and native hoes. Partial stumping was carried out using mattocks and axes to remove stumps and biomass from the land. Varieties were direct seeded in two replicates on 26 June 1996 in plots consisting three rows of 3 m length. Fertilizer at the rate of 80:40:40 NPK ha^{-1} was applied. Phosphorus (as Single Superphoshate) was applied basally at seeding and nitrogen (as urea) and potassium (as muriate of potash) applied in two equal splits at 14 and 42 days after seeding, which coincided with the beginning of the vegetative and reproductive growth stages. Two weeks after seeding, four plants per plot were randomly selected and identified for data collection. Weeding was done manually before the second and third fertilizer applications and whenever necessary. Trials were repeated at the same site in 1997. Seeding date for the second season was 20 June 1997, with the same management practices as in 1996.

5.2.1 Data collection

The Standard Evaluation System (SES) for rice from the International Rice Research Institute (IRRI) was used for characterization (IRRI SES, 1996). The characters that were recorded are given in Table 5. 2. Descriptive codes were used for traits with discontinuous variation or expression not easily translated into numerical units, *e.g.*, color and leaf angle. For each character, data from 5 tillers from the randomly selected plants per plot were used and averages computed and recorded as plot means. In the case of plants with less than 5 tillers, data was taken on all the available tillers.

5.2.2 Data analysis

Data were analyzed with GENSTAT 5.3. Analysis of variance (ANOVA), based on plot means, was used to analyze and test the contribution of species, variety and year to total variation for each character.

Table 5. 2: Morphological traits documented for this study of rice genetic diversity

Character (abbreviation)	Scale	Moment of observation	Remarks
Plant height at 2 weeks (PH2)	Centimeters (cm)	Two weeks after seeding	Height at two weeks
Plant height at maturity (PHM)	cm	90 % maturity	Height at maturity
Leaf length (LFLEN)	cm	Heading	Leaf just below flag leaf
Leaf width (LW)	cm	Heading	Leaf just below flag leaf
Leaf blade pubescence (PUB)	IRR SES 1-3	Booting	Finger tip rub to class hairiness
Leaf blade color (BLCO)	IRRI SES I-7	Stem elongation	Visual assessment
Basal leaf sheath color (SHCO)	IRRI SES 1-9	Tillering	Visual assessment
Leaf angle (ANG)	IRRI SES 1-3	Stem elongation	Angle of openness to culm
Ligule length (LIGLEN)	Millimeters (mm)	Stem elongation	Measurement
Ligule color (LIGCO)	IRRI SES 1-3	Stem elongation	Visual assessment
Ligule shape (LIGSHA)	IRRI SES 1-3	Stem elongation	Visual assessment
Collar color (COCO)	IRRI SES 1-3	Stem elongation	Visual assessment
Auricle color (AURCO)	IRRI SES 1-2	Stem elongation	Visual assessment
Panicle length (PANLEN)	cm	Maturity	Measures panicle base to tip
Panicle type (PANTP)	IRRI SES 1-9	Maturity	Panicle mode of branching,
Secondary branching (SECBR)	IRRI SES 0-3	Grain dough	Primary branches on panicle
Panicle exertion (PANEX)	IRRI SES 1-9	Grain dough	Exertion rate from flag leaf
Awning (AWNS)	IRRI SES 0-9	Milk stage	Number and length of awns
Awn color (AWNCO)	IRRI SES 0-6	Heading	Visual assessment
Apiculus color (APICO)	IRRI SES 1-7	Maturity	Visual assessment
Lemma and palea color (PLCO)	IRRI SES 1-5	Maturity	Visual assessment
Spikelet fertility (SPFER)	Percentage	Maturity	Measurement
Grain length (GRLE)	mm	Maturity	Measurement
Grain width (GRWI)	mm	Maturity	Measurement
Seed coat color (SECO)	IRRI SES 1-7	Maturity	Visual measurement
Maturity (MAT)	Days	90 % maturity	Count
Culm length (CULE)	cm	Maturity	Measurement
Culm diameter(CUDIA)	cm	Grain dough	Measurements
Culm strength (CUSTR)	IRRI SES 1-9	Grain dough	Visual assessment
Culm number (CUNO)	Count	Maturity	Count
Culm Internode color (CUDIA)	IRRI SES 1-4	Milk stage	Visual assessment
Flag leaf angle (FLLANG)	IRRI SES 1-7	Milk stage	Angle b/w leaf blade and panicle
Culm angle (CUANG)	IRRI SES 1-9	Milk stage	Angle of spread of tillers
100 grain weight (HGW)	Grams (gm)	Maturity	Weight

Principal Component Analysis (PCA) was used to describe in 2-dimensional space the variation between varieties within species, and varieties within Chiefdoms. Euclidean distance, which determines the dissimilarity and distance between varieties, was used to measure the relationship between the varieties. The variate type for similarity matrix was of the City Block type.

A spanning tree on the basis of the same morphological data was constructed to test the consistency of the varietal grouping in species.

5.3 Results and Discussion

5.3.1 Morphological Characters

Successful utilization of rice varieties by farmers, and crop improvement by breeders, depend on, among other things, the diversity of genes governing various characters. Relatively wide variation for some traits was found in the farmers' varieties (Table 5. 3). Differences among varieties were very high for awning and awn color; apiculus color, leaf angle, palea and lemma color, and secondary branching on

Table 5.3: Minimum, mean and maximum values, standard deviation (SD) and coefficient of variation (CV) of characters for which local germplasm was evaluated in 1996 and 1997 cropping season

Character	Minimum	Mean	Maximum	SD	CV
Plant height at 2 weeks (cm)	6	21.5	40.0	5.7	21.7
Plant height at maturity (cm)	51.0	128.1	160.0	11.9	9.3
Leaf length (cm)	19.5	45.1	77.4	8.3	18.4
Leaf width (cm)	0.6	1.6	2.8	0.2	15.0
Leaf blade pubescence (IRRI SES)	1	1.5	3	0.2	15.5
Leaf lade color (IRRI SES)	1	1.5	3	0.4	0.3
Leaf sheath color(IRRI SES)	1	1.2	4	02	36.2
Leaf angle(IRRI SES)	1	1.8	9	1.0	55.6
Ligule length (mm)	3	2.4	5	04	15.4
Ligule color (IRRI SES)	1	1.1	3	0.3	18.9
Ligule shape (IRRI SES)	1	1.7	3	0.2	19.8
Collar color (IRRI SES)	1	1	2	0.04	3.6
Auricle color (IRRI SES)	1	1	2	0.14	13.3
Panicle length (cm)	10	22.1	31.2	2.4	10.9
Panicle type (IRRI SES)	5	5.9	9	0.5	10.9
Secondary branching (IRRI SES)	0	1.2	3	0.4	35.5
Panicle exertion (IRRI SES)	1	3.5	5	0.5	15.6
Awning (IRRI SES)	0	0.8	9	1.1	140.4
Awn color (IRRI SES)	0	0.6	6	0.6	95.5
Apiculus color (IRRI SES)	1	2.3	9	12.4	78.5
Lemma and palea color (IRRI SES)	0	1.6	9	0.9	38.4
Spikelet fertility (%)	1	86.7	99.2	9.6	11.0
Grain length (mm)	0.3	0.8	1.1	0.03	5.3
Grain width (mm)	0.2	0.3	0.4	0.0	3.5
Seed coat color (IRRI SES)	1	2.9	5	0.5	16.5
Maturity (days)	95	125.3	158.0	5.8	5.0
Culm length (cm)	45.0	105.4	156	10.7	10.2
Culm diameter (cm)	2.0	3.6	6	0.7	17.9
Culm strength (IRRI SES)	1	5.8	9	1.0	17.4
Culm number	1	3.1	9	1.4	43.4
Culm internode color (IRRI SES)	1	1.2	3	0.0	0.0
Flag leaf angle (IRRI SES)	1	2.8	7	0.9	31.5
Culm angle (IRRI SES)	1	1.0	3	0.14	13.8
100 grain weight (gm)	1	2.17	3.2	0.17	7.6

Where SES refers to International Rice Research Institute (IRRI) Standard Evaluations System for rice

the panicle. Variation was low for culm internode color, leaf color, collar color, days to maturity and plant height at maturity, grain length and grain width. The data suggest a valuable gene pool in local germplasm for potential development of rice varieties adapted to traditional rice farming systems in Sierra Leone.

Table 5. 4: Mean values of the species characters

Character	*O. glaberrima*	*O. sativa*	Pa Three Month
Plant height at 2 weeks (cm)	20.6	22.8	18.3
Plant height at maturity (cm)	130.1	129.3	104.9
Leaf length (cm)	39.9	50.3	42.4
Leaf width (cm)	1.6	1.7	1.3
Leaf blade pubescence (IRRI SES)	1.2	1.8	1
Leaf blade color (IRRI SES)	1.2	1.8	1
Leaf sheath color (IRRI SES)	1.2	1.3	1
Leaf angle (IRRI SES)	1.2	1.9	4.8
Ligule length (mm)	23	26	19
Ligule color (IRRI SES)	1.7	1.5	1.7
Ligule shape (IRRI SES)	1.7	1.8	1.7
Collar color (IRRI SES)	1	1	1
Auricle color(IRRI SES)	1	1	1
Panicle length (cm)	21.5	23.1	19.0
Panicle type (IRRI SES)	6	5.5	8.3
Secondary branching (IRRI SES)	0.8	1.5	1.7
Panicle exertion (IRRI SES)	4.9	2.3	3
Awning (IRRI SES)	0.4	1.3	0
Awn color (IRRI SES)	0.6	0.7	0
Apiculus color (IRRI SES)	2.9	1.7	2.3
Lemma and palea color (IRRI SES)	2.8	2.4	2.3
Spikelet fertility (%)	88	85.9	83.9
Grain length (mm)	0.8	0.9	0.6
Grain width (mm)	0.8	0.3	0.3
Seed coat color (IRRI SES)	4.0	1.7	3.5
Maturity (days)	122.9	127.8	106.7
Culm length (cm)	106.5	105.1	84.6
Culm diameter (IRRI SES)	3.2	4.0	3.2
Culm strength (IRRI SES)	8.1	3.4	8.0
Culm number	2.9	3.4	3.7
Culm internode color (IRRI SES)	1.2	1.3	1
Flag leaf angle (IRRI SES)	2.4	3.0	4.1
Culm angle (IRRI SES)	1	1	1
100 grain weight (gm)	2.1	2.2	1.9

Morphological variation between *O. sativa, O. glaberrima* and the Pa Three Month type is shown in Table 5. 4. Differences between the two *Oryza* species and Pa Three Month were considerable.

The *O. sativa* varieties were taller at seedling stage, had longer and broader leaves, had longer panicles and needed more time to reach maturity. The *O. glaberrima* varieties were taller at maturity and had shorter leaves than both *O. sativa* and Pa Three Month. Pa Three Month, on the other hand, had shorter panicles, low spikelet fertility, was shorter in duration, and had lower 100-grain weight. A majority of traits measured for Pa Three Month was similar to or ranged between, the traits of the varieties of *O. sativa* and *O. glaberrima* species. Pa Three Month was shorter in height and duration and had shorter ligule length. The tillering capacity of Pa Three Month was higher than both the *O. sativa* and *O. glaberrima* varieties. The secondary branching index of Pa Three Month was higher than the average for both *O. sativa* and *O. glaberrima.* Plant height and short duration of Pa Three Month could be used to improve farmers varieties that are tall and long in duration.

5.3.2 Characters: species, varieties and year interactions

The species and variety effects, and interaction effects of the characters and the summary of the ANOVA for characters used in the characterization of local germplasm are presented in Table 5.5 and Appendix 1 respectively.

Table 5.5: Interaction effect of Year (Y), Species (S) and Variety (V) in the morphological characterization of rice germplasm

	S	Y	SxY	V	Y	VxY
Character						
Plant height at 2 weeks	***	***	ns	***	***	***
Plant height at maturity	***	**	ns	***	***	**
Leaf length	***	***	ns	***	***	ns
Leaf width	***	ns	ns	***	ns	ns
Leaf blade pubescence	***	ns	ns	***	ns	***
Leaf blade color	***	ns	ns	***	**	ns
Leaf sheath color	***	ns	ns	***	ns	ns
Leaf angle	***	**	***	***	ns	ns
Ligule length	***	ns	ns	***	ns	ns
Ligule color	*	**	**	***	***	***
Ligule shape	ns	***	ns	***	***	***
Collar color	ns	ns	ns	ns	ns	ns
Auricle color	*	**	ns	***	***	***
Panicle length	***	**	ns	***	***	ns
Panicle type	**	***	ns	***	ns	***
Secondary branching	***	ns	ns	***	**	ns
Panicle exertion	***	ns	ns	***	ns	***
Awning	***	ns	ns	***	ns	ns
Awn color	***	**	ns	***	***	***
Apiculus color	***	ns	ns	***	ns	***
Lemma and palea color	***	ns	ns	***	ns	*
Spikelet fertility	**	***	***	***	***	***
Grain length	***	**	ns	***	***	***
Grain width	***	ns	ns	***	**	**
Seed coat color	***	ns	**	***	ns	***
Maturity	***	**	***	***	***	***
Culm length	***	ns	**	***	**	***
Culm diameter	***	ns	**	***	ns	ns
Culm strength	***	ns	**	***	ns	***
Culm number	***	***	ns	***	***	ns
Culm internode color	***	ns	ns	***	***	***
Flag leaf angle	***	ns	***	***	**	***
Culm angle	*	ns	ns	***	ns	ns
100 grain weight	***	ns	ns	***	***	***

*: $P<0.05$
**: $P<0.01$
***$P< 0.001$

The species main effect was highly significant ($p < 0.001$) for most of the characters except for ligule shape and collar color. The species main effects were significant for spikelet fertility and panicle type at $p < 0.01$ and for culm angle, auricle color and ligule length at $p < 0.05$. The varietal main effect was also significant for all the characters (p

< 001) except for collar color. The year main effect (Table 5.5 and Appendix 2) was not significant for most of the qualitative characters for both species and varieties. However, the year effect for most quantitative characters was significant. The year x species interaction effect was not significant for most of the characters. The different species and variety responses to environmental change (year interaction) was only significant for days to maturity and spikelet fertility. This indicated that the days to maturity and fertility of the species and varieties were significantly different in the two years.

Figures 5.1 to 5.10 give a pictorial presentation of some agronomic, panicle and grain characteristics of farmers' varieties in the research area.

Plant height at two weeks after sowing ranged from 17 to 30 cm with an average of 22 cm. (Figure 5.1 and Appendix 5.1). *O. sativa* variety Ngolo Yomboi was the tallest at two weeks (Appendix 5.1). The shortest variety at two weeks was *O. glaberrima* variety Dissi Forie 3. Both are local farmers' varieties. Ngolo Yomboi was collected in the south of Sierra Leone and selected for a low-input environment and for its weed suppression at RRS. Fast seedling growth is necessary for weed suppressing ability at early growth stages. Most local varieties, especially the *O. glaberrima* varieties, grow very rapidly at early growth stages, producing many leaves and tillers (Jennings *et al*, 1979). Weed suppression ability is very important for rice production in Sierra Leone, since weeding is usually done manually and effective weed removal may be impossible due to labor shortages.

For most varieties, plant height at maturity of most varieties was between 100 and 140 cm, with an average height of 100 cm tall (Figure 5.2 and Appendix 5.1). The *O. glaberrima* cultivar, Saliforeh 2, was the tallest and the *O. sativa* cultivar No Name was the shortest at maturity. Plant height at maturity is a very important plant character because it influences the lodging tolerance and constraints at harvest. Very tall varieties lodge easily. And because the common method of harvesting in the research area is bulk harvesting (chapter 3) farmers prefer tall varieties so that they can harvest without bending. Farmers reject most fertilizer-responsive varieties because they are short, requiring farmers to bend down while harvesting. Some farmers refer to them as "back breaking varieties". Plant height, therefore is a difficult issue for breeders in developing varieties for farmers in this area. Short stature varieties are appropriate for fertilizer responsiveness and tall varieties for farmers who prefer them for ease of harvesting. Labor shortage (including shortage at harvest) is as big a production constraint as shortage of funds for fertilizer.

There were also differences in ligule length between varieties, closely related to species. With the exception of Black Sallay and Saliforeh, all varieties with a ligule length greater than 3 mm were *O. sativa* varieties. All the varieties with short ligule length (average 1 mm) were *O. glaberrima* varieties, except ROK 5, Nylon and Pa Bop. The short rounded ligule shape is a common characteristic of *O. glaberrima* cultivars (Ng *et al* 1988).

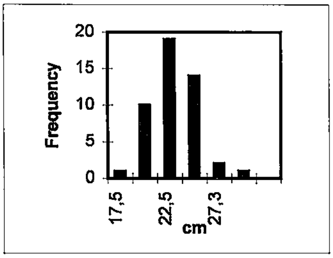


Figure 5.1: Plant height at two weeks

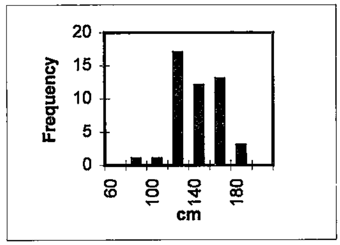


Figure 5.2: Plant height at maturity

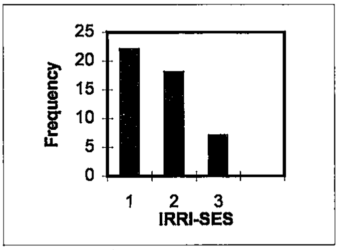


Figure 5.3: Leaf pubescence

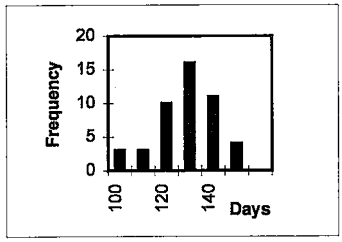


Figure 5.4: Days to maturity

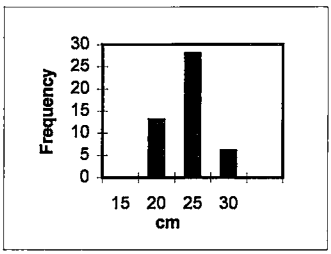


Figure 5.5 panicle length

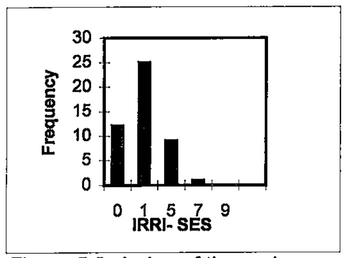


Figure 5.6: Awing of the grain

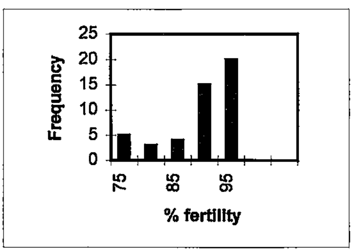


Figure 5.7: Spikelet fertility

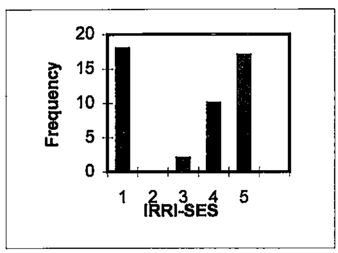


Figure 5.8: Seed coat clor

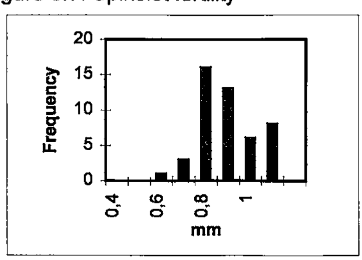


Figure 5.9: Grain length

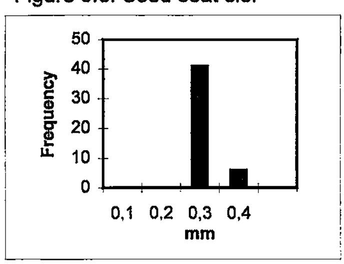


Figure 5.10: Grain width

Figure 5.1 - 5.10: Characteristics of local rice germplasm in North-western Sierra Leone.

The *O. sativa* varieties had the greatest leaf pubescence, with Ngolo Yomboi, Nylon, ROK 16, and the group containing ROK 3 and Samba Konkon (local name for ROK 3), Nyarie Bomboi and No Name having the highest rating. Leaf pubescence is a characteristic of interest during cultivation and processing. The farmers mostly selected varieties that are glabrous and intermediate (Figure 5.3) because highly pubescent varieties cause a lot of itching during weeding, harvesting and processing.

The tillering ability of the varieties was low, with most varieties producing between 3 and 4 panicle bearing tillers per plant (Appendix 5.1). Most of the varieties were very leafy producing many non panicle-bearing tillers.

Lodging was common for all *O. glaberrima* varieties and Pa Three Month. This is one of the defects of the *O. glaberrima* species (Koffi, 1980; Dingkuhn *et al.*, 1997).

The number of days from seeding to maturity ranged from 100 to 150 days with most varieties coming to maturity between 120 and 130 days (Figure 5.4). The growth duration of the varieties can be divided into very short for No Name, Dissi Temne and Pa Three Month 3 (less than 100 days); short for Damba and Pa Damba (100 to 110 days); intermediate for Black Sallay, Janet, Dissi Forie, Pa Temne (115 to 125 days); long for ROK 3 1; ROK 3 2 and Samba Konkon (125 to 140) and very long for Kebleh, ROK 5 and Thabunsu (more than 140 days) for the uplands. The variety ROK 5 is an RRS release for the lowland but a few farmers have adapted it to uplands in Magbema Chiefdom where rainfall is higher. This classification depends on the specific rainfall patterns associated with areas of production. Farmers in the research area planted early duration varieties that matured during the peak hungry season when farmers were awaiting the main harvest in September and October. A small part of the farm was planted to these varieties. The medium and late duration varieties were planted for sale and for family food after harvest.

Panicle length ranged between 10 and 30 cm. The average panicle length of most varieties was about 25 cm (Figure 5.5). The *O. sativa* varieties had longer panicles than the *O glaberrima* varieties except for Saliforeh 1. The varieties with panicle length above 24 cm were mostly RRS releases subsequently selected by farmers. These included Ngolo Yomboi, Joe Wanjei, Samba Konkon and the ROK 3 series.

The mode of branching and the angle of the primary branches of the panicles were intermediate for most of the cultivars. The panicles of the *O. glaberrima* varieties such as Black Sallay, Saliforeh (also Pa Three Month) were open and secondary branching of the panicles was absent or very light, a typical species characteristics. This is one of the main causes of their low yields as compared to *O. sativa* cultivars (Jones *et.al*, 1997). Very few awned varieties were found in the research area (Figure 5.6), though farmers were interested in awned varieties during selection of newly introduced rice varieties, as awning reduces bird damage between flowering and maturity (Chapter 4). ROK 16 was the only variety with awns. A few have partial awns on the grains including ROK 3 and the Samba

Konkon series. Spikelet fertility(that is the fraction of filled kernels) was high for most varieties and ranged from 75 to 99 percent (Figure 5.7).

The seed coat (Figure 5.8) of the farmers' varieties was predominantly brown, with the exception of the RRS selections, and the local varieties Bayiba, Khorry Kindeh and No Name.

Seed coat color varies from white to brown. All *O. glaberrima* varieties were red or brown in color. The white grained varieties were generally the recently introduced *O. sativa* varieties from research institutions. Farmers like varieties with brown and red grain color because they say this kind of rice lasts longer in the stomach after eating (i.e., it digests more slowly after eating). For 100-grain weight, grain length grain width , and seed coat color see Figure 5.8 to Figure 5.10.

5.3.3 Principal Component Analysis (PCA)

PCA was carried out to determine which linear combinations of characters best separated groups of cultivars in two-dimensional space. Two PCAs were generated using varietal averages, viz. one to group varieties in species, and one to group varieties in chiefdoms. The first grouping was to find support for the hypothesis that farmers' varieties in the study area consist of two different *Oryza* species and a distinct possible hybrid Pa Three Month.

5.3.3.1 Principal Component Analysis of species

The PCA of the distribution of varieties over species is presented in Figure 12. Varieties were grouped into three well-separated clusters, formed by the two *Oryza* species and Pa Three Month. The coordinates of the mean of varieties belonging to *O. sativa* and *O. glaberimma* were -12.04, -7.75 and 1.67, 7.82 respectively, and the coordinates of the mean of Pa Three Month were 66.89, 10.86. This clear separation at the species level provides support for the hypothesis that *O. sativa*, *O. glaberrima* and the Pa Three Month form three distinct morphological groups.

The first and second canonical variates explained 84% and 16% of total variation respectively. The most important quantitative morphological characters that dominated the definition of the canonical variates, and therefore contributed most to separation of the varieties, were plant height at two weeks, the length of the panicle and grain, grain width and the number of days from seeding to maturity, culm length, and culm diameter. Most important qualitative characters were the color of the leaf sheath and collar, panicle type, awning and leaf angle. The large differences could also be due to the scales used in recording the observations. While grain length and width were measured in millimeters plant height leaf length and width were measured in centimeters The separation of the varieties into three groups was due to differences in most of the traits. There were large differences for ligule length, color and shape. The species also differ in grain length width, and colors (Table 5. 7).

This demonstrates the morphological distinctness of Pa Three Month , *O. sativa* and *O. glaberrima*. The distinctiveness of Pa Three Month is confirmed, suggesting that this rice may be an exotic, or the product of interspecific crossing.

Table 5.7: Mean vector loadings of the original characters in the two canonical variates, separating varieties into three clusters

Character	First axis	Second axis
Variation explained (%)	85.47	15.57
Plant height at 2 weeks (cm)	0.84	2.87
Plant height at maturity (cm)	-0.45	-0.17
Leaf length (cm)	0.15	-0.30
Leaf width (cm)	1.6	3.03
Leaf blade pubescence (IRRI SES)	-5.12	-6.15
Leaf blade color (IRRI SES)	9.48	5.68
Leaf sheath color (IRRI SES)	-3.09	11.52
Leaf angle (IRRI SES)	1.03	-1.66
Ligule length (IRRI SES)	-9.32	-2.97
Ligule color (IRRI SES)	13.95	9.78
Ligule shape (IRRI SES)	-6.78	-0.11
Collar color (IRRI SES)	-397.84	-138.60
Auricle color (IRRI SES)	19.27	29.62
Panicle length (cm)	-0.31	0.66
Panicle type (IRRI SES)	3.97	-0.21
Secondary branching (IRRI SES)	7.72	6.57
Panicle exertion (IRRI SES)	-13.29	-8.29
Awning (IRRI SES)	3.27	-1.68
Awn color (IRRI SES)	-6.95	1.55
Apiculus color (IRRI SES)	-0.92	0.68
Lemma and palea color (IRRI SES)	2.70	-0.86
Spikelet fertility (%)	-0.72	-0.42
Grain length (mm)	-63.03	7.95
Grain width (mm)	-369.50	15.71
Seed coat color (IRRI SES)	-5.49	-3.66
Maturity (days)	0.40	0.02
Culm length (cm)	0.42	0.21
Culm diameter (cm)	2.14	-11.61
Culm strength (IRRI SES)	5.42	2.24
Culm number	2.73	-6.43
Culm internode color (IRRI SES)	5.33	-5.13
Flag leaf angle (IRRI SES)	-2.37	-2.51
Culm angle (IRRI SES)	-7.12	59.69
100 grain weight (gm)	-3.36	-15.74

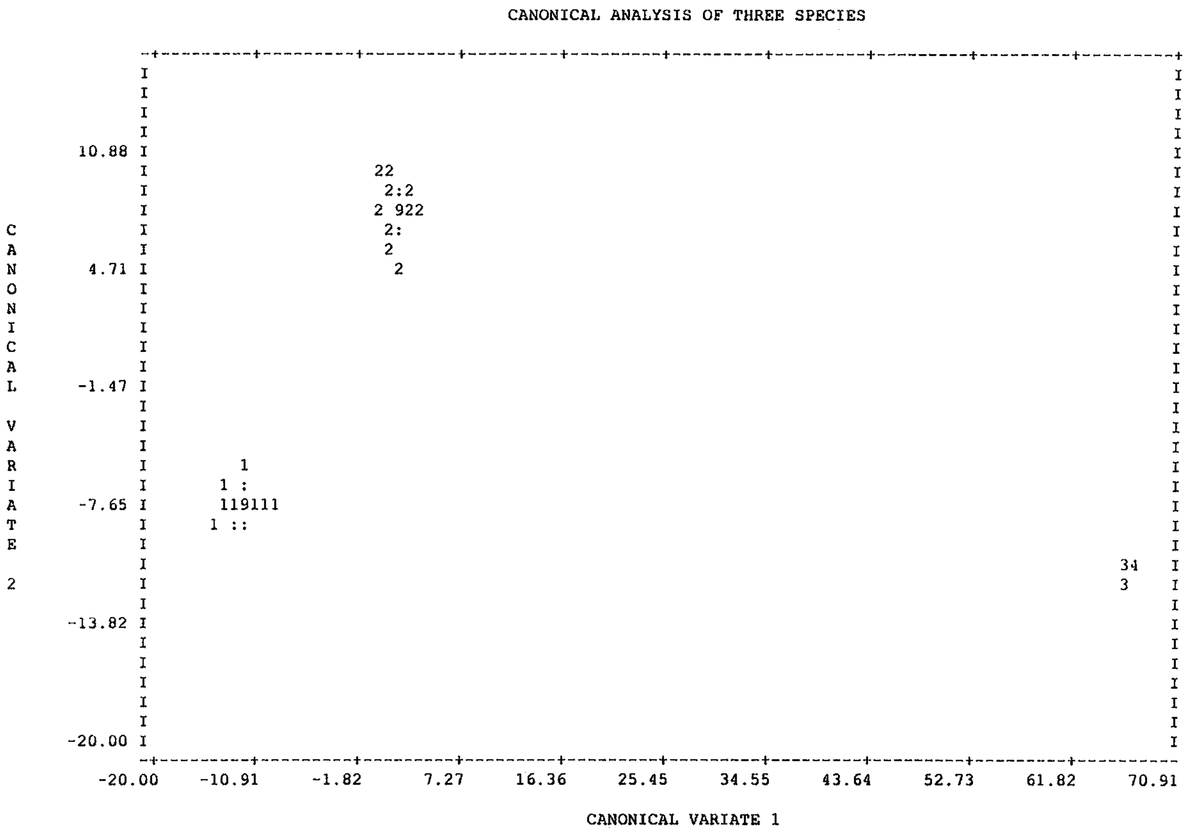


Figure 5.12 : Principal component analysis scatter diagram for 47 farmers' varieties, grouped in three species, *viz. O.sativa* (indicated by number 1), *O. glabberima* (indicated by number 2) and the presumed hybrid varieties of Pa Three Month (indicated by number 3). Higher numbers indicate overlap of varieties at that place.

5.3.3.2 Principal Component Analysis for Chiefdoms

The distribution of the varieties by PCA per Chiefdom is presented in Figure 5.13. The varieties were distributed into well-separated clusters, formed by the three Chiefdoms. First and second canonical variates accounted for 60.20 % and 39.80 % of total variation, respectively. The canonical variate means indicate a positive relationship for the Magbema Chiefdom for all the varieties for the second axis (2.901, 5.869) and both positive and negative relationship for Tonko Limba (-11.480, +0.233) and Bramaia (2.586, -5.364).

Table 5.8 : Mean Vector loading from the Canonical Variate Analysis for the three Chiefdoms

	First axis 60.20	Second axis 39.80
Character		
Plant height at 2 weeks (cm)	0.19	2.87
Plant height at maturity (cm)	1.44	0.05
Leaf length (cm)	-1.01	-0.29
Leaf width (cm)	10.65	8.79
Leaf blade pubescence (IRRI SES)	7.07	-3.87
Leaf lade color (IRRI SES)	-1.29	1.67
Leaf sheath color (IRRI SES)	15.48	-15.38
Leaf angle (IRRI SES)	-1.84	-5.01
Ligule length (mm)	-9.39	-7.54
Ligule color(IRRI SES)	-28.70	3.80
Ligule shape (IRRI SES)	-3.99	5.62
Collar color (IRRI SES)	-31.47	-253.68
Auricle color (IRRI SES)	-5.75	35.39
Panicle length (cm)	-1.01	0.98
Panicle type (IRRI SES)	-2.14	5.12
Secondary branching (IRRI SES)	-23.04	-3.16
Panicle exertion (IRRI SES)	0.74	-10.48
Awning (IRRI SES)	2.31	2.16
Awn color (IRRI SES)	-3.32	-6.61
Apiculus color (IRRI SES)	-1.30	2.10
Lemma and palea color (IRRI SES)	-2.90	-3.21
Spikelet fertility (%)	-1.03	-0.53
Grain length (mm)	18.56	15.08
Grain width (mm)	-1236.07	277.00
Seed coat color (IRRI SES)	5.58	-0.59
Maturity (days)	-0.26	0.26
Culm length (cm)	-1.27	-0.29
Culm diameter (IRRI SES)	-3.19	3.46
Culm strength (IRRI SES)	-5.74	5.57
Culm number	-22.95	7.15
Culm internode color (IRRI SES)	-15.14	-8.52
Flag leaf angle (IRRI SES)	5.17	-3.03
Culm angle (IRRI SES)	-1001.07	25.62
100 grain weight (gm)	53.43	-35.31

There was large variation in the varieties collected from the three Chiefdoms and the leading discriminating morphological characters in grouping the varieties per Chiefdom were quantitative ones such as plant height at two weeks, and maturity, grain width, 100 grain weight, and culm length and number (tillering ability). Collar color and culm angle were the only qualitative characters that contributed highly to grouping the varieties in the three Chiefdoms. Other characters such as colors of the leaf sheath, ligule, collar, and auricle and secondary branching (Table 5.8) also contributed to the grouping of the varieties.

The morphological distinctiveness of varieties from each of the three Chiefdoms should be noted, and corresponds to the quite distinctive selection strategies of the three different ethnic groups discussed earlier.

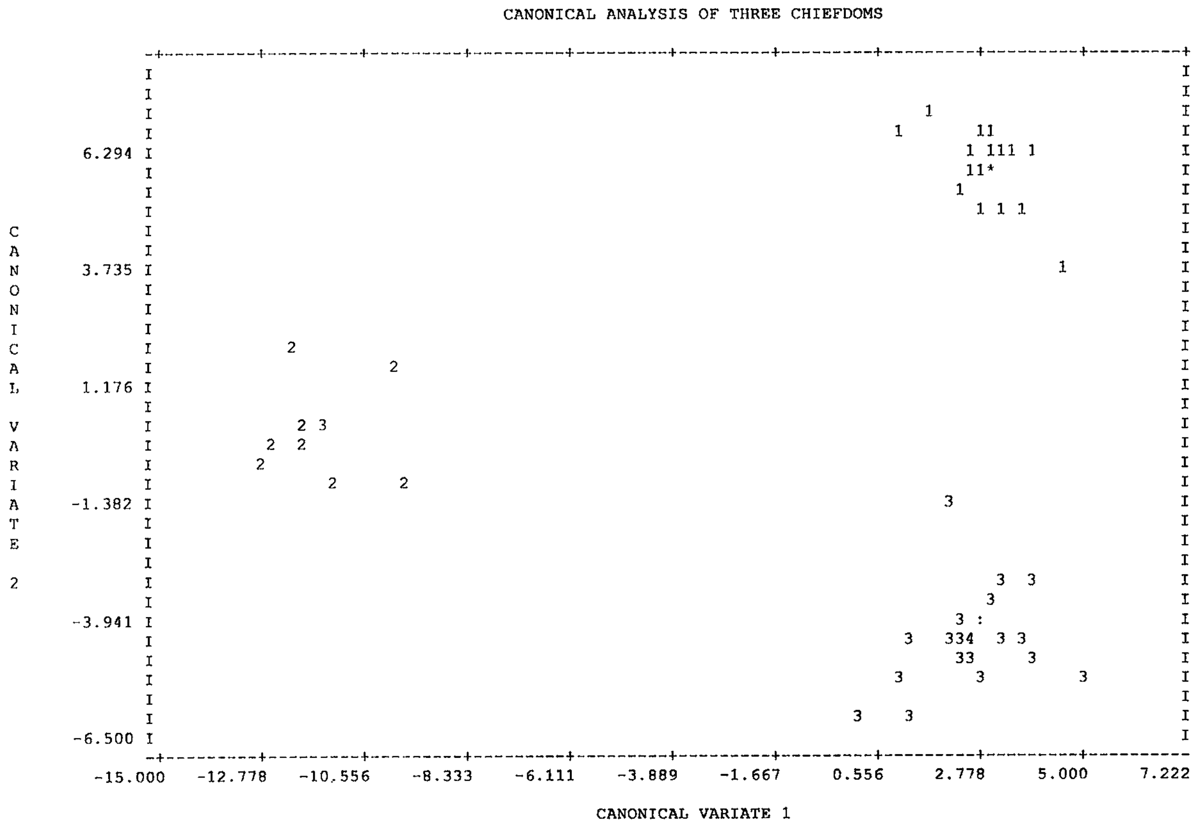


Figure5. 13 : Principal component analysis scatter diagram for 47 farmers' varieties, grouped in three Chiefdoms, *viz.* Magbema (indicated by number 1), Tonko Limba (indicated by number 2) and Bramaia (indicated by number 3). Higher numbers indicate overlap of varieties at that place. Where 1 = Magbema Chiefdom; 2 = Tonko Limba Chiefdom; 3 = Bramaia Chiefdom

5.3.4 Cluster analysis

The dendogram sorts the material in the coherent way:

- the main *O. sativa* material belongs to the first main branch at the bottom of Figure 5.14.
- ROK 3, Samba Konkon, and Bayiba belong to a distinct sub-group. (ROK 3 is called Sama Konkon among the Susu, the Limba also call it Ba Isatu or Bayiba).
- The material in the top half of the graph is nearly all *O. glaberrima.*
- The "Sali" varieties form a sub-group, as do the varieties with a "Dissi" element in the name (Pa Dissi Temne and Pa Temne may be used interchangeably, Richards pers. comm.).
- Some very long duration *O. glaberrima* varieties sit in a mixed group at the top of the graph with some similar long duration wetland *O. sativa* varieties. Sierra Leoneans sometimes refer to these rices by the category name Yaka - a catch crop of late season swamp rices, including wild or semi-wild types. (Richards pers. comm.).
- The Pa Three Month samples straddle the Dissi cluster, suggesting a closer relationship to this group of *O. glaberrima* varieties than we realized. The Dissi prefix is rich in possible meaning. The first colonial rice in North-west Sierra Leone (1915) was Demerara Creole (from British Guyana) known locally as DC or Dissi rice. Many people locally took up "Dissi" to mean government rice. DC was interpreted as meaning "District Commissioner's rice"(Migeod, 1926). Evidently, the name came to be applied also to "new" *O. glaberrima* varieties (never the subject of research promotion). The dendogram clearly confirms that all the "new" *O. glaberrima* varieties belong to a single broad cluster, differentiated from the "traditional" *O. glaberrima* varieties of the Sali/Sallay types.

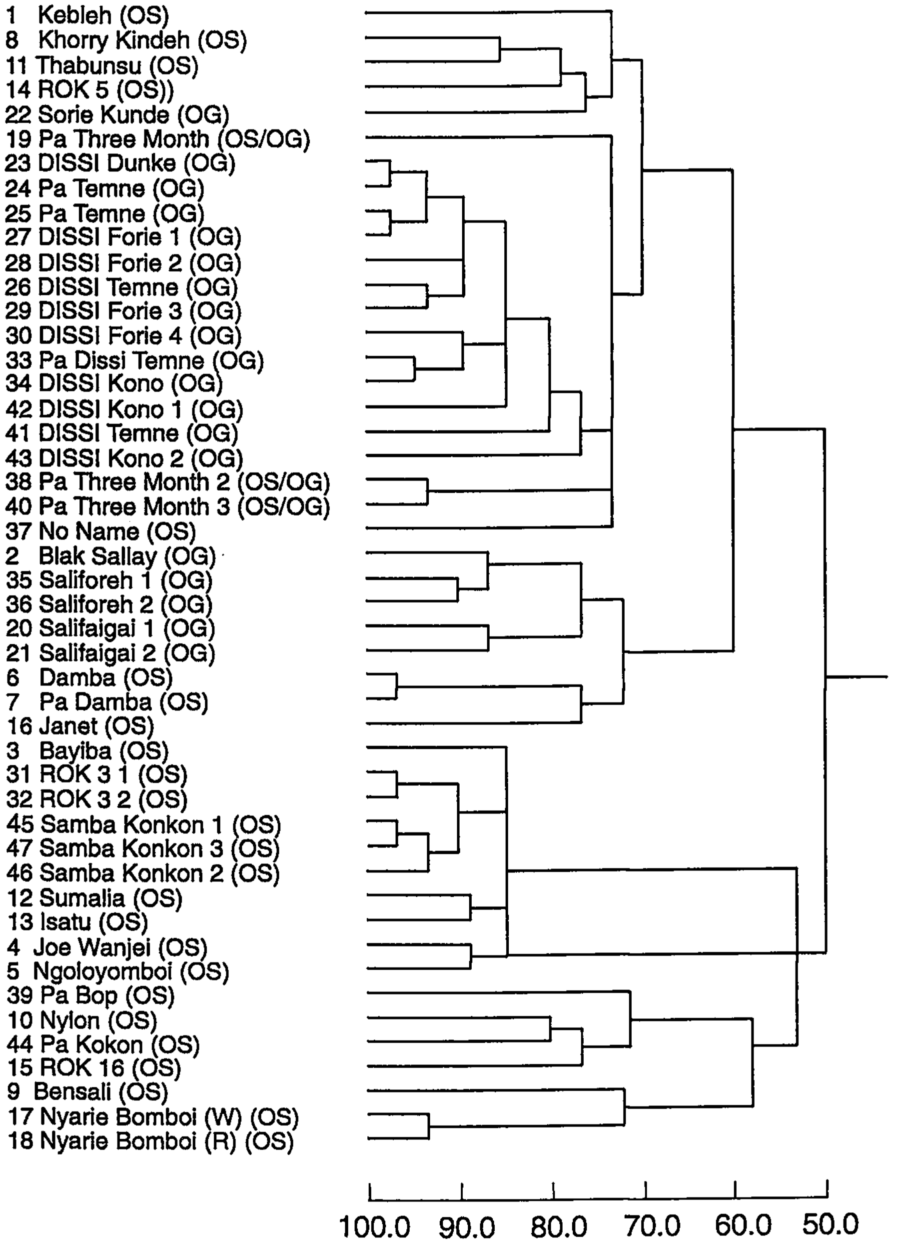


FIGURE 16 : SPANNING (DENDROGRAM) TREE FOR VARIETES EVALUATED(95 left)

5.4 General Discussion and Conclusion

5.4.1 Distribution of genetic diversity within the collections.

In Sierra Leone, farmers cultivate a large number of varieties that are diverse with respect to adaptation to various biotic and abiotic factors, growth duration and consumer preferences. The results reported here confirm the great diversity resulting from farmers' management of rice germplasm in traditional farming systems. It supports the contention that farmers' selection and adaptation of varieties for wide environmental variation on their farms has assisted in the maintenance of high genetic diversity in the *Oryza* species in this area.

A major research finding therefore concerns the identification of the third group of rice varieties grown by farmers, Pa Three Month, which is morphologically different from *O. Sativa* and *O. glaberrima* varieties. These varieties were first reported in the research area in the last 15 years. Results from the mean differences between the species, PCA and cluster analysis based on morphological traits confirms the Pa Three Month group to be morphologically different from the *O. Sativa* and *O. glaberrima* varieties.

Of the Pa Three Month types collected, the one originating among the Temne in Magbema Chiefdom was longer in growth duration than those collected in Bramaia and Tonko Limba Chiefdoms. According to farmers, Pa Three Month matures three months after seeding, which was confirmed by the two samples collected from farmers in Tonko Limba and Bramaia Chiefdoms. These samples matured in 96 and 97 days, respectively, and both had brown husk color. The Pa Three Month collected from Magbema Chiefdom, on the other hand, matured in 125 days and had a white husk color.

Some landraces grown by farmers are specific to certain areas and ethnic groups. Of the *O. glaberrima* varieties, Pa Temne, Pa Dissi Temne, and Dissi Temne were common among the Temne whereas Saliforeh (black Sali), Dissi Dunke, Sorie Dunke, Salifaigai (white Sali) were common among the Susu. These were all *O. glaberrima* varieties, and the farmers themselves could not exactly remember when their fathers started growing them. The three ethnic groups also cultivated a more recent *O. glaberrima* variety, Dissi Kono. According to a farmer, Pa Alimany Bangura (about 78 years old) in Magbema Chiefdom, this was introduced sometimes between 1918 and 1939. It was also reported that Saliforeh was grown by Temne farmers many years ago, but was replaced when farmers adopted Pa Temne and later Dissi Kono. The varieties ROK 3, Ngolo Yomboi and Joe Wanjei, released and pre-released RRS varieties, were found only among the Temne farmers who live closest to RRS. One farmer obtained Joe Wanjei when an on-farm trial was conducted on his farm by RRS staff and he retained Joe Wanjei for further testing. The variety was only grown by very few farmers.

Close observation in the field, information from key informants, and characterization of the rice germplasm provided insights into how the names of the varieties vary among the three ethnic groups (Monde *et al* 1997). In Magbema the variety ROK 3 is commonly known among farmers around RRS as ROK 3, or as Yainke Yaka among Temne farmers in other parts of the Chiefdom. The same variety was called Samba Konkon among the Susu and

Limba of Bramaia and Tonko Limba respectively. Some Limba farmers also refer to the same variety as Ba Isatu or Ba Yiba, and in Guinea it was known by the Susu as Bassia.

Salifaigai (faigai meaning white in Susu) and Saliforeh (foreh meaning black in Susu) were other common examples of farmers varieties classification among the Susu. Any *O. glaberrima* variety with black husk is referred to a Foreh variety and any *O. glaberrima* variety with a white husk is referred to a Faigai variety. Of the Nyarie Bomboi samples collected in Bramaia Chiefdom, one had a red seed husk color and the other had white seed husk color (Nyarie means cat in Susu and the mottling on a grain of Nyarie Bomboi resembles the hairs on the cat). Pa Damba and Saliforeh are similar in all respects but the husk color of Pa Damba changes from black to brown when the grains are filled and fully matured. The unfilled grains are black, just like the matured grains of Saliforeh. Among the Temne the *O. glaberrima* variety, Dissi Kono, was similar to Pa Temne but had smaller grains. The apiculus color of Pa Temne was brown and the variety displayed was less tillering than Dissi Kono. Such differences were also be observed in other varieties with similar names. There was no difference in the performance of ROK 3 collected from the farmers' fields in Magbema Chiefdom and Samba Konkon collected from the three Chiefdoms. This is evident that farmers had been able to maintain the genetic purity of this variety introduced to this area in 1973. The Dissi Forie varieties were also similar in most of their characteristics. This further testified that farmers give names to varieties based on certain morphological characteristics that readily distinguish them from other varieties. During germplasm collection it was necessary to collect several samples of rices with the same name to ensure capture of most of the genes. Lipton *et al* (1995) made a similar collection from all over the country and showed a similar range of morphological features under single names (Richards, 1997).

More generally, results from morphological analysis support the view that there may be considerable diversity in local gene pools and that the diversity may serve as basis for farmer/breeder adaptive and participatory plant improvement for difficult environments.

6 VARIETY MIXTURES

6.1 Introduction

Most tropical agriculture is subsistence-oriented, accounting for approximately 60% of global agriculture on an area basis (Smithson and Lenne, 1996), producing only 5 to 20% of the World food supply (Francis, 1986). Subsistence farmers often use both mixed cropping and varietal diversity in their farming systems. In mixed cropping they grow landrace populations that are genetically diverse and distinctly recognizable. These populations have been developed through human and natural selection processes over the years. This system of agriculture centers on food and income security, and harvest diversity. It promotes diversity of diet, stability of production, minimization of risk, and reduces insect pest and disease damage (Harlan, 1975).

The crops cultivated by farmers in subsistence farming are selected and adapted to local environmental conditions and social needs. For the adaptation of crops to various environmental conditions of farmer, the competitive interaction of crops in mixtures is a major factor conditioning adaptive strategies in plant co-habitation (Sano *et al*, 1984). Interactive mediated selection as practiced by farmers in risk prone areas can accelerate co-adaptation of species and diversification of crops in various agro-ecological zones.

The use of variety mixtures in modern agriculture has some limited application in wheat and barley in Europe and Russia, and in grasslands and soybean in USA (Smithson and Lenne, 1996). There has also been successful use of mixtures for cotton in Africa (Smithson and Lenne, 1996),and groundnut and oat in USA, using multilines (Knauft and Gorbet, 1991; Frey *et al* 1971a and b), and wheat in India (Wolfe, 1985). The use of variety mixtures in modern agriculture is hindered by market requirements, seed production and distribution systems (Wolfe *et al*,1992).

The cultivation of heterogeneous rice varieties is widespread in tropical subsistence farming. The Hanunoo in the Philippines can classify up to 90 rice varieties (Conklin, 1957); rice farmers in central Sierra Leone deploy a large range of rice varieties (up to 50 in one village of c. 500, Richards, 1986); the Kanta of Kalimantan in Indonesia plant at least 44 rice varieties in one area with an average of 17 varieties per household (Dove, 1985); rice mixtures are also frequently encountered in Vietnam, Madagascar and Bhutan (Clawson, 1985); and Bangladesh (Bonman, *et al.*,1986). How much this involves matching variety to soil type, and how much the mixing of different varieties in one plot, is not always clear in the literature. The latter practice occurs for rice, but is not common in Sierra Leone (Richards, 1985) except as described for Susu farmers in this thesis (Longley, 1999).

The advantage of variety mixtures over their components in monoculture includes increased yields, more stable performance; improved lodging resistance and product quality (Trenbath, 1974), and disease and pest resistance.

The ratio of the yield of a variety in mixture to that of its monoculture yield is referred to as its Relative Yield (RY) and in a two component mixture the sum of the two relative yields is the Relative Yield Total (RYT) (de Wet, 1975).

Scientists have studied the depression of yield as well as over-yielding in RYT in the past. Competition between species and varieties has been studied using Replacement Series Analysis (RSA). This technique has been used to compare the actual yields in monoculture and the expected yield obtained when varieties are grown in mixtures. A replacement series experiment contains different proportions of two varieties in mixtures, in addition to pure stands (monoculture) of each variety.

Jollifee *et al* (1984), for instance, did a re-interpretation of yield relationships in RSA and concluded that when two crops are grown in competition, the degree of depression of yield depends on the effectiveness of each species in competing for limited resources, the responsiveness of each species to the resources supplied, and the effect of different species proportions in the mixture. Spitters (1980), on the other hand, concluded that over-yielding of mixtures is due to non-similar growth period of the varieties in the mixture making different demands on the resource, possibly at different times. When the components have different root depth the deep-rooted varieties extract nutrients from the deeper soil layers. Thus component varieties are limited by different resources, neither variety limiting the other variety (in theory).

Varieties in mixtures compete for a limited amount of light, water and nutrient. These limited resources have been referred to as 'space' by Spitters (1980) and each variety expands during growth, to make use of the its share of the total available resources in 'space'. The yield of each variety is therefore proportional to the resources required and utilized by those varieties.

De Wit (1960) conducted an RSA using a constant total density of plants per species (wheat and barley), in which planting density of one species was proportionally decreased as the planting density of the second species was increased. The seed in the mixtures and those in the monoculture plots were sown at equal densities. The proportions of the seed planted in mixture and in monoculture were compared with the proportion of the seed harvested from the mixture and monoculture plots. It is expected that the yield of the varieties will increase linearly with the relative seed frequency in the mixture when there is no competition or when both varieties are equally competitive.

In West Africa, the two cultivated rice species *O. sativa* and *O. glaberrima* are widely cultivated as sole crops and less commonly as mixtures in farmer's fields. But some Susu farmers in the research area deliberately cultivate these two *Oryza* species in mixtures (Longley, 1999). In the mixed cropping system in the research area, farmers grow landraces populations that are genetically diverse, discretely recognizable and adapted to the various ecological zones. These farmers have selected, among the upland rice varieties, certain types that will grow together in mixtures to adapt varieties to varying soil conditions to secure a good harvest, and to address nutritional balance in the diet (Longley, 1999). The present research was conducted to investigate the advantages and disadvantages of farmer's practices in deliberately mixing varieties before seeding in the upland. Mixing may also offer enhanced opportunities for the gene flow sustaining farmer selection (see as analyzed in Chapter 3.)

In modern agriculture, intra-specific mixtures have been variously described as multilines or multiline mixtures of varieties, cultivars or variety mixtures, blends, biblends (Federer *et al*, 1982) or composites (Mumaw and Weber, 1957). The various components have also been termed components, genotypes, lines, varieties, cultivars and even multiblends (Federer, *et al*, 1982).

In this chapter we refer to the intra-specific mixtures as "mixtures of varieties" (*O. sativa* and *O. glaberrima)* and the two components as the monoculture of *O. sativa* and *O. glaberrima* varieties.

The main objective of this study was to determine the advantages of the mixed-planting of the two species and how one species influences the performance of the other. Farmers do not know Mendelian genetics. So our basic assumption is that the advantage to farmers of mixtures is agronomic, and any geneflow benefits will be incidental. Longley and Richards (1993) do indicate, however, that farmers appreciate the likelihood of changes in seed harvested from mixtures.

The following activities were undertaken to:
assess the effect of fertilizer application on the performance of variety mixtures in upland

assess the effect of irrigation on the performance of variety mixtures.
study the effect of competition on plant height, tillering ability, duration, and panicle length of the varieties on competition effect.

6.2 Materials and methods

Four varieties usually mixed by Susu farmers in their farming system were selected for this trial. These included two *Oryza sativa* and two *O. glaberrima* varieties (Table 6. 1).

Table 6.1: Characteristics of two Oryza sativa and two O. glaberrima varieties tested in the varietal mixture trials in the 1996 and 1997 cropping seasons

Species	Varieties	Characters			
		Husk color	Seed shape	100 grain wt (gram)	Awning
Oryza glaberrima	1. Dissi Kono (G1)	Brown	Bold	2.02	Absent
	2. Saliforeh (G2)	Black	Slender	2.18	Partial
Oryza sativa	3. Pa Bop (S1)	Straw	Bold	3.00	Absent
	4. Samba Konkon (S2)	Straw	Slender	2.23	Partial

Each variety was grown in monoculture (*T1-T4*) and in a 1:1 mixture with another variety (*T5-T10*) as shown below.

Treatment Combinations:

T1	Dissi Kono	T2	Saliforeh
T3	Pa Bop	T4	Samba Konkon
T5	Dissi Kono + Saliforeh	T6	Dissi Kono + Pa Bop
T7	Dissi Kono + Samba Konkon	T8	Saliforeh + Pa Bop
T9	Saliforeh + Samba Konkon	T10	Pa Bop + Samba Konkon

Two trials were conducted. One was conducted in upland conditions to study the effect of fertilization on performance of varieties in mixtures. The second trial was conducted in a pot experiment under irrigated condition and on rainfed upland to compare the effect of water regime on variety mixtures

6.2.1 Upland trials

The seed requirement for the upland trial was calculated as follows:

$$SRP_X = Vx / \{ Vx + Vy \} \times 100$$

Where SRP_X = Seed Rate per Plot for variety x when in combination

Vx = The 100 grain weight of variety x in mixture with variety y.

Vy = The 100 grain weight of variety y in mixture with variety x.

100 = RRS recommended seed rate in kg ha^{-1}.

The seed rate of one variety (x) in combination with another variety (y) per plot (SRP^{-1}) was calculated using the 100 seed weight (Table 6. 1) and the seed rate for the upland ecology was recommended by the Rice Research Station, Rokupr (RRS) which is 100 kg ha^{-1}. This formula was used because the seed size and weight varied for each variety. This correction ensures that approximately equal numbers of seeds per plot for each variety were used in the mixture. The correction was done for all the treatments from T5 to T10, and the seed rate per treatments are shown in Table 6.2.

Table 6.2:The treatment combinations, varieties and seed rate used in the 1996 cropping season

Treatments	Varieties used	Seed rates (kg ha^{-1})
T1	1	100
T2	2	100
T3	3	100
T4	4	100
T5	1+2	48.1 + 51.9
T6	1+3	40.7 + 59.3
T7	1+4	47.5 + 52.5
T8	2+3	42.1 + 57.9
T9	2+4	49.4 + 50.6
T10	3+4	57.4 + 42.6

Note : The numbers and characteristics for varieties used are as indicated in Table 6.1

The experimental site at the Masorie upland RRS experimental land was brushed, cleared of stumps and debris and dug using typical local tools such as cutlasses, hoes and mattock. Seed was drilled sown at a spacing of 20 cm between rows. The size of each plot was 2m x 5m (10 m^2) with 3 rows per plot. The trial was sown in a split plot design and replicated twice with variety as major and fertilizer as the sub-effect. One plot was fertilized and the other was left without fertilizer. The fertilizer rate of 80kg N ha^{-1} (ai N = 46%), 40 kg P_2O_5 ha^{-1} (ai P = 7.3%) and 40 kg K_2O ha^{-1} (ai K = 60%) was used for the fertilized plot. Phosphorus as single super phosphate (SSP) was applied basally at seedling and nitrogen as urea, and potassium as muriate of potash (MOP) was applied in two equal doses at 14 and 40 days after seeding. The application of the nitrogen and potash fertilizers at 14 and 40 days after seeding was done for plants to make maximum use of these nutrients during the vegetative and reproductive phases of the varieties (RRS Annual Report, 1934 - 1989). The trial was sown on 26th June 1996.

The trial was repeated at the same site in 1997 using the same experimental procedure and sown on 26 June 1997. The seeds obtained in the 1996 trial were used for each variety. The seeds from the monoculture and from the mixtures were weighed at 100 gm. per plot. The ratio of the weight of seeds of the varieties per treatments is shown in Table

6.3 below for each variety in monoculture (T1 to T4) and in mixture (T5 to T10). Adjustment of the weight proportions was similar to that for the 1996 trial, but now using the ratios of the weight of the varieties harvested from the 1996 season. The number of seeds produced per variety in 1996 varied. Therefore, the ratio of seed planted per variety in 1997 differed from 1996.

Table 6.3:The treatment combinations, varieties and seed rate and fertilizer regimes used in the 1996 cropping season; (-) and (+) refers to without and with fertilizer application for the mixed plots

Treatments	Variety used	Seed rates kg ha $^{-1}$	Fertilization
T1	1	100	
T2	2	100	
T3	3	100	
T4	4	100	
T5	1+2	46.7 + 53.3 54.7 + 45.3	(-) (+)
T6	1+3	50.7 + 49.3 53.5 + 46.5	(-) (+)
T7	1+4	48.7 + 51.3 52.5 + 47.5	(-) (+)
T8	2+3	74.6 + 25.4 71.96 + 28.04	(-) (+)
T9	2+4	58 + 42 58.3 + 41.7	(-) (+)
T10	3+2	53.4 + 46.6 54.5 + 45.5	(-) (+)

6.2.2 Data collection

The following data were collected from two one-meter square quadrants per plot for each treatment:

- Grain yield in kg ha $^{-1}$ at 14% moisture content.
- Duration (days).
- Plant height at maturity from the tallest panicle (cm).
- Culm strength.

At harvest the varieties in the mixed plots were separated into individual varieties and the traits recorded for each variety. Days to maturity were recorded as the number of days from sowing to the time when 90% of the variety was matured for harvesting, to avoid shattering. Shattering was a major problem with the *O. glaberrima* varieties in the execution of this trial. Plant height was recorded as the height of the plant from the surface of the soil to the tip of the tallest panicle, excluding the awns. Culm strength was measured between heading and maturity by using the International Rice Research Institute (IRRI) Standard Evaluation System (IRRI-SES, 1996) The plants were gently pushed back and forth several times to measure the culm stiffness and resilience. Plants with strong and stiff stems that did not bend were rated as 1 and those with very weak stems as 9. The other ratings fell between these two values as 3, 5 and 7, depending on the strength of the culm, as judged by the researchers.

6.2.3 Small plot/pot experiment

A second trial consisting of the same varieties (Table 6.1) was conducted in concrete troughs under irrigated and rainfed upland condition at RRS in 1997. Sixteen plants per concrete trough in the irrigated condition and 16 plants in the rainfed upland per plots were planted in two replications in each of the two water regimes. The varieties were also planted in pure stand to compare their performance in monoculture and in mixtures.

The treatment combinations were as follow:

1.	*12 G1 + 4 G2*	*13.*	*12 G2 + 4 S2*
2.	*8 G1 + 8 G2*	*14.*	*8 G2 + 8 S2*
3.	*4 G1 + 12 G2*	*16.*	*4 G2 + 12 S2*
4.	*12 G1 + 4 S1*	*16.*	*12 S1 + 4 S2*
6.	*8 G1 + 8 S1*	*17.*	*8 S1 + 8 S2*
6.	*4 G1 + 12 S1*	*18.*	*4 S1 + 12 S2*
7.	*12 G1 + 4 S2*	*19.*	*16 G1*
8.	*8 G1 + 8 S2*	*20.*	*16 G2*
9.	*4 G1 + 12 S2*	*21.*	*16 S1*
10	*12 G2 + 4 S1*	*22.*	*16 S2*
11.	*8 G2 + 8 S1*		
12.	*4 G2 + 12 S1*		

Note: The numbers in front of the varietal identification refer to plants grown in mixture in the irrigated condition in pots or in plots under the rainfed upland condition.

The proportion of the varieties in mixtures was thus varied while total density of plants per pot under the irrigated condition and per plot under the rainfed upland remained constant.

In the concrete trough experiment, the seeds were pre-germinated in petri-dishes for 5 days and transplanted in troughs of dimension 86 cm long, 54cm wide and 25 cm deep. The troughs were filled with lowland (swamp) rice soil and flooded five days before transplanting. For the purpose of gap filling seedlings were also raised on dry seedbeds on the same day the seeds for the concrete troughs were nursed in petri-dishes. Seedlings were transplanted at 20 cm by 10 cm spacing. Gap filling continued up to two weeks after transplanting. The troughs were kept flooded, from transplanting until just before harvest.

The same varieties were directly sown on the rainfed upland site about 100 meters from the concrete trough experiment at a spacing of 20 cm by 10 cm. The concrete trough experiment and the dry land trial were sown on the same day. The seedlings in the dry land trial were thinned to one seedling per hill two weeks after seeding and gaps were filled using the same seedlings nursed for the irrigated experiment.

In both the irrigated and rainfed trials, fertilizer was applied at the rate of 80kg N ha^{-1} (ai N = 46), 40 kg P_2O_5 ha^{-1} (ai P 7.3) and 40 kg K_20 ha^{-1} (ai K 60). Phosphorus as SSP was applied basally and nitrogen as urea and MOP were applied in two equal doses at 14 and 42 days after seeding. Weeding was done manually before the nitrogen and potassium fertilizers were applied, and when necessary.

6.2.4 Data collection

The following traits were recorded for the irrigated and rainfed upland experiments at various growth stages of the varieties:

- Plant height at two weeks after sowing in the rainfed upland and after transplanting in the irrigated condition.
- Plant height at maturity.
- Tiller number at two weeks after sowing in the rainfed upland and after transplanting in the irrigated condition.
- Total number of panicle bearing tillers at maturity.
- Grain weight per plant (calculated).
- Grain weight per pot and per plot (calculated).
- Duration from seeding to maturity (days).

Two weeks after sowing in the upland and after transplanting in the irrigated treatment, plant height and the number of tillers of each of the plants were recorded in each pot in irrigated condition and each plot in the rainfed upland treatment. At maturity, plant height was measured from the soil level of the plant to the tip of the tallest panicle. The total number of plants per variety, total number of tillers and panicle bearing tillers per plant were recorded before harvest. At harvest the varieties in the mixed plot in both treatments were separated into individual varieties and the traits recorded for each. The varieties were harvested when 90% of the grain was matured, to avoid shattering (visual observation). The number of days from seeding to 90% maturity was recorded. The number of grains per panicle were counted for each panicle-bearing tiller. The grain weight, per pot and per plot, of each variety in mixture and in pure stand was then calculated using the 100 grain weight, grains per panicle and the number of panicle bearing tillers per plant.

6.2.5 Data analysis

Average yields of the varieties in monoculture and in mixture were calculated to compare the changes in yield of the varieties due to competition under fertilizer application in the upland, and under the rainfed upland and under irrigated conditions in plot and pot experiments respectively.

The competition effect on the varieties in mixtures under fertilizer and no fertilizer application in the upland in 1996 and in 1997 was calculated as the change in the performance of the varieties, as indicated by the differences in the ratio of seed planted to seed harvested per variety.

The following analyses were also done to measure the effect of competition:

- The relative yield total, *RYT*, which measures the differential resource utilization of each variety was calculated as

$$RYT = ½(Y_{ab}/Y_{aa} + Y_{ba}/Y_{bb}),$$

Where Y_{aa} is the performance (yield per unit area) of variety *a* in pure stand and Y_{ab} is the performance of variety *a* in mixture with another variety, Y_{bb} is the performance of variety *b* in pure stand and Y_{ba} is the performance of variety *b* in mixture with another variety (Firbank and Watkinson, 1985).

When the two varieties use different components of the available resources, each thus escaping to a certain extent competitive interference, RYT may be greater than unity. When components of a mixture compete for the same resources, having equal or different competitive abilities, the RYT is equal to unity. In case there is mutual antagonism, such that one variety inhibits the performance of the other variety, the RYT value is less than unity. Observed RYT values were interpreted accordingly.

- The Relative Crowding Coefficient *(RCC)*, the ratio of the performance of variety *a* in competition with variety *b* was computed as:
  $RCC_{ab} = \{Y_{ab} / (Y_{aa} \times Z_{ab})\} / \{Y_{ba} /(Y_{bb} \times Z_{ab}\}$, (from Willey and Rao, 1980).

where RCC_{ab} = Relative Crowding Coefficient of variety *a* inter-cropped with variety *b*,
Y_{ab} = yield per unit area of variety *a* inter-cropped with variety *b* (expressed over the area occupied by both varieties),
Y_{aa} = yield per unit area of sole variety *a*,
Z_{ab} = proportion of inter-cropped area initially allocated to variety *a*, and
Z_{ab} = proportion of inter-cropped area initially allocated to variety *b*.

The *RCC* is the ratio of individual Land Equivalent Ratio (*LER*) of the two component varieties, or as in this experiment, the ratio by which the two varieties were planted. The R*CC* gives the degree of competition by indicating the number of times one variety is more competitive than the other in competition.

6.3 Results and Discussion

6.3.1 Upland trial

The average grain yield of the cultivars in monoculture under fertilizer and no fertilizer application in the upland trials for the 1996 and 1997 cropping seasons are presented in Table 6. 4. The grain yields of the varieties in mixture was higher than the monoculture yield in all the treatments except when G2 (Saliforeh) was in competition with S1 (Pa Bop). The low average grain yield of the G1 + S1 mixture was due to the total replacement of S1 by G2 in the 1997 cropping season.

For both the *O. sativa* and *O. glaberrima* varieties the yields were higher when no fertilizer was applied. This could be due to increased lodging in these cultivars under fertilization, as will be observed later.

Table 6.4: The average grain yield (kg ha^{-1}) in monoculture and in mixtures of the varieties under fertilizer and no fertilizer application in the upland in the 1996 and 1997 cropping seasons

Varieties	With Fertilizer (N2)				Without Fertilizer (N1)			
	G1	G2	S1	S2	G1	G2	S1	S2
G1	**2052.9**				**2496.6**			
G2	2776.4	**1954.4**			2749.7	**2374.2**		
S1	2679.7	2376.3	**1962.4**		2834.7	2091.0	**2043.2**	
S2	2733.0	2856.4	2749.6	**1771.7**	2652.4	2908.0	3021.3	**2048.6**

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon, and bold is monoculture yield

6.3.1.1 Performance in mixtures

The effect of growing the varieties in mixtures (changes in proportion by seed weight of the varieties in mixture) was evaluated by computing the ratio of the relative changes in weight of seed harvested to the weight of seed planted in the first and second year. The results are presented in Table 6. 5.

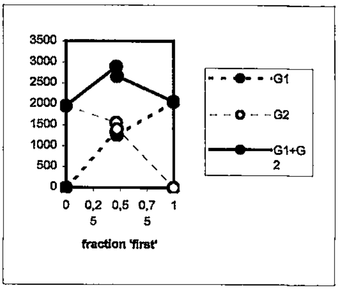
Table 6. 5: The ratio of relative changes (ratio of seed weight harvested to seed weight planted) of the varieties due to the effect of neighboring varieties under fertilizer and non-fertilizer application in the upland in the 1996 and 1997 cropping seasons

Treatment	G1	G2	G1	S1	G1	S2	G2	S1	G2	S2	S1	S2
Fert., 1996	0.97	1.03	1.25	.83	1.03	.97	2.27	0.44	1.17	0.86	0.93	.09
Fert., 1997	0.99	1.01	0.94	.08	0.95	1.05	1.75	0.00	0.95	1.07	1.11	.90
Non-Fert. 1996	1.14	0.88	1.32	0.78	1.11	.91	2.04	0.49	1.18	0.82	0.95	1.07
Non-Fert., 1997	1.67	0.60	0.86	.16	1.01	0.99	1.32	0.00	1.08	0.89	1.40	.60

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon

In most of the cases studied, the *O. glaberrima* varieties performed better on average when in competition with the *O. sativa* varieties in the upland in the two years under fertilizer and no fertilizer application. Among the *O. glaberrima* varieties, G1 (Dissi Kono) and G2 (Saliforeh) were equally competitive when fertilizer was applied and G1 (Dissi Kono) was a better competitor than G2 under no fertilizer application. The *O. sativa* variety, S1 (Pa Bop) performed better than G1 (Dissi Kono) in 1996 under both fertilizer and no fertilizer application. The performance of Dissi Kono, on the other hand, was better than that of Pa Bop in 1997 under both fertilizer regimes. Saliforeh (G2) was a better competitor than Pa Bop, and in the second year Saliforeh totally displaced Pa Bop in mixture.

The better performance of *O. glaberrima* varieties could be due the low fertility of the site where the trial was conducted. The site was in use for experimentation for a second and third year. Generally the *O. glaberrima* varieties are more adapted to poor soil conditions than the *O. sativa* varieties and yield better than the *O. sativa* varieties on poor soils (Chapter 3). This observation is also confirmed by the data of Table 6.4.



Without fertilizer

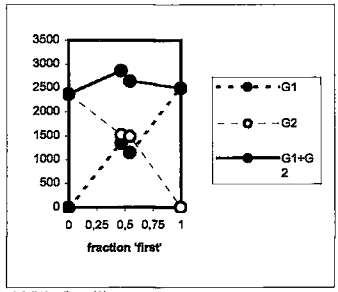
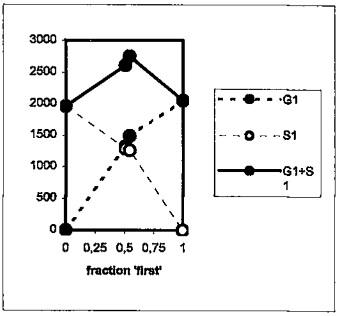


Figure 1 With fertilizer



Without fertilizer

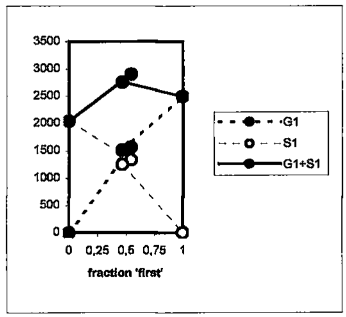
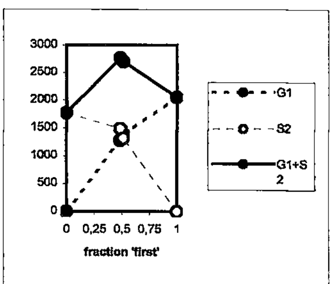


Figure 2 With fertilizer



Without fertilizer

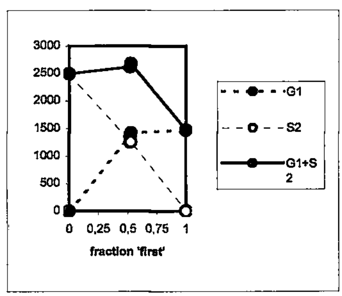
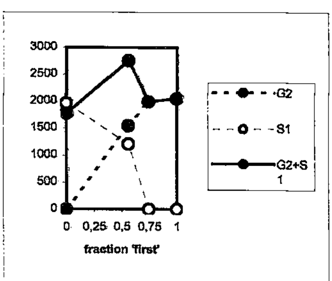


Figure 3 With fertilizer



Without fertilizer

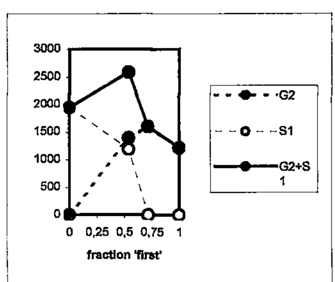
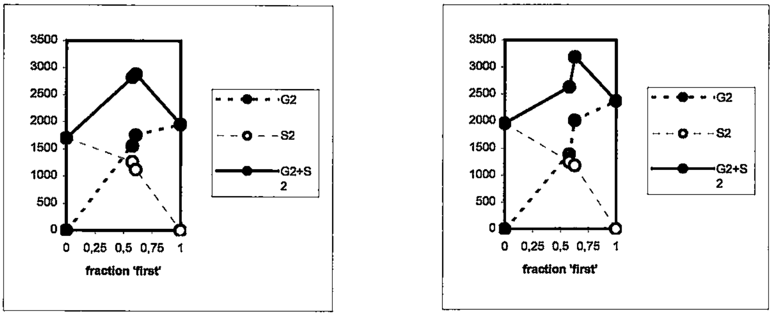
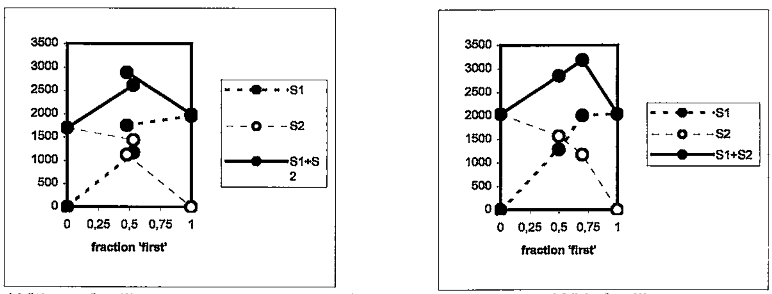


Figure 4 With fertilizer



Without fertilizer Figure 5 With fertilizer



Without fertilizer Figure 6 With fertilizer

Figures 6.1 - 6.6: Performance of test varieties under fertilizer and no fertilizer regimes under the upland condition

Where G1 = Dissi Kono; G2 = Saliforeh; S1 = Pa Bop; S2 = samba Konkon and 'fraction first' refers to the ratio of plants per variety planted.

6.3.1.2 Grain yield (kg ha^{-1})

The grain yield differences of the varieties under both fertilized treatments in the two years is presented graphically in Figures 6.1 to 6.6.

As shown in Figure 6.1, G2 (Saliforeh) out-yielded G1 (Dissi Kono) in the two years under both treatments and as shown in Figure6.2, G1 also out yielded S1 under both fertilizer treatments. In the G1 + S2 mixture (Figure 6.3), S2 (Samba Konkon) out yielded G1 in the two years under fertilizer application and G1 out-yielded S2 in the two years when fertilizer was not applied. The variety G2 out-yielded S1 (Figure 6. 4) and S2 (Figure 6.5) in both years under fertilizer and no fertilizer regimes. The performance of the *O. sativa* varieties (S1 and S2) under the two fertilizer regimes was inconsistent. While S1 out-yielded S2 in the first year, S2 out yielded S1 in the second year under fertilizer application. In the non-fertilized plots, S2 out yielded S1 in the first year and S1 out-yielded S2 in the second year.

The yield data show *O. glaberrima* variety G2 (Saliforeh) to have been a better competitor than all the varieties in the two years under fertilizer and no fertilizer application overall. G1 was also a better competitor than S1 and S2 under no fertilizer application. In mixtures, the *O. glaberrima* varieties performed better than the *O. sativa* varieties.

6.3.1.3 Relative Yield Total (RYT) and Relative Crowding Coefficient

Under non-fertilizer conditions, RYT values were larger than unity for all combinations of varieties (Table 5.6). This indicates that under these conditions the mixture components utilize different element of the available resources, resulting in a yield higher than expected from performance in monoculture.

Under fertilizer application, RYT values also exceeded unity, except for the G2 + S1 combinations. In the latter cases an antagonistic mechanism seems to be active, reducing the total yield in mixture to a level below the expected yield based on performance in monoculture.

Table 6.6: Relative Yield Total (RYT) of O. sativa and O. glaberrima varietal mixtures in upland condition under fertilizer and no fertilizer application in the 1996 and 1997 cropping season (based on grain yield per hectare)

Varietal Combinations	With fertilizer		Without fertilizer	
	1996	1997	1996	1997
G1 + G2	1.45	1.33	1.18	1.09
G1 + S1	1.30	1.38	1.42	1.22
G1 + S2	1.46	1.42	1.43	1.47
G2 + S1	1.43	0.97	1.76	1.32
G2 + S2	1.54	1.56	1.22	1.45
S1 + S2	1.45	1.56	1.40	1.56

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon, and RYT values are based on the yield of the first named variety in the combination

RCC values are presented in Table 6.7. These suggest that the *O. glaberrima* varieties out compete the *O. sativa* varieties when grown in mixture. As for the varieties for each species, (G1 + G2 and S1 + S2), the results are inconclusive, but in fairly good agreement with results as presented in Table 6.6.

Table 6.7:Relative Crowding Coefficient (RCC) of *O. sativa* and *O. glaberrima* varieties in the upland condition under fertilizer and no fertilizer application in the 1996 and 1997 cropping seasons based on grain yield per hectare

Varietal Combinations	With fertilizer				Without fertilizer			
	1996		1997		1996		1997	
i *j*	*i*	*j*	*i*	*j*	*i*	*j*	*i*	*j*
G1 + G2	0.82	1.22	1.18	0.85	0.84	1.19	0.73	1.37
G1 + S1	0.98	1.02	1.13	0.88	0.96	1.04	0.99	1.01
G1 + S2	0.74	1.35	0.91	1.10	1.85	0.54	1.92	0.52
G2 + S1	1.10	0.91	0.0*	0.0*	1.89	0.53	0.0*	0.0*
G2 + S2	1.07	0.94	1.35	0.74	0.92	1.09	1.41	0.71
S1 + S2	0.70	1.42	1.35	0.74	0.82	1.22	1.70	0.59

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon, (*) is based on the yield of G2; i and j are the individual varieties

6.3.1.4 Other characters

In addition to the effect of mixing varieties on grain yield, other characters studied to understand the performance of the varieties when grown in pure stand and in mixtures under fertilized and non fertilizer treatment in the upland included plant height at maturity, days to 50% flowering, and lodging.

6.3.1.4.1 Plant height at maturity

The performance of the varieties in mixed planting and in pure stand when grown under fertilizer and no fertilizer applications is presented in Table 6. 8

Table 6.8: Average plant height at maturity of the test varieties in monoculture and in mixture under fertilizer and no fertilizer applications in the 1996 and 1997 cropping seasons

Varietal Combinations	Monoculture				Mixtures			
	Without fertilizer		With fertilizer		Without fertilizer		With fertilizer	
i j	i	j	i	j	i	j	i	j
G1+ G2 1996	96.5	116	117	137	108>	126>	113<	126<
1997	96	128	122	135	114>	134>	134>	146>
G1+ S1 1996	96.5	102	117	126	108>	126>	113<	126=
1997	96	91.5	122	121	103>	96>	117<	114<
G1+ S2 1996	96.5	128	117	136	120>	137>	103<	130<
1997	96	147	122	150	126>	146<	124>	91.5>
G2+ S1 1996	116	102	137	126	124>	91.5<	149>	118<
1997	128	91.5	135	121	122<	0.0<	148>	0.0<
G2+ S2 1996	116	128	137	136	118>	124.5<	140>	141.5>
1997	128	147	135	150	129>	128.5<	148>	142.5<
S1+ S2 1996	102	128	126	136	102=	125<	118<	143.5>
1997	91.5	147	121	150	107>	127.5>	116<	142.5<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the plant height of the varieties in mixture as compared to the plants of the varieties in monoculture

In some cases (especially with the G and S combinations) the difference in plant height increases when grown in mixture. This indicates that the better competitor outgrows the "loser" and hence has an advantage in the utilization of light for photosynthesis.

In most of the mixtures, as the plant height of one variety increased the height of the other variety decreased in the two years under fertilizer and no fertilizer application. In a few instances the height of the varieties remained the same from year to year. In most of the mixtures, the height of tall varieties either remained the same or decreased, and the height of short varieties became taller.

6.3.1.4.2 Duration (earliness)

The results of the comparison of the number of days from seeding to when 50% of the varieties flowered in mixtures and in monoculture are shown in Table 6.9. In plots with no fertilizer application, as the duration of one variety in mixture was increased, the duration of the other variety was decreased in the G1 + G2 mixture in 1997, G1 + S1 mixture in 1996, and in the G2 + S1, G2 + S2, and S1 + S2 mixtures in both years. The duration of the varieties in the G1 + G2 mixture in 1996, and G1 + S2 mixture in 1997 was increased.

In the fertilized plots, there was an increase in earliness of the varieties from their monoculture duration in the mixture G1 + G1 in 1996, G2 + S1 in 1996 and S1 + S2 in the two years. Generally as the duration of the varieties in mixture increased in one year there was a decrease in the following year.

In the plots with no fertilizer application, the varieties tended towards greater synchrony of flowering when in mixture. (The differences in the duration between the two years could probably be due to temperature differences in the 1996 and 1997 cropping season.). The average difference in days to 50% flowering for varieties without fertilizer in monoculture is 8.6 days (Table 6.9). For the same variety grown without fertilizer in mixtures the figure reduces to 6.45 days (75%). (In both cases the result for G1 + S1 combination in 1997 is excluded.). This is a result with 25% improvement in synchrony under mixture, bearing on the geneflow sustaining farmers' interest in varietal selection, as will be explored in chapter 7.

Table 6.9: 50% flowering (days) of the test varieties in monoculture and in pure stand under fertilizer and no fertilizer applications in the 1996 and 1997 cropping seasons

Varietal Combinations		Monoculture				Mixtures			
		Without fertilizer		With fertilizer		Without fertilizer		With fertilizer	
i	j	i	j	i	j	i	j	i	j
G1+G2	1996	90.5	92	90.0	93.0	94.0>	96.0>	90.5>	89.5<
	1997	99.5	102.5	96.5	103.0	103.5>	101.0<	97.50>	103.0=
G1+S1	1996	90.5	100.5	90.0	106.0	94>	93.0<	94.0>	99.5<
	97	99.5	98.5	96.5	107.5	98.0<	104.0>	96.0<	103.5<
G1+ S2	1996	90.5	106.5	99.5	104.5	91.5>	106.5<	96.5<	106.5<
	1997	99.5	111.5	96.5	113.0	103.0>	112.0>	97.0<	111.5>
G2+ S1	1996	92.0	100.5	93.0	106.0	94.0>	96.0<	92.5<	90.5<
	1997	102.5	98.5	103.0	107.5	102.5=	0.0<	101.0<	0.0<
G2+ S2	1996	92.0	106.5	93.2	104.5	93.5>	101.5<	96.5>	106.5>
	1997	102.5	111.5	103.0	113.5	102.0<	111.5=	100.5<	112.5<
S1+ S2	1996	100.5	106.5	126	104.5	91.5<	101.0<	122.0<	106.0<
	1997	98.5	111.5	121	113.5	113.0>	106.5<	119.0<	107.0<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are the individual varieties ; >, <, and = refers to greater than, less than and equal to the duration of the varieties in mixture as compared to the duration of the varieties in monoculture

6.3.1.4.3 Lodging

The lodging of the varieties in monoculture and in pure stand was also recorded using the International Rice Research Institute Standard Evaluation System for rice to compare the lodging performance of the varieties in mixtures and in monoculture (Table 6.10). In plots with no fertilizer application, the tendency of the *O. glaberrima* varieties to lodge was reduced when grown in mixtures, whereas for the *O. sativa* varieties lodging increased. The lodging propensity of the *O. sativa S1* and *S2* increased when grown in mixtures. When fertilizer was applied, all varieties tended to lodge.

The results showed that *O. glaberrima* varieties became more tolerant of lodging when in a mixture with *O. sativa* varieties while the *O. sativa* varieties became more susceptible to lodging when in mixture with *O. glaberrima* varieties. The results also showed that when *O. sativa* varieties are planted in mixtures they tend to lodge.

The lodging of varieties in a mixture was found to be one of the ways in which a variety replaces another when grown in mixture. This depended, however, on when lodging took place. If the lodging occurred between pre-flowering and grain filling stages the chances of securing a harvest were greatly reduced. Therefore, if one variety in a mixture lodged while the other component variety was at any of these stages, the variety that lodged hindered the grain filling of that other variety. This was observed in the G2 + S1 mixture when G2 lodged while S1 was still in the grain filling stage. In the first year, the early lodging of G2 reduced the grain filling capacity of S1 and only a few grains were harvested. In the second year, G2 completely replaced S1 from the mixture since it flowered earlier than S1 and lodged when S1 was in the grain filling stage. No grains were harvested from S1 in the second year.

These results confirm what farmers informed us earlier that they always add some quantity of the variety planted in mixture with G2 (Saliforeh). Saliforeh is considered a "witch" variety that replaces all the other varieties when planted in mixture with them (Longley, 1999). African ideas of witchcraft are strongly organized around the notion of life as a zero-sum game (or "man live by man", as a Sierra Leone proverb puts it) (Richards, Pers comm. cf Gamble, 1967).Witches are beings who live by feeding off other creatures. Saliforeh is a "witch" because it supplants any companion variety.

Table 6.10: The lodging of the test varieties in monoculture and in pure stand under fertilizer and no fertilizer applications in the 1996 and 1997 cropping season

Varietal Combinations	Monoculture				Mixtures			
	Without fertilizer		With fertilizer		Without fertilizer		With fertilizer	
I j	i	j	i	j	i	i	i	j
G1+ G2 1996	7	8	9	9	6>	7<	9>	9>
1997	6	9	8	9	8>	9=	9>	9>
G1+ S1 1996	7	1	9	1	4<	2>	6>	3>
1997	6	1	8	1	6=	2>	8>	4>
G1+ S2 1996	7	1	9	1	4<	2>	5>	2>
1997	6	1	8	1	5<	2>	7>	3>
G2+ S1 1996	8	1	9	1	7<	5>	9<	9<
1997	9	1	9	1	8<	0.0<	9=	0.0<
G2+ S2 1996	8	1	9	1	6<	5>	9<	7<
1997	9	1	9	1	7<	5>	9=	6<
S1+ S2 1996	1	1	1	1	1.5>	2>	2.5>	2.5>
1997	1	1	1	1	1.5>	2.5>	1=	2.5>

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Kŏnkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the lodging of the varieties in mixture as compared to the lodging of the varieties in monoculture

6.3.2 Pot and plot experiments

6.3.2.1 Monoculture yield

Average grain yield in monoculture of the cultivars under irrigated and rainfed upland conditions is shown in Table 6.11. In the rainfed upland, the grain yield of G1 in monoculture was lower than the mixture yield except when grown with G2 at 1:3 and 3:1 ratios and with S2 at 1:3 ratio. The monoculture yield of G2 was less than the yield in mixture with all the other varieties. The monoculture grain yield of S1 was only higher when grown with S2 at 1:1 ratio The monoculture grain yield of S2 was less than the mixture yield in all combinations.

Table 6.11: The average grain yield (grams per pot and grams per plot) in monoculture and in mixtures of the varieties under rainfed upland and irrigated conditions in the 1997 cropping season

Varietal combination	Average grain yield plot $^{-1}$ Rainfed upland				Average grain yield pot^{-1} Irrigated condition			
	G1	G2	S1	S2	G1	G2	S1	S2
G1	**194.9**				**546.1**			
G2 1:3	189.9				418.3			
1:1	208.7				336.2			
3:1	187.9	**192.7**			463.1	**351.0**		
S1 1:3	200.5	234.0			230.9	236.0		
1:1	246.3	236.5			232.5	234.0		
3:1	209.2	236.0	**194.9**		232.0	242.0	**208.3**	
S2 1:3	149.5	266.0	263.0		247.0	268.0	319.1	
1:1	250.5	266.5	168.2		253.0	256.5	438.0	
3:1	246.5	264.5	198.8	**138.0**	254.5	261.5	417.3	**137.5**

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon, and bold is the monoculture yield

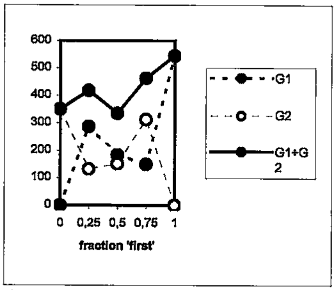
Under irrigation, while the monoculture yield of *O. glaberrima* varieties G1 and G2 was higher than the total mixture yields in all combinations, the monoculture yield of the *O. sativa* varieties was less than the mixture yields.

The graphical representation of the performance of the varieties in mixture under irrigated and upland conditions and at lower (1:3), equal (1:1) and higher (3:1) proportions is presented in Figure 6.7 to 6.12. A summary of the grain yield is presented per pot in irrigated and per plot in upland rainfed conditions (Box 6.1).

6.3.2.2 Grain yield

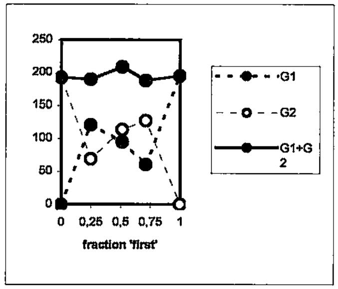
The grain yield per pot under irrigated and per plot upland rainfed condition is both reported in grammes and, is presented graphically in Figures 6.7 to 6.12 and in (Box 6.1). In the irrigated condition, the *O. glaberrima* variety G1 was more competitive when grown in mixture with G2 and S1, and less competitive than S2 at 1:3 and 1:1 ratios. At the 1:3 ratio it was less competitive than all the varieties tested (Box 6.1). In the rainfed upland condition, G1 was less competitive than G2 and S2 at 3:1 and 1:1 ratios. It was less competitive in all combinations when planted at 3:1 ratio.

In both the irrigated and rainfed upland condition, the variety G2 was less competitive than all the other varieties except S1 in the irrigated condition and more competitive than all varieties except S2 under the rainfed upland condition. The variety S1 was less competitive except for S2 at 1:3 and 1:1 ratios under irrigated condition. Whereas in the rainfed upland condition, it was less competitive than most varieties. The variety S2 was more competitive than most varieties in both water regimes.

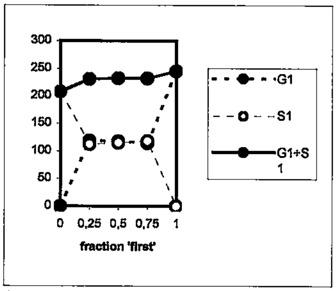


Irrigated lowland

Figure 7

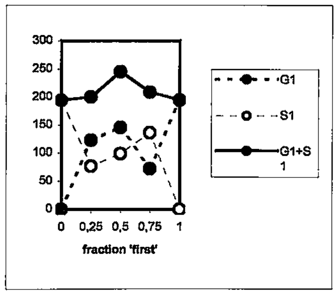


Rainfed upland

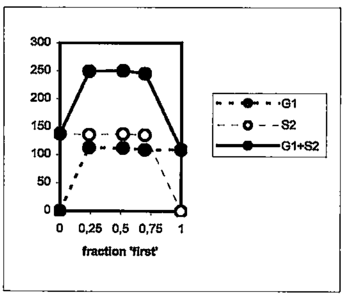


Irrigated lowland

Figure 8

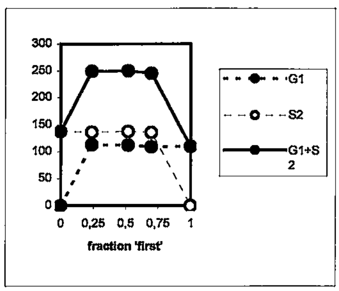


Rainfed upland

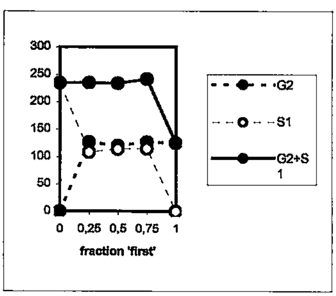


Irrigated lowland

Figure 9

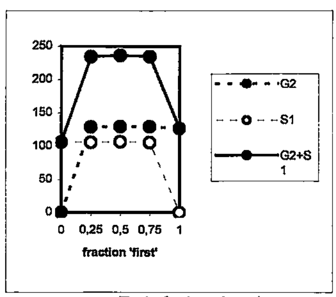


Rainfed upland

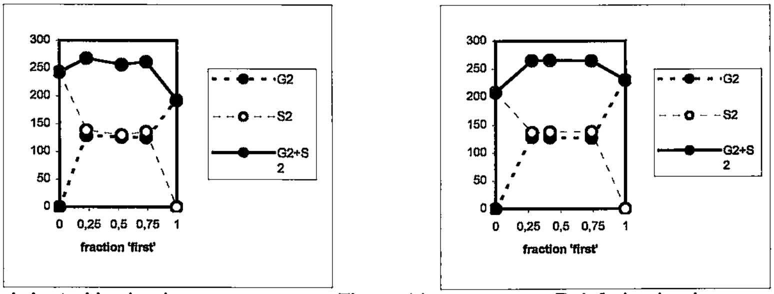


Irrigated lowland

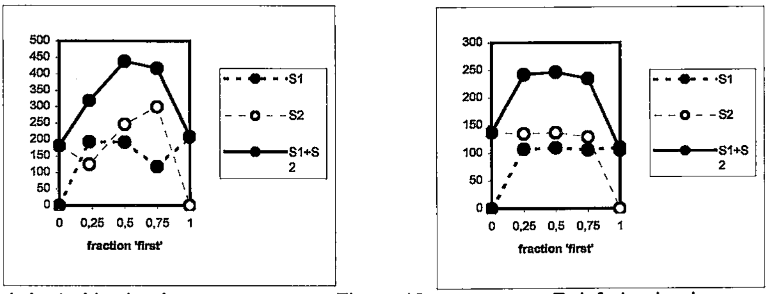
Figure 10



Rainfed upland



Irrigated lowland Figure 11 Rainfed upland



Irrigated lowland Figure 12 Rainfed upland

Figure 6.7 - 6.12: Performance of rice varieties in mixture under irrigated and upland condition in yield per pot (gm)

Where G1 = Dissi Kono; G2 = Saliforeh; S1 = Pa Bop; S2 = samba Konkon and 'fraction first' refers to the ratio of plants per variety planted.

The results show that the *O. glaberrima* varieties G1 and G2 were inconsistent in competing with other varieties. Among the *O. sativa* varieties, however, S2 was more competitive in most combinations and S1 less competitive when in a mixture with other varieties. The variety S2 more was competitive when grown under the irrigated and rainfed upland conditions in all combinations of varieties.

Box 6.1 : The relative performance of* O. sativa *and* O. glaberrima *varieties in competition under rainfed upland and irrigated conditions in the 1997 cropping season

Ratio of grain yield in the irrigated and in the upland treatment

***G1* under irrigated condition (Pot)**
1:3 ratio : *G1 > G2, S1; G1 < S2, G1* was more competitive except when in combination with S2
1:1 ratio : *G1 > G2, S1; G1 < S2, G1* was more competitive except when in combination with S2
3:1 ratio : *G1 < G2, S1, S2. G1* was less competitive in all combinations

***G1* under upland condition (Plot)**
1:3 ratio : *G1 > G2, S1; G1 < S2, G1* was more competitive except when in combination with *S2*
1:1 ratio : *G1 < G2; G1, S2, G1 > S1, G1* was less competitive except when in combination with S1
3:1 ratio : *G1 < G2, S1, S2, G1* was less competitive in all combinations

***G2* under irrigated condition (Pot)**
1:3 ratio : *G2 < G1, S2; G1 > S1 G2* was less competitive except when in combination with S1
1:1 ratio : *G2 < G1, S2, G1 > S1* G2 was less competitive except when in combination with S1
3:1 ratio : *G2 > G1, S1; G2 < S2 G2* was more competitive except when in combination with S2

***G2* under upland condition (Plot)**
1:3 ratio : *G2 < G1, S2; G2 > S1, G2* was less competitive except when in combination with S*1*
1:1 ratio : *G2 > G1, S1; G2 < S2, G2* was more competitive except when in combination with S2
3:1 ratio : *G2 > G1, S1; G2 > S2, G2* was more competitive except when in combination with S2

***S1* under irrigated condition (Pot)**
1:3 ratio : *S1 < G1, G2; S1 > S2, S1* was less competitive except when in combination with S2
1:1 ratio : *S1 < G1, G2; S1 > S2, S1* was less competitive except when in combination with S2
3:1 ratio : *S1 > G1, S1; S2 < G2. S1* was more competitive except in combination with G2

***S1* under upland condition (Plot)**
1:3 ratio : *S1 < G1, G2; S1 > S2, S1* was less competitive except when in combination with S2
1:1 ratio : *S1 < G1, G2, S2, S1* was less competitive in all combinations
3:1 ratio : *S1 < G2, S2 ;S1 > G1, S1* was less competitive except when in combination with *G1*

***S2* under irrigated condition (Pot)**
1:3 ratio : *S2 > G1, G2, S1 S2* was more competitive when in all combinations
1:1 ratio : *S2 > G1, G2, S1 S2* was more competitive when in all combinations
3:1 ratio : *S2 > G1, G2; S2 < S1. S2* was more competitive except when in combination with S1

***S2* under upland condition (Plot)**
1:3 ratio : *S2 > G1, G2 ; S2 < S1, S2* was more competitive except when in combination with S1
1:1 ratio : *S2 > G1, G2 ; S2 < S1, S2* was more competitive except when in combination with S1
3:1 ratio : *S2 > G1, G2, S1, S2* was more competitive in all combinations

Table 6.12: Relative Yield Total (RYT) of *O. sativa* and *O. glaberrima* varieties in pot experiment based on grain yield per plot under rainfed upland, and grain yield per pot under irrigated conditions, 1997 cropping season

Varietal combinations & Ratio of varieties in mixture		Upland	irrigated
G1 + G2	1:3	0.98	0.90
	1:1	1.08	0.77
	3:1	0.97	1.17
G1 + S1	*1:3*	1.03	1.02
	1:1	1.26	1.03
	3:1	1.08	1.03
G1 + S2	*1:3*	2.02	1.95
	1:1	2.02	2.01
	3:1	1.98	2.02
G2 + S1	*1:3*	2.01	1.47
	1:1	2.03	1.45
	3:1	2.02	1.51
G2 + S2	*1:3*	1.21	1.24
	1:1	1.22	1.19
	3:1	1.21	1.21
S1 + S2	*1:3*	1.40	1.62
	1:1	0.88	2.27
	3:1	0.97	2.21

Where G1 = Dissi Kono; G2 = Saliforeh: S1 = Pa Bop; and S2 = Samba Konkon

Under rainfed upland and irrigated conditions, RYT values were larger than unity for all mixtures except for G1+G2 at 1:3 ratio under both rainfed upland and irrigated condition; at 1:1 under the irrigated condition, and at 3:1 under the rainfed upland condition. The RYT values were also less than unity in the S1 + S2 mixture in the rainfed upland at 1:1 and 3:1 ratios. RYT values greater than unity indicate that under these conditions the mixture elements utilize different components of the available resources, resulting in a yield higher than performance in monoculture. RYT values less than unity indicate that an antagonistic mechanism seems to be active, reducing the total yield in mixture to a level below the expected yield based on performance in monoculture.

Table 6.13: Relative Crowding Coefficient (RCC) of *O. sativa* and *O. glaberrima* varieties in the rainfed upland in yield per plot and irrigated conditions in yield per pot in 1997 cropping season based on grain yield

Varietal combinations & Ratio of varieties in mixture		Upland		Irrigated	
i	j	i	j	i	j
G1 + G2	1:3	1.72	0.58	1.40	0.72
	1:1	2.50	0.40	0.78	1.28
	3:1	0.47	2.13	0.31	3.23
G1 + S1	*1:3*	1.59	0:63	0.90	1.11
	1:1	1.47	0.68	0.87	1.15
	3:1	0.53	1.88	0.82	1.22
G1 + S2	*1:3*	1.04	0.96	1.04	0.96
	1:1	1.02	0.98	1.00	1.00
	3:1	1.01	0.99	1.04	0.96
G2 + S1	*1:3*	1.02	0.98	1.27	0.79
	1:1	1.01	0.99	1.96	0.51
	3:1	1.01	0.99	2.08	0.48
G2 + S2	*1:3*	0.85	1.17	1.18	0.85
	1:1	0.84	1.19	1.24	0.81
	3:1	0.83	1.21	1.16	0.86
S1 + S2	*1:3*	1.35	0.74	2.38	0.42
	1:1	0.68	1.47	1.21	0.83
	3:1	0.35	2.90	0.35	2.90

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are the component varieties in mixture

The *RCC* value indicates the degree to which one variety in a combination is more competitive than the other. With the G1 + G2 mixture, it was higher than unity for G1 at 3:1 and 1:1 under the rainfed upland condition, and at 1:1 and 3:1 ratios for G2 under irrigated condition. In the G1 + S1 mixture, the RCC values for G1 in the rainfed upland was higher than unity at 3:1 and 1:1 under the rainfed upland condition, while the RCC was higher than unity for S1 in all combinations under the irrigated condition. The RCC values in the G1 + S2 mixture were higher than unity for G1 in all combinations in the rainfed upland and irrigated conditions. With the G2 + S1 mixture, the RCC values for G2 were higher than unity in the irrigated condition. The performance of the varieties in the G2 + S2 mixture was such that while the RCC values were higher than unity for G2 in the rainfed upland, they were higher than unity for S2 under the irrigated condition. With the S1 + S2 mixture, RCC was higher than unity for S1 at 3:1 and 1:1 under the irrigated condition, and at 1:1 and 3:1 ratios for S2 under rainfed upland condition.

The results show that Dissi Kono (G1) was more competitive in the rainfed upland in all combination, and Samba Konkon (S2) was more competitive in all combinations in the irrigated conditions. Saliforeh (G2) and Pa Bop (S1) were more flexible in their adaptation to the two water regimes.

6.3.2.3 Other characters

In the pot experiment, the other characters that were studied to understand the performance of the varieties in the irrigated and rainfed upland conditions included the tillering at two weeks and at maturity, plant height at two weeks and at maturity, and days to maturity.

6.3.2.3.1 Number of tillers at two weeks

Table 6.14: The number of tillers per plant at two weeks of the varieties in mixture and monoculture in the irrigated and rainfed upland conditions in the 1997 cropping season

Varietal combinations	Monoculture				Mixtures			
	Upland Condition		Irrigated Condition		Upland Condition		Irrigated Condition	
i j	i	j	i	j	i	j	i	j
G1+ G2 1 : 3	4	4	8	7	4=	4=	9>	7=
1 : 1					3<	4=	7<	7=
3 : 1					3<	5>	8=	5<
G1+ S1 1 : 3	4	3	8	3	4=	2<	6<	7>
1 : 1					5>	2<	5<	4>
3 : 1					5>	3=	6<	2<
G1+ S2 1 : 3	4	4	8	5	5>	3<	5<	5=
1 : 1					5>	4=	5<	5=
3 : 1					4=	2<	5<	4<
G2+ S1 1 : 3	4	3	7	3	4=	2<	7=	5<
1 : 1					4=	2<	7=	5<
3 : 1					5>	2<	6<	2<
G2+ S2 1 : 3	4	4	7	5	3<	3<	5<	5=
1 : 1					4=	4=	6<	5=
3 : 1					3<	4=	6<	2<
S1+ S2 1 : 3	3	4	3	5	2<	4=	4>	5=
1 : 1					2<	3<	5>	6>
3 : 1					3=	4=	4>	4<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the tillering ability at two weeks of the varieties in mixture as compared to the tillering *ability at two weeks of the varieties in monoculture*

With the varieties in the rainfed upland plots, the tiller number of G2 at two weeks after seeding in the G1 + G2 mixture for G1 was either similar to or decreased in the monoculture (Table 6.14). The tiller number of G2 was similar or increased as compared to the monoculture height. In the G1 + S1, G1 + S2, and G2 + S1 mixtures, the tiller number for G1 and G2 was either similar to that in the monoculture or increased while the tiller number of S1 and S2 were similar or lower than that in the monoculture. The tiller number of G2, S1, and S2 were similar to that in monoculture or lower in the G2 + S2 and S1 + S2 mixtures.

In the irrigated condition, the tiller numbers of the varieties in the G1 + S2, G2 + S1 and G2 + S2 mixtures at two weeks after transplanting were lower than or equal to that in the monoculture. There was no consistency in the tiller number of the varieties in the G1 + G2, G1 + S1 and S1 + S2 mixtures. The tiller number of variety S1 decreased while in competition with variety S2, and the height of the variety G2 was decreased or was equal to the monoculture height when in mixture with the variety G1.

The results of the tillering data showed that in the first two weeks of competition the varieties have already started expressing changes in the number of tillers produced while in competition with one another. The tillering ability was higher under irrigated than rainfed upland conditions. Tillering was more vigorous for the *O. glaberrima* than the *O. sativa* varieties.

6.3.2.3.2 Number of panicle bearing tillers at maturity

Table 6.15: The tillering ability at maturity of the test varieties in mixture and monoculture in the rainfed upland and irrigated condition 1997 cropping season

Varietal combinations		Monoculture				Mixture			
		Upland Condition		Irrigated Condition		Upland Condition		Irrigated Condition	
i	j	i	j	i	j	i	j	i	j
G1+ G2	1 : 3	15	11	24	19	12<	14>	19<	19=
	1 : 1					11<	11=	18<	18<
	3 : 1					14<	11=	18<	18<
G1+ S1	1 : 3	15	4	24	18	12<	4=	20<	22>
	1 : 1					18>	5>	26>	12<
	3 : 1					16>	5>	23<	13<
G1+ S2	1 : 3	15	5	24	19	13<	8>	20<	15<
	1 : 1					13<	11>	15<	27>
	3 : 1					12<	7>	17<	26>
G2+ S1	1 : 3	11	4	19	15	9<	4=	19=	15=
	1 : 1					12>	5>	29>	14<
	3 : 1					18>	4=	24>	9<
G2+ S2	1 : 3	11	5	19	15	9<	9>	13<	17>
	1 : 1					10<	10>	14<	9<
	3 : 1					9<	9>	16<	10<
S1+ S2	1 : 3	4	5	8	9	7>	12>	4<	4<
	1 : 1					7>	11>	5<	6<
	3 : 1					6>	10>	4<	6<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the tillering ability at maturity of the varieties in mixture as compared to the tillering ability at maturity of the varieties in monoculture

In the rainfed upland condition, the tillering ability of the G1 + G2, G1 + S2 and G2 + S2 mixtures showed that as the tillering ability of one variety is increased the tillering ability of the other variety is decreased (Table 6. 15). The tillering ability of the varieties tended to increase when in competition in the G1 + S1, G2 + S1 and S1 + S2 mixtures.

In the irrigated condition, the tiller number of the varieties in the G1 + G2, G2 + S2 and S2 + S1 mixtures was generally lower than that in the monoculture for all the test varieties. The result with the G1 + S1 G2 + S1 and G1 + S2 mixtures indicated that as the tiller number of one variety is increased the tiller number of the other variety in the mixture is decreased (Table 6. 15).

The results show that the tillering ability of varieties in mixtures was on average somewhat lower than that in monoculture (in 36 cases tillering was less than for the corresponding variety, the monoculture, but in 27 cases was greater than under monoculture, Table 6.16). The reduction in number of panicles was more pronounced in the irrigated condition than in the rainfed upland condition. This was also higher under irrigated than rainfed upland conditions at maturity. Tillering was more vigorous for the *O. glaberrima* than the *O. sativa* varieties under upland and irrigated conditions.

The *O. glaberrima* varieties produce more tillers per plant than the *O. sativa* varieties. This is contrary, however, to the findings of Jones *et al* (1997) for the two species when evaluated in rainfed uplands in Cote d'Ivoire. The *O. sativa* varieties, on the other hand, produce more grains per panicle than the *O. glaberrima* varieties.

6.3.2.3.3 Plant height at two weeks

Table 6.16: Plant height at two weeks, varieties in mixture and monoculture in the rainfed upland and irrigated conditions in the 1997 cropping season

Varietal combinations		Monoculture				Mixtures			
		Upland Condition		Irrigated Condition		Upland Condition		Irrigated Condition	
i	j	i	i	i	j	i	j	i	j
G1+ G2	1 : 3	22.3	28.2	24.8	30.3	24.9>	29.0>	26.4>	28.2<
	1 : 1					20.9<	24.0<	22.4<	23.6<
	3 : 1					19.7<	23.7<	26.7>	27.4<
G1+ S1	1 : 3	22.3	20.3	24.8	21.5	27.7>	19.5<	24.8<	24.0>
	1 : 1					26.5>	21.0>	27.4>	23.3>
	3 : 1					24.9>	19.7>	22.8<	18.6<
G1+ S2	1 : 3	22.3	28.8	24.8	29.1	22.4>	26.0<	22.1<	24.5<
	1 : 1					22.8>	26.8<	24.2<	24.0<
	3 : 1					24.6>	29.2>	26.5>	24.3<
G2+ S1	1 : 3	28.2	20.3	30.3	21.5	30.9>	19.6<	19.0<	46.4>
	1 : 1					28.7>	20.2<	22.5<	49.8>
	3 : 1					27.6<	21.8>	27.7<	58.1>
G2+ S2	1 : 3	28.2	28.8	30.3	29.1	26.8<	26.6<	26.3<	26.3<
	1 : 1					28.9>	26.5<	27.2<	27.2<
	3 : 1					29.2>	29.9>	29.7<	29.7>
S1+ S2	1 : 3	20.3	28.8	21.5	29.1	21.7>	26.7<	29.8>	28.6<
	1 : 1					21.0>	28.1<	24.2>	28.3<
	3 : 1					20.5>	27.5<	26.2>	28.4<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the plant height at two weeks of the varieties in mixture as compared to the plants at two weeks of the varieties in monoculture

In both rainfed upland and irrigated conditions as plant height at two weeks of one variety increased, the plant height of the other variety in mixture was decreased from the monoculture height in the G2 + S1 and S1 + S2 mixtures. In the other combinations, both varieties either increased or decreased in height, with a few exceptions (Table 6. 16). Generally, in most of the mixtures, as the plant height of one variety was increased the height of other variety was decreased in both the rainfed upland and irrigated conditions. The varieties were taller under irrigated than under rainfed upland conditions. Pa Bop (S1) was the shortest and Samba Konkon (S2) the tallest variety.

6.3.2.4.4 Plant height at maturity

Table 6.17: Plant height at maturity of the test varieties in monoculture and in mixture in the rainfed upland and irrigated conditions in the 1997 cropping season

Varietal combinations	Monoculture				Mixture			
	Upland Condition		Irrigated Condition		Upland Condition		Irrigated Condition	
i j	i	j	i	j	i	j	i	j
G1+ G2 1 : 3	119	150	127.5	149.0	124.9>	144.1<	121.8<	141.4<
1 : 1					124.7>	144.8<	120.7<	130.9<
3 : 1					123.5>	143.2<	124.4<	138.4<
G1+ S1 1 : 3	119	115	127.5	129.0	133.8>	116.0>	131.8>	110.4<
1 : 1					129.7>	140.8>	131.6>	117.3<
3 : 1					132.8>	118.5>	129.6>	116.9<
G1+ S2 1 : 3	119	146	127.5	148.0	131.0>	146.5>	127.3<	149.3>
1 : 1					126.9>	142.0<	131.8>	156.1<
3 : 1					126.2>	139.8<	129.9>	140.8>
G2+ S1 1 : 3	150	115	149.0	129.0	137.5<	110.6<	127.3<	149.3>
1 : 1					140.8<	112.7<	131.8<	156.1>
3 : 1					142.6<	113.0<	129.9<	140.8>
G2+ S2 1 : 3	150	146	149.0	148.0	144.7<	154.6>	146.0<	149.4>
1 : 1					141.6<	149.6>	136.0<	140.3<
3 : 1					143.6<	153.9>	146.5<	144.2<
S1+ S2 1 : 3	115	146	129.0	148.0	120.0>	146.3=	121.8<	147.5<
1 : 1					118.0>	146.1<	124.4<	144.1<
3 : 1					117.5>	140.5<	116.7<	138.0<

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the plant height of the varieties in mixture as compared to the plants of the varieties in monoculture

The plant height at maturity of the test varieties is shown in Table 6.17. In the rainfed upland condition as the plant height of one variety was increased, the plant height of the other variety was decreased for all the mixtures except for the G1 + S1 mixture in which the two component varieties showed an increased in height from their monoculture height. The plant height of the varieties in the G2 + S1 were also decreased. In the irrigated condition, as the plant height of one variety was increased, the plant height of the other variety was decreased for the G1 + S1, G1 + S2 and G2 + S1 mixtures. The plant height of the varieties in the G1 + G2, G2 +S2 and S1 + S2 mixtures were also decreased from their monoculture height when planted in the irrigated condition at maturity.

In most of the mixtures, as the plant height of one variety was increased the height of the other variety was decreased at maturity in the rainfed upland and irrigated conditions. In some mixtures however the plant height of both varieties either increased or decreased in the two water regimes. The increase in height of the short varieties could be due to competition for light when in mixture with tall varieties. In such a situation, light could be the most limiting factor for short plants.

6.3.2.3.5 Days to maturity

Table 6.18: The number of days to maturity of the test varieties in mixtures and in pure stands in the rainfed upland and irrigated conditions in the 1997 cropping season

Varietal Combinations		Monoculture				Mixture			
		Upland Condition		Irrigated Condition		Upland Condition		Irrigated Condition	
I	j	i	j	i	j	i	j	i	j
G1+ G2	1 : 3	110	127	115	135	112>	122<	114<	126<
	1 : 1					112>	127=	110<	121<
	3 : 1					111>	127=	114<	126<
G1+ S1	1 : 3	110	109	115	111	112>	110>	119>	112>
	1 : 1					114>	107<	118>	115>
	3 : 1					112>	112>	114>	118>
G1+ S2	1 : 3	110	138	115	135	113>	137<	110<	137>
	1 : 1					113>	138=	116>	138>
	3 : 1					110=	136<	119>	136>
G2+ S1	1 : 3	127	109	125	111	129>	106<	126>	109<
	1 : 1					130>	107<	120<	114>
	3 : 1					130>	106<	127>	115>
G2+ S2	1 : 3	127	138	125	135	129>	137<	129>	139>
	1 : 1					128>	138=	127>	130>
	3 : 1					127=	138=	126>	136>
S1+ S2	1 : 3	109	138	111	135	113<	137<	108<	135>
	1 : 1					110<	138=	110<	137>
	3 : 1					109=	137<	106<	129>

Where G1 = Dissi Kono; G2 = Saliforeh, S1 = Pa Bop; and S2 = Samba Konkon and i and j are individual varieties; >, <, and = refers to greater than, less than and equal to the duration of the varieties in mixture as compared to the duration of the varieties in monoculture

The results of the comparison of the number of days from seeding to maturity in monoculture and in mixtures are shown is Table 6.18. In the rainfed upland condition, there was a slight tendency for the differential in maturity of the two varieties. The duration of the varieties however increased in the G1 + S1 mixture at lower (1:3) and higher (3:1) ratios.

In the irrigated condition, as the duration of one variety in mixture was increased the duration of the other variety was decreased in the G1 + G2, G2 + S1 and S1 + S2 mixtures. The duration of both varieties in the G1 + S1, G1 + S2 and G2 + S2 mixtures tended to increased while in mixture.

The difference in duration between the varieties was quite marked (except for G1 + S1), especially between Samba Konkon and other varieties. The difference between Pa Bop and Saliforeh was also great. In competition Saliforeh flowered two weeks before Pa Bop and this early flowering resulted in the displacement of Pa Bop in competition when grown with Saliforeh. The high incidence of lodging of Saliforeh is another contributing factor to replacing Pa Bop in competition.

6.4 General Discussion

O. glaberrima is endemic to West Africa and *O. sativa* to South East Asia (Chapter 5). After introduction, *O sativa* spread into the *O. glaberrima* zone and at present the two species grow side by side. Their use as mixtures, however tends to be limited. It was found in field work only among Susu farmers in Bramaia Chiefdom and then only quite rarely. Some work has been done on the topic, experimentally (Sano *et al*, 1984), but apparently not with actual combinations planted by farmers, under farmers' conditions. The present analysis is based on actual combinations planted by Susu farmers, which farmers claim to be advantageous.

These varieties offered a good opportunity to study neighbor effect as a mechanism of co-existence. The study was carried out under the rainfed upland conditions where the two species are grown by farmers in mixtures and under fertilizer and no fertilizer application. The same varieties were also evaluated in a pot experiment under irrigated and rainfed condition in small plots to compare the effect of water regime on the performance of the species in mixture. Extrapolation of conclusions from the second trial under irrigated and rainfed upland condition in the 1997 season must be made with caution since these trials were conducted under controlled conditions different from the real field conditions in the farmers' field in Bramaia Chiefdom.

Regarding the competition effect of *O. glaberrima* and *O. sativa* species, Sano *et al* (1984) reported significant changes with water regimes when the two species were mix-planted. Sano *et al* (1984) showed that the *O. glaberrima* variety gained in yield in dry condition when mixed with *O. sativa* but the *O. sativa* gained in yield in wet condition. This result suggests each species has a narrow range of adaptability in response to moisture gradient. In the research area, the two species are widely cultivated as sole crops, and less commonly as mixtures in farmer's fields in the uplands. Some reasons farmers deliberately cultivate the two *Oryza* species in mixtures have been mentioned in Chapter 3. Farmers have selected mixtures to adapt varieties to varying soil conditions to secure a reliable harvest and to add nutritional value to the diet. Farmers are also aware that mixed planting changes plant performance.

In most of the cases studied the *O. glaberrima* varieties performed better when mix-planted with *O. sativa* varieties in the upland. The *O. glaberrima* variety G2 (Saliforeh) was a better competitor than all the other varieties under fertilizer and no fertilizer application. Saliforeh is one of the oldest of the *O. glaberrima* varieties (Chapter 5).

Most farmers deny knowledge of when it was first introduced but said their grand parents grew the variety. It should be noted that all the mixtures in non fertilized plots had positive advantage in grain yield over the same variety grown in pure stand, whereas, in fertilized plots, there was a reduction in yield in the G1 + S2 and G2 + S1 mixtures. Only a few Susu farmers in the research areas practice the technique of mixed planting. Farmers do not use fertilizer and use of fertilizer even reduced the yield of the test varieties (Table 6.4). Since mixed planting of varieties without fertilizer was advantageous, as indicated by the RYT values (Table 6.6 and 6.12), farmers should be encouraged to mix-plant varieties that yield better than the pure stand under this condition. More research is necessary, however, to identify the best combinations before the technique can be extended to other farmers in the upland. Farmers in other areas might also benefit from this technique if their local varieties are evaluated for mixed planting. Researchers at NARS should work with resource-limited farmers in identifying both local and foreign germplasm that could yield better in mixtures than in monoculture under low input conditions. It is worth noting that S2, Samba Konkon, is a RRS release, ROK 3. In other words, some Susu farmers have discovered that it is advantageous to mix plant a "traditional" and modern variety.

In the pot experiment, the *O. glaberrima* varieties performed better than the *O. sativa* varieties in the irrigated and rainfed upland condition. The varieties included in this study are upland types that are rarely grown in the lowlands except Samba Konkon, which can be cultivated in both upland and lowland conditions. The result showed that the *O. glaberrima* varieties are more variable in the two water regimes. This result also indicated that although the *O. sativa* species has replaced the *O. glaberrima* species in the wetlands, the potential for improving on the performance of *O. glaberrima* is still quite high. Traits such as high tillering ability and earliness of the *O. glaberrima* varieties can be used to increase tillering and reduce the duration of *O. sativa* varieties. The results are from controlled experiment, however, and may not reflect the actual performance of varieties under field conditions in farmers' fields.

When a variety produces more seed than the other variety in competition, its frequency will increase in the next generation. It does not follow, however, that the total yield of the mixture will become ever higher. The other varieties in mixture will become so severely depressed by the prolific varieties that the total yield is lowered (Zang *et al.*, 1999). Under the fertilizer regime in the upland, Saliforeh displaced Pa Bop completely in the mixture. In the first year, Saliforeh produced more seeds than Pa Bop. Since the seed harvested from the first year were the same seeds sown in the second year without altering the percentage of seeds in each component in the mixture, there were more seeds of Saliforeh planted than those of Pa Bop in the second year. The prolific yield effect of Saliforeh in mixture was not expressed in the total mixture yield. The monoculture yield of Saliforeh was higher than that of its total mixture yield with Pa Bop. In most of the mixtures, there was a consistent increase in the seed production of the prolific variety in the second year except for S1 + S2 mixtures under fertilizer application in the upland.

Donald (1968; 1981) suggested that in order to increase yield potential in annual crops, breeders would have to develop "communal ideotypes" that would not perform well in competition with other genotypes. With such ideotypes, the natural selection through competition occurs in a crop where a plant takes up more limiting resources at the expense others. The more successful the plant is in exploiting the limited resources, the greater will be its potential to be represented in the succeeding generation and hence it will be preferred through selection. In the present study, fertilizer was varied in the upland trial and water in the pot experiment. The varieties that were more competitive might have been more successful in exploiting these resources than the less competitive varieties. Differences in height might also have affected the performance of the varieties. The tall varieties naturally exploited more light for photosynthesis than shorter varieties. Pa Bop was shorter than Saliforeh and hence exploited sunlight less well than Saliforeh in competition. Other characters such as lodging and duration differ for most varieties which subsequently might affect the performance of other varieties in mixture in like manner.

6.5 Summary

The results of this study confirm the practice of some Susu farmers in the case study area who mix varieties before seeding on the uplands (Longley, 1999). The farmers grow these mix varieties for two reasons. Firstly, they grow *O. glaberrima* and *O. sativa* varieties in mixtures to secure a harvest. According to the Susu farmers, *O. glaberrima* varieties perform better on poor soils even when the rainfall is not certain at the time of maturity (chapter 3). The *O. sativa* varieties on the other hand, yielded better on good soils and when there was enough rainfall during the growing season. The varieties were therefore always mix-planted to secure a harvest on soils that were infertile or variable and also when farmers were not certain about the rainfall pattern. The second reason for mixing varieties was related to the eating quality of the varieties. The *O. glaberrima* varieties are more palatable and stay longer in the stomach when eaten. *O. sativa* varieties, on the other hand, are considered less palatable and farmers are hungry a few hours after consumption. The farmers therefore mix the varieties for both environmental and nutritive reasons. The varieties used in experimentation were the type of varieties that farmer use in their variety mixture plots. They have selected these genetically diverse and recognizable varieties so that when the proportion of one variety reduces, a result here demonstrated, farmers can increase the quantity to the desired proportion. Farmers have used their indigenous knowledge to develop a cropping system to address certain environmental and nutritional problems.

The most important observation of this study is that RYT is larger than unity when *O. sativa* and *O. glaberrima* varieties are grown in mixtures under upland condition, without fertilizer application.

The reasons for mixing mentioned by farmers to ensure harvest and nutritional value are strictly speaking not valid reasons, because growing different varieties in pure stand will also meet the stated requirements. The only rationale for growing mixtures is that RYT is larger than unity, i.e. certain mixtures out-yield the averages of the monoculture. Apparently, farmers are only intuitively aware that certain mixtures out-perform the average of monoculture. A second but explicitly recognized factor, is that varieties in mixture tend towards greater synchronicity of flowering, perhaps opening windows of opportunity for out crossing that may provide farmers access to spontaneous hybrids. This possibility is explored further in the next chapter.

7 FLOWERING BEHAVIOR OF LOCAL RICE VARIETIES IN NORTH-WESTERN SIERRA LEONE

7.1 Introduction

This final brief chapter is in effect a footnote to matters discussed earlier in the thesis, especially in chapters 5 and 6. Much evidence has been presented to show that low-resource farmers in North-western Sierra Leone carefully select rice varieties, and match them to local land types. Some farmers also appear to be aware, at some level, of the genetic advantages of out-crossing in rice, otherwise an in-breeding crop. Further work might reveal that this as one of the considerations underlying the practice of some Susu farmers of mixing different rice varieties in the same field (Longley & Richards 1993). In chapter 6 it has been reported that farmers themselves claim to notice changes as a result of mixed planting, and experimental data show that these changes are real, and have an agronomic basis. But mixing of different varieties in the same field may also open up opportunities for spontaneous hybridization, with farmers further benefiting through selecting among progeny. The present chapter asks questions more generally about opportunities for geneflow in local rice-farming practice. Varieties can only out-cross if there is proximity in time and space between varieties at flowering. The chapter reports experiments and observations concerning the flowering behavior of local rice varieties in North-western Sierra Leone.

Several workers (Harlan, 1965; de Wet, 1975; Langevin, 1990) have reported gene flow between cultivated species and their weedy relatives. This gene flow, causing hybridization between the cultivated and wild species, is mainly unidirectional, that is from the cultivated into the wild species. This has been shown to be high in sorghum (Doggett and Majisu, 1968) and pearl millet (Brunken *et al*, 1977) and in corn populations (Doebley *et al*, 1987). The unidirectionality of gene flow in these crops was typically found to be due to the elimination of the pistillate contribution by the cultivated species with the harvest of the crop. The primary transfer of genetic material is through the pollen donation during flowering by the cultivated species into the weedy species (Ladizinsky, 1985).

In the *Oryza* species also, several authors have reported gene flow between the cultivated and wild species (Oka and Chang, 1959; 1961; Oka and Morishima, 1971). Oka and Chang (1959, 1961) also reported the incidence of natural hybridization between wild and cultivated rice in Africa (*O. glaberrima* Steud and *O. breviligulata* Chev.*et* Roehr) and in Asia (*O. Sativa* L. and *O. perennis* Moench) Out-crossing was reported to be comparatively low within the cultivated species and ranged from zero to 7.5 %, while within the wild species, the rate of out-crossing ranged from 30 to 40% (Oka and Chang, 1961).

In the case study area, the Pa Three-Month group of varieties was found to combine the morphological characteristics of both *O. sativa* and *O. glaberrima species* (see Chapter 5). Longley (1999) speculates the farmer variety Saliforeh may originate from crosses between cultivated and wild Oryza species. Richards (1991) has made the same suggestion regarding the weedy variety Sanganya widely grown by farmers in Southern Sierra Leone.

The rice plant is normally self-pollinated but cross-pollination between varieties is possible, depending on climatic factors and varietal differences. The flower of the rice plant opens from the tip of the panicle downwards over a period of a few days and each floret remains open from a few minutes to over an hour (Grist, 1983). In the USA, red rice (of the *O. sativa* species) is considered weedy rice grown with other varieties. Red rice is morphologically different from the cultivated rice in terms of height, pericarp color, leaf color and seed pubescence. Langevin *et al.* (1990) found a high percentage of gene flow between the two *O. sativa* types and was able to distinguish their natural hybrids. It was observed that the rate of out-crossing depended on the variety. The fraction of hybrids produced due to overlapping of flowering ranged from 1% to 52%.

Philippine farmers reported that when they acquire new varieties, local or modern, new types of varieties appear after the second and third generation (Berg, 1995). These new types may come from variety mixture during processing and cultivation, or from hybrid swarms including from spontaneous hybridization between varieties (Richards, 1993). Farmers carry out selection for the development of new varieties. In Sierra Leone, Mende farmers have a specific name for new varieties developed from selections (Mbeibeihun: literally, "rice in rice", Richards, 1993). Out-crossing in rice is especially likely in areas where landraces are inter-sown in one field or in adjacent plots.

The possibility of the generation of hybrids between these varieties depends on the overlapping of flowering, the topic in this chapter.

Richards (1986) cites an agronomic report by Squire (1945) in which it is claimed that Mende farmers in eastern and southern Sierra Leone avoid collecting seed material from the edges of their farms, knowing the progeny are likely to be mixed (as a result, presumably, of cross-pollination between different varieties planted in neighboring plots).

In rice, Xinyou *et al.* (1996) described the response to temperature and photo-period; a short photo-period accelerated flowering in short-day plants and delaying flowering in long-day plants, high temperatures accelerating flowering, and low temperatures delayed flowering. Vergara and Chang (1985) also found the interval between seeding and flowering to vary among the varieties and this depended largely on the growing conditions such as humidity, nutrients and water availability.

Palaniswamy (1991) studied the relationship between plant height and 50% flowering of different tillers in a rice plant. He did not, however, report duration of flowering for 1%, 50% and 100% of the tillers, and neither did he consider the effect of tiller number and other agronomic characters on flowering duration. Duration to 50% or 100% flowering are normally reported without considering the spread over tillers within plants. There may, however, be differences in the period from sowing to the time when each tiller of a variety need to reach 1%, 50% and 100% flowering.

The literature suggest that there is some gene flow between cultivated and wild and weedy rices, and that farmers recognize the potential for new types to emerge as a result of outcrossing between varieties. But apart from the observation of Squire cited above there is little systematic information on the actual windows of opportunity for gene flow in rice under local management.

Variation in flowering periods for 1%, 50% and 100% may be found between *O. sativa* and *O. glaberrima* species. These periods are potentially important for gene flow between varieties grown as mixtures in farmers' fields or even pure varieties grown in close proximity.

Rice is primarily self-pollinating, and rates of natural outcrossing are low (about 1%) (Grist, 1983). But low rates of hybridization over many generations between varieties that are distributed over many small farm plots may have major consequences for genetic diversity. The questions are; where is such natural outcrossing possible and under which farming practices?

To answer these questions, information is needed on:

- time of planting
- time to flowering
- flowering periods (whether the flowering period varies over varieties)
- adjacency i.e. physical proximity in the field (what varieties are planted next to each other in the farm and on adjacent farms)

The importance of interaction between adjacency, time of planting, earliness and flowering interval can be described by the following example.

Consider rice varieties A and B. Variety A reaches 50% flowering after 100 days after planting (DAP) and variety B after 115 DAP. Both varieties pass from 1% to 100% flowering in 8 days, and therefore, variety A flowers from 96 to 104 days after planting, and variety B from 111 to 119 days after planting. Even if planted at the same time and in adjacent plots the flowering periods will not overlap and cross-pollination can not occur.

However, if, in order to spread labor, planting variety A takes 15 days, and that the last plants of variety A are planted on an up-slope boundary with the plot where another farmer has completed planting variety B within one day (day 15 - let us assume the second farmer could afford to hire sufficient labor). Cross-pollination at the common boundary between the two plots might then occur.

In other words, site layout, farming practice, and flowering characteristics are all part of the equation for cross-pollination.

In another study (Jusu and Richards, in preparation) site layout and farming practice have been studied, for upland rice farms in central Sierra Leone. Here, we concentrate on flowering characteristics.

In this present study, assessment of co-flowering to predict the possibility of gene flow in farmers' varieties was done by measuring the duration of a) 1%, 50% and 100% flowering of all tillers per variety, b) 1% to 100% flowering of all tillers per variety, c) 1% to 100% flowering of the of a sampling of plants of a given variety, and then considering the relationship between flowering duration and agronomic traits. (1 to 100% flowering is the period from first flowering to completion of flowering).

7.2 Materials and Methods

Fifty different upland rice cultivars collected from three chiefdoms in Kambia District of North-western Sierra Leone were studied at the Masorie upland site, 9 km from the Rice Research Station (RRS) at Rokupr in order to record the pattern of flowering of farmers' varieties (see Chapter 5, Table 5.1 for varieties and also the materials and methods).

Two weeks after sowing, four plants per plot were labelled for data collection from seeding to harvest. In the second year, heads to row seed harvested from the first year plants were grown in four rows for data collection.

Panicle-bearing tillers in each plant were numbered and tagged, and data were collected on each separate tiller. The day when the tip of the panicle emerged out of the flag leaf was recorded as the day of 1% flowering of that particular tiller of the plant. Days of 50% and 100% flowering were also recorded for all the panicle bearing tillers, and the total number of tillers per variety were counted at 100% flowering (Chapter 5).

Data Analysis

Flowering dates were converted to number of days from seeding to 1%, 50% and 100% flowering to measure the flowering differences in days between and within varieties and species. This was done to calculate the differences in:

- Duration per plant of 1% flowering. This was calculated as the period between 1% flowering of the first tiller and the 1% flowering of the last tiller to flower on a particular plant.
- Duration of 50% flowering. This was calculated as the period between 50% flowering of the first tiller and 50% flowering of the last tiller that flowered on a particular plant.
- Duration of 100% flowering. This was calculated as the period between 100% flowering of the first tiller and the 100% flowering of the last tiller that flowered on a particular plant.

7.3 Results and Discussion

The result of the duration of flowering from seeding to 100% flowering, and for flowering duration for one tiller, one plant, and four plants per variety (hence the four plants per variety as referred to as variety) are presented graphically in Figures 7.1 to 7.10. The duration from seeding to 100% flowering of the varieties ranged form 66 to 98 days (Figure 7.1). The duration per plant of 1%, 50% and 100% flowering, and 1% to 100% flowering of most varieties were each 3 to 4 days. (Figures 7.2, 7.3 and 7.4). The duration per tiller of 1%, 50% and 100% flowering was 1 to 6 days. For the plants that were selected in each variety, the average duration of flowering ranged from 5 to 12 days to complete the duration of 1%, 50% and 100% (Figures 7.5, 7.6 and 7.7). The duration of flowering in one tiller when 1% flowering was recorded to when 100% flowering was ranged from 3 to 6 days. A majority of the tillers in the selected plants completed this period in 4 days (Figure 7.8). When all tillers in the selected plants were considered, the duration of flowering, from the time when 1% flowering was recorded to the time when 100 % flowering was attained ranged from 3 to 10 days (Figure 7.9). The duration of flowering by variety took on

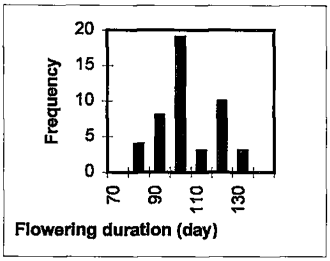


Figure 7.1: 100% flowering from seeding all varieties

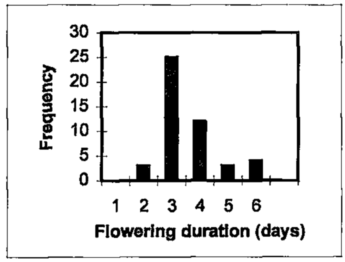


Figure 7.2: 1% flowering of all tiller per plant

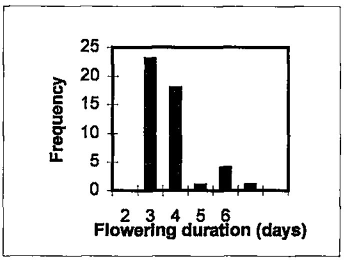


Figure 7.3: 50%flowering of all tillers per plant

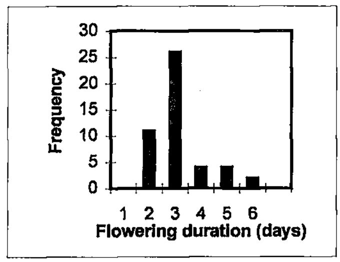


Figure 7.4: 100% flowering of all tillers per plant

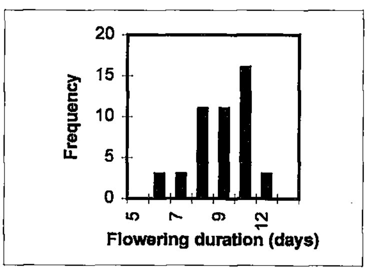


Figure 7.5: 1% flowering of all tillers per variety

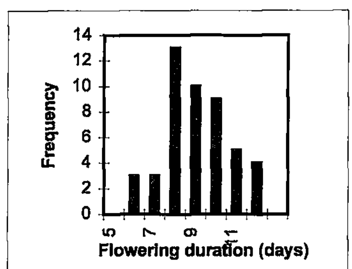


Figure 7.6: 50% flowering of all tillers per variety

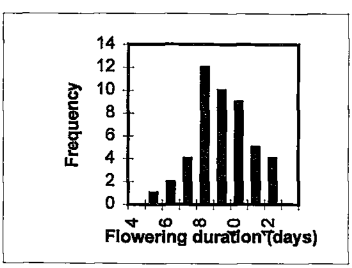


Figure 7.7: 100% flowering of all per variety

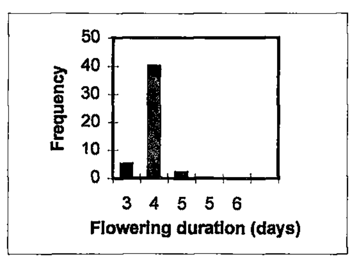


Figure 7.8: 1 to 100% flowering of one tiller

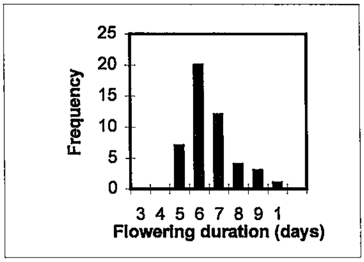


Figure 7.9: 1 to 100% flowering of all tillers per variety

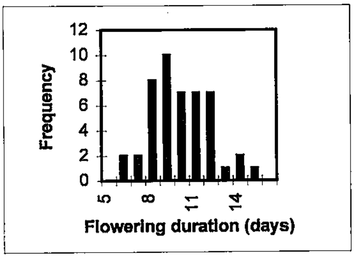


Figure 7.10: 1 to 10% flowering of all tillers per variety.

Figure 7.1 - 7.10; Frequency distribution of flowering duration of local rice germplasm in north-west Sierra Leone.

average 9 days to complete 1% to 100 % for all the four tillers on four plants. But this period varied by variety and ranged from 6 to 15 days (Figure 7.10).

These data indicate that there is wide variation in flowering behavior of rice varieties even in a single environment. There was variation from seeding to 100% flowering both within and between varieties. Farmers' varieties are usually mixed, producing plants that are phenotypically similar and genetically different as indicated by the differences in the flowering duration between plants within the test varieties. The range of duration of varieties from seeding to 100% flowering may be important for gene flow between these varieties, especially where these varieties are planted in close proximity in the field.

Variations in the duration of flowering give an indication of when gene flow within and between varieties is possible especially when grown in close proximity in experimental plots or in mixtures in farmers' fields. The data show the number of days the rice plants and varieties take to complete the duration of 1%, 50% 100% and 1% to 100% flowering. Emasculation and pollination would have to be completed in 3 to 4 days in each tiller of the rice plant if cross-pollination is to be effectively carried out. This will take longer however for several plants in a variety sample, and could take from 9 to 19 days.

When the materials were observed over the two years, differences in the duration of flowering were identified. In the first year, the majority of the tillers (panicles) completed the 1% to 100% flowering period in two days. In the second year, most varieties took four days to complete the same flowering period. But some *O. sativa* varieties such as ROK 3, Bayiba, Isatu, Pa Nylon, Joe Wanjei, Dambara Bali and Samba Konkon had a constant duration per variety of 1% to 100% flowering over the two years (4 days).

Table 7.1: Minimum, mean and maximum values for flowering duration of varieties evaluated in the morphological characterization of local rice species and varieties in 1996 and 1997 cropping season

All varieties				Species		Varieties	
Character	Minimum	Mean	Maximum	CV	SD	CV	SD
100%F	66.0	98.1	128.0	12.2	0.440	3.20	0.013
1%P	0.0	3.2	17.0	82.5	0.097	81.13	0.009
50%P	0.0	3.1	18.0	86.1	0.096	84.55	0.009
100%P	0.0	2.7	17.0	92.5	0.092	90.55	0.009
100%T	0.0	3.5	7.0	24.7	0.001	23.80	0.032
1-100%TP	1.0	6.1	20.0	45.3	0.100	44.40	0.010
1%V	2.0	8.7	19.0	104.3	0.963	102.00	0.312
50%V	1.0	8.7	20.0	155.7	0.421	151.80	0.423
100%V	1.0	8.2	20.0	111.8	0.311	108.96	0.312
100%WV	2.0	11.6	22.0	79.9	0.319	78.40	0.323

Note
100%F: duration per variety of 100% flowering from seeding.
1%P: duration per plant of 1% flowering.
50%P: duration per plant of 50% flowering.
100%P: duration per plant of 100% flowering.
100%T: duration per tiller of 100% flowering.
1-100%TP: duration of all tillers per plant 1% to 100% flowering.
1%V: duration per variety of 1% flowering
50%V: duration per variety of 50% flowering
100%V: duration per variety of 100% flowering
1-100%T: duration per tiller of 1% to 100% flowering
1-100%P: duration per plant of 1% to 100% flowering
1-100%WV: duration per variety of 1% to 100% flowering

The minimum number of days in duration of flowering ranged from zero (i.e. within one day) for individual tillers and for plants within a variety, to 2 days for varieties. The maximum number of days ranged from 7 days for one tiller to 22 days for a variety (Table 7.1).

The variation in flowering duration was comparatively low for one tiller, all tillers per plant and for the whole variety in both species as indicated by the relatively low Coefficient of variation (CV %). The variation was much higher between tillers per plants and for plants within varieties. Generally, however, the variation was higher within species than within varieties.

This result also shows that duration of flowering in low tillering varieties can be short, and the 1% to 100% flowering can be completed within one week. Gene flow between these varieties would have to take place within the few days from the time when the tip of the first panicle emerges out of the flag leaf to the time when the last panicle in the variety has flowered. In varieties with more tillers, this period can be extended to three weeks. Gene flow in high tillering varieties is more likely than in low tillering varieties.

The mean values for the 47 varieties evaluated for the various flowering traits recorded are shown in Appendix 7.1. Tillering was generally low for all the test varieties. The number of tillers per plant ranged from 1.3 for DC Kono 1 and Samba Konkon 3 to 3.4 for Joe Wanjei. The number of effective tillers was lower for the *O. glaberrima* varieties compared to *O. sativa* varieties.

Table 7.2:Minimum, mean and maximum values for flowering duration of *Oryza sativa, O. glaberrima* and Pa Three Month variety evaluated in the morphological characterization of local germplasm in 1996 and 1997 cropping season

Species	Characters									
	100% F	1% P	50% P	100 %P	100 %T	1-100% TP	1% V	50% V	100% V	100% WV
Oryza sativa										
Minimum		2.1	2	1.8	3.0	4.8	7.0	7.0	7.0	7.0
Maximum	74.7	7.3	6	5.7	4.3	9.3	11.0	11.5	11.8	14.7
Mean	118.4	3.2	3.1	2.8	3.7	7.4	8.7	8.6	8.5	10.0
Std Deviation	106.3	0.96	0.98	0.94	0.38	1.12	1.31	1.40	1.46	2.33
	1.28									
O.glaberrima										
Minimum		2.1	2.0	1.6	2.9	4.7	5.3	5.3	4.8	5.3
Maximum	85.2	4.1	4.1	3.9	3.8	7.1	11.8	11.8	11.8	11.8
Mean	10.4	2.9	2.7	2.4	3.3	5.6	8.3	8.3	8.3	8.7
Std Deviation	95.6	0.60	0.61	0.63	0.26	0.63	1.62	1.64	1.71	1.63
	1.54									
Pa 3 month										
Minimum	70.9	5.1	4.4	4.1	3.1	7.1	10.8	10.8	10.8	10.8
Maximum	82.4	5.6	5.3	5.2	3.3	8.3	12.0	12.0	12.0	12.0
Mean	76.4	5.4	4.9	4.8	3.2	7.5	11.5	11.5	11.5	11.5
Std Deviation	0.17	0.24	0.50	0.57	0.13	1.21	0.66	0.66	0.66	0.66

Note
100%F: duration per variety of 100% flowering from seeding.
1%P: duration per plant of 1% flowering.
50%P: duration per plant of 50% flowering.
100%P: duration per plant of 100% flowering.
100%T: duration per tiller of 100% flowering.
1-100%TP: duration of all tillers per plant 1% to 100% flowering.
1%V: duration per variety of 1% flowering
50%V: duration per variety of 50% flowering
100%V: duration per variety of 100% flowering
1-100%T: duration per tiller of 1% to 100% flowering
1-100%P: duration per plant of 1% to 100% flowering
1-100%WV: duration per variety of 1% to 100% flowering

When the duration of flowering by species was compared, duration of flowering for plants within varieties was higher for the *O. sativa* varieties than for the *O. glaberrima* varieties (Table 7.2). The duration of flowering for the Pa Three-month variety was also higher than that of *O. glaberrima* varieties. The duration of flowering of the whole variety was also higher for the *O. sativa* varieties than for both *O. glaberrima* varieties and Pa Three-month.

The duration of flowering for 1%, 50% and 100% flowering for the varieties was variable for the *O. sativa* varieties and constant for the *O. glaberrima* and Pa Three month variety. The variation in the duration of flowering, as indicated by the standard deviation was also found to be higher in *O. sativa* than in both *O. glaberrima* species and the Pa Three month variety. This result further demonstrated high variability in the *O. sativa* varieties.

Table 7.3: Mean values of flowering duration and tillering ability of local germplasm evaluated in the 1996 and 1997 growing season

Name of varieties	100% F	1%P	50% P	100 %P	100% T	1-100%TP	1%V	50%V	100% V	100% WV	Tillers per plant
Dissi Kono1	93.8	3.2	3.0	2.7	3.4	6.0	7.75	7.8	7.8	7.8	1.9
Dissi Kono2	95.2	2.1	2.0	1.6	3.0	4.7	5.3	5.3	5.3	5.3	1.3
Dissi Kono3	95.7	3.5	3.1	2.7	3.3	5.8	10.5	10.5	10.5	10.5	2.5
Saliforeh 1	87.6	4.0	4.1	3.6	3.8	7.1	10.0	10.0	10.0	10.0	2.5
Saliforeh 2	85.2	2.3	2.4	1.8	3.6	5.8	7.3	7.3	7.3	7.3	1.8
Pa Bop	74.6	3.3	3.1	2.8	3.1	5.7	10.3	10.3	10.3	10.3	2.6
Samba Konkon1	110.6	3.4	3.1	2.8	4.0	6.7	8.8	8.8	8.8	8.8	2.2
Samba Konkon2	113.1	3.6	3.4	2.9	4.0	7.2	8.5	8.5	8.5	8.5	2.1
Samba Konkon3	113.1	3.8	3.6	3.1	4.0	7.1	9.5	9.5	9.5	9.5	2.4
ROK 3 1	112.6	5.6	5.6	4.9	4.0	9.0	9.5	9.5	9.5	9.5	2.4
ROK 3 2	110.7	2.5	2.5	2.1	4.0	6.8	9.3	9.3	9.3	9.3	2.3
Pa 3 Month1	92.4	5.6	5.1	5.0	3.3	8.1	12.0	12.0	12.0	12.0	3.0
Pa 3 Month 2	70.9	5.5	5.3	5.2	3.3	8.3	11.8	11.8	11.8	11.8	2.9
Pa 3 Month 3	71.6	5.1	4.4	4.1	3.1	6.1	10.8	10.8	10.8	10.8	2.7

Note
100%F: duration per variety of 100% flowering from seeding.
1%P: duration per plant of 1% flowering.
50%P: duration per plant of 50% flowering.
100%P: duration per plant of 100% flowering.
100%T: duration per tiller of 100% flowering.
1-100%TP: duration of all tillers per plant from 1% to 100% flowering.
1%V: duration per variety of 1% flowering
50%V: duration per variety of 50% flowering
100%V: duration per variety of 100% flowering
1-100%T: duration per tiller of 1% to 100% flowering
1-100%P: duration per plant of 1% to 100% flowering
1-100%WV: duration per variety of 1% to 100% flowering

A comparison of the duration of flowering of varieties that are mix-planted by farmers indicated a high tillering ability and more days to complete the flowering period in the *O. sativa* varieties and Pa Three Month than the *O. glaberrima* varieties (Table 7.3). Differences in tiller number and duration of flowering were observed between *O. sativa* and *O. glaberrima* species and Pa Three Month. Differences were also observed in the tillering ability and duration of flowering within these groups.

7.4 General discussion

The data presented confirm that duration of flowering interval is variable, between varieties, and from year to year. The flowering "window" tends to be on average about 9-10 days per variety. It is somewhat larger for *O. sativa* (averaging 10.0 days) than *O. glaberrima* (averaging 8.7 days), though there was also greater variability among *O. sativa* varieties (SD 2.33) than among *O. glaberrima* varieties (SD 1.63). The Pa Three Month variety has one of the longest flowering periods of varieties tested (averaging 11.5 days). As a group, *O. glaberrima* varieties tend to flower earlier than *O. sativa* varieties.

To bring out the general significance of these data will require further detailed work on where farmers plant varieties, and timing of planting and germination (cf. Jusu & Richards, in preparation). Possibly, geneflow opportunities are relatively more restricted in the *O. glaberrima* group, but any such restriction may be easily compensated (or obliterated) by farmer planting strategy. A range of such strategies - including mixed planting - are discussed in Jusu & Richards (in preparation).

Here we may revert, specifically, to one of the findings discussed in chapter 6, where it was reported that on average mixed planting reduced the gap in earliness (days to 50% flowering) of two varieties planted in mixtures by 25 per cent (from 8.6 days to 6.45 days). If we re-examine data presented in Table 6.9 there are three (out of eleven) variety combinations - G2/S1 in year 1997, G2/S2 in 1996 and S1/S2 in 1997 - where increased synchronicity of flowering when planted in unfertilized mixture (over planting in unfertilized monoculture) was apparently sufficiently great to open or significantly widen a potential window of opportunity for geneflow (reductions from 12 to 9, 14.5 to 8.0, and 13.0 to 7.5 days difference in date of 50% flowering for the two varieties in question). Two of these combinations are sativa/glaberrima combinations. It may be through such mixed planting of O. sativa and O. glaberrima materials that "intermediate" types such as Pa Three Month first came into existence on farmers' fields, without research intervention.

8. MAIN RESEARCH FINDINGS AND GENERAL CONCLUSION

8.1 Main research findings reviewed

Chapter 2 introduced small-scale rice farming in North-western Sierra Leone (the research area), considered the history of rice farming and rice research in the area, discussed ethnicity and the history of slavery as factors in shaping the attitudes of different ethnic groups to their rice varieties, and outlined the main production ecologies for rice farming in the region. Variety survey in the area revealed that farmers in the three case study chiefdoms mainly produce annual crops. Farmers in Magbema Chiefdom have significant holdings of cash crops. Those in Bramaia farmers earn cash from pepper and groundnuts. Rice remains by far the most important food crop, and this is reflected in level of varietal diversity. Traditional grains (sorghum and Digitaria) continue to supplement rice, but there has been a significant spread of introduced roots and tubers (cassava and sweet potato) varieties in recent years. Science has had more impact on roots and tubers than on rice, a crop grown for millennia. Farmers in the research area mainly grow rice on the upland-swamp continuum and have more lowland than upland varieties. Farmers report dependence on the wider regional system for rice germplasm. Magbema farmers tend to get new local varieties from Tonko Limba and Bramaia. Tonko Limba and Bramaia farmers tend to get new wetland varieties from Magbema, an area with a long history of wetland cultivation (in mangrove blackish water) and associated (fresh water) swamps. Rices from species *O. glaberrima* remain important in the region. The proposed "intermediate" (farmer selected inter-specific hybrid) rice, *Pa Three Month* is a main variety.

Chapter 3 looked at how farmers in North-western Sierra Leone manage seed. It discussed the organization of farm labor, farmer seed selection and development activities, the role of gender in seed processing, and considered all the stages in seed processing through harvesting into storage. The chapter concluded with comments on farmers' knowledge of varieties and soil types, and information about the original sources of farmer varieties.

Chapter 4 reported the results of a number of experiments to discover what farmers considered important in selecting rice varieties. Trials were established in collaboration with farmers in order to identify the rice variety and characteristics that farmers prefer in their varieties, and to evaluate the performance of the varieties at RRS and on farmers' fields, to find out whether the varietal characteristics and preferences varied as between ethnic groups and to assess variation in selection criteria between farmers and scientists.

Farmers were invited to make selections from a large number of farmer varieties including RRS release and pre-release materials (including WARDA inter-specific hybrids) on three village trial sites. What farmers chose and why was analyzed. International sativa rices were selected about as frequently as local land race materials. *O glaberrima* materials and inter-specific hybrids attracted significant attention, as did established Rokupr pure line selections from farmer varieties (released in the 1970s). But there was a worrying lack of interest in current RRS advanced lines. This led to an examination of the "ideotypes" of professional rice scientists and farmers. Professionals were asked to rank the characteristics in the IRRI standard upland rice "ideotype". A farmer ranked "ideotype" was induced from information on selection choices. Degree of agreement/disagreement between the two ideotypes was measured. The lack of correlation suggests important divergences in the way farmers and researchers view selection decisions.

Chapter 5 suggested a representative collection of farmer varieties (including varieties of *O. glaberrima* and *O. sativa*, together with "intermediate" types, research releases and advanced lines) to detailed morphological analysis using multivariate methods. The major finding was that there was considerable diversity in local rices, suggesting farmer selection is not yet "bottlenecked". *Pa three month* clustered separately from the main *O. glaberrima* and *O. sativa* cultivars, indicating that there is something distinctive about this farmer selection. A dendrogram from the multivariate analysis clearly separated *O. sativa* and *O. glaberrima* materials, and differentiated those *O. glaberrima* varieties farmers consider to be "traditional" and "new" (including *Pa three month*). The results confirmed that farmer indigenous knowledge as apparent in rice selection is well grounded. Marker analysis should now be used to explore these materials further.

Chapter 6 analyzed one aspect of farmer varietal management in detail. In preliminary fieldwork it was discovered that Limba farmers in one of the case-study chiefdoms (Tonko Limba Chiefdom) took a rather rigorous approach to rogueing (see Chapter 3). Limba farmers generally maintained very pure varietal stands. But the rice plots of neighboring Susu farmers were often rather mixed. In a parallel anthropological study, Catherine Longley (1999) working with Susu farmers, discovered that farmers sometimes chose to interplant different rice varieties in the same field. According to the farmers there were definite advantages in this practice. This chapter reported a number of experiments designed to investigate aspects of this practice.

The results explain the practice of some Susu farmers in the case study area who mix varieties before seeding on the uplands (Longley, 1998). The most important finding was that RYT is larger than unity when *O. sativa* and *O. glaberrima* varieties are grown in mixtures under upland condition, without fertilizer application.

The reasons for mixing mentioned by farmers (to insure the harvest and to increase nutritional value) are strictly speaking no reasons, because growing different varieties in pure stand would also will meet these objectives. The research suggests another reason for growing mixtures, namely that RYT is larger than unity (i.e. certain mixtures out-yield the monocultures). Apparently, farmers are not aware that certain mixtures out-perform the average of monoculture. Their understanding is intuitive. But perhaps there are also benefits in terms of out-crossing and subsequent farmer selection.

Chapter 7 focuses on flowering in rice, as the "window of opportunity" for natural outcrossing. From a review of the literature on farmer selection, the chapter identified the interaction of four factors governing chances of introgression between varieties, or between varieties and wild and weedy sympatric species. The four factors are timing of planting, earliness, adjacency and length of flowering period. The way the first three factors interact is examined through data from central Sierra Leone in a forth coming paper by Jusu and Richards. This study confirms there is considerable scope for natural out-crossing due to the way farmers manage planting strategies in the field, and their tendency to make block clearings, planted with several co-flowering rices. But there is little systematic information on the forth factor - variation in flowering intervals for rice varieties. The experimental data reported in this chapter showed that flowering intervals in rice vary from c. 5 to 15 days, and that this variation is to some extent under genetic control. *Pa three month* is a variety with one of the longest flowering periods. Plants with long flowering period presumably have some advantage in terms of chances of out-crossing.

8.2 General conclusion

Can low-resource farmers in difficult environments select appropriate planting materials?

Do they have so much skill and genetic diversity that they could be safely left to look after their own interests, unsupported by agricultural research?

On the basis of this study of farmer management of rice genetic resources in North-western Sierra Leone the answer to the first question is a clear "yes", but the answer to the second question is an emphatic "no".

The central experiment in the research reported above was to get farmers to select across a range of their own and researchers' materials, including local novelties (e.g. *pa three month*), research station releases, and various advanced lines from national and international programs, including WARDA inter-specific hybrid material combining genetic resources from African and Asian Rice.

Despite the participating farmers being among the world's most impoverished people working in highly insecure war-time conditions it was clear that they knew what they were looking for. Likewise, they could always explain the selection choices they made. There was considerable agreement among the farmers about what they chose and why, even though these choices would not necessarily agree with researchers' choices. But there was also considerable variation by ethnic group and environment, despite the three groups having lived together in one rather small region for perhaps many hundreds of years.

The actual results supported neither those who argue that farmers need only a few broadly adopted modern varieties, developed according to a standard international ideotype, or the populists ranged against them who argue that farmers have their own ideas and genetic resources, and no need of external assistance or materials.

Farmers have their own indicators of performance and quality, not well anticipated by breeders' criteria, but despite this international high-yielding *(sativa)* material proved to be the single most frequently chosen class of material. Results make clear that low-resource farmers like variety (a range of options) and not just a few high performing varieties. Strongly included in farmer selections were many local varieties, including *glaberrima* materials ignored until recently by scientific plant improvement programs. Initial indications suggested that some of the WARDA inter-specific (*O. sativa* x *O. glaberrima*) material may prove popular.

By exploring the context of farmers' choices this thesis has made clear that breeders cannot afford to ignore local cultural, historical and environmental circumstances. Factors as various as exposure to the slave trade and inter-regional commerce, desiccation, soil impoverishment, G x E interaction, and variations in modes of labor mobilization and farming style (e.g. when, how and by which genders harvesting and seed purification are managed) all tend to account for why a sample of male, upland-rice-farming heads of households in three contiguous and small chiefdoms tends to diverge (but systematically) in their selection responses to a single body of trial material. In relation to low-resource farming, the devil, as the saying goes, is in the detail.

So here we have an apparent paradox. Farmers like the look of international improved rices, but they also want plenty of access to the best local types. As Dennis (1989) found in Thailand, this changes our picture of the "innovative" farmer. The innovative farmer is one actively juggling a set of modern and local selections. Nor are the local selections static. Even among the apparently "traditional" *glaberrima* rices farmers differentiate "older" and "newer" types, and quantitative morphological analysis confirms, that the newer local types are distinctive. Probably Pa Three Month is not alone. It may well be that the name element "DC" (also Dissi) (variously "Demerara Creole" and "District Commissioner") is used to mark the larger range of *O. glaberrimas* being actively shaped through out-crossing and farmer selection (Richards, per. Comm.)

In general, morphological analysis supports the idea that there may be considerable variation in the local rices, both within and between species groups, perhaps as the result of the meeting of different streams of material where coastal and interior trade routes have converged, and that the potential for selecting upon, or breeding from, this local material is still not exhausted.

One of the vehicles for mixing and merging among these convergent local gene pools may be the habit of some farmers (among the trade-oriented Susu) to interplant distinct varieties in the same field in the hope of spreading risks and ensuring supplies of nutritionally favored varieties. Susu farmers do not have access to modern genetic theory based on ideas of Mendelian inheritance, but inter-specific inter-planting has some interesting agronomic properties, especially where fertilizer is unavailable (as shown, with the right combinations yields are higher than under mono-cropping) and this may provide the incidental basis for considerable natural out-crossing upon which farmers subsequently select. More generally, however, the thesis confirms considerable potential for gene-flow among local rices, and between local rices and improved cultivars in upland rice farming in Sierra Leone, even if more detailed experiments are now needed.

Quite clearly, farmers look for and welcome exotic material, both for its own sake, and for its potential to complement existing material, and to enrich the local gene pool. The apparent paradox alluded to above ceases to be a paradox when we realize that modern varieties serve two purposes - as innovations in themselves and as ways of bringing about local genetic base broadening from which farmer selection can then derive renewed energy. It is interesting to note that the mixtures planted by Susu farmers are "old" glaberrima types and "modern" *sativas* (or vice versa), and that these combinations out-yield the varieties planted as mono-crops. The tendency to achieve synchronization of flowering in mixtures may open an important window for natural out-crossing.

This still leaves us with some questions about the kind of research strategy that will best support local selection initiative. The thesis has very clearly suggested that existing strategy in the Sierra Leone national rice research program may not be optimum.

Farmers have adopted, and continue to show interest in RRS varieties, but mainly the pure-line selections from local varieties introduced during the 1970s. Much could still be done to extend access to these varieties beyond the immediate station vicinity (farmers no more than 75 km from the station were still not familiar with these releases even 25 years after their first introduction). But much more worrying, farmers hardly showed any interest in the current advanced lines from RRS. International (including WARDA hybrids) and local materials both attracted more interest in the selection trials.

Comparing "ideotypes" suggested quite a gap between farmers and national rice professionals. An under-funded national program has been almost totally dependent for funds on the international programs led by IRRI. Loyalty to one's patron is a marked characteristic of social and political systems in Sierra Leone (Richards, 1986). But perhaps the distantly formulated IRRI Standard Evaluation criteria are too rigidly applied?

What seems now to be needed to revitalize the program for low-resource upland farmers is the further extension of the kind of methodology explored in this thesis. Breeders need to learn that their varieties sometimes do good by stealth - that releases many times "disappear", but perhaps not without first enriching the local gene pool, and that this boosts farmers' confidence in their own selection practices. Breeders, therefore, need both to select and cross, but also to monitor farmers' selection processes, and adjust according to the lessons they can derive from such monitoring. They also need to learn the lessons from farmers' experiments with mixtures. In low-input conditions choosing complementary mixtures of *O. sativa* and *O. glaberrima* (the approach of some farmers) may be more fruitful than an inter-specific hybridization program.

But to pick up on such lessons some institutional innovation is needed to make farmers' selection experiments a regular part of an interactive process binding together farmers and researchers in a necessary and complementary relationship.

Donors will have to adjust their research support and assessment processes accordingly. They will need to channel more funding through decentralized initiatives such as the Community Biodiversity Development & Conservation program. But they will also have to consider new approaches to monitoring and evaluation. Sending an economist to track innovations may be less important than it once was. The new approach may be better based on marker probes to track where the useful genes have gone, and who makes use of them, in farmers' practice as well as in station releases.

Whatever the case, this thesis makes plain that farmer agency is a resource not to be lightly disregarded in plant improvement. As we move into a new world shaped by radical bio-technologies such as apomixis it may transpire that there is much more scope for alternatives to the top-down Green Revolution programs planned and regulated by far-sighted but remote international scientists. There may be much more scope for the tailoring of plants to local social and environmental need. If so, we may come to regard the farmer's eye for selection and experimentation as crucial skills enabling this to happen. Perhaps one day farmer knowledge itself will become a candidate for a Nobel Prize.

CURRICULUM VITAE:

Malcolm Sellu Jusu was born on the 21st April 1955 in Sandeyalu, Luawa chiefdom, Kailahun District, Eastern Province, Sierra Leone. He attended the Methodist Primary school Sandeyalu and later went to Holy Ghost Secondary school, Segbwema, from 1969 to 1974. In 1978, he entered Njala University College and studied for a B. Sc. degree in Agriculture General and graduated in 1982. From 1976 to 1977, he studied for a Master of Philosophy degree in Plant Breeding and Genetics in Cambridge University. He has worked as a researcher since 1977, first as a Field Assistant and later as Senior Staff. During these years he has worked with a variety of crops including rice as the main crop, cassava, sweet potatoes, sorghum, Irish potatoes and vegetables. He is a member of several research communities including EEC/IITA/RRS on-farm trials,1990 to date; WARDA Taskforce Trials 1990 to date, Community Biodiversity Development and Conservation (CBDC) 1993 to date and Technology and Agrarian Development Group (TAO), Wageningen University. He wrote his thesis based on the TAO and CBDC concept.

APPENDICES

Appendix 3.1: Farmers' Questionnaire on Seed Management Practices in Kambia District in 1996 and 1997 harvesting seasons

1. Name of head of house hold ================
2. 2. Tribe : Temne (1),), Limba (2), Susu (3)
3. Village ==========================
4. Age of the farmer ===================
5. Religion : Muslim (1), Christian (2), None of the above (3)
6. Sex : Male (1), Female (2)
7. Citizenship : Yes (1), No (2)
8. Tenancy arrangement of the land use
   Bought ================ ( ) 01
   Inherited ================( ) 02
   Rented =================( ) 03
   Mortgage ===============( ) 04
   State owned ============( ) 05
   Exchanged ==============( ) 06

9. Do you carry out any rogueing of your rice varieties
   Yes (1), No (2)

10. If yes when
    Before harvest ===============01
    At harvest =================02
    At gathering ===============03
    At packing ================04

11. Who does the rogueing?
    Men ===================01
    Women =================02
    Boys ===================03
    Girls ===================04
    Men & women ============05
    Men & Boys ==============06
    Men & Girls ==============07
    Women & Boys ============08
    Women & Girls ============09
    The whole family ==========10

12. Who does the harvesting
    Men ==================01
    Women =================02
    Boys ==================03
    Girls ===================04
    Men & women ============05
    Men & Boys ==============06
    Men & Girls ==============07

Women & Boys ========08
Women & Girls ========09
The whole family =======10

13. How is the rogued panicle used
Food ===========================01
Tested for varietal development =============02
Discarded ==========================03

14. What harvesting method do you use:
Bulk harvesting by Men ==================01
Bulk harvesting by Women =================02
Bulk harvesting by Boys ==================03
Bulk harvesting by Girls ==================04
Bulk harvesting by Men & women =============05
Bulk harvesting by Men & Boys ==============06
Bulk harvesting by Men & Girls =============07
Bulk harvesting by Women & Boys ============08
Bulk harvesting by Women & Girls ============09
Bulk harvesting by The whole family ===========10
Panicle harvesting by men =================11
Panicle harvesting by Women ================12
Panicle harvesting by Boys =================13
Panicle harvesting by Girls =================14
Panicle harvesting by Men & women ===========15
Panicle harvesting by Men & Boys ============16
Panicle harvesting by Men & Girls ============17
Panicle harvesting by Women & Boys ==========18
Panicle harvesting by Women & Girls ==========19
Panicle harvesting by the whole family ==========20

15 Who does the gathering
Men ==================01
Women ================02
Boys =================03
Girls =================04
Men & women ============05
Men & Boys =============06
Men & Girls =============07
Women & Boys ==========08
Women & Girls ==========09
The whole family =========10

16 Period between harvesting and gathering
The same day ===========01
The following day =========02
Within one week ==========03
Within two weeks =========04
Within three weeks =========05

After one month ==========06
After two month ==========07
After three month =========08
After four month ==========09

17. Who does the threshing
Men =================01
Women ==============02
Boys =================03
Girls =================04
Men & women ===========05
Men & Boys ============06
Men & Girls ============07
Women & Boys ==========08
Women & Girls ==========09
The whole family =========10

18. Period between threshing and winnowing
One day ============01
Two days ===========02
Three days ===========03
Four days ============04
Five days ============05

19 Who does the winnowing
Men =================01
Women ===============02
Boys =================03
Girls =================04
Men & women ============05
Men & Boys =============06
Men & Girls =============07
Women & Boys ===========08
Women & Girls ===========09
The whole family ==========10

20 Period between winnowing and drying
One day =============01
Two days =============02
Three days ============03
Four days =============04
Five days =============05
Six days ==============06

21 Who does the drying
Men =================01
Women ===============02
Boys =================03

Girls ================04
Men & women =============05
Men & Boys =============06
Men & Girls =============07
Women & Boys ===========08
Women & Girls ===========09
The whole family ==========10

22 Duration of drying
One day =============01
Two days ============02
Three days ===========03
Four days ============04
Five days ============05
Six days =============06

23 in which of the following containers do you store your seeds :
Baskets ============01
Jute bags ===========02
Others ============03

24 When is seed rice removed from the main harvest.
Before harvest ===========01
After harvest ===========02
Before threshing =========03
After threshing ==========04
Before winnowing ========05
After winnowing =========06
Before drying ===========07
After drying ===========08
Before storage ==========09
After storage ===========10

25 How do you determine the type of variety to grown on a particular part of the land in terms of soil suitability, fallow period and water regime.

26 Name the variety selected for cultivation in 25 and give reasons.

Thank you very much for your co-operation
Malcolm S. Jusu

Appendix 4.1 Questionnaire for varietal evaluation by the workers at the Rice Research Station, Rokupr , Sierra Leone.

Name===============
Department========

Instructions
The list of characters below are used in variety selection for the upland rice ecology. It is divided into two parts.

A. Characteristics of the rice model developed by the International Rice Research Institute (IRRI) in 1990.

B. Characters recorded from farmers as most important in their variety selection in 1996. Please rank in ascending order of preference where 1 = most important and 19 least important

A IRRI Characters (Model)
1. High rate of germination ---------. 2. Faster seedling growth---------

3. High tillering ability ---------------. 4. Semi-compact to open --------

5. Long, erect, and stiff leaves with high photosynthetic efficiency ------

6. Very sturdy stem and non-lodging-----------

7. Semi-tall (100-130 cm) --------------

8. Multiple resistance to diseases --------------

9. Multiple resistance to pest --------------

10. Six to 12 tillers per plant.-------------

11. 150 to 200 grains per panicle -------------

12. Medium to long panicles ------------- 13. Non-shattering---------

14. Acceptable grain quality ------------- 15. high yield -------------

16. Weed suppression ability ------------

17. Heat and drought tolerance -------------

18. 100-130 days maturity--------- 19. Yield (3 - 4 ton/ hectares)--------

B. Farmers characters

1. Tillering ability ---------- 2. plant height ------------

3. Duration (3-4 month) --------- 4. Weed suppression ability ---------

6. Performance on poor soils -----------

7. Recovery after rodent damage ----------- 8. Lodging resistance----------

9. Panicle length ---------- 10. Percent sterility ------------

11. Threshability ------------ 12. Awning -------- 13. Grain size ----------

14. Grain Yield ---------- 15. Grain colour --------- 16. Palatability --------

17. Filling quality after eating -------------

18 Aroma ---------- 19. Cooking -----------

Appendix 5.1: Mean values of charaters used in the evaluation of varieties in the construction of the spanning tree.

VAR	PH2	PHM	LFL	LW	PUB	BLCO	SHCO	ANG	LIGL	LIGCO
1	20.94	118.0	55.86	1.325	1.000	1.313	1.000	1.000	2.394	1.000
2	20.68	165.0	51.99	1.500	1.000	1.000	1.688	5.000	3.000	1.063
3	24.64	138.6	64.83	1.394	1.500	1.500	1.250	1.000	3.306	1.000
4	25.08	143.6	67.83	1.656	1.750	2.500	1.000	1.250	3.088	1.000
5	29.68	143.2	62.79	1.631	2.375	1.875	1.000	2.750	3.094	1.063
6	22.95	109.1	39.58	1.950	1.000	1.063	2.063	7.250	2.750	2.125
7	23.00	114.3	38.83	1.906	1.000	1.063	2.063	7.250	2.688	1.875
8	20.55	101.7	46.14	1.063	1.000	1.250	1.000	1.000	1.981	1.000
9	22.54	95.7	40.64	2.394	2.000	1.813	1.938	2.000	2.438	1.000
10	22.27	142.5	48.07	2.119	3.000	2.937	1.000	1.000	1.875	1.000
11	23.02	125.8	52.56	1.206	2.000	1.125	1.000	1.000	2.006	1.000
12	21.14	149.6	50.33	1.625	1.000	1.000	1.000	1.000	3.369	1.000
13	23.58	149.6	60.16	1.563	1.000	1.938	1.375	1.000	3.256	1.000
14	25.11	115.5	59.02	1.306	1.000	1.125	1.000	1.000	1.700	1.000
15	22.17	134.1	45.13	2.206	3.000	2.688	1.000	1.000	2.156	1.000
16	21.48	122.3	36.75	1.800	1.000	1.188	2.000	1.000	2.625	3.000
17	18.84	116.3	42.46	2.075	3.000	2.438	2.000	1.000	2.037	1.000
18	19.52	109.3	39.30	2.281	3.000	2.500	2.000	1.000	2.044	1.000
19	17.79	108.3	43.24	1.075	1.000	1.250	1.125	4.000	1.900	1.000
20	21.61	108.6	42.71	1.925	1.000	1.938	2.000	1.250	2.875	1.000
21	21.20	110.5	39.91	1.944	1.000	1.375	2.000	1.000	3.000	1.000
22	20.94	101.2	49.61	1.112	1.000	1.000	1.000	1.000	1.931	1.000
23	19.21	112.6	30.55	1.313	1.000	1.000	1.000	1.000	1.694	1.000
24	20.67	120.7	39.46	1.519	1.438	1.000	1.000	1.000	2.100	1.000
25	20.32	129.0	35.93	1.419	1.500	1.000	1.000	1.000	2.075	1.000
26	20.41	132.8	38.14	1.406	1.125	1.000	1.000	1.000	2.325	1.000
27	22.17	136.9	35.30	1.375	1.062	1.000	1.000	1.000	2.138	1.000
28	18.49	132.9	35.67	1.362	1.188	1.000	1.000	1.000	1.981	1.000
29	17.45	146.1	36.02	1.350	1.063	1.000	1.000	1.000	2.538	1.000
30	18.34	141.9	36.17	1.444	1.000	1.000	1.125	1.000	2.106	1.000
31	24.75	147.7	58.78	1.506	2.000	1.000	1.000	1.000	3.175	1.000
32	22.77	146.9	55.12	1.481	2.000	1.000	1.000	1.000	3.275	1.000
33	22.62	123.9	33.47	1.438	1.000	1.000	1.000	1.000	1.875	1.000
34	20.52	151.9	45.42	1.713	1.000	1.000	1.000	1.000	2.013	1.000
35	22.61	170.1	36.89	1.750	1.000	1.000	1.000	1.000	2.688	1.000
36	21.93	171.9	44.39	1.719	1.000	1.000	1.125	1.000	2.938	1.000
37	17.88	78.2	34.50	1.500	1.000	1.000	1.000	4.000	1.731	1.000
38	17.86	102.2	41.36	1.406	1.000	1.000	1.000	4.250	1.963	1.000
39	23.82	116.6	36.06	1.900	2.000	2.875	1.125	3.000	1.794	1.000
40	19.02	104.0	42.39	1.294	1.000	1.000	1.000	6.250	1.900	1.000
41	21.84	119.9	36.51	1.337	1.062	1.000	1.000	1.000	2.181	1.000
42	20.15	120.8	44.81	1.513	1.563	1.000	1.000	1.000	1.975	1.000
43	18.54	113.2	39.03	1.419	1.688	1.250	1.000	1.000	2.381	1.000
44	22.36	121.4	38.74	2.050	2.938	2.812	1.000	1.000	2.119	2.875
45	23.81	156.3	57.18	1.738	2.125	2.875	1.000	1.000	3.275	1.000
46	22.51	151.6	55.60	1.613	2.000	2.750	1.000	1.000	3.150	1.000
47	22.82	149.7	56.09	1.581	2.000	2.750	1.000	1.125	3.294	1.000
General Mean	21.52	128.1	45.13	1.600	1.497	1.493	1.210	1.774	2.430	1.128
Species										
F-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.011
V-ratio	30.60	24.18	80.0	80.0	96.58	85.92	15.01	101.91	101.91	4.56
MS	697.65	13857	9842.4	7.2547	37.4297	43.38	2.8747	281.492	17.355	2.7545
Varieties										
F-values	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
V-ratio	4.71	36.98	21.46	32.46	172.85	58.71	40.40	105.36	11.93	154.97
MS	90.40	6952.5	1427.46	1.6103	7.0925	7.6857	2.3648	45.235	4.6588	3.6551

APPENDIX 5.1 COUNT.

LIGS	COCO	AURCO	PANL	PANTP	SECBR	PANEX	AW	AWCO	APICO	PLCO
1.875	1.000	1.000	22.67	6.000	0.187	3.625	0.0000	0.0000	1.000	1.188
2.000	1.000	1.000	24.31	8.750	0.000	5.000	0.8750	3.0000	7.875	8.625
2.000	1.000	1.000	22.03	5.000	1.563	1.000	1.2500	1.0000	1.000	0.000
1.188	1.000	1.000	25.34	5.000	1.500	1.000	1.3125	1.0000	1.000	0.000
1.188	1.000	1.000	25.45	5.000	1.688	1.000	1.7500	1.0000	1.000	0.000
3.000	1.000	1.000	23.24	9.000	0.750	5.000	0.0625	0.0000	3.813	0.000
3.000	1.000	1.000	23.01	8.500	0.750	5.000	0.0625	0.0625	3.438	0.000
1.250	1.000	1.000	19.59	5.000	1.438	5.000	0.0000	0.0000	1.000	0.000
1.250	1.000	1.000	19.68	5.000	0.625	2.875	0.3125	0.3125	3.000	0.000
1.250	1.000	1.000	25.71	5.000	2.000	2.000	0.0000	0.0000	1.000	0.000
1.125	1.000	1.000	19.89	5.000	1.000	3.000	0.0000	0.0000	1.000	0.500
1.250	1.000	1.000	24.26	5.000	1.938	1.000	0.8750	0.8750	1.000	0.000
1.250	1.000	1.000	24.06	5.000	1.938	1.000	2.3125	0.8750	1.000	0.000
1.250	1.000	1.000	20.97	5.000	2.000	2.875	0.4375	0.6250	1.000	0.000
2.000	1.000	1.000	27.72	5.000	2.938	1.875	9.0000	3.2500	3.000	0.000
2.000	1.000	1.000	23.39	9.000	0.062	5.000	0.1875	0.4375	3.625	2.313
1.250	1.000	1.937	20.56	5.000	1.125	3.125	0.0000	0.0000	3.063	2.688
1.250	1.000	1.750	19.85	5.000	1.063	3.000	0.0625	0.1875	3.063	2.625
1.188	1.000	1.000	20.84	7.000	1.313	3.000	0.0000	0.0000	2.000	1.000
2.000	1.063	1.250	20.86	8.750	0.000	5.000	0.4375	0.3125	2.375	1.750
2.000	1.000	1.250	21.76	9.000	0.000	5.000	0.6875	1.4375	2.875	3.250
1.250	1.000	1.500	18.78	5.000	0.875	5.000	0.0000	0.0000	1.000	0.000
1.125	1.000	1.000	21.04	5.000	1.000	5.000	0.2500	0.3125	1.750	2.500
1.438	1.000	1.000	19.69	5.000	1.000	5.000	0.0625	0.0625	2.625	1.750
1.625	1.000	1.000	19.49	5.000	0.750	4.875	0.0625	0.0625	2.250	1.813
1.813	1.000	1.000	20.12	5.000	1.000	5.000	0.0000	0.0000	2.875	0.250
1.375	1.000	1.000	19.94	5.000	0.938	5.000	0.1250	0.2500	2.000	1.938
1.438	1.000	1.000	19.99	5.000	1.000	5.000	0.1250	0.2500	1.750	1.500
1.438	1.000	1.000	22.86	5.000	1.125	5.000	0.2500	0.2500	1.500	1.000
1.500	1.000	1.000	20.86	5.000	1.063	4.750	0.2500	0.2500	1.500	0.250
2.000	1.000	1.000	24.18	5.000	1.938	1.000	3.5625	0.9375	1.000	0.000
2.000	1.000	1.000	24.25	5.000	2.000	1.000	3.2500	1.0000	1.000	0.000
2.000	1.000	1.000	22.24	5.000	1.000	5.000	0.6875	1.8125	2.625	3.000
2.000	1.000	1.000	23.18	5.000	1.063	5.000	0.0625	0.1250	2.500	3.188
2.000	1.000	1.000	22.36	9.000	0.125	5.000	0.8750	2.6250	7.500	9.000
2.000	1.000	1.000	24.52	9.000	0.062	4.750	0.5625	1.4375	8.250	9.000
2.000	1.000	1.000	18.18	5.000	1.375	3.000	0.0000	0.0000	1.000	0.000
2.000	1.000	1.000	18.28	9.000	1.750	2.875	0.0000	0.0000	2.625	3.500
2.000	1.000	1.000	21.29	5.000	2.000	1.000	0.6875	0.6875	1.000	0.000
2.000	1.000	1.000	17.72	9.000	1.875	3.000	0.0000	0.0000	2.250	2.250
2.000	1.000	1.000	19.83	5.000	0.750	4.750	2.5000	0.6250	2.125	1.750
2.000	1.000	1.000	22.86	5.000	1.188	5.000	0.0625	0.1875	3.000	3.000
2.000	1.000	1.000	20.87	5.000	1.063	4.500	0.1875	0.1875	2.000	1.250
2.000	1.000	1.000	25.48	5.000	1.938	3.500	0.0000	0.0000	1.250	3.063
2.000	1.000	1.000	24.83	5.000	2.000	1.125	2.0625	0.8750	1.000	0.000
2.000	1.000	1.000	23.96	5.000	2.125	1.500	0.8750	0.8750	1.000	0.000
2.000	1.000	1.000	25.76	5.000	2.000	1.000	1.6875	0.9375	1.000	0.000

General											
Mean	1.735	1.001	1.057	22.08	5.894	1.210	3.468	0.8045	0.5984	2.266	1.573
Species											
F-value	0.900	0.542	0.073	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
V-ratio	0.11	0.610	2.620	48.62	71.2	86.45	475.23	27.86	10.72	38.25	96.59
MS	0.0304	0.0008	0.1406	474.16	165.68	44.964	601.36	89.26	9.311	124.69	497.134
Varieties											
F-Values	<.001	0.475	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001
V-ratio	38.56	1.00	34.98	15.34	277.54	50.18	172.5	28.47	36.42	70.97	54.74
MS	3.14255	0.00133	0.578	90.874	41.692	7.629	42.22	36.343	9.7412	47.36	81.749

APPENDIX 5.1 COUNT

	SPF	GRLE	GRW	SECO	MAT	CLE	CDIA	CSTR	CNO	INTCO	FLANG
	74.96	0.9375	0.2750	1.000	150.0	80.5	4.062	3.000	2.188	1.000	2.875
	79.73	0.8169	0.2806	4.000	123.1	97.0	3.500	8.875	2.313	1.000	4.250
	90.12	1.0050	0.2644	1.000	136.4	96.0	4.500	2.250	3.813	1.000	2.500
	87.38	1.0050	0.2769	1.000	136.6	78.0	4.250	3.000	3.375	1.000	4.000
	92.25	1.0044	0.2744	1.000	137.0	100.0	4.500	2.750	3.375	1.000	3.875
	77.64	0.8025	0.2738	4.062	108.7	94.0	3.438	8.875	3.000	1.000	6.750
	76.35	0.7988	0.2744	4.000	108.9	88.0	3.375	8.625	3.250	1.000	6.500
	72.73	0.9525	0.2631	1.000	149.1	92.0	3.563	3.000	3.250	1.000	1.000
	89.18	0.8606	0.3019	1.000	114.3	104.0	3.563	4.125	3.063	3.000	3.000
	94.77	0.8988	0.2875	1.000	130.6	95.0	4.500	3.000	2.313	1.000	2.875
	70.54	0.7869	0.2975	1.000	149.5	110.0	3.750	1.625	3.125	1.000	1.000
	87.26	0.9494	0.2594	1.000	137.3	125.0	4.375	2.750	3.250	1.000	2.875
	91.07	0.9744	0.2675	1.000	136.9	110.0	4.312	1.750	3.938	1.000	3.000
	83.38	1.0425	0.2669	1.000	141.5	125.0	3.625	1.875	4.375	1.000	1.000
	81.57	0.9406	0.3050	1.000	116.2	115.0	4.000	3.000	2.625	1.000	1.000
	85.39	0.7825	0.2925	4.250	121.5	124.0	3.313	8.500	2.938	1.000	3.000
	84.53	0.7925	0.3388	2.063	114.4	147.0	3.625	3.000	3.438	3.000	1.000
	86.08	0.7925	0.3356	4.125	113.2	130.0	3.563	4.375	2.625	3.000	1.000
	75.13	0.6125	0.2606	2.500	125.2	150.0	3.125	6.000	4.813	1.000	2.000
	72.02	0.8062	0.2756	4.625	114.6	136.0	2.750	8.625	3.688	3.000	4.875
	85.84	0.8094	0.2788	4.688	114.6	148.0	2.937	9.000	3.125	3.000	4.375
	90.58	0.6387	0.2762	4.563	127.0	153.0	3.313	2.875	3.438	1.000	1.000
	92.91	0.7656	0.2888	4.125	121.8	145.0	3.125	9.000	2.563	1.000	2.875
	92.13	0.7644	0.2881	4.062	123.4	153.0	3.188	9.000	2.875	1.000	3.000
	90.03	0.7538	0.2888	4.187	123.5	132.0	3.125	9.000	2.750	1.000	2.625
	92.62	0.7262	0.2800	4.000	123.4	127.0	3.250	9.000	3.063	1.000	3.250
	91.29	0.7450	0.2894	4.187	123.3	138.0	3.438	9.000	2.875	1.000	1.625
	89.78	0.7569	0.2838	4.187	123.4	128.0	3.125	9.000	2.625	1.000	1.750
	88.16	0.8263	0.2831	3.750	123.3	122.0	3.313	9.000	3.063	1.000	1.625
	90.53	0.7756	0.2838	4.187	123.4	106.0	3.125	9.000	3.313	1.000	1.875
	94.64	1.0200	0.2750	1.000	137.0	124.0	4.375	2.375	3.313	1.000	2.125
	91.19	1.0156	0.2681	1.000	136.8	117.0	4.812	2.250	2.438	1.000	1.750
	90.52	0.7956	0.2788	4.062	120.0	122.0	3.188	9.000	2.438	1.000	1.250
	92.41	0.8025	0.2780	4.125	119.6	122.0	3.125	9.000	3.063	1.000	1.500
	84.40	0.7900	0.2775	4.000	123.7	104.8	3.250	9.000	3.125	1.000	2.750
	88.56	0.8150	0.2813	4.000	123.4	123.3	3.313	9.000	2.625	1.000	2.500
	74.88	0.7750	0.2919	1.000	96.1	109.0	3.438	1.625	4.750	1.000	4.875
	87.86	0.6263	0.2619	4.000	97.3	106.0	3.438	9.000	2.875	1.000	5.000
	91.79	0.8025	0.3419	4.000	106.0	103.0	3.875	2.750	3.063	1.000	4.250
	88.26	0.5994	0.2563	4.062	97.6	115.0	3.063	9.000	3.438	1.000	5.375
	90.92	0.7838	0.2888	4.000	120.5	126.0	2.938	9.000	3.000	1.000	1.375
	90.81	0.8056	0.2794	4.000	120.0	122.0	3.000	9.000	2.688	1.000	1.375
	93.22	0.8144	0.2806	4.125	120.4	109.0	3.313	9.000	2.875	1.000	2.000
	89.28	0.8419	0.3006	4.188	118.5	120.0	3.750	2.750	2.750	1.000	2.625
	89.58	1.0156	0.2775	1.000	136.9	120.0	4.563	2.500	3.313	1.000	3.000
	89.39	0.9950	0.2781	1.000	137.0	125.0	4.312	2.500	3.375	1.000	3.000
	91.54	1.0144	0.2781	1.000	136.9	109.0	4.563	2.500	3.500	1.000	3.000
General Mean	86.70	0.8391	0.2831	2.854	124.3	104.4	3.616	5.811	3.129	1.213	2.769
Species F-value	0.006	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.0015	<.001
V-ratio	5.09	363.55	43.24	376.69	65.51	27.22	119.81	382.4	9.35	4.21	31.37
MS	594.3	2.6562	0.0161	470.141	10064.1	10224.2	61.823	2035.08	17.43	1.5953	79.66
Mean Varieties F-value	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	<.001	0.00	<.001
V-ratio	9.54	186.86	58.09	215.99	1699.12	4869.01	11.24	243.81	2.99	0.00	64.33
MS	681.35	0.21495	0.0054	37.503	2646.36	10224.2	4.7467	160.168	5.055	6.23	33.9

APPENDIX 5.1 COUNT

CANG	HGW
1.000	2.019
1.000	2.000
1.000	2.063
1.000	2.250
1.000	2.194
1.000	2.025
1.000	2.013
1.000	2.088
1.000	2.338
1.000	2.169
1.000	2.219
1.000	1.919
1.000	1.838
1.000	2.181
1.000	2.369
1.000	2.531
1.000	2.644
1.000	2.813
1.000	1.894
1.000	2.081
1.000	2.019
1.000	2.119
1.000	2.050
1.000	2.125
1.000	2.006
1.000	2.144
1.000	2.256
1.000	2.200
1.000	2.294
1.000	2.256
1.000	2.013
1.000	2.119
1.000	1.994
1.000	2.056
1.000	2.081
1.000	2.131
1.625	2.306
1.000	1.894
1.000	2.981
1.000	1.950
1.000	2.313
1.000	2.150
1.000	2.206
1.000	2.244
1.000	2.175
1.000	2.169
1.000	2.219

General		
Mean	1.013	2.173
Species		
F-ratio	2.62	4.56
V-ratio	0.73	0.011
MS	0.6938	1.0483
Varieties		
F-value	6.48	28.67
V-ratio	<001	<001
MS	0.13298	0.77570

Appendix 5.2.1: ANOVA Table showing the effect of year and species on the varieties evaluated in the 1996 and 1997 cropping season.

Source of variation	degree of freedom	Sum of squares	Means squares	VR	F-Prob
Plt Ht at 2 Wk					
Year	1	1103.39	1103.39	48.40	<.001
Species	2	1395.31	697.65	30.60	<.001
Yr x spec		17005.77	22.80		
Plt at Mat					
Year	1	3574.5	3534.5	6.17	0.013
Species	2	27714.1	13857.0	24.18	<.001
Yr x spec	2	1345.2	672.6	1.17	0.310
Residual	746	427471.2	573.0		
Leaf Length					
Year	1	2890.2	2890.2	23.49	<.001
Species	2	19684.8	9842.4	80.0	<.001
Yr x spec	2	137.4	68.7	0.56	0.572
Residual	746	91782.0	123.0		
Leaf Width					
Year	1	0.2388	0.2388	1.89	0.170
Species	2	14.5095	7.2547	80.0	<.001
Yr x spec	2	0.1688	0.0844	0.67	0.513
Residual	746	94.3030	0.1264		
Leaf Pubescence					
Year	1	0.0054	0.0054	0.01	0.906
Species	2	74.8594	37.4297	96.58	<.001
Yr x spec	2	0.0050	0.0025	0.01	0.994
Residual	746	289.1249	0.3876		
Blade Leaf color					
Year	1	0.7019	0.7019	1.39	0.239
Species	2	86.7635	43.3818	85.92	<.001
Yr x spec	2	1.8596	0.9298	1.84	0.159
Residual	746	376.6418	0.5049		
Leaf sheath color					
Year	1	0.0682	0.0682	0.36	0.551
Species	2	5.7494	2.8747	15.01	<.001
Yr x spec	2	0.1199	0.0600	0.31	0.731
Residual	746	142.8657	0.1915		

APPENDIX 5.2 :COUNT.

Leaf Angle					
Year	1	11.977	11.977	4.34	0.038
Species	2	562.983	281.492	101.91	<.001
Yr x spec	2	133.959	66.979	24.25	<.001
Residual	746	2060.650	2.762		
Ligule length					
Year	1	0.9708	0.9708	1.60	0.206
Species	2	34.7093	17.3546	101.91	<.001
Yr x spec	2	0.2584	0.1292	0.21	0.808
Residual	746	452.3702	0.6064		
Ligule Shape					
Year	1	4.4862	4.4862	15.50	<.001
Species	2	0.0608	0.0304	0.11	0.900
Yr x spec	2	0.0924	0.0462	0.16	0.852
Residual	746	215.7033	0.2891		
Collar Color					
Year	1	0.001344	0.001344	1.01	0.316
Species	2	0.001632	0.000816	0.61	0.542
Yr x spec	2	0.001646	0.000823	0.62	0.539
Residual	746	0.994048	0.001333		
Auricle Color					
Year	1	0.23272	0.23272	4.34	0.038
Species	2	0.28124	0.14062	2.62	0.073
Yr x spec	2	0.03260	0.01630	0.30	0.738
Residual	746	39.99466	0.05361		
Panicle Length					
Year	1	60.345	60.345	6.19	0.013
Species	2	948.328	474.164	48.62	<.001
Yr x spec	2	2.348	1.174	0.120	0.887
Residual	746	7275.842	9.753		
Panicle Type					
Year	1	0.178	0.178	0.08	0.782
Species	2	331.361	165.681	71.20	<.001
Yr x spec	2	19.924	9.962	4.28	0.014
Residual	746	1736.026	2.327		
Secondary Branching					
Year	1	0.6937	0.6937	1.33	0.248
Species	2	89.9272	44.9636	86.45	<.001
Yr x spec	2	2.1694	1.0847	2.09	0.125
Residual	746	388.019	0.5201		

5.2 :COUNT

Panicle Exertion					
Year	1	0.050	0.050	0.04	0.843
Species	2	1202.714	601.357	475.23	<.001
Yr x spec	2	0.476	0.238	1.19	0.828
Residual	746	943.993	1.265		
Awning					
Year	1	0.752	0.752	0.23	0.628
Species	2	178.527	89.264	27.86	<.001
Yr x spec	2	2.649	1.325	0.41	0.662
Residual	746	2390.336	3.204		
Awn Color					
Year	1	5.0471	4.0471	5.81	0.016
Species	2	18.6210	9.3105	10.72	<.001
Yr x spec	2	1.3307	0.6654	0.77	0.465
Residual	746	647.7192	0.8683		
Apiculus Color					
Year	1	1.623	1.623	0.50	0.481
Species	2	249.378	124.689	38.25	<.001
Yr x spec	2	2.107	1.054	0.32	0.724
Residual	746	2431.700	3.260		
Palea & Lemma Color					
Year	1	0.495	0.495	0.10	0.757
Species	2	994.268	497.134	96.59	<.001
Yr x spec	2	1.859	0.930	0.18	0.835
Residual	746	3839.355	5.147		
Spikelet Fertility					
Year	1	11760.0	11760.0	100.64	<.001
Species	2	1188.6	594.3	5.09	0.006
Yr x spec	2	2253.3	1126.6	9.64	<.001
Residual	746	87172.1	116.9		
Grain Length					
Year	1	0.032142	0.32142	4.40	0.036
Species	2	5.312406	2.656203	363.55	<.001
Yr x spec	2	0.003318	0.001659	0.23	0.797
Residual	746	5.450483	0.007306		
Grain Width					
Year	1	0.0004105	0.0004105	1.09	0.297
Species	2	0.0326221	0.016111	43.24	<.001
Yr x spec	2	0.0008436	0.0004218	1.12	0.327
Residual	746	0.2813208	0.0003772		

APPENDIX 5.2 :COUNT

Seed Coat Color					
Year	1	0.403	0.403	0.32	0.570
Species	2	940.281	470.141	376.69	<.001
Yr x spec	2	10.157	5.079	4.07	0.017
Residual	746	931.068	1.248		
Maturity					
Year	1	695.2	695.2	4.52	0.034
Species	2	20092.3	10046.1	65.51	<.001
Yr x spec	2	3172.6	1586.3	10.34	<.001
Residual	746	114404.9	153.4		
Culm Length					
Year	1	895.2	895.2	2.38	0.123
Species	2	20448.5	10224.2	27.22	<.001
Yr x spec	2	3093.6	1546.8	4.12	0.017
Residual	746	280194.1	375.6		
Culm Diameter					
Year	1	0.1747	0.1747	0.34	0.561
Species	2	123.6450	61.8225	119.81	<.001
Yr x spec	2	3.1678	1.5839	3.07	0.047
Residual	74 6	384.9448	0.5160		
Culm Strength					
Year	1	0.847	0.847	0.16	0.690
Species	2	4070.167	2035.083	382.40	<.001
Yr x spec	2	44.059	22.030	4.14	0.016
Residual	746	3970.167	5.322		
Culm Number					
Year	1	98.036	98.036	52.57	<.001
Species	2	34.855	17.427	9.35	<.001
Yr x spec	2	8.469	4.235	2.27	0.104
Residual	746	1391.128	1.865		
Internode Color					
Year	1	0.0010	0.0010	0.00	0.960
Species	2	3.1907	1.5953	4.21	0.0015
Yr x spec	2	0.0005	0.0003	0.00	0.999
Residual	746	282.7653	0.3790		
Flag Leaf Angle					
Year	1	3.449	3.449	1.36	0.244
Species	2	159.317	79.658	31.37	<.001
Yr x spec	2	42.443	21.221	8.36	<.001
Residual	746	1894.531	2.540		

APPENDIX 5.2 :COUNT

Culm Angle					
Year	1	0.00504	0.00504	0.19	0.662
Species	2	0.13875	0.6938	2.62	0.073
Yr x spec	2	0.00525	0.00263	0.10	0.905
Residual	746	19.71797	0.02643		
100 Grain Weight					
Year	1	0.03722	0.03722	0.56	0.454
Species	2	5.50907	2.75453	41.58	<.001
Yr x spec	2	0.02642	0.01321	0.20	0.819
Residual	746	49.42299	0.06625		
Ligule Color					
Year	1	0.8640	0.8640	3.76	0.053
Species	2	2.0965	1.0483	4.56	0.011
Yr x spec	2	1.3821	0.6910	3.01	0.050
Residual	746	171.4021	0.2298		

Appendix 5.2.2: ANOVA Table showing the effect of year and variety on the varieties evaluated in the 1996 and 1997 cropping season.

Source of variation	degree of freedom	Sum of squares	Means squares	VR	F-Prob
Plt Ht at 2 Wk					
Year	1	1103.39	1103.39	57.45	<.001
Variety	46	4158.18	90.40	4.71	<.001
Yr x Var	46	1619.34	35.20	1.83	<.001
Residual	658	12637.22	19.21		
Plt at Mat					
Year	1	3534.5	3534.5	18.8	<.001
Variety	46	319814.0	6952.5	36.98	<.001
Yr x Var	46	13017.9	283.0	1.51	0.019
Residual	658	123698.6	188.0		
Leaf Length					
Year	1	2890.21	2890.21	43.46	<.001
Variety	46	65663.19	1427.46	21.46	<.001
Yr x Var	46	2179.51	47.38	0.71	0.924
Residual	658	43761.48	66.51		
Leaf W idth					
Year	1	0.23878	0.23878	4.81	0.170
Variety	46	74.07442	1.61031	32.46	<.001
Yr x Var	46	2.26354	0.04921	0.99	0.490
Residual	658	32.64325	0.04961		
Leaf Pubescence					
Year	1	0.00538	0.00538	0.13	0.717
Variety	46	326.25532	7.09251	172.85	<.001
Yr x Var	46	10.73398	0.23335	5.69	<.001
Residual	658	27.0000	04103		
Blade Leaf color					
Year	1	0.7019	0.7019	5.36	0.021
Variety	46	353.5418	7.6857	58.71	<.001
Yr x Var	46	25.5843	0.5362	4.25	0.159
Residual	658	86.1389	0.1309		
Leaf sheath color					
Year	1	0.06817	0.06817	1.16	0.281
Variety	46	108.77877	2.36476	40.40	<.001
Yr x Var	46	1.44236	0.3136	0.3136	0.995
Residual	658	3851389	0.05853		
Leaf Angle					
Year	1	11.9775	11.9775	27.90	<.001
Variety	46	2080.8123	45.2351	105.36	<.001
Yr x Var	46	394.2634	8.5709	19.96	<.001
Residual	658	282.5159	0.4294		
Ligule length					
Year	1	0.9708	0.9708	2.49	0.115
Variety	46	214.3061	4.6588	11.93	<.001

APPENDIX 5.2.2 :COUNT

Yr x Var	46	15.9937	0.3477	0.89	0.680
Residual	658	257.0381	0.3906		

Ligule Shape

Year	1	4.48256	4.48256	55.00	<.001
Variety	46	144.55717	3.14255	38.56	<.001
Yr x Var	46	17.67437	0.38423	4.71	<.001
Residual	658	53.6250	0.08150		

Collar Color

Year	1	0.001344	0.001344	1.01	0.315
Variety	46	0.061157	0.001329	1.00	0.475
Yr x Var	46	0.061169	0.001330	1.00	0.475
Residual	658	0.875000	0.001330		

Auricle Color

Year	1	0.23272	0.23272	14.08	<.00
Variety	46	26.59528	0.57817	34.98	<.001
Yr x Var	46	2.83768	0.6169	3.73	<.001
Residual	658	1087500	0.01653		

Panicle Length ******

Year	1	60.345	60.345	1.19	<.001
Variety	46	4180.216	90.874	15.34	<.001
Yr x Var	46	148.888	3.237	0.55	0.994
Residual	658	3897.413	3.237		

Panicle Type

Year	1	0.1782	0.1782	1.19	0.277
Variety	46	1917.8412	41.6922	277.51	<.001
Yr x Var	46	70.6129	1.5351	10.22	<.001
Residual	658	98.8571	0.102		

Secondary Branching

Year	1	0.6937	0.6937	4.56	0.033
Variety	46	350.9383	7.6291	50.18	<.001
Yr x Var	46	29.1354	0.6334	4.17	<.001
Residual	658	100.0357	0.1520		

Panicle Exertion

Year	1	0.0499	0.0499	0.20	0.652
Variety	46	1942.2035	42.2218	172.50	<.001
Yr x Var	46	43.9251	0.9549	3.90	<.001
Residual	658	161.0556	0.2448		

Awning

Year	1	0.752	0.752	0.59	0.44
Variety	46	1671.773	36.343	28.47	<.001
Yr x Var	46	59.850	1.301	1.02	0.440
Residual	658	839.889	1.276		

Awn Color

Year	1	5.0471	4.0471	18.87	<.001
Variety	46	448.0930	9.7412	36.42	<.001
Yr x Var	46	43.5640	0.9470	3.54	<.001
Residual	658	176.0139	0.2675		

APPENDIX 5.2.2 :COUNT

Apiculus Color					
Year	1	1.6231	1.6231	2.43	0.119
Variety	46	2178.5251	47.3592	70.97	<.001
Yr x Var	46	65.5512	1.4250	2.14	<.001
Residual	658	439.1091	0.6673		
Palea & Lemma Color					
Year	1	0.495	0.495	0.33	0.565
Variety	46	3760.452	81.749	54.74	<.001
Yr x Var	46	92.299	2.006	1.34	0.068
Residual	658	982.732	1.494		
Spikelet Fertility					
Year	1	11759.97	11759.97	100.64	<.001
Variety	46	31342.12	681.35	9.54	<.001
Yr x Var	46	12296.57	267.34	3.74	<.001
Residual	658	46974.33	71.39		
Grain Length					
Year	1	0.032142	0.32142	27.94	<.001
Variety	46	9.887499	0.214946	186.86	<.001
Yr x Var	46	0.121820	0.002648	2.30	<.001
Residual	658	0.756888	0.001150		
Grain Width					
Year	1	0.00041053	0.00041053	4.44	0.036
Variety	46	0.02472959	0.00537600	58.09	<.001
Yr x Var	46	0.00665607	0.00014470	1.56	0.012
Residual	658	658.060895	0.00009255		
Seed Coat Color					
Year	1	0.4033	0.4033	2.32	0.128
Variety	46	1725.1222	37.5027	215.99	<.001
Yr x Var	46	42.1341	0.9160	5.28	<.001
Residual	658	114.2500	0.1726		
Maturity					
Year	1	695.179	695.179	446.35	<.001
Variety	46	121732.763	2646.364	1699.12	<.001
Yr x Var	46	14912.207	324.178	208.14	<.001
Residual	658	1024.829	153.4		
Culm Length					
Year	1	895.15	895.15	9.68	0.002
Variety	46	223974.49	10224.2	4869.01	<.001
Yr x Var	46	18893.49	410.73	4.44	<.001
Residual	658	60868/.21	92.500		
Culm Diameter					
Year	1	0.1747	0.1747	0.41	0.520
Variety	46	218.3469	4.7467	11.24	<.001
Yr x spec	46	15.6116	0.3394	0.80	0.821
Residual	658	277.8016	0.4222		
Culm Strength					
Year	1	0.8475	0.8475	01.29	0.256

APPENDIX 5.2.2 :COUNT

Variety	46	7367.7428	160.1683	243.81	<.001
Yr x Var	46	284.3261	6.1810	9.41	<.001
Residual	658	432.2698	6.1810		
Culm Number					
Year	1	98.036	98.036	58.01	<.001
Variety	46	232.546	5.055	2.99	<.001
Yr x Var	46	89.833	1.953	1.16	0.228
Residual	658	1112.073	1.690		
Internode Color					
Year	1	0.00096	0.00096	0.00	0.00
Variety	46	285.95552	6.21642	0.00	0.00
Yr x Var	46	0.00096	0.00002	0.00	0.00
Residual	658	0.00000	0.0000		
Flag Leaf Angle					
Year	1	3.4488	3.4488	6.53	0.011
Variety	46	1562.3763	33.9647	64.33	<.001
Yr x Var	46	186.5254	4.0549	7.68	<.001
Residual	658	347.3889	0.05279		
Culm Angle					
Year	1	0.00504	0.00504	0.25	0.620
Var	46	6.11730	0.13298	6.48	<.001
Yr x Var	46	0.24468	0.00532	0.26	1.00
Residual	658	13.5000	0.02052		
100 Grain Weight					
Year	1	0.03722	0.03722	1.38	0.241
Variety	46	35.68211	0.77570	28.67	<.001
Yr x Var	46	1.47265	0.03201	1.18	0.195
Residual	658	17.80371	0.02706		
Ligule Color					
Year	1	0.8640	0.8640	43.83	<.001
Variety	46	140.53621	3.65514	154.97	<.001
Yr x Var	46	21.3725	0.46461	23.57	<.001
Residual	658	12.97222	0.01971		

Appendix 7.1: Mean Values, Grand Mean, SS, V-Ratio and F-Probability 100% Flowering and Flowering duration of local germplasm evaluated in the 1996 and 1997 growing season.

Name of varieties	HPF	OPF ATP	FPF ATP	HPF ATP	HPF OT	HPF ATP	OPF ATV	FPF ATV	HPF ATV	HPF VW	TNT/ plt
Keblek	121.6	2,7	2,3	2,0	3,5	5,6	9,8	9,0	9,8	12,8	2.1
Black Sallay	96.1	2,1	2,0	1,9	3.8	5,4	5,5	5,3	5,5	8,8	2.0
Bayiba	108.7	3,1	2,9	2,6	3,9	6,6	9,5	9,5	9,5	13,8	3.2
Joe Wanjei	111.6	3,9	4,1	4,1	4,0	7,8	11,0	11,5	11,0	14,8	3.4
Ngo Yumboi	110.7	2,8	2,6	2,6	3,8	6,1	8,0	7,8	8,0	10,8	2.9
Damba	84.6	2,3	2,3	1,9	3,3	5,2	10,5	10,0	10,5	14,0	2.9
Pa Damba	85.1	2,1	2,1	1,8	3,5	4,9	7,5	7,8	7,5	11,8	2.4
K. Kindeh	120.4	3,0	2,9	2,6	3,3	6,1	7,5	7,5	7,5	7,5	1.9
Bensali	91.6	3,1	2,9	2,7	3,0	5,0	8,3	8,0	8,3	11,5	2.6
Nylon	105.0	2,6	2,6	2,3	4,1	5,9	7,0	6,3	7,0	11,5	2.1
Thabunsu	123.8	2,7	2,5	1,9	3,7	5,6	8,0	7,8	8,0	10,8	2.6
Sumaila	113.4	2,3	2,1	1,9	3,9	5,8	8,5	7,3	8,5	12,0	2.8
Isatu	116.1	3,3	3,2	2,9	4,0	6,7	8,5	8,5	8,5	8,5	2.1
ROK 5	118.4	3,8	3,7	3,4	3,6	6,9	8,8	8,8	8,8	8,8	2.2
ROK 16	89.4	3,1	2,6	2,6	4,3	6,4	9,3	9,3	9,3	9,3	2.3
Janet	93.3	2,7	2,4	2,1	3,8	5,6	8,5	8,5	8,5	8,5	2.1
N. Bomb. W	86.9	3,2	3,1	2,4	3,6	6,3	7,5	7,5	7,5	7,5	1.9
N. Bomb. R	86.1	2,1	2,0	1,8	3,1	4,8	6,3	6.3	6,3	6,3	1.6
Pa 3 Month 1	82.4	5,6	5,1	5,0	3,3	8,1	12,0	12,0	12,0	12,0	3.0
Salifaigai 1	87.6	4,1	3,9	3,9	3,3	6,8	11,8	11,8	11,8	11,8	2.9
Salifaigai 2	85.2	2,5	2,6	2,2	3,2	5,0	8,3	8,3	8,3	8,3	2.1
Sorie Kunde	102.4	3,1	2,9	2,4	3,3	5,8	10,5	10,5	10,5	10,5	2.6
Disi Kunde	97.0	2,6	2,2	2,1	3,4	5,4	8,3	8,3	8,3	8,3	2.1
Pa Temne 1	98.3	2,9	2,9	2,4	3,0	5,3	9,3	9,3	9,3	9,3	2.3
Pa Temne 2	97.8	3,3	3,1	2,8	3,2	5,8	8,5	8,5	8,5	8,5	2.1
Disi Temne	97.2	3,5	3,4	2,9	3,0	5,9	8,0	8,0	8,0	8,0	2.0
Dissi Forie 1	97.1	2,9	2,7	2,1	3,6	5,6	7,5	7,5	7,5	7,5	1.9
Dissi Forie 2	96.8	2,4	2,3	1,9	2,9	4,8	7,5	7,5	7,5	7,5	1.9
Dissi Forie 3	97.3	2,3	2,1	1,6	3,1	4,9	8,8	8,8	8,8	8,8	2.2
Dissi Forie 4	97.8	2,9	2,6	2,3	3,3	5,6	9,5	9,5	9,5	9,5	2.4
ROK 3 1	112.6	5,6	5,6	4,9	4,0	9,0	9,5	9,5	9,5	9,5	2.4
ROK 3 2	110.7	2,5	2,5	2,1	4,0	6,8	9,3	9,3	9,3	9,3	2.3
Pa Dissi Temne	94.6	2,7	2,4	2,2	3,1	5,2	6,8	6,8	6,8	6,8	1.7
Disi Kono	93.8	3,2	3,0	2,7	3,4	6,0	7,75	7,8	7,8	7,8	1.9
Saliforeh 1	97.9	4,0	4,1	3,6	3,8	7,1	10,0	10,0	10,0	10,0	2.5
Saliforeh 2	97.6	2,3	2,4	1,8	3,6	5,8	7,3	7,3	7,3	7,3	1.8
No Name	71.1	6,3	6,0	5,6	3,1	9,3	10,8	10,8	10,8	10,8	2.7
Pa 3 month 2	70.9	5,5	5,3	5,2	3,3	8,3	11,8	11,8	11,8	11,8	2.9
Pa Bop	74.6	3,3	3,1	2,8	3,1	5,7	10,3	10,3	10,3	10,3	2.6
Pa 3 month 3	71.6	5,1	4,4	4,1	3,1	6,1	10,8	10,8	10,8	10,8	2.7
Disi Temne	94.9	3,4	3,1	2,9	3,4	6,1	8,0	8,0	8,0	8,0	2.0
Dissi Kono1	95.2	2,1	2,0	1,6	3,0	4,7	5,3	5,3	5,3	5,3	1.3
Disi Kono2	95.7	3,5	3,1	2,7	3,3	5,8	10,5	10,5	10,5	10,5	2.5
Pa Konkon	91.5	2,8	2,4	2,1	3,4	5,4	6,0	6,0	6,0	6,0	1.5
Samba Konkon1	1106	3,4	3,1	2,8	4,0	6,7	8,8	8,8	8,8	8,8	2.2
Samba Konkon2	113.1	3,6	3,4	2,9	4,0	7,2	8,5	8,5	8,5	8,5	2.1
Samba Konkon3	113.1	3,8	3,6	3,1	4,0	7,1	9,5	9,5	9,5	9,5	2.4

Note on Appendix 7.1
100%F: duration per variety of 100% flowering from seeding.
1%P: duration per plant of 1% flowering.
50%P: duration per plant of 50% flowering.
100%P: duration per plant of 100% flowering.
100%T: duration per tiller of 100% flowering.
1-100%TP: duration of all tillers per plant of 100% flowering.
1%V: duration per variety of 1% flowering
50%V: duration per variety of 50% flowering
100%V: duration per variety of 100% flowering
1-100%T: duration per tiller of 1% to 100% flowering
1-100%P: duration per plant of 1% to 100% flowering
1-100%WV: duration

REFERENCES.

Adam, J. M. (1985). *Assessment of technology for mangrove swamp rice in West Africa: Case studies from the Great Scarcies area of Sierra Leone*. Unpublished Ph. D. Thesis. (R3832, ESR 538/190/01).Wye Colledge, University of London

Ashby, J. A.; Gracia, T., del Pilar Guerrero, M., Quiros, C. A., Roa, J. I. and Beltran, J. A. (1995). "Innovation in the organization of participatory plant breeding" In Eyzaguirre, P. and Iwanaga, M. (eds.), *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding*. 26-29 July 1995, Wageningen, The Netherlands. IPGRI: Rome. pp 77-97.

Assemat, L. and Oka, H. I. (1980). "Neighbor effect between rice and barnyard grass strain. I. Aggressiveness and resistance to aggression as influenced by planting density". *Ecologica Plantarum* 15: 371 - 394.

Balandier, G. (1948). "Economy of the Kakossa, Kabak and Matakong Islands (Lower Guinea)." *Farm and Forest,* January to June, 1948.

Bellagio Apomixis Declaration (1998). "Designing a research Strategy for Achieving Asexual Seed Production in Cereals".A conference held at the Rockefeller Foundation's Conference and Study Center (Italy) from the 27th April-May 1st, 1998.

Berg T. (1995). "Farmer management of crop diversity. The compatibility of grassroots breeding and modern farming. In Sperling, L. and Loevinsohn, M. (eds). Using diversity: Enhancing and Maintaining Genetic Resources On-farm . Proceedings of a workshop held 19-20 June, 1995, New Delhi. International Development Research Centre. New Delhi, India, pp. 87–101.

Berlin, B. (1992). *Ethnobiological classification: Principles and categorization of plants and animals in traditional societies*. Princeton: Princeton University Press.

Biggs S. D. (1989). "Resource-poor farmers' participation in research: a synthesis of experiences from nine national agricultural research systems". *OFCOR. Co-operative Study Paper no. 3,* ISNAR, The Hague, The Netherlands.

Birchall, C. J., Gordon, O.L.A., Lamin, A.S., and Alkire, W.K. (1980). *Land esources Survey Project FAO/UNDP-MANR,* Miscellaneous Report. SL/73/002, (July, 1980), Freetown, Sierra Leone.

Bonman, J. M., Estrada, B. A.; and Denton, R. J. (1986). "Blast management with upland rice cultivar mixture." In proceedings of the 1985 Jakarta conference. *Progress in upland rice research* . pp 375 - 382. Los Banos, Philippines, IRRI.

Bray, F. (1986). *The Rice economies.* Blackwell: Oxford.

Brunken, J., de Wet, J. M. J. and Harlan J. R. (1977). "The morphology and domestication of pearl millet". *Econ. Bot.* 31:163-174.

Brush, S. B. (1995). "In situ conservation of landraces in centers of crop diversity". *Crop Science* 35: 346 - 354.

Brush, S. B., Taylor, J. E. and Bellon, M. (1992). "Technology adoption and biological diversity in Andean potato agriculture". *Journal of Developmental Economics* 39: 365-387.

Carpenter A. J. (1978). "Rice in history". In Buddenhagen, I. W. and Persley, G. J. (eds). *Rice in Africa*. London U K, Academic Press.

Cartwright, J. R. (1978). *Political leadership in Sierra Leone*. London: Croom Helm.

Ceccarelli, S.. Grando, S. and Booth, R. H. (1996). "International breeding programs and resource-poor farmers: Crop improvement in difficult environments". In Eyzaguire, P. and Iwanaga M. (eds.), *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding.* (26 - 29 July 1995, Wageningen, The Netherlands. IPGRI: Rome Pp. 66-76.

Chambers R. (1989). "Reversals, Institutions and Changes". In Chambers, R., Pacey, and Thrupp, L. A. (eds). *Farmer First.* London: Intermediate Technology.

Chang, T.T. (1975). "Exploration and survey of rice". In Frankel, O.H and Hawkes G. (eds). *Crop genetic resources for today and tomorrow.* , Cambridge university Press,Cambridge. pp 159-165.

Chang, T. T. (1976)."The origin, evolution, cultivation, dissemination and diversity of Asian and African rices". *Euphytica* 25:435-444.

Chang T.T. (1976). "The Rice Cultivars". *The early history of agriculture*. London: The Royal Society.

Clawson, D. L. (1985). "Harvest security and intra-specific diversity in traditional tropical agriculture". *Economic Botany* 39: 56 - 67.

Conklin, H. C. (1957). *Hanunoo agriculture: Report on an integrated system of shifting cultivation in the Philippines*. FAO Forestry Development Paper No.12 pp 9-209, Rome.

Dennis, J. V. (1989). *Farmers management of rice varieties in Northern Thailand.* Unpublished Ph.D. Thesis, Cornell University. (Ann Arbor: University Microfilms.)

Dewey, D. R. and Lu, K. H. (1995). "Acceleration and path coefficient analysis of component wheat grass seed production". *Agronomy Journal* 51: 515 - 518.

de Wet, J. M. J. (1975). "Evolutionary dynamics of cereal domestication". *Bull. Torr. Bot. Club* 102.

de Wet C. T. (1960). "On competition". *Verslagen van Landbouwkundige Ondersoekingen*, 66 (8), 1 - 82.

Dingkuhn, M., Jones, M. P., Fofana, B. and. Sow, A. (1997). "New high yielding weed competitive rice plant types drawing from *O. sativa* and *O. glaberrima* gene pools". In Kropff, M. J., Teng, P. S., Aggarwal, P. K, Bouma, J., Bouman, B. A. M., Jones, J. W., van Laar, H. H. (eds), *Application of Systems Approaches at the Field Level,* Vol. 2. Kluwer Academic Publishers, Doordrecht, The Netherlands, pp. 37 - 52.

Doebley, J. Goodman, M. M. and Stuber, C. W. (1987). "Patterns of isozyme variation between maize and the Mexican annual Teseosine". *Econ. Bot* 41 (2): 234-246.

Donald, C. M. (1958). "The interaction of competition for light and nutrients." *Australian Journal of Agricultural Research,* 9: 421 - 432.

Doggett, H. and. Majisu B. N. (1968). "Disruptive selection in crop development". *Heredity,* 23:1-23.

Douglas, M. 1987. *How institutions think* Routledge: London.

Dove, M. R. (1985). *Swidden agriculture in Indonesia: The subsistence strategy of the Kalimantan Kantu:* New Babylon, Berlin: Mouton Publishers.

Evans, L. T. (1993). *Crop Evolution, Adaptation and Yield.* Cambridge University Press: Cambridge.

Eyzaguirre P. and Iwanaga, M. (1996). "Farmers' contribution to maintaining genetic diversity in crops,and its role within the total genetic resources system". In Eyzaguirre, P. and Iwanaga, M. (eds.), *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding*. 26 - 29 July 1995, Wageningen, The Netherlands. IPGRI: Rome.

Federer, W. T., Connigale, J. C., Rutger, J. N. and Wijesinda, A. (1982). "Statistical analysis of yield from uniblends and biblends of eight dry bean cultivars." *Crop Science* 22: 111 - 115.

Fernandez., P. G. (1999) "Indigenous seed practices for sustainable agriculture". *Biotechnology Monitor* 2 (2).

Finlay, K. W., and Wilkinson, G. N. (1963). "The analysis of adaptation in a plant breeding program". *Australian Journal of Agricultural Research,* 14: 742 - 754.

Finnegan, R. H. (1965). *Survey of the Limba people of northern Sierra Leone*. London: HM Stationary Office.

Fisher, K. S. and Palmer, A. F. E. (1991). "Maize". In Smith, W. H. and Banata S. J. (eds). *Symposium on Potential productivity of field crops under different environments.* IRRI, Los Banos, Philippines., pp 155 - 180.

Firbank, L.G.; and Watkinson, A. R. (1985). "On the analysis of competition within two-species mixtures of plants." *Journal of Applied Ecology* 22, 503-517.

Francis, C.A. (1986). *Multiple cropping systems.* New York, Macmillian.

Frey, J., Browing, J. A., and Grindeland, R. L. (1971a). "Registration of multiline E68, multiline E69, multiline E70 oat cultivars". *Crop Science* 11: 939.

Frey,K. J., Browing, J. A., Grindeland, R. L. (1971b). "Registration of multiline M68, multiline M69, multiline M70 oat cultivars". *Crop Science* 11: 940.

Friis-Hansen, E. (1989). 'Village-base seed production." *ILEIA* 4:26-27.

Friis-Hansen, E. (1996). "The role of local plant genetic resource management in participatory plant breeding." In Eyzaguirre, P. and Iwanaga, M. (eds.), *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding.* 26 - 29 July 1995, Wageningen, The Netherlands. IPGRI: Rome.

Gamble D. P. (1967). "Traditional Temne beliefs and the introduction of new rice varieties" (Mimeo: Rice Research Station, Rokupr).

GRAIN (1990). "Building on farmers' knowledge" *Seedling* 7(4) 9.

Glanville, R. R. (1933). *Sierra Leone: rice cultivation. Report on a visit to Ceylon and South India with proposal for Sierra Leone.* Freetown: Government Printer.

Glanville, R. R. (1938). "Rice production on swamps." *Sierra Leone Agricultural Notes* no. 7 (mimeo.).

Green Revolution Working Paper (1986). Document number 2. Rice. Ministry of Agriculture and Natural Resources. Freetown , Sierra Leone.

Grist, D. H. (1983). *Rice.* (Fifth edition), Longman, London.

Haverkort, B., van de Kamp, J. and Waters-Bayer, A. (1991). *Joining Farmers' Experiments: Experiences in Participatory Technology Development.* London: IT Publications.

Hardon, J.J. and de Boef, W.S. (1993) "Linking farmers and breeders in local crop development". In *cultivating knowledge, genetic diversity, farmers' experimentation and crop research.* Walter de Boef, Kojo Amanor and Kate Wellard (eds), London: IT Publications.

Harlan, J. R. (1965). "The possible role of weed races in the evolution of cultivated plants". *Euphytica* 14: 173-176.

Harlan, J. R. (1992). *Crops and man*. Madison. Crop Science Society of America.

Haverkort, B. (1991). "Farmers' Experimentation and Participatory Technology Development." In *Joining Farmers' Experiments*. Haverkort B., van de Kamp, B. J. and Waters-Bayer, A. (eds.) London: IT Publications.

Hesse, P. R. (1963). "Phosphorus relationships in a mangrove swamp mud with particular reference to aluminum toxicity". *Plant and Soil*. 19 (2), pp 205 - 218.

Hoque, T. (1974) "Iron toxicity in Sierra Leone", *IRRI newsletter* 2, 1.

Howard, A. M. (1972). *Big men, traders, and chiefs: power, commerce, and spatial changes in the Sierra Leone-Guinea plain 1865 - 1895*. Unpublished Ph.D Thesis, University of Wisconsin. Madison.

IRRI (1976). *Annual Report for 1975*. International Rice Research Institute, Manila, Philippines.

IRRI (1977). *Annual Report for 1976*. International Rice Research Institute, Manila, Philippines.

IRRI-SES (1996). *International Center For Genetic Evaluation of Rice (INGER)* Genetic Resource Center, IRRI. P.O Box 933, 1099 Manila, Philippines.

Jacquot, M. (1977). "IRAT and rice genetic resources." Paper presented at *Rice genetic conservation workshop*. IRRI/IBPGR, December 1977 (Unpublished).

Jennings, P. R. and Herrera, R. M. (1968). "Studies on competition in rice I. Competition in mixtures of varieties." *Evolution* 22:119 - 124.

Jennings, P. R. and de Jesus Jr., J. (1968). "Studies on competition in rice II. Competition in segregating populations." *Evolution* 22 : 332 - 336.

Jennings , P. R., Coffman, W. R., and Kauffman, H. E. (1979). *Rice improvement*. IRRI. Los Banos, Philippines.

Jensen, N. F. (1988). *Plant Breeding Methodology*. New York: John Wiley and Sons.

Jollifee, P. A.; Minjas, A. N. and Runeckle,V. C (1984). "A reinterpretation of yield relationship a in replacement series experiments." *Journal of Applied Ecology* 21: 227 - 243.

Jones, M. P., Dingkuhn, M., Aluko, G. K., Mande, S. (1997). "Interspecific *Oryza sativa L. x O. glaberrima* Steud. progenies in upland rice improvement." *Euphytica* 92: 237-246.

Jones M. P., Dingkuhn, M., Aluko G. K. and Semon M. (1997). "Using Backcrossing and Doubled Haploid Breeding to Generate Weed Competitive Rices from *O. sativa* L. x *O. glaberrima* Steud. genepool." In *Interspecific Hybridization: Progress and Prospects. Proceedings of the Workshop: Africa / Asia Joint Research on Interspecific Hybridization between the African and Asian Rice Species (O. sativa and O. glaberrima)*. WARDA, Bouake, Cote d' Ivoire.

Jusu, M. S. and Monde, S. S. (1990). "Panicle and grain characteristics of some *O. glaberrima* cultivars in Sierra Leone." *IRRI News letter* 15 (3).

Kamara, A., Defoer, T., and De Groote, H. (1996). "Selection of new varieties through participatory research. The case of corn in south Mali." *Tropicultura* 14 (3), 100 - 105.

Knauft, D. A., and Gorbet, D. W (1991). "Agronomic performance and genetic shift of genotype mixtures of peanut." *Euphytica* 52: 85 - 90.

Koffi, G. (1980). "Collection and conservation of existing rice species and varieties of Africa." *Agronomie Tropicale* 34:228 - 237.

Khush, G. S. (1997). "Origin, dispersal, cultivation and variation of rice. " *Plant Breeding, and Biochemistry Division, IRRI*, P.O. Box 933, Manila, Philippine.

Ladizinsky, G. (1985). "Founder effect in crop-plant evolution." *Econ. Bot.* 39: 191-199.

Langvin, S A., Clay, K., and Grace, J. M. (1990). " The incidence and effect of hybridization between cultivated rice and its related weed red rice (*Oryza sativa* L.)". *Evolution,* 44(4), pp 1000-1008.

Lin, C. S., and Binns, M. R. (1991). "Genetic properties of four types of stability parameters". *Theoretical and Applied Genetics* 82: 505 - 509.

Lipton, M. Pain, A. and Richards, P. (1995) *Rice research in Sierra Leone and Sri Lanka: Policy, spread, impact* (unpublished typescript).

Littlefield, D. L (1981). *Rice and Slaves: Ethnicity and the Slave Trade in Colonial South Carolina.* Louisiana State University Press: Baton Rouge.

Longley, C. A. (1999). *A social life of seeds: Local management of crop variability in north-west Sierra Leone*, Unpublished Ph.D Thesis, Department of Anthropology, University College London.

Longley C. A. (1995). "Local seed management and crop improvement among the Susus of West Africa. Preliminary report, " Unpublished, Ph. D Thesis Research proposal, Anthropology Dept. University College London.

Mackie, R. B., Dawe M. T. and Loxley, C. F. (1927). *Report of the rice commission on its inquiry into the position of the rice industry*. Sessional Paper no. 7 of 1927. Freetown: Government Printer.

Maji; A. T., and Singh, B. N. (1993). "Drought tolerance in African Rice *Oryza glaberrima* Steud." (Abstract). 121. In *Proceedings of the Seventeenth International Congress of Genetics* 15-21. August (1993). Birmingham, U.K.

M.A.N.R. (1994). *Ministry of Agriculture and Natural Resources, Sierra Leone. Expanded Rice Program. Direct Government Intervention in Production and Marketing of Rice*. Freetown, Sierra Leone, 1994.

Migeod, F. W. H. (1926). *A view of Sierra Leone*, London: Kegan Paul, Trench, Trubner.

Mezien, K. and Ghesquiere, A. (1985). "Genetic structure of African traditional rice cultivars". *In Rice Genetics*: *Proceedings of IRRI Rice Genetics symposium,* 21-31 May, 1985. pp 91-107.

Monde, S. S., Bagie, I. and Jusu, M. S. (1991). "Rice genotypes with tolerance for low available phosphorus in Sierra Leone". *IRRI Newsletter* 16 (3).

Monde, S. S. and Richards, P. (1992.) "Rice biodiversity conservation and plant improvement in Sierra Leone." In Putter, A. (ed), *Safeguarding the genetic basis of Africa's traditional crops*. Proceedings of the CTA/IBPGR/KARI/UNEP seminar, Nairobi, October 1992, pp. 83-100. CTA, Wageningen & IPGRI, Rome, 1994.

Monde, S. S., Jusu, M. S., and Longley, C. A. (1997). *Annual Report of the Community Biodiversity Development and Conservation (CBDC),1997. Sierra Leone Project.* Rokupr, Sierra Leone (Mimeo).

Moore-Sieray, D. (1988). *Pre-colonial history of Tonko and its neighbor s: a study in the nature of Soso-Limba relations in the 19th century.* Unpublished M. A. Thesis, University of Sierra Leone.

Morden, C., Doebley, W. J., and. Schertz, K. F. (1987). *A manual of techniques for starch-gel electrophoresis of sorghum isozymes*. Texas A&M University, College Station.

Mumaw, C. R., and Weber, C. R. (1957). "Competition and natural selection in soybean variety mixtures". *Agronomy Journal* 49: pp. 154–160.

Ng, N.Q., Chang, T.T., Vaughan, D. Zuno, C. and Altoveros, P. (1988). "African rice diversity, conservation and prospects for improvement". In Proceedings of an International

Conference on crop genetic resources of Africa, IITA, Ibadan, Nigeria 17th - 20th October 1988.

Odell, R. T., Dijkerman, J. C., van Vuur, W., Melsted, S. W., Beaver, A. H., Sutton, P. M., Kurtz, L. T. and Miedema, R. (1974). *Characteristics, classification and adaptation of soils in selected areas in Sierra Leone, West Africa.* Njala University College, University of Sierra Leone and the University of Illinois Bulls. 4 and 748 respectively.

Oka, H. I. and Chang, W. T. (1959). "The impact of cultivation on a population of wild rice, *Oryza perennis* and *O. sativa* f. *spontanea.* "*Phyton* 13:104-117.

Oka, H. I. and Chang, W. T. (1961). "Hybrid swarms between wild and cultivated rice species *Oryza perennis* and *O. sativa*". *Evolution* 15: 418 - 430.

Oka, H. I., and Morishima, H. (1971). "The dynamics of plant domestication: cultivation experiments with *Oryza perennis* and its hybrids with *O. sativa.*" *Evolution* 25:356-364.

Palaniswamy, P. M (1991). "Relation between height and flowering duration of different tillers in a rice plant". *Oryza* 28: 407-409.

Pillai, A. C. (1921). *Report of Senior Agricultural Instructor to Director of Agriculture, Njala, for half year ending December 1921. Correspondence and report on irrigation for and cultivation of rice in Sierra Leone.* Freetown: Government Printer.

Porteres, R. (1956). "Taxonomie agrobotanique des Riz cultives, *O. sativa* L. *et* O. *glaberrima*. Steud" *J. Agr. Trop. Bot. Appl.* 3 :341-856.

Porteres, R. (1976). "African cereals", in Harlan, J. *et al* (eds). *The origin of African plants domestication.* The Hague: Mouton.

Rao, C. S., Rao, V, and Prasap, A. S. R. (1991). " Effect of inadmissible path analysis" *Indian J. of Agric. Sci.* 61: 471-475.

Rice Research Station Annual Reports (1934 - 1989). Freetown, Sierra Leone.

Richards, P. (1985). *Indigenous agricultural revolution, ecology and food production in West Africa.* London: Hutchinson.

Richards, P. (1986). *Coping with hunger: Hazard and experiment in an African rice-farming system.* London, Unwin Hyman.

Richards, P. (1991). "Mende names for Rice". Seminar on *Cultural Analysis of agricultural knowledge systems and the role of extension.* Universitaet Hohenheim, Stuttgart.

Richards, P. (1995). "The versatility of the poor: indigenous wetland management systems in Sierra Leone." GeoJournal 35(2), 197-203.

Richards, P. (1996a). "Culture and community values in the selection and maintenance of African rice." In Brush S. and Stabinsky, D. (eds). *Valuing local knowledge: indigenous people and intellectual property rights*. Island Press: Washington DC.

Richards, P. (1996b). "Agrarian creolization: the ethnobiology, history, culture & politics of West African rice". In Ellen R. and Fukui, K. (eds)., *Redefining nature: ecology, culture and domestication*. Oxford: Berg Press.

Richards, P. (1997). "Towards an African Green Revolution?: an anthropology of rice research in Sierra Leone", In Nyerges, E. (ed)., *The ecology of practice: studies of food crop production in sub-Saharan West Africa*. Newark: Gordon & Breach.

Richards, P. and Ruivenkamp, G. (1998) (with Malcolm Jusu and others). *Seeds and survival: plant genetic resource management in conflict and post-war recovery*. International Plant Genetic Resources Institute, Rome.

Riley, K. W. (1996). "Decentralized breeding and selection: A tool to link diversity and development". In Sperling L. and Loevinsohn, M. (eds). *Using diversity: Enhancing and Maintaining Genetic Resources On-farm. Proceedings of a workshop held 19-20 June, 1995, New Delhi. International Development Research Centre*. New Delhi, India, pp. 87-101.

Rodney, W. A. (1970). *A History of the Upper Guinea Coast, 1545 - 1800*. Oxford.

Rogers, P. (1991). "The prospect for agricultural development in Sierra Leone. " *Paper presented at the Workshop on the Development of Agricultural Policy in Sierra Leone,* Freetown, Sierra Leone.

RRS and WARDA (1987). "Towards achieving the Green Revolution in Sierra Leone: The role of the National Rice Research Station and the West Africa Rice Development Association at Rokupr." *Paper presented at the 16th meeting of the Sierra Leone Agric. Society,* Bo, 2 - 6 September, 1987.

Sano, Y., Sano, R., and Morishima, H. (1984). "Neighbor effect between two co-occurring rice species of *Oryza sativa* and *O. glaberrima*". *Journal of Applied Ecology* 21, 245-254.

Simmonds, N. W. (1991). "Selection for local adaptation in a plant breeding program". *Theoretical and Applied Genetics* 82: 363 - 367.

Smithson, J. B. and. Lenne, J. M (1996). "Varietal mixtures: a viable strategy for sustainable production in subsistence farming." *Ann. Appl. Biol.* 128: 127 – 158.

Steel R. G. D., and Torrie J. H. (1980). *Principles and procedures of statistics. A biometrics approach.* (Second edition). International edition, McGraw-Hill Book Company.

Spencer, D. S. C (1982). "Incentives for increased food production in West Africa. The role of Agricultural Economic and Extension Specialists". *Paper presented at the West Africa Regional Seminar of the Commonwealth Association of Scientific Agricultural Societies*, Freetown, Sierra Leone, 15 - 19 November, 1982.

Snedecor, G. W. and Cochran, W. G. (1967). *Statistical Methods*.(6th edition) The Iowa State Univ. Press, America.

Spitters, C. J. T. (1980). "Competition effects within mixed stands". In R. G. Hurd, P. and Biscce V. (eds): *Opportunities for increasing Crop Yields*. Pitman Publ., London, 1980.

Thayer, J. S, (1981). *Religion and social organization among a West Africa muslem people: the Susu os Sierra Leone*. Unpublished Ph. D. Thesis. University of Michigan.

Trenbath, B. R. (1974). "Biomass productivity of mixtures. " *Advances in Agronomy* 26: 177 - 210.

Vergara, B. S. and Chang, T. T. (1985). *The flowering response of rice plant to photoperio*d, IRRI, Los Banos, Philippines, Fourth Edition.

WARDA Rokupr (1977-1988). *Regional Mangrove Swamp Rice Research Station, Sierra Leone, Annual Reports*.

WARDA (1982). *Upland rices in West Africa, Upland Rice Base Papers*. Bouake, Ivory Coast, October, 1982 , IRRI draft papers for discussion.

WARDA (1994). *West Africa Rice Development Association Annual Report,* 1994. Bouake, Cote d'Ivoire.

WARDA (1997). *West Africa Rice Development Association Annual Report,* 1997. Bouake, Cote d'Ivoire.

WARRS (1953-1964) *Annual Reports of the West Africa Rice Research Station*. Freetown Sierra Leone.

Weltzien, E. R., Whitaker, M. L. and Anders, M. M. (1996). "Farmers' participation in pearl millet breeding for marginal environments". In Eyzaguirre P. and Iwanaga, M. (eds.), *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding*. (26 - 29 July 1995, Wageningen, The Netherlands). IPGRI: Rome.

Wily, R. W. and Rao M. R. (1980). " A competitive ratio for quantifying competition between intercrops." *Experimental Agriculture* 16: 117 - 125.

Wilkinson, R. J.(1920). "Wilkinson to Viscount Milner (SL No 28 of 21/1/20)". *Correspondence and report on irrigation for and cultivation of rice in Sierra Leone.* Freetown: Government Printer.

Witcombe, J. R. and Joshi, A. (1996). "Farmer participatory approaches for varietal breeding and selection and linkages to the formal sector". In Eyzaguirre, P. and Iwanaga, M. (Eds). *Participatory plant breeding. Proceedings of a workshop on participatory plant breeding*. 26-9 July 1995, Wageningen, The Netherlands. IPGRI: Rome.

Witcombe, J. R. and Joshi, A. (1995). "The impact of farmers participatory research on biodiversity of crops". In Sperling, L. and Loevinsohn, M (eds). *Using diversity: Enhancing and Maintaining Genetic Resources On-farm.* Proceedings of a workshop held 19 - 20 June, 1995, New Delhi. International Development Research Centre. New Delhi, India, pp. 87–101.

Wolfe, M. S. (1985). "The current status and prospects of multiline cultivars and variety mixtures for disease resistance". *Annual Review of Phytopathology* 23: 251–273.

Wolfe, M. S., Brandel, U., Koller, B., Limpert, E. McDermott, J. M., Muller, K., and Schaffer, D. (1992). "Bark mildew in Europe. Population biology and resistance". In *Breeding for disease Resistance.* " pp 125 - 129. Johnson R. and Jellis G.J. (eds). Netherlands; Kluwer Academic Publications.

Wood, D. and Lenne J. M. (1993). "Dynamic management of domesticated biodiversity by farming communities. " *In Proceedings of the Norway/UNEP expert conference on biodiversity.* Trondheim, Norway, May 1993, pp. 64-98.

Worede, M. (1993). "Linking genetic resource conservation to farmers in Ethiopia." In W. de Boef, K. Amanor,Wellard , K. and Bebbington, A. B. (eds).

World Bank (1993) "Project redesign and implementation report". *Republic of Sierra Leone, Agric Ssector Support Project. Main report, Agric. Operation*, West Africa Dept. Depart.

Yagbasanlar,T. and Ozkan, H. (1995). "Correlation and path analysis for ear character in Triticale under Mediterranean conditions". *Agronomy and crop science* 1715: 297-300.

Yoshida , S. (1981). *Fundamentals of rice crop science.* IRRI, Los Banos, Philippines.
Xinyou, Y.(1996). *Quantifying the effect of temperature and photoperiod phenological development of flowering in rice.* Ph.D. Thesis, Wageningen Agricultural university", The Netherlands.

SAMENVATTING
BELANGRIJKSTE ONDERZOEKSRESULTATEN EN CONCLUSIES

Overzicht van de belangrijkste onderzoeksresultaten
Hoofstuk 2 behandelt de kleinschalige rijstteelt in noordwest Sierra Leone (het onderzoeksgebied) en beschrijft de geschiedenis van de rijstteelt en het wetenschappelijk onderzoek naar rijst. Het hoofdstuk bespreekt ook de etniciteit van de bevolking en de geschiedenis van de slavernij als factoren die de houdingen van verschillende etnische groepen tegenover de hun ter beschikking staande rijstrassen bepalen en beschrijft in het kort de belangrijkste productie-ecologieën in de regio.

Een rassenoverzicht van het gebied laat zien dat de boeren in de drie onderzochte stamgebieden voornamelijk eenjarige gewassen verbouwen. Boeren in het Magbema-gebied verbouwen belangrijke hoeveelheden cash crops. Die in het Bramaia-gebied verwerven zich een inkomen met de verbouw van paprika en aardnoten. Rijst blijft verreweg het belangrijkste voedselgewas en dat weerspiegelt zich in de mate van diversiteit binnen rassen. Traditionele granen, zoals sorghum en Digitaria, vormen nog steeds een aanvulling op de rijst maar er is de laatste jaren een belangrijke verspreiding van ingevoerde rassen van wortel- en knolgewassen (cassave en zoete aardappel) geconstateerd. De wetenschap heeft blijkbaar een grotere invloed gehad op deze wortel- en knolgewassen dan op een gewas dat al duizenden jaren wordt verbouwd. In het onderzochte gebied verbouwen de boeren hun rijst van het hoogland tot aan de moerasgebieden toe; zij beschikken over meer laagland - dan hoogland rassen. Zij verklaren voor het genetisch uitgangsmateriaal afhankelijk te zijn van een breder regionaal systeem dan hun eigen gebied. Zo krijgen boeren uit Magbema gewoonlijk nieuwe lokale rassen uit Tonko Limba en Bramaia. Boeren uit Tonko Limba en Bramaia verkrijgen nieuwe "wetland" rassen uit Magbema. Dit gebied heeft een lange geschiedenis van "wetland" rijstbouw zoals verbouw in brak water en zoetwater-moerassen. Rassen van de soort *O. glaberrima* blijven belangrijk in het gebied. De "tussenvorm", *Pa Three Month*, een door boeren geselecteerde soortshybride, is een van de belangrijkste rassen.

Hoofdstuk drie bespreekt hoe de boeren in noordwest Sierra Leone hun zaaigoed beheren. Het beschrijft de organisatie van de boerenarbeid, de selectie van zaden en ontwikkelingsactiviteiten door boeren, de rol van "gender" in alle stadia van zaadverwerking, van de oogst tot en met de opslag. Dit hoofdstuk wordt afgesloten met commentaar op de kennis die de boeren hebben van de rijstrassen en bodemtypen, en met informatie betreffende de herkomst van deze boerenrassen.

In hoofstuk 4 wordt verslag gedaan van een aantal experimenten die uitgevoerd werden om te ontdekken wat boeren belangrijk vinden bij de rassenkeuze. In samenwerking met boeren werden proeven opgezet om de rijstrassen en de eigenschappen te identificeren waaraan boeren de voorkeur geven. Ook werden de resultaten geëvalueerd van de rassen, verbouwd op de velden van het Rice Research Station (RRS) en op die van boeren, teneinde te ontdekken of de voorkeuren voor de eigenschappen van de diverse rijstrassen verschillen tussen etnische groepen en om mogelijke verschillen vast te stellen tussen de selectiecriteria van boeren en die van wetenschappers.

Boeren werden uitgenodigd selecties te maken uit een groot aantal boerenrassen, RRS-rassen en -lijnen (inclusief WARDA interspecifieke hybriden) op drie proefvelden in de dorpen. Een analyse werd gemaakt van wat boeren kozen en van de redenen voor deze keuzen. Internationale *sativa* rijstrassen werden ongeveer even vaak geselecteerd als lokaal materiaal. *O. glaberrima* materiaal en inter-specifieke hybriden kregen veel belangstelling, evenals de zuivere lijnen verkregen uit Rokupr landrassen, uitgegeven in de zeventiger jaren. Verontrustend was het gebrek aan belangstelling voor de recente geavanceerde RRS lijnen. Dit leidde tot een onderzoek naar de "ideotypen" van rijst zoals geformuleerd door wetenschappers en door boeren. De onderzoekers werd gevraagd een rangvolgorde te geven van de eigenschappen van het "hoogland rijst ideotype van IRRI". Uit de selectiecriteria van boeren werd de classificatie van "hun ideotype" afgeleid. De mate van overeenkomst en verschil tussen de beide ideotypes werd vastgesteld. Het gebrek aan overeenkomst, dat daaruit naar voren kwam, gaf aan dat er belangrijke verschillen zijn in de wijze waarop boeren en deskundigen selectiebeslissingen nemen.

Hoofdstuk 5 geeft met behulp van multivariate methoden, toegepast op morfologische eigenschappen, een gedetailleerde analyse van een representatieve verzameling van boerenrassen, inclusief rassen van *O. glaberrima* en *O. sativa,* "tussenvormen", onderzoeklijnen en elite lijnen. De belangrijkste conclusie was dat er een aanzienlijke variatie aan locale rijsttypen bestond, hetgeen suggereert dat de selectie door de boeren ongehinderd voortgaat.
Pa Three Month groepeerde zich apart van de belangrijkste *O. glaberrima* en *O. sativa* cultivars.

Een dendrogram onderscheidde duidelijk het *O. sativa* van het *O. glaberrima* materiaal, en differentieerde die *O. glaberrima* rassen die de boeren als "traditioneel" of "nieuw" beschouwen (inclusief *Pa Three Month).* De resultaten bevestigden dat de kennis van de boeren, zoals die bij de rijstselectie naar voren kwam, zeer wel gegrond is. Het is aan te bevelen dat dit materiaal door middel van merker-analyse verder onderzocht wordt.

Hoofdstuk 6 analyseert op gedetailleerde wijze één aspect van het beheer van rassen door boeren. In voorafgaand veldwerk was ontdekt dat Limba-boeren in een van de onderzochte stamgebieden (het Tonko Limba gebied) op tamelijk rigoureuze wijze afwijkende en 'minderwaardige' planten verwijderen uit hun velden (zie Hoofdstuk drie). De rassen van Limba-boeren waren in het algemeen zuivere rassen. De rijstvelden van de naburige Susu-boeren bestonden vooral uit gemengde rassen. In een gelijktijdig plaatsvindend antropologisch onderzoek ontdekte Longley (1999) dat Susu-boeren er dikwijls voor kozen verschillende rijstrassen door elkaar te planten in een en hetzelfde veld. Deze boeren waren er van overtuigd dat er aan deze methode bepaalde voordelen zijn verbonden. In dit hoofdstuk zijn een aantal experimenten beschreven waarmee bepaalde aspecten van deze teeltwijze kunnen worden onderzocht.

De resultaten verklaren de gewoonte van sommige Susu-boeren uit het onderzoeksgebied om rassen in de hooglanden te mengen voor het zaaien (Longley, 1998). De belangrijkste bevinding was dat "Relative Yield Total" (RYT) groter was dan 1 als *O. sativa* en O. *glaberrima* rassen gemengd worden verbouwd onder hoogland-omstandigheden, zonder toediening van meststoffen.

De redenen, die boeren voor het mengen opgaven (oogstzekerheid en hogere voedingswaarde) zijn strikt genomen geen goede redenen, want oogstzekerheid en de (vermeende) hogere voedingswaarde toegeschreven aan *O. glaberrima*, kan ook bereikt worden door de rassen op aparte velden te verbouwen in monocultuur. Het onderzoek lijkt aan te tonen dat er een andere reden is om mengsels te verbouwen, namelijk dat RYT groter is dan 1 (d.w.z. dat bepaalde mengsels een hogere opbrengst leveren dan de gemiddelde monoculturen). Blijkbaar zijn de boeren zich hier niet van bewust. Zij handelen intuïtief. Maar misschien stimuleert dit kruisbestuiving en levert het voordelen op voor selectie door de boeren.

Hoofdstuk 7 richt zich op de bloei van de rijst als een factor die gelegenheid biedt voor spontane kruisbevruchting. Uit een overzicht van de literatuur over selectie door boeren wordt in dit hoofdstuk de interactie geïdentificeerd van vier factoren, die de kans op introgressie tussen rassen bepalen, of tussen rassen en wilde en onkruidachtige soorten. Deze vier factoren zijn het tijdstip van planten, tijdstip van rijping (vroeg of laat), de beplanting van het aangrenzend perceel en de lengte van de bloeiperiode. De manier waarop de eerste drie factoren op elkaar inwerken wordt besproken aan de hand van gegevens uit Sierra Leone in een binnenkort te verschijnen rapport van Jusu en Richards. Dit onderzoek bevestigt dat er een ruime mogelijkheid voor spontane kruisbestuiving bestaat als gevolg van de manier waarop boeren de beplanting van het veld regelen, en hun gewoonte om blokvormige velden te beplanten met verscheidene gelijktijdig bloeiende rijstsoorten. Er bestaat echter weinig systematische informatie over de vierde factor; de variatie in bloeitijd van rijstrassen. De gegevens verkregen uit de experimenten zoals weergegeven in dit hoofdstuk laten zien dat de bloeitijd van rijst varieert van ongeveer 5 tot 15 dagen en dat deze variatie tot op zekere hoogte genetisch bepaald is. *Pa Three Month* is een ras met één van de langste bloeiperioden. Het is aannemelijk dat planten met lange bloeiperioden de kans op kruisbestuiving verhogen.

Algemene conclusies

Kunnen *low-resource* boeren, levend in moeilijke natuurlijke en sociale omstandigheden geschikt plantmateriaal selecteren?

Zijn boeren bekwaam genoeg en beschikken zij over voldoende genetische diversiteit om voor hun eigen belangen op te komen zonder dat zij daarbij steun nodig hebben van landbouwkundige onderzoeksinstellingen?

Op basis van dit onderzoek naar het beheer door boeren van de genetische bronnen van rijst in noordwest Sierra Leone is het antwoord op de eerste vraag een duidelijk "ja", maar het antwoord op de tweede vraag is een nadrukkelijk "nee".

Het voornaamste experiment in dit onderzoek was dat boeren een selectie maakten uit een hoeveelheid materiaal afkomstig van henzelf en van onderzoekers, waaronder locale nieuwigheden zoals *Pa Three Month*, door onderzoeksinstellingen uitgegeven rassen, en verschillende geavanceerde lijnen uit nationale en internationale programma's, zoals hybridemateriaal van WARDA waarin Afrikaans en Aziatisch rijstmateriaal gecombineerd is.

Ondanks het feit dat de deelnemende boeren behoren tot de armste bevolkingsgroepen ter wereld en dat zij werken in een oorlogssituatie, was het duidelijk dat zij wisten waar ze naar moesten kijken. Bovendien konden ze altijd hun voorkeuren verklaren. Er bestond een belangrijke mate van overeenstemming tussen de boeren omtrent wat zij kozen en de redenen waarom; zelfs als deze keuzen niet direct in overeenstemming waren met de keuzen van de onderzoekers. Maar er bestond ook een grote mate van variatie in selectiekeuzen onder verschillende etnische groepen en binnen verschillende natuurlijke omgevingen, ondanks het feit dat de drie etnische groepen gedurende wellicht vele honderden jaren naast elkaar hebben geleefd in een tamelijk klein gebied.

De resultaten ondersteunen noch diegenen die beweren dat de boeren slechts een paar breed aangepaste rassen nodig hebben, ontwikkeld volgens een internationaal standaard ideotype, noch de populisten die daarentegen beweren dat boeren hun eigen ideeën en genetische bronnen hebben en geen externe hulp of materiaal van node hebben.

Boeren hebben hun eigen criteria voor opbrengst en kwaliteit, die niet altijd overeenstemmen met de criteria van de veredelaars. Desondanks bleek het hoogopbrengende (*sativa)* materiaal van internationale onderzoeksinstellingen het meest gekozen te worden. Uit de resultaten blijkt dat *low-resource* boeren verscheidenheid (d.w.z. verschillende opties) prefereren en niet slechts enkele rassen met hoge opbrengsten. Sterk vertegenwoordigd in de selecties van boeren waren veel lokale rassen, inclusief *glaberrima* materiaal dat tot nu toe door de wetenschappelijke veredelingsprogramma's genegeerd werd. De eerste aanwijzingen suggereren dat een deel van het hybridemateriaal van WARDA, (*O. sativa* x *O. glaberrima)* populair zal blijken te zijn.

Door onderzoek van de context waarin boeren keuzes maken wordt in dit proefschrift duidelijk gemaakt dat kwekers het zich niet kunnen veroorloven geen aandacht te besteden aan lokale culturele, historische en milieuomstandigheden.
Factoren, zo divers als de invloed van de slavenhandel en interregionale handel, ontwatering, verarming van landbouwgronden, genotype-milieu interactie, verschillen in de beschikbaarheid van arbeid en verschillen in bedrijfsstijlen (bijvoorbeeld wanneer, hoe en door welk van de beide geslachten de oogst wordt binnengehaald en zaad wordt geschoond) hebben allemaal invloed op het systematisch verschil in de keuzen van de mannelijke hoogland rijstboeren en gezinshoofden in drie aan elkaar grenzende kleine stamgebieden. Bij de complexe low-resource farming is, zoals het spreekwoord zegt: "the devil is in the detail".

Het is duidelijk dat wij hier te maken hebben met een paradox. Boeren zien graag de internationale verbeterde rijstrassen, maar ze willen tegelijkertijd ook ruime toegang tot de beste lokale rassen. Zoals Dennis (1989) in Thailand opmerkte, dit verandert ons idee van de "innovatieve" boer. De innovatieve boer is iemand die actief experimenteert met een aantal moderne en lokale selecties. Bovendien zijn ook de lokale rassen niet statisch. Zelfs in de klaarblijkelijk "traditionele" *glaberrima* rijstrassen onderscheiden boeren "oude" en "nieuwe" types en kwantitatieve morfologische analyses bevestigen dit. Waarschijnlijk staat *Pa Three Month* niet op zichzelf. Het is goed mogelijk dat de toevoeging "DC", ook wel Dissi (of "Demerara Creole" en "District Commissioner"), wordt gebruikt om de bredere reeks *O. glaberrima*'s die ontstaat door spontane kruising en selectie door boeren aan te duiden (Richards, persoonlijke mededeling).

Morfologische analyses ondersteunen in het algemeen het idee dat er grote variatie zou bestaan in de lokale rijsttypen, zowel binnen soortgroepen als daartussen, waarschijnlijk als gevolg van het samenkomen van verschillend plantmateriaal op die plaatsen waar handelsroutes van het kustgebied en het binnenland elkaar ontmoeten. Het potentieel voor selectie uit of kweken met dit lokale materiaal is nog steeds niet uitgeput.

Een van de verbreidingsmiddelen bij de vermenging en samengaan van deze lokale gene pools is mogelijk de gewoonte van sommigen (van de op de handel gerichte Susu-boeren) om duidelijk verschillende rassen tezamen in hetzelfde veld te planten in de hoop zodoende risico te spreiden en de levering van veelgevraagde rassen voor consumptie veilig te stellen. Susu-boeren hebben geen weet van de moderne genetische theorie gebaseerd op Mendels erfelijkheidsleer, maar het gemengd aanplanten van verschillende soorten heeft enkele interessante agronomische gevolgen, in het bijzonder daar waar mest niet beschikbaar is (zoals aangetoond, zijn de opbrengsten bij de juiste combinaties hoger dan bij monocultuur) en dit zou de (toevallige) basis kunnen zijn van spontane soortshybriden waaruit boeren vervolgens selecteren. Meer in het algemeen bevestigt dit proefschrift het bestaan van een aanzienlijk potentieel voor uitwisseling van genen tussen lokale rijstrassen onderling en tussen lokale rassen en verbeterde cultivars in de hoogland rijstteelt in Sierra Leone, alhoewel meer gedetailleerd onderzoek nodig is.

Het is duidelijk dat boeren uitkijken naar exotisch / buitenlands materiaal en dit ook verwelkomen, zowel om het materiaal als zodanig als om de mogelijkheid om bestaand materiaal aan te vullen en de lokale genenvoorraad te verrijken. De duidelijke paradox waarnaar hierboven werd verwezen, houdt op een paradox te zijn als wij ons realiseren dat modere rassen twee doeleinden dienen: als vernieuwing op zichzelf en als mogelijkheid om een verbreding van de lokale genetische basis te bewerkstelligen waaruit boerenselectie nieuwe energie kan putten. Het is interessant op te merken dat de mengsels aangeplant door Susu- boeren "oude" *glaberrima* types en "moderne" *sativa*'s zijn (of *vice versa)* en dat deze combinaties hogere opbrengsten leveren dan de rassen die als monoculturen zijn aangeplant. Hun streven om gelijktijdige bloei van mengsels te verkrijgen zou een belangrijke mogelijkheid voor spontane kruisbevruchting kunnen betekenen.

Blijft de vraag welke onderzoekstrategieën het lokale selectie-initiatief het best zouden kunnen ondersteunen. Dit proefschrift heeft duidelijk gemaakt dat de bestaande strategie van Sierra Leone's nationale rijstresearchprogramma niet optimaal is.

Boeren hebben de RRS rassen geaccepteerd en zijn er nog steeds in geïnteresseerd, met name in de zuivere lijnen geselecteerd uit lokale landrassen, geïntroduceerd in de jaren zeventig. Er zou nog veel gedaan kunnen worden om de beschikbaarheid van deze rassen te vergroten tot buiten de onmiddellijke omgeving van het onderzoekstation (boeren op niet meer dan 75 km afstand van het station waren nog steeds niet bekend met deze uitgegeven rassen, zelfs 25 jaar na hun introductie). Het is echter verontrustend dat boeren nauwelijks belangstelling tonen in de huidige geavanceerde lijnen van RRS. Lokaal en internationaal materiaal (inclusief WARDA-hybriden) trokken meer belangstelling bij de selectieproeven.

Vergelijking van "ideotypes" gaf een duidelijke kloof aan tussen boeren en nationale professionele rijstkwekers. Een onder-gefinancierd nationaal programma is voor fondsen bijna geheel afhankelijk van internationale programma's, geleid door IRRI. Loyaliteit ten opzicht van een weldoener is een belangrijk kenmerk van het sociale en politieke systeem in Sierra Leone (Richards, 1986). Maar misschien zijn ook de op grote afstand geformuleerde IRRI Standaard Evaluatie criteria te strikt toegepast?

Wat nu nodig lijkt te zijn om het programma voor *low-resource* hoogland boeren nieuw leven in te blazen is het uitbreiden van het type methodologieën zoals in dit proefschrift beschreven. Kwekers dienen in te zien dat hun rassen het soms "stiekem" goed doen en dat uitgegeven types soms "verdwijnen", maar dan misschien niet zonder eerst de lokale genenvoorraad te verrijken hetgeen het vertrouwen van boeren in hun eigen selectie praktijken versterkt. Kwekers moeten dus selecteren en kruisen, maar ook de selectieprocessen van boeren bestuderen en de lessen in de praktijk brengen die ze daaruit kunnen trekken. Zij moeten ook lessen trekken uit de experimenten van boeren met mengsels.
De keuze van complementaire mengsels van *O. sativa* en *O. glaberrima,* zoals door sommige boeren toegepast in low-input omstandigheden, zou wel eens beter kunnen renderen dan een inter-specifiek hybridiseringsprogramma.

Maar om dergelijke lessen toe te passen is het nodig dat, daartoe aangespoord door institutionele veranderingen, selectieproeven door boeren deel gaan uitmaken van een interactief proces dat boeren en onderzoekers tezamen brengt in een noodzakelijke en complementaire relatie.

Donoren zouden hun steun voor onderzoek en hun beoordelingsprocessen dienen aan te passen. Zij zouden meer financiën beschikbaar dienen te stellen aan gedecentraliseerde initiatieven zoals het "Community Biodiversity Development & Conservation Program". Maar zij zouden ook hun monitoring en evaluatie moeten aanpassen. Een econoom uitzenden om innovaties te beoordelen zou wel eens minder belangrijk kunnen blijken te zijn dan het eertijds was. Deze nieuwe benadering zou mogelijk gebaseerd kunnen worden op merker tests om te achterhalen waar de nuttige genen zijn gebleven en wie er gebruikt van maakt, zowel in de boerenpraktijk als met betrekking tot rassen uitgegeven door onderzoekstations
Hoe dit ook zij, dit proefschrift maakt duidelijk dat de betrokkenheid van boeren een bron is in de plantenveredeling die niet veronachtzaamd mag worden. Nu we op weg zijn naar een nieuwe wereld van radicale biotechnologieën zoals apomixie, mag het duidelijk zijn dat er veel meer ruimte is voor alternatieven voor de *top-down* Groene Revolutie programma's, opgezet en gereguleerd door vooruitziende, maar zich op grote afstand bevindende, internationale wetenschappers. Het aanpassen van planten aan de lokale sociale en milieubehoeften verdient meer aandacht en ruimte. Bij een dergelijke ontwikkeling zou de kennis en kunde die de boer heeft van selectie en experimenteren een vaardigheid van doorslaggevende betekenis kunnen zijn om dit te bereiken. Misschien zal ooit de kennis van de boer kandidaat gesteld worden voor de Nobelprijs.