Crop Protection Programme

Management of Weedy Rices in Africa

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Executive Summary

Studies on wild rice (*O. longistaminata*, *O. barthii* and *O. punctata*) were conducted in Mali, Ghana and Tanzania, and in glasshouses at Long Ashton Research Station, UK. Yield losses of 2 t ha, or almost 40% were caused by infestations of 70 shoots m^2 of *O. barthii* in Mali. In Ghana, where yields were generally lower, infestation of 100 shoots m^2 of *O. longistaminata* caused yield losses of 0.9 t ha.

Socio-economic studies were conducted in northern Ghana. Farmers mainly cultivated areas of land less than 2 ha, they considered weeds a major constraint and that wild rices were the most serious weed problems. Hand pulling and hoeing were the major means of weed control and few farmers used any purchased inputs.

Following glasshouse studies, slight indications were found that the Mali accession might be more tolerant to glyphosate than other *O. longistaminata* biotypes. Field studies in Tanzania showed that an application at 1.08 kg a.e. ha^{-1} to *O. longistaminata* regrowth of 4 weeks old would provide effective control. Studies in Ghana also showed advantage to allowing the *O. longistaminata* to grow to 4 or 6 weeks after cutting before applying glyphosate.

Experiments at Long Ashton indicated that, providing the imidazolinone resistant rice cultivars were available to farmers, imazethapyr could be used successfully as a post emergence application at low rates (40 g a.i. 200 l) to control *O. barthii* and *O. longistaminata* growing from seed.

Studies in Mali showed that introductions of *O. barthii* from the irrigation canals and the nursery beds were important and that these should be the focus of measures to reduce infestations. Field trials in Ghana, with farmer participation, over a two-year period on a range of integrated control measures for the control of *O. longistaminata* showed farmers favoured the use of glyphosate or bunding, puddling and transplanting treatments to combat wild rice. Almost 70% said they would like to adopt the latter method. Promising studies were conducted on the scope for dry season cropping of vegetables to aid the control of wild rice and wells were dug to assist two farmer groups.

A review was undertaken on herbicide resistant crops (HRC) as a means of improved management systems for wild and weedy rice. The current understanding of the breeding system and genetic relationships within the genus *Oryza* however suggests that transgene flow from HRCs to volunteers of conventional *O. sativa* cultivars should be expected. This may significantly increase the weed problems related to wild rice. It is therefore essential that the extent of gene flow from *O. sativa* to wild and weedy rice be quantified prior to the introduction of herbicide resistant cultivars in W. Africa.

An end of project workshop, with members from six African countries, was held to discuss and extend the project's findings. A leaflet has been developed to promote some findings of the project.

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1. Background

Wild rices affect all the major rice growing areas in the tropics, and are particular weed problems in the direct seeded systems in Latin America, Caribbean, Africa, South and South East Asia. Holm *et al*. (1979) in a review of the World's worst weeds, listed seven *Oryza* species as being weeds of rice. In Africa there are three species of wild rice which pose major problems to rice cultivation, *Oryza barthii* A. Chev. and *O. longistaminata* A. Chev. & Roehr and *O. punctata* Kotschy ex Steudel (Holm *et al*. 1997). Widely distributed, from Botswana to Ethiopia and Senegal, they are closely related and often found in the same habitat (Vaughan, 1994). *O. barthii* is an annual weed which can become a major problem particularly in direct seeded rice, and it is easily distributed in contaminated rice seed (Johnson, 1997). *O. longistaminata* is a rhizomatous perennial, and both species have vigorous growth and readily shed grains prior to harvest. The rhizomes and perennial habit of *O. longistaminata*, enable this species to survive fire, shallow cultivation and prolonged dry seasons. The uncertainty as to the genesis and identity of weedy rices, the extent of weedy rice gene introgression with crop cultivars and the degree of morphological and genetic variation further complicates the development of management strategies for these weeds.

In a recent survey in northern Ghana, researchers identified *O. barthii* and *O. longistaminata* as being problems in farmers' fields at a number of locations. Surveys in the Senegal River valley, of irrigated rice throughout the Sahel, and of rice producing areas of Cote d'Ivoire have identified both species to be a problem (Godderis, 1990; Diallo and Johnson, 1997; Marnotte, 1990). In Mali, populations of *O. longistaminata* have been reported to be more than 150 plants m^{-2} at some on-farm sites in the Niger valley (Dembele *et al*, 1990). This species is also a dominant weed of deep water rice fields on the floodplains of Sierra Leone and has caused farmers to abandon extensive areas previously used for rice cultivation (Riches, 1989). In Tanzania, weeds were reported as the main problem in rainfed rice, and annual and perennial wild rices were, the cause of very low yields on large scale farms (Kanyeka, 1994) and a major problem confronting small scale farmers (Matthews et al., 1994). Wild rices are the only known alternative hosts for African Rice Gall Midge (ARGM) and are important hosts for Rice Yellow Mottle Virus (RYMV). RYMV and

ARGM are important pests of rice in Tanzania and a number of West African countries including Nigeria, Burkina Faso, Mali, Sierra Leone and Ghana.

In parts of West Africa many fields have been abandoned due to this weed (Davies, 1983). In addition to yield loss due to competition, wild rice causes loss of quality by contamination of the grain which leads to increased milling losses, and because of unevenness of crop ripening it can cause delays at harvest. Infestations of annual wild rice pose particular problems due to difficulties of distinguishing young plants, their similar ecology to the crop and the lack of selective herbicides. "Weedy rices", including wild rice species and weedy derivatives of cultivated rice which shatter prior to harvest, are therefore a threat in irrigated rice in situations where farmers are switching out of transplanting as a consequence of water and labour shortages.

The problem of weedy rices has been identified at different of levels. Investment in research on weedy rice management was identified as a priority in the review of weed research requirements undertaken for CPP Management in early 1998. At regional and national levels, research institutes in West Africa identified the problem from field surveys and interaction with farmers.

2. Project purpose

The Purpose of the project was to develop and promote improved and cost-effective methods for the control of weeds in floodplain rice production systems. The project aimed to contribute to this purpose by providing a better understanding of the problems related to infestations of weedy and wild rice (*Oryza* spp), and by developing cost effective cultural and agronomic control measures.

3. **Research Activities** - Trial Design and Approach

The Savanna Agricultural Research Institute (SARI) has the mandate for agricultural research and development in northern Ghana. It is a multi-disciplinary organisation and had been strengthened considerably in the recent past by a GTZ funded Farming System project. The collaborators at SARI comprised a weed scientist, agricultural economists and sociologist. Field studies and experiments were conducted in northern Ghana in Bontanga, Kadia, Tono and Fumbisi. These are all sites where SARI had existing contacts and where studies had been conducted in the past.

In the Office du Niger, Mali, studies were conducted at Niono, Kogoni and Macina. *O. barthii* infestations were serious at the first two locations while *O. longistaminata* infestations were serious in the last site. Surveys were conducted in the areas of Mopti, Segou and Niono (Mopti nord, Soufroulaye, Kouiana, Kolongo and Dioro). In southern Mali studies were conducted in the region of Sikasso and in the areas of Longorolo, M'Pegnesso, Zoloko and Laminibougou.

In Tanzania, field surveys were conducted in the south of the country around Mbeya, Kyela and Ifakara and the para-statal rice farms of Ruvu, Dakawa, M'Barali and Kapunga. In each case, working with the main collaborators J. Keyeke and J. Mbapila, initial contacts were made with the local agricultural officials before joint field visits and discussions with farmers were undertaken. Field experiments were conducted at the main rice station, KATRIN, Ifakara.

Glasshouse experiments were conducted at Long Ashton Research Station, UK. Standard glasshouse procedures were used, with temperatures maintained at a minimum of 26 C and supplementary lighting as required. A mineral-based loam soil was used as the standard potting mixture with no additional nutrients added to the initial mix.

Outputs

4.1 An understanding of farmers' perceptions of wild rices in relation to the complete weed flora, sources of infestation, current control methods and estimated yield losses due to wild rice.

Farmers' perceptions

The social and economic dimensions of wild rice control in northern Ghana were studied by Osman Gyasi and Paulinus Terbobri of SARI and Monica Janowski of NRI, and are reported by these authors in an attached report (Appendix 1). In addition, two students of the Department of Agricultural Economics and Extension of the University of Development Studies in Tamale conducted a study on the economic effects of wild rice on rice cultivation.

Rice is important as a food and cash crop; it contributes about a third of household incomes and most of the crop is sold. Most farmers in Fumbisi, where a survey was conducted with 49 farmers, have less than 2 ha. All farmers reported that weeds were a significant constraint of rice production and that wild rice was the most serious of the weed problems they encountered. Other serious weeds cited were *Imperata cylindrica*, *Digitaria* sp and *Cyperus esculentus*. It was considered that wild rice growth was a good indication of good soil fertility and suitability for rice cultivation. Farmers were able to distinguish wild rice from cultivated rices at very early growth stage. The wild rice problem in northern Ghana was reported to have increased greatly in the 1960's due to the expansion of mechanisation. Farmers used hand pulling and hoeing as the major method for wild rice control; few used purchase inputs for the crop and there was little knowledge on the use of herbicides.

Yield losses

Studies to estimate the yield losses that occur due to wild rice were conducted in Ghana and Mali. On a selection of farmers' fields, field transects were taken at 28 days after rice establishment to identify the wild rice species present, their relative population densities and approximate spatial distribution on each farmer's field. On average, 12 quadrats (1m x 1m) were mapped and marked-out on each field based on the level of wild rice infestation. Quadrats were sited to cover the range of infestation levels: areas free of wild rice, or with low, medium, high and very high numbers of wild rice plants. Stem counts of the wild rice and *O. sativa* were made approximately twelve weeks after crop establishment. At harvest, plant biomass and grain yields were recorded. In Ghana, 128 quadrats were marked out on 12 farmers' fields at Tono, Fumbisi and Kadia in the Northern and Upper East regions. Around Sikasso (Kadiolo, Longorola and M'Pégnesso) in southern Mali, this study was conducted on 12 farmers' fields infested with *O. longistaminata*. In the Office du Niger, Mali, the studies were conducted on 14 farmers fields infested with *O. longistaminata* at Macina and with *O. barthii* at Kogoni.

In Ghana, grain yields ranged from 0 - 4.1 t/ha and the maximum number of *O. longistaminata* stems recorded was 166 per m^2. Regression analysis indicated a loss of rice grain equivalent to 0.98 g/m^2 for every stem/m^2 of *O. longistaminata.* At Macina, Mali, grain yields ranged from 1.76-5.33 t/ha and the highest level of *O. longistaminata* was 432 stems/m^2. Regression indicated a yield loss equivalent to of 0.75 g/m^2 for every stem/m^2 of *O. longistaminata* present. Infestations of *O. barthii*, at densities of 70 tillers/m^2, caused grain yield losses were more than 2 t/ha, or almost 40%, at Kogoni. In southern Mali, around Sikasso, *O. longistaminata* was recorded in 47 of the 120 plots. Rice grain yield averaged 1.16 t/ha and there was an average 29 stems/m^2 of *O. longistaminata* (Fig 1). Regression indicates a grain yield decline of 0.9 g/m^2 for each stem of wild rice present at 12 weeks after sowing.

Results of yield losses due to *O. longistaminata* were remarkably consistent across the sites with close negative correlation with yields and yield losses that equated to grain loss of 0.75 to 0.98 g/m^2 for every stem per m^2 of *O. longistaminata*. With an average level of infestation of 100 stems/m^2 of *O. longistaminata*, this equates to yield loss of 0.87 t/ha. Where infestations are severe, a common strategy of farmers is to abandon areas of the field that are infested with wild rice.

In the Office du Niger, losses due to *O. barthii* were somewhat higher, losses of 2 t/ha being equated with populations of 70 tillers/m^2 of *O. barthii*. Greater losses in the system partly reflect the higher productivity of these systems compared to those in Ghana and southern Mali.

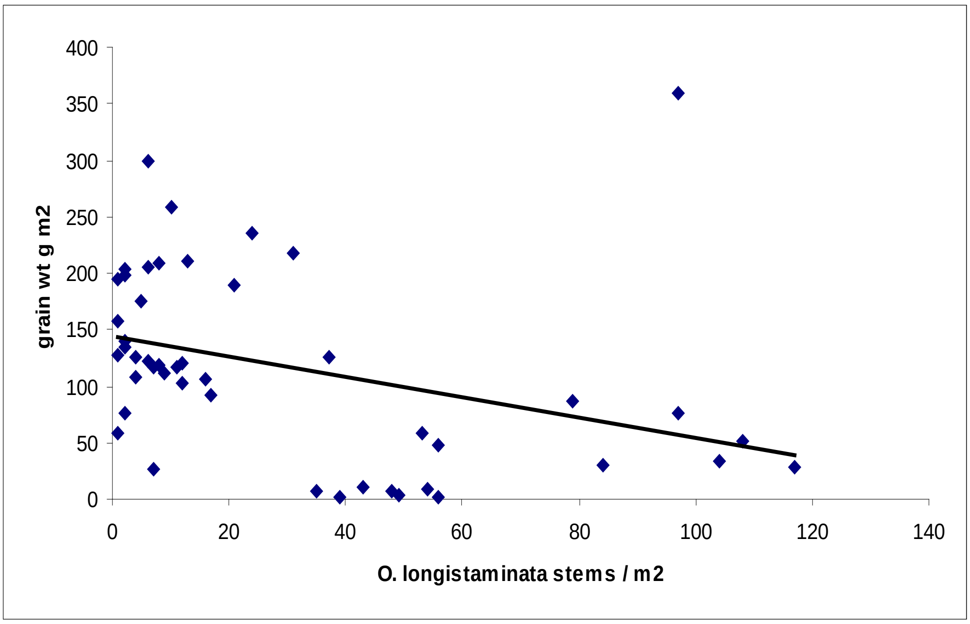

Fig 1. The relationship between *O. longistaminata* infestation and rice yield in southern Mali.

4.2 Information on the distribution and the relative importance of wild rice species in selected areas of Ghana, Mali and Tanzania.

Along the Niger river, Mali
There are 235,000 ha of rice in Mali of which 60,000 ha is grown in the Office du Niger. This is currently being expanded with government investment. The average yield is 4.1 t ha. Much of the area in the Office du Niger has been rehabilitated with improvements made to the land levelling and drainage. Farmers had been encouraged to undertake transplanting in many areas to reduce the losses due to weeds and tackle the problem of wild rice, and *O. barthii* in particular. 34,000 ha of rice is grown around Mopti of which 17,600 ha is floating/deep water rice with the remaining area having controlled or partially controlled flooding. In the latter system rice is grown on the flood plains that are flooded through controlled release of water from the river. In these areas, 12,000 ha are reported to be affected by wild rices (mainly *O. longistaminata*) and 4,300 ha had been abandoned primarily due to wild rice infestations. It was not clear whether farmers had simply temporarily abandoned the land while they cropped fields that were less infested or whether the fields had been permanently abandoned. Similar levels of infestation occur towards Gao to the east of Mopti.

Wild rices, particularly *O. barthii*, infests the numerous flooded depressions during the wet season between Markala and Niono. *O. longistaminata* was found in areas that appeared to be flooded for longer periods of the year. At Niono, *O. barthii* and *O. longistaminata* was commonly seen infesting the drains and canals but there were varying levels of infestations in the fields.

An informal survey of farmers was conducted in 1999 across an area from Segou to Mopti and 24 farmers were interviewed. These farmers (n = numbers of farmers) cropped areas with controlled wet season flooding but not drainage at: Mopti Nord (4), Soufroulaye (5); areas with some control over wet season flooding - Kouniana (6), Dioro (3) and areas with complete water control including drainage - Kolongo (2) and Kogoni (4). While all rice in these areas is grown under lowland conditions, the sites covered a range of production systems and ecologies. Where there is some control over the flooding the rice is direct sown at the beginning of the rainy season and the land is only flooded once the rice was developed sufficiently. Rice is transplanted where there is complete water control.

Half the farmers questioned in the survey had been cultivating rice for between 11-30 years. Almost all farmers recognized *O. barthii* and *O. longistaminata* and the majority had known the weed for more than six years. Many farmers also distinguished different forms of *O. barthii* (red and white awns, and also "off-types" of *O. sativa*). The majority of the farmers considered *O. longistaminata* to be the most serious of the two species with the major concern being that it reduced yields.

Underwater mowing (faucardage) is practised for the control *O. longistaminata* in the flood plain rice and this is undertaken during the wet season while the land is flooded. Farmers mow twice during the wet season followed by ploughing and harrowing in the dry season before the rice crop is sown. This is practised around Mopti, Soufroulaye, Kouiana and Dioro. Farmers reported this is effective in killing a large proportion of the wild rice. The majority of farmers also hand weed in the crop to control wild rice.

Farmers estimated the added costs of controlling the wild rice and said this was between 20-40,000 ha (33%) and between 40-60,000 ha (54%). 75% of the farmers used, or had used fertiliser on the rice and about half the farmers had used urea and phosphate. Most of the farmers in the irrigated areas, and a smaller proportion on the controlled flooding area, used manure on the land. The variety rice Kao and Gambiaka were grown in the controlled flooded areas and Kogoni 91-1 in the irrigated areas. Mean reported yields were 1.6 and 5.6 t ha respectively. Farmers in Mopti, Kogoni and Kolongo farmed between 2-8 ha, while at the other two sites about half the farmers had less than 2 ha. The majority of farmers in Mopti and Soufroulaye had abandoned land due to wild rice infestations.

Southern Mali
Office du Mali Sud occupies the area to the south of the Office du Niger. All rice is grown in the lowlands with varying levels of land development. It is estimated that 41,000 ha of land were grown in 1995 of which 4,600 ha were improved lowlands, 19,800 ha in non-improved and 16,900 ha were strictly rainfed. The average yield was 1.69 t ha. *O. longistaminata* is reported to be the major problem throughout the area, though *O. barthii*/*O. glaberrima* (as a weed) are widespread and can be locally important.

Southern Tanzania
Lowland rice production is undertaken by large mechanised parastatal farms and by smallholders who cultivate either by hand or by bullock-drawn plough. *O. longistaminata* occurs widely in Kyela district - on a rainfed floodplain areas of 4,600 ha at Kilasilo towards the Malawian border, and also towards Itungi and Matema. In these areas the wild rice is in dense patches and infesting bunds and canals. Cultivation is either by hand, tractors or bullocks. Farmers report to have known of wild rice for many years. Control was based on cultivation, removal of rhizomes by hand and hand weeding. Little herbicides or fertiliser are used and rice is dry seeded and transplanted. There are 18,000 ha of rice in the district, 13,000 ha of which are in the lowlands. Similar situations occur in the Kilombero valley where large expanses of wild rice are grown on the river flood-plains.

At the Regional Food and Agriculture Corporation (NAFCO) farms at M'barali, Dakawa and Ruvu annual and perennial wild rices are a major problem. At Mbarali, (7200 ha total) more than 2,250 ha had been abandoned to wild rice. Transplanting had been adopted on remaining areas, which were well-developed land and fully mechanised. Smallholders now manage a large proportion of the farm areas. *O. longistaminata*, the weed forms of *O. sativa* and *O. punctata* are significant problems in the areas visited at M'barali. The Kapunga estate is infested by *O. longistaminata* and this is likely to be one of the major reasons for African Rice Gall Midge being such a problem at this site. To deal with the wild rice problem the estate has adopted the strategies of transplanting rice rather than direct seeding and transferring management of some areas to smallholders. At Dakawa and Ruvu, infestations of wild rice (*O. punctata)* have largely led to the collapse of the schemes and large areas abandoned. A much-reduced area is now cultivated and land has been allocated to small farmers.

Wild Rice in northern Ghana
Approximately 38% of the rice grown in Ghana is from the Northern Region compared to 24% for the Upper East and 1% for the Upper West. In the Northern Region the majority of the production comes from large mechanised farms that are up to 200 ha in size. In the Upper East farms were much smaller though use of tractors for cultivation, from private or

government hire schemes, are important. Wild rice was reported from many areas in the north of Ghana.

Contamination levels of rice seed supplies with “wild rices” are reported to be up to 20% and samples taken from the Seed Growers Association (SGA), that handles 20% of the seed supplies, were found to have 69-97% purity. The majority of seed farmers use is from retained seed and farmer trading The major contamination was seed with a red pericarp from *O. glaberrima* and “off type” *O. sativa*. In the market this mixed rice greatly reduces the sale price of the crop. In the Tamale market, samples of par-boiled hand milled rice contaminated with red pericarp grains was sold at 400 cides kg compared to 900 cides kg for pure grains. Contamination of the rice with the red pericarp grains was reported as a major problem and had resulted in farmers being unable to sell their stocks. There was apparently little demand in Accra for the mixed grain as this was regarded as sub-standard and consumers preferred to purchase the pure grain, which was often imported rice.

In the Upper East region the major areas of rice production, were a rainfed valley at Fumbisi and irrigated schemes at Tono and Vea (3,300 ha). *O. longistaminata* is a major problem in the irrigated schemes and a major effort had been undertaken recently to clear the fields with repeated puddling during land preparation and hand weeding. Some areas however remain fallow because of wild rice infestation and the canals required annual clearance with a "drag-line". In the Fumbisi valley, farmers prepared the land by hand, with bullock ploughs or, depending on their availability with tractors from the government hire schemes. The rice crop is direct seeded with retained seed from the previous crop. Contamination of the seed was clearly a major problem with upto c. 20% of the grain having red pericarp. The grain with the red pericarp comprised *O. glaberrima* and *O. sativa* (off-types), farmers reported that the red peri-carp types shattered easily. *O. longistaminata* was a major problem throughout the valley with farmers selecting areas to cultivate that had lower levels of infestation. Farmers in Fumbisi used few, if any, inputs and these were limited to fertiliser. Farmers at Fumbisi and the irrigation schemes reported that sites of severe *O. longistaminata* infestation indicated areas of high potential productivity for cultivated rice.

The distribution of wild rices in Africa was reviewed for an FAO workshop paper published as: Johnson, D. E., Riches, C. R., Kayake, J., Sarra, S. and Tuor, F. A. (2000) Wild rice in sub-Saharan Africa: its incidence and scope for improved management. FAO Global Workshop on Red Rice Control, 30 August - 3 September 1999, Cuba. pp 87-94.

Glasshouse studies at LARS
Characterisation wild rices - growth studies 01.

The objective of this experiment was to provide some information on comparative growth rates of different wild, weedy and cultivated rices. This would then be used to develop subsequent experiments.

Pre-germinated seeds were sown in 8 l pots of compost with no additional fertiliser added. Seedlings were later thinned to three plants per pot. Fertiliser plugs were added after one month. The experiment was arranged with 4 complete replicates in a randomised block design. Pot positions were rotated at weekly intervals. The pots were stood on capillary mat and kept permanently moist.

The following entries were sown in a Long Ashton glasshouse

1. *Oryza barthii* (Niono # 1, Mali)
2. *O. barthii* (Niono # 2, Mali)
3. *O. barthii* (Niono # 3, Mali)
4. *O. barthii* (Kogoni # 4, Mali)
5. *O. barthii* (Niono # 6, Mali)
6. *O. barthii* (Ross Bethio, Senegal)
7. *O. longistaminata* (Niono #9, Mali)
8. *O. longistaminata* (Kapunga # 11, Tanzania
9. *O. longistaminata* (Kogoni # 9, Mali)
10. *O. punctata* (Zanzibar #13)
11. O. sativa (Bouake 189)
12. O. glaberrima (CG14)
13. O. sativa (Suakoko 8)
14. O. sativa (WAB 56-104)
16. O. sativa (weed rice PN20, Bical Philippines)
17. O. sativa(weed rice PN28, C. Luzon, Philippines)
18. O. sativa (weed rice PN37, Bical Philippines)
19. *O. punctata* (Kampula, Tanzania)

Growth was recorded as follows: plant height to extended leaf tip of tallest leaf; specific leaf area from 3 fully expanded leaves per pot, leaf, tiller and panicle number per pot.

Results.

Table 1 **Wild rice initial characterisation. Plant height cm (Ht), leaf number (Lf), specific leaf area (SLA) and tiller number at 14, 28 and 42 days after seeding**.

Entry	Ht 14	Ht 28	Ht 42	Lf 14	Lf 28	SLA 28	Till 28	Till 42
1	38.0	68.5	96.8	4.0	18.8	298	6.5	8.5
2	43.5	71.8	101.8	4.0	32.0	308	13.8	13.0
3	28.3	64.5	98.8	3.5	14.8	332	9.0	10.8
4	51.0	74.3	92.5	4.5	26.3	287	11.8	11.8
5	28.8	71.4	108.6	3.0	13.4	324	7.3	8.3
6	48.3	78.0	104.0	3.8	26.0	327	11.0	11.8
7	38.8	88.3	133.0	3.0	9.5	309	3.5	3.0
8	38.3	85.0	136.5	3.3	10.8	307	4.5	4.0
9	40.3	87.3	128.6	3.3	9.8	262	3.8	3.5
10	38.3	83.5	115.5	4.0	25.0	418	10.0	10.8
11	34.5	60.0	68.3	5.3	27.0	323	10.0	12.3
12	38.8	58.3	89.8	4.0	28.8	358	13.0	12.3
13	45.3	75.8	91.0	5.0	24.8	343	11.5	10.0
14	38.4	61.9	97.3	4.0	12.7	274	4.5	5.9
16	48.8	75.0	92.3	5.0	31.3	332	15.3	17.8
17	51.3	76.0	97.0	4.5	32.8	310	16.0	18.0
18	51.3	80.8	101.5	4.8	32.5	285	14.8	19.0

19	45.8	87.3	112.8	4.0	26.8	423	12.0	17.3
S.E. ±	6.15	5.04	6.52	0.46	5.52	32.7	4.52	2.46

There were significant differences in height at 14, 28 and 42 days after seeding (DAS) and there was considerable variability between accessions of the same species (Table 1). Bouake 189, a widely grown *O. sativa* cultivar, was among the shortest of the entries. *O. longistaminata* accessions were the tallest of the entries by 42 DAS, though had the fewest number of leaves by 28 DAS. *O. punctata* (10, 19) had the highest values of SLA while values for the *O. sativa*, *O. barthii* and *O. longistaminata* accessions appeared broadly similar.

Table 2 W**ild rice initial characterisation. Plant height cm (Ht), tiller number and panicles number at 90 days after seeding**

Entry	Ht 90	Tiller 90	Panicles 90
1	101	9	0
2	118	13	0
3	112	9	0
4	106	12	0
5	133	9	0
6	115	12	0
7	171	3	0
8	172	3	0
9	156	2	0
10	212	15	7
11	91	9	0
12	157	9	8
13	131	6	0
14	110	4	4
16	124	16	11
17	144	17	5
18	153	16	6
19	197	20	4
S.E. ±	8.6	2.2	1.81

By 90 days only 7 of the accessions had entered the reproductive phase (Table 2). The plants were kept in the glasshouse until 143 days after seeding but no other cultivars/species entered the reproductive phase and this did not change after plants were then kept in 12 hr light for 42 days. The experiment was conducted during shortening days with supplementary lighting to maintain a minimum 12 hr period. This indicates that *O. barthii*, *O. longistaminata* and Suakoko are photoperiodic - long day plants, while *O. punctata* and weedy rices from Asia are photoperiod neutral or short day plants. Difference in photo-periodism may account for the differences in the incidence of these wild/weedy rices in rice crops between east and west Africa.

Competition study 1 - Determining the competitive ability of a range of wild rices

The competitive ability of a range of wild/weedy rices was measured in a pot experiment where Bouake 189 was used as a standard competitor. The approach was that when the test cultivars were grown with a standard competitor, the relative performance of the two would give an indication of the competitive ability under these conditions. The data obtained from this experiment would be used to select entries for a replacement series experiment that was to follow.

Test cultivars grown in the experiment

1. *O. barthii* (awn white and long, Niono, Mali)
2. *O. barthii* (awn red, Niono, Mali)
3. *O. barthii* (awn white & short, Niono, Mali)
4. *O. longistaminata* (Niono)
5. *O. punctata* (Zanzibar)
6. *O. sativa* (red rice, straw hull - Brazil)
7. *O. sativa* (red rice, black hull - Brazil)
8. *O. sativa* (Bouake 189)
9. *O. glaberrima* (CG14)
10. *O. sativa* (Suakoko 8)

Entries were sown 3 seeds to hole in three holes on a 3 cm radius in the centre of an 8 l pot. Bouake 189 was sown, 3 seeds to a hole, in 8 holes about the circumference of the pot. Mineral compost was used in the pots and no additional fertiliser was added at the beginning of the experiment. Plants at each hill were thinned to 1 plant after one week. At 28 DAS plant dry weights were recorded from the plants in the inner and outer rows.

Table 3 Plant dry weights (g) from test cultivars and Bouake 189 at 28 DAS.

	Wt of test line	Bouake 189	Total wt (test line +B189)	Test line as % of total
1	3.41	9.16	12.57	27
2	2.78	10.10	12.88	22
3	4.60	8.94	13.54	33
4	3.36	9.69	13.05	26
5	2.17	10.61	12.78	17
6	4.08	9.05	13.13	31
7	6.16	8.15	14.31	43
8	3.29	8.32	11.61	28
9	4.76	8.80	13.56	35
10	4.84	8.95	13.79	35
SED	0.612	0.501	0.564	4.0

O. longistaminata (grown from seed) appeared to be the least competitive entry when grown together with Bouake 189 while the weedy rice (black hull) from Brazil appeared to the most competitive (Table 3). Bouake 189 appeared to have a similar competitive ability to the *O. barthii*. Suakoko 8 *(O. sativa*) and CG14 (*O. glaberrima*) appeared to have similar competitive abilities under these conditions.

Determining the competitive ability of wild rices - replacement series

To examine the relative competitive abilities of *O. barthii*, *O. longistaminata* and Bouake 189 a replacement series experiment was undertaken where different proportions of the species were grown. Pre-germinated rice was sown 2/3 seeds per hill in 8 hills per pot. The proportions were:

Bouake 189	0	25	50	75	100 %
Wild rice	100	75	50	25	0 %

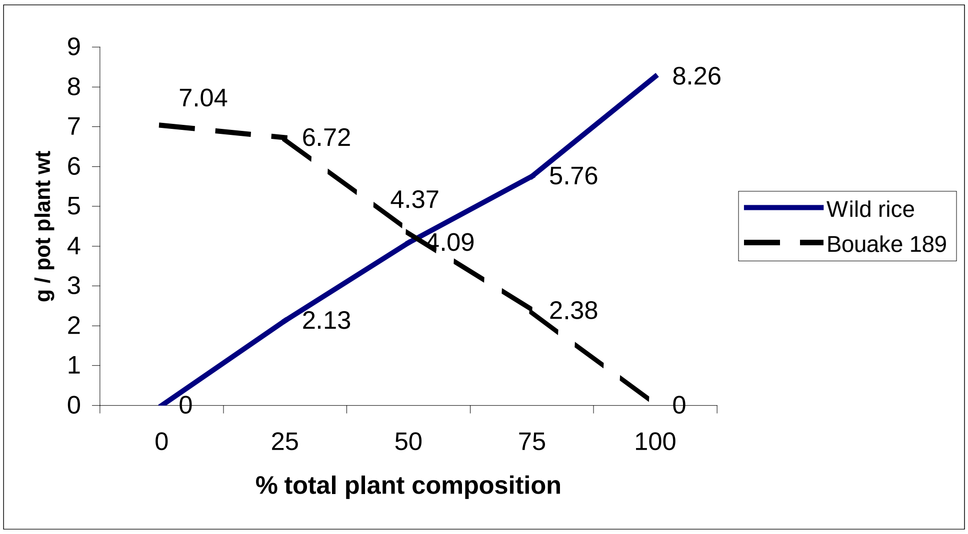

Fig 2 Interaction of *O. barthii* / *O. longistaminata* (mean) and Bouake 189 - biomass per pot after 28 days.

After 28 days, the *O. barthii* accumulated 12% more biomass than the *O. longistaminata* though there was no significant differences in the effects of the competition on the growth of Bouake 189 (Fig 2). The different proportions of the species did not significantly affect the total biomass for the pots.

The competition studies were continued as part of an MSc study and published as an MSc thesis R. Pell (2001). These studies compared a wider range of germplasm including *O. punctata*, *O. latifolia*, *O. barthii* and *O. longistaminata*. These studies suggested that *O. punctata* and *O. latifolia* were less competitive than *O .barthii* and therefore may be more easily suppressed by the rice crop. *O. latifolia*, in particular produced short, leafy plants, that had high specific leaf area. Both species exhibited only modest tillering.

4.3 Integrated weed management methods for prevention and management of wild rice species and rehabilitation of infested areas.

Depth of burial and the effects on emergence

To complement a study in Mali on the longevity of seeds in the soil (see below p. 13), a study was undertaken in the glasshouse to determine the depth from which seeds could emerge. 10 seeds per pot of the wild rice were placed at the required depth in pots filled with moist loam soil. Four complete replicates, in randomised design, were used. These pots were then placed on a capillary mat with counts of shoot emergence made at intervals until 14 DAS. The experiment was conducted with initially with *O. longistaminata* and then repeated with *O. barthii*.

Table 4. Effect of depth of seed burial on emergence at 14 DAS

Depth of burial (mm)	0	10	20	40	80	120	160
			% emergence				
O. barthii	85	93	90	90	95	35	3
O. longistaminata	78	65	68	55	38	-	-

35% of the *O. barthii* was able to emerge from 120 mm depth and some seeds were able to emerge from 160 mm (Table 4). The emergence of *O. longistaminata* occurred at slightly lower rates and emergence from 80 mm was 38%. The emergence of this seed was not tested below 80 mm.

The results indicate that to reduce the seed burden in the soil's seedbank, through stale seedbed techniques and other control measures, it would therefore be important to cultivate to only a maximum depth of 150 mm to prevent quantities of deeper seed being brought to the surface.

Sources of infestation of *O. barthii* in Mali

Little is known of the sources of infestation of *O. barthii* in the Office du Niger which contains large areas (*c.* 60,000 ha) of highly developed irrigated land used for rice. This information was regarded as crucial in enabling effective preventive measures. A study was conducted to measure the purity of farmers' seed, the levels of contamination in the seedbed and the levels of infestation in the drains and canals. The levels of contamination were determined in 2 kg seed samples from each of nine farms, and in samples of 200 rice plants taken from nurseries on each of 20 farms. To describe the levels of infestations along the irrigation canals, *O. longistaminata* infestations were recorded in 60 $1m^2$ quadrats in each of 10 tertiary canals and ten drains.

The majority of the rice area in the Office du Niger is sown with seed retained from the previous harvest and farmers only intermittently replace seed stocks with purchased seed. In nine samples of seed from farms, each containing approximately 8×10^4 seeds and all retained from previous harvest, only two samples were contaminated and only three grains of *O. barthii* were found. In the samples of plants taken from the nurseries, *O. barthii* seedlings were present in eight of the twenty samples. 9.5% of the seedlings in one sample were *O. barthii*. The remaining samples, however, contained a lower proportion and the overall average contamination of the seedlings with *O. barthii* was 3%.

The assessment of infestations in the waterways showed all the ten drains and canals visited were severely infested with *O. barthii*. On average, the drains contained 167 stems/m^2 (SD ± 53.5) of *O. barthii* and the canals 208 (± 25.1).

Contrary to what had been understood, levels of *O. barthii* contamination in the seed appeared to be at a relatively low level. Infestations were, however, occurring in the nursery beds, probably due to germinating *O. barthii* from the soil seed bank. This could possibly be addressed using a "stale seedbed" technique to reduce the levels of infestation prior to establishing the nursery. The likely source of much of the infestation appeared to be the canals that were very heavily infested and which undoubtedly are a source of seed carried to the fields in the irrigation water. Clearing canals of *O. barthii*, it is suggested, could have a big impact in reducing the ingression of *O. barthii* into this major rice growing area. Farmers currently have the responsibility for this though it is rarely enforced perhaps because its importance for the control of *O. barthii* is not adequately appreciated.

Duration of viability of *O. barthii* seeds in the soil

Nylon gauze bags, each with 100 grains of *O. barthii* seed inside, were buried in buckets with holes in them that were in turn buried in a padi field at Niono, Mali. Two bags were retrieved each month. The viability and the germination ability of these seeds was then determined. While the germination % of seed after 12 months appeared very low when the glumes were removed germination rose slightly to 15% (Fig. 3).

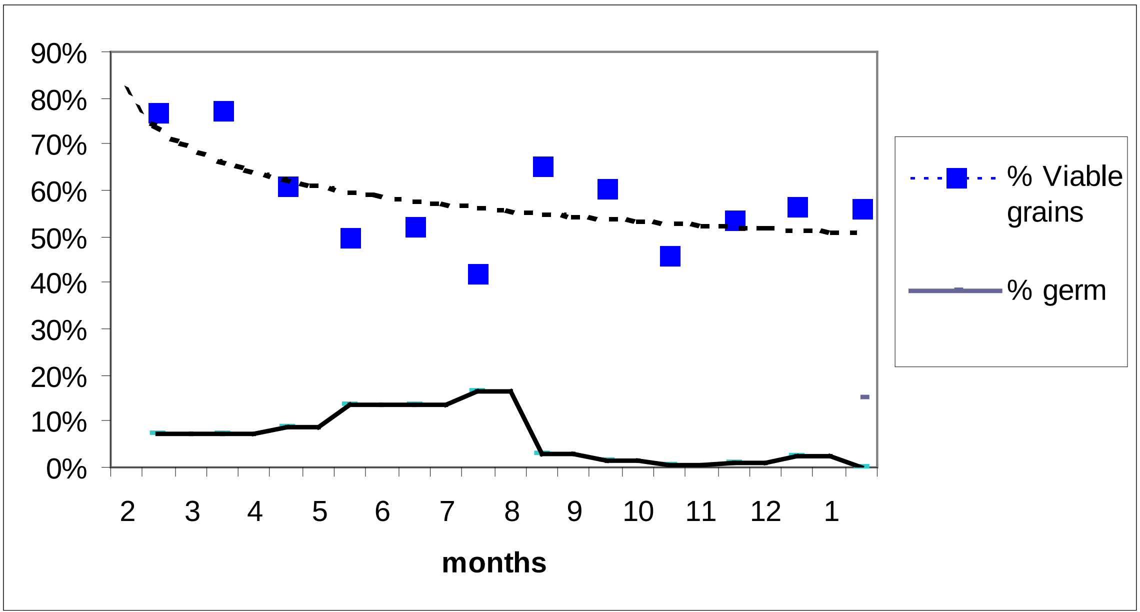

Fig 3. Viability and germination % of buried *O. barthii* seed over a 12 month period

The use of herbicides to control wild rices

Glyphosate is likely to the herbicide of choice for the control of wild rice because of its relatively low cost and efficacy in a wide range of situations. There are knowledge gaps however concerning whether differences in susceptibility exist between land races of *O. longistaminata*, and the timing and rates of application. To answer some of the questions experiments were conducted in glasshouses at Long Ashton Research Station and in the field in Ghana and Tanzania (see attached report Appendix 2).

After the glasshouse studies it was concluded that top growth of *O. longistaminata* and any subsequent regrowth from the root and rhizome system can be controlled effectively by glyphosate used at a rate of 640 g a.e. ha^{-1}. At this rate even very large plants (12.5 weeks old) with a substantial rhizome system were killed. Smaller plants generating from seed or rhizomes can usually be completely controlled by a lower rate of 320 g a.e. ha^{-1}. There were indications of a slight trend for the Mali accession to be more tolerant to glyphoste than the other biotypes. Field studies in Tanzania examined the effect of different doses of glyphosate and the age of *O. longistaminata* regrowth after cutting at which the herbicide was applied. It was shown that 1.08 kg a.e. ha^{-1} reduced shoot numbers by more than 90% and there appeared to be no additional benefit of increasing the application rate above this. There appeared to be only a small or marginal effect of the age of the regrowth at the time of spraying. It appeared from this study that an application at 1.08 kg a.e. ha^{-1} to *O. longistaminata* regrowth of 4 weeks old would provide effective control. Studies in Ghana confirmed that they may be an advantage of allowing the *O. longistaminata* to grow to 4 or 6 weeks after cutting before applying glyphosate.

Wild rices are so genetically similar to cultivated rice that selective herbicides are not available for the control of these weeds in rice. The availability however of imidazolinone-tolerant (IMI-tolerant) rice cultivars resistant to aceto-lactate synthase (ALS)-inhibiting herbicides could allow the selective control of wild rices in the rice crop. These IMI-tolerant rices are produced through chemically induced mutation rather than genetic modification and their use has been reported from the USA. These could therefore be grown widely without contravening legislation prohibiting the utilisation of genetically modified crops. Experiments were conducted to examine the effect of imazamox, imazapyr and imazethapyr on *O. barthii* and *O. longistaminata* applied at the pre-emergence and post-emergence stages. A fourth herbicide, oxadiazon, was included in this study as it had been suggested as a possibility for controlling *O. barthii* after studies in Mauritania. In glasshouse studies at Long Ashton Research Station, pre-emergence applications of imazethapyr and imazamox had more effect on the germination of *O. longistaminata* than imazapyr and oxadiazon application, while there were no significant effects on *O. barthii*. Oxadiazon at the highest rate depressed the growth of *O. longistaminata, O. sativa* and *O. barthii* and reduced the biomass per plant by more than 50%. With the post emergence applications of the herbicides, imazethapyr had the greatest effect on growth, reducing weight per plant by 95% across rates and species compared to controls. There appeared to be little benefit of applying rates higher than 40 g a.i. 200 l , the minimum used, as this rate decreased growth by 90% compared to the control. Oxadiazon had the least effect of the herbicides across rates and species and even the highest rate only decreased growth of *O. barthii* and *O. longistaminata* by c. 50%. Oxadiazon had a similar effect on IDSA 6. The results of these experiments suggest that oxadiazon, applied pre- or post emergence, would not be suitable for the selective control of *O. barthii* or *O. longistaminata* in rice. Providing the imidazolinone resistant rice cultivars were available to farmers, the results indicate that imazethapyr could be used successfully as a post emergence application at low rates (40 g a.i. 200 l) to control *O. barthii* and *O. longistaminata growing* from seed.

Integrated control measures for *O. longistaminata*

Experiments were established in farmers' fields in Ghana, at Fumbisi (Upper East Region) and Kadia in the (Northern Region), and at Macina, Office du Niger in Mali, to examine the potential advantages of utilising glyphosate in the preparation of land for rice.

Treatments in Ghana were T1. Stale seed-bed, glyphosate (2.16 kg a.e. ha, Roundup) applied as two equal doses at two weeks interval, rice dibble seeded ; T2. Plough, bund, puddle, rice transplanted; T3. Plough, rice dibble seeded with intercrop of taro (*Colocasia esculenta*[*]; and T4. Plough, rice dibble seeded. At Kadia, rice was sown at double seed rate at 200 kg/ha instead of the Taro intercrop.

Treatments in Mali were: M1. Plough, harrow, transplant (farmers' practice);
M2. Glyphosate (2.16 kg a.e./ha, Roundup), 21 days later plough, harrow, transplant rice;
M3. Glyphosate (2.88 kg a.e./ha, Roundup), 21 days later plough, harrow, transplant rice;
M4. Glyphosate (2.72 kg a.e./ha, Biosec), 21 days later plough, harrow, transplant rice; and
M5. Plough twice, harrow and transplanting

Wild rice populations were recorded before the treatments were applied and at four weeks after planting (WAP).

Control measures for O. longistaminata in Mali

At the start of the study there were an average of 177 stems/m^2 of *O. longistaminata* on the experimental site with no significant differences between the plots. All the treatments proved to be equally effective at controlling the *O. longistaminata* and there were no significant differences in rice yields between the treatments. The mean yield of the treatments was 3.89 t/ha with the largest yield of 4.54 t/ha from treatment M4. The effectiveness of the farmers' treatment (M5) was due to the thoroughness of the land preparation. Harrowing of land after ploughing under wet conditions facilitates hand removal of the rhizomes that proved as effective as the herbicides at controlling wild rice. The removal of rhizomes by hand, which was not practised where glyphosate was used, required between 30-39 man days/ha.

Control measures for O. longistaminata in Ghana

At Kadia and Fumbisi, application of glyphosate (T1) to regrowth of *O. longistaminata* reduced the populations of this weed in the subsequent crop, but control was not complete. This treatment gave a significantly greater grain yield than traditional (T4) practice (Table 5). Bunding the land, puddling and transplanting the rice (T2) appeared effective at controlling the *O. longistaminata* at Kadia, but was less effective at Fumbisi. At Fumbisi, however, the treatment did result in the highest grain yield. At Kadia, the higher seeding rate (T3) gave an increased yield compared to traditional practice, but the intercropping with taro produced no rice yield improvement or suppression of the *O. longistaminata*. No yields of taro were recorded as pigs consumed this crop.

Table 5. The effectiveness of control measures on *O. longistaminata* population and rice grain yield in Ghana, wet season, 2000**.**

Site	Kadia			Fumbisi		
Treatment	Population m^2, initial	Population m^2 4 WAP	Grain yield (t/ha)	Population m^2, initial	Population m^2, 4 WAP	Grain yield (t/ha)
T1	182	8	2.30	134	29	2.12
T2	257	15	1.82	119	47	2.17
T3	183	95	1.41	112	64	1.32
T4	246	119	0.79	135	77	1.55
Mean	217	59	1.58	125	54	1.79
CV (%)	28.6	33.1	16.6	10.0	29.2	11.2
SE ±	35.9	11.3	0.15	7.2	9.1	0.12

Use of glyphosate in the rice system must be evaluated in terms of its economic impact on the returns to farmers. In Mali, partial budgeting of control methods indicated that treatment M4 gave the highest returns. This reflects the higher yield with this treatment that gave £114/ha extra at harvest at cost of £69/ha for the herbicide. There was also the saving of labour required for raking the rhizomes that was necessary where the glyphosate was not used. This is estimated to be valued at £33/ha. Herbicide use however requires the necessary resources and knowledge base and, to some extent, increases the risks to the farmer. Further, labour is not always available or farmers may allocate any available labour to tasks that have a higher priority. This would increase the value of labour-saving technologies.

At Kadia, in Ghana, the farmers' practice had the lowest costs of production. The stale seedbed (T1, using glyphosate), transplanting (T2) and double seeding (T3) treatments increased costs, compared to farmer' practice, by £92, £152 and £121/ha. Only the stale seedbed option with glyphosate gave a ratio cost : benefit greater than one, but again there are factors that may mitigate against adoption of herbicides by some farmers. Where the market exists, rotations with sweet potato seemed to have a marked effect on reducing the wild rice populations and this option may be further developed. Another promising line of research is thought to be the development of dry season cropping in rotation with the rice crop as the returns for crops such as vegetables could justify the use of inputs and the intensified land use would be likely to reduce the build-up of *O. longistaminata*.

Farmer evaluation

Over a two-year period farmers were involved in the evaluation of wild rice control methods. In the first year the trials were researcher managed and were conducted at two sites, Kadia and Fumbisi. At the end of the 2000 growing season, which had involved researcher-managed trials of control methods, farm walks involving both men and women farmers were organised to allow farmers to critically observe each plot. In the second year farmers at Fumbisi selected treatments they wished to test further and they were assisted in the application of the treatments. In that year the treatments tested were: T1. stale seedbed treatment glyphosate applied before dibble seeding of rice; T2. rice broadcast at double the seed rate (200 kg ha); T3. farmers practice of removal of rhizomes by hand as the land is prepared and rice dibble seeded; T4. bunding, puddling and transplanting of rice seedlings; T5. dibble seeding of site fallowed the previous year.

After the 2000 and 2001 growing seasons, the chemical treatment (T1) was ranked first. Reasons given for this ranking were that with the chemical treatment no ploughing has to be done before sowing; hence the money or labour that could have been used for this activity is invested elsewhere. The disadvantages of this treatment were the high cost and unavailability of the chemical. The intercropping of taro with rice was ranked second after the 2000 growing season, although this treatment resulted in negative net returns. The main advantage of this treatment is that it is a risk aversion venture. Farmers expressed the feeling that in case of one crop failing the other may survive. Other advantages were the suppression of the wild rice by the taro and the avoidance of the high cost and unavailability of the chemical. Farmers' own practice (T3) was ranked third after the 2000 growing season, and also in late 2001. Its advantage was said to be that it is a low cost technology that can easily be practised by any farmer. Its disadvantages were that weeding must be timely and it is only applicable in low-lying parts of the valley. Bunding and transplanting was ranked fourth after the 2000 growing season even though it actually came second in terms of financial returns. By late 2001, however, farmers ranked it second in the questionnaires. Farmers said that it has the advantage of the rice seedlings establishing before the wild rice and the bunding improving on the water retention capacity of the soil, and that it leads to good plant growth and good yields. The respondents attributed good yields to improved plant population and spacing. Its constraint was the fact that it is labour intensive and therefore time consuming. This is due to the labour involved in the nursery management and construction of the bunds. High labour input was seen as making it not very practicable on a large scale. Fallowing (T5) was assigned fourth rank in late 2001.

The most striking change in farmer views that took place was that bunding and transplanting, which was ranked last after the 2000 growing season, was ranked second in late 2001. This seems to reflect the fact that the farmers concerned had little knowledge of this method of cultivation and that their exposure to it during 2000/1 led to a marked interest in it. This was also reflected in focus group discussions held in early 2002 with both male and female farmers after farmer-controlled trials had been carried out for a year, when bunding and transplanting was rated as the most likely treatment to be adopted. While chemical treatment was ranked first, farmers, by a large margin, said that bunding and transplanting was the method they would be most likely to adopt (67%). Chemical control came second (27%). The remainder of the respondents said that they would continue to use their own practice (7%).

Effects of dry season cropping

During the yield loss studies it was recorded farmers' observations were that growing sweet potato substantially reduced infestations of wild rice. This was supported by observations that show rice grown after sweet potato (*Ipomoea batatus*) had only 4 stems/m^2 of *O. longistaminata* compared to 50 stems/m^2 (SE ± 9.1) where it had not been grown.

The growing of vegetables in the dry season provides a clear opportunity for improving control of wild rice. By using these rice fields for vegetable production in the dry season, the level of wild rice infestation could be reduced through the additional cultivation and weeding.

In the dry season of 2000/01 and again in the dry season of 2001/02, a trial of dry season vegetable growing was conducted in Fumbisi, on the fields where the on-season trials of direct control methods for *O. longistaminata*. In the first year, this was researcher controlled; in the second year it was mainly farmer-controlled, with a control plot managed by researchers. There are precedents for growing vegetables in the dry season in this area. In a community close to Fumbisi called Wiaga where dry season vegetable growing is practised under irrigation, the land is used for rice production in the wet season and in the dry season it is used for vegetable production. At Kobore, a village near Bawku, this is also practised and farmers have sunk wells for watering in the dry season.

There is considerable potential for sale of vegetables produced in the dry season, since there is a shortage of vegetables in this period. A constraint is the lack of water, but as the water table is quite close to the surface in the valleys in which rice is grown and can be reached through sinking wells. A well was sunk to allow access to water for a trial of vegetable growing in the dry season of 2000/2001 on the same land on which the wet, on-season trial of control methods was being conducted. There was considerable interest on the part of the members of the farmer group owning the land on which the trial was being conducted.

Unfortunately, during the dry season of 2000/2001 most of the vegetables were eaten by grasshoppers. The dry season cultivations had however almost eradicated the growth of *O. longistaminata*. Members of the group were still very interested in being involved in the work and at a focus group held by researchers, the women expressed their interest in being involved in the trial and a second well was sunk for their use.

At the two focus groups held at Fumbisi, with male and female farmers, all the farmers expressed great interest in dry season vegetable growing and it was clear that they would take this forward in future years. Farmers were clear that so long as they have a reliable and sustainable source of water supply in the dry season they would want to practice dry season gardening. They were very aware of the economic opportunities that it gave in terms of marketing their vegetable crops. The women farmers involved in the trial said that they planned to open a group savings account for the money that they got from selling the vegetables grown.

4.4 A bi-lingual (French and English) technical leaflet covering the identification and control of wild rices.

A leaflet has been developed entitled "The management of wild rices in Africa" that is being developed into a bi-lingual pamphlet for distribution in Africa. The draft version of the text, with photographs and line drawings can be seen as Appendix 3.

4.5 Regional workshop to present project's findings on the advances in the management of wild rices.

a) A workshop was held at WARDA in April 2002 to coincide with the biennial Regional Rice Research Review. Presentation of the research and findings were presented and there were opportunities for discusssion. The meeting was well attended with 15 participants from six African countries. Following the presentations there were discussions held on the potential for the application of technologies, considerations and locations. Approaches for improved management were classified as: a) Intensification of cropping systems / development of rotations; b) Cultural approaches/ water management; c) Preventative measures. Regarding the application of the technologies the following points were made :

Tanzania

a) Development of cropping systems eg rice- maize- fallow, rice beans fallow or rice vegetables are constrained by socio-economic issues including access to markets. Possible sites of application include Kilombero, Usangu Plains, Kilombero and Kyela.
b) Irrigation - there were institutional issues and cost implications of improved irrigation on the Usangu plains, Kilimanjaro, NAFCO farms - Mbarali, Kapunga, Ruvu and Dakawa; bunding - Mwanza, Shinyanga, Usangu plains
c) Mainly seed purity and burning of residues; their are technical and socio-economic/institutional issues involved. Kilombero (seed producers) Ulanga, Kilosa, Kilombero and Kyela

Southern Mali

a) Considerable scope around Sikasso for the diversification of rice based systems, socio-economic and agronomic aspects important, particular consideration should be given to division of enterprises between men and women.
b) As above but also much of the land has other use outside of the rice season with grazing, vegetable production, particularly in Sikasso area.
c) Crop diversification and preventive measure has potential application around Sikasso.

Mali - Office du Niger

a) Office du Niger now encouraging crop diversification including dry season vegetables
b) In Office du Niger wild rice has tended to give way to *Ishaemum rugosum* and Eleocharis sp. as the main problems.
c) Office du Riz Segou and Office du Niger are the key institutions to promote preventive measures. Control of water and irrigation structure are at state, Office du Niger and local organizations and the control of seed also lies with these organizations.

Senegal
Sweet potatoes, vegetables, tomato, onion have considerable scope. There is the institutional framework in place for developments in the Senegal River valley and Casemance.

a) Use of pre-irrigation treatments and destruction of germination wild rice by cultivation or herbicides has been tested. Senegal River Valley.
b) Certified seed is available, scope for cleaning bunds, canals and drains. Requires sensitisation of the local producers and farmers groups and other local organisations. Senegal River valley and Casemance.

Discussion took place on what information should be included in the leaflet and what the format of this should be. Participants will be sent copies of the Final Technical Report.

4.6 Feasibility and risk assessment for the deployment of GM herbicide tolerant cultivars for wild rice management in the context of African systems.

Herbicide resistant crops (HRC) allow the application of an overall application of herbicide that would kill all the weeds while the crop survives. These HRC's are generally produced from genetic modification and these are perceived as posing potential risks to biodiversity, the composition of weed floras, consumer choice, and “traditional” farming practices including the use of local cultivars and farm saved seed. The study concentrated upon biological considerations but it is relevant to consider the likely opportunity for adoption of HRC rice in the West African context. Farmers in the region mainly plant farm saved seed. Improved cultivars are grown in the majority of lowland areas but there is a relatively slow turn over of cultivars and many have been grown for many years. As rice is self-pollinated farmers are able to maintain both improved and traditional types. Exceptions to this are the large irrigation schemes on which farmers may purchase seed every year, including the Senegal River Valley, Office du Niger (Mali) and the Ghana Rice Growers Association (in northern Ghana). There could therefore be a place for HRC rice as a seasonally purchased input on these schemes for land on which wild rice is a problem. Commercial considerations of the biotech companies will ultimately determine if HRC rice is to become available in W. Africa as adapted HRCs will only be developed if the market is perceived to be large enough. Likely adoption will also depend upon the cost – Monsanto for example is likely to protect it’s rights to glyphosate resistant rice by a legal agreement with growers to prevent them from saving home grown seed and, will charge a “technology fee” as part of the seed cost.

A risk analysis of whether HRC rice will create problems after adoption needs to consider the following:

- Direct effects of HRC’s involving:

i Increased volunteer crop problems
ii Invasion of the environment beyond the farm boundary

- Escape of transgenes from HRCs involving:

iii Introgression to weedy relatives on a field scale, amplification effects of existing weeds

- Indirect effects of introduction of HRCs involving:

iv Increased selection pressure for evolution of herbicide-resistant weeds
v Effect on non-target organisms from increased use of herbicides

HRC introduce the possibility of improved management systems for wild and weedy rice populations which pose major constraints in many of the world's rice production systems, including those in West Africa. The current understanding of the breeding system and genetic relationships within the genus *Oryza* suggests that transgene flow from HRCs to volunteers of conventional *O. sativa* cultivars should however be expected. This would confer a selective advantage within the herbicide resistance system and, the potential to become difficult control "weedy rices" if allowed to contaminate seed multiplication fields or if seed head shattering or seed dormancy traits lead to a persistent seed bank. It is therefore essential that the extent of gene flow from *O. sativa* to wild and weedy rice be quantified prior to the introduction of herbicide resistant cultivars in W. Africa. If, after an appropriate risk assessment, commercialisation occurs it should be accompanied by measures that are designed to prevent the development and spread of resistant wild and weedy rice or, of herbicide resistant populations of other weeds.

5. **Contribution of Outputs**

5.1 Contribution of outputs to project goal

The goal of the Land/Water Interface production system is " yields in rice-based systems in flood plain areas increased by environmentally benign pest control methods." Glass house studies showed that *O. barthii,* O .punctata and *O. longistaminata* grown from seed had a similar competitive ability as a cutivated O. sativa Bouake 189, and were much less competitive that an O. sativa "wild rice" from Brazil. In trials over a number of sites in West Africa, wild rices were shown to cause serious yield losses to rice. *O. barthii* seed was shown to be able to emerge from a depth of 160 mm and seed had a germination percentage of 15% after burial for 12 months in a padi soils. Potential sources of contamination of the annual wild rice species *O. barthii* were the nursery beds and infestations in the drains and canals. Preventive measures would be likely to be feasible in many areas. *O. longistaminata* could be controlled by glyphosate, an environmentally benign herbicide, or cultivation. There did not appear to be any differences between *O. longistaminata* from Tanzania, Ghana, Mali or Ivory Coast in their susceptibility to glyphosate. Infestations of *O. longistaminata* were greatly reduced where farmers were practising dry season vegetable cropping. To test the feasibility of this in one infested area in Ghana the project initiated farming groups of men and women dry season cropping. Farmers were enthusiastic about the possibilities of dry season cropping and it appeared as if this would be developed. The project had made a substantial contribution in the knowledge that is available on wild rices in Africa and has developed a number of strategies to control the weed. These will, if employed, reduce losses due to pests in the infested areas.

Seed from some of the materials collected in Africa were supplied to the DFID funded project at the International Rice Research Institute that is undertaking molecular level studies to determine the genetic background of wild rices and the genesis of infestations.

5.2 Achievement of outputs stated in the project memorandum

Ouput 1. An understanding of farmers' perceptions of wild rices in relation to the complete weed flora, sources of infestation, current control methods and estimated yield losses due to wild rice.

Collaboration with farmers was established in Ghana, Mali and Tanzania was established and through field visits and focus group discussions information on farmers' perceptions and current control methods was gathered. The emphasis of these studies was on Ghana. Yield loss studies on farmers fields were conducted in five areas in Ghana and Mali. These studies provided the background against which the rest of the research was conducted.

Output 2. Information on the distribution and the relative importance of wild rice species in selected areas of Ghana, Mali and Tanzania.

Information on the distribution and importance of wild rices was gathered through field visits and literature review. This was in part published as a presentation to an FAO workshop (Johnson *et al.* 2000). Materials for identification were collected from the field and have been conserved at Long Ashton Research Station.

Output 3. Integrated weed management methods for prevention and management of wild rice species and rehabilitation of infested areas.

This was the major area of activity in the project with field activities in five sites in and with glasshouse studies being conducted in UK. Glasshouse studies were conducted on the comparative growth of wild rice species to measure differences and to describe their characteristics. Aspects of biology including the duration of seed viability and abilities to emerge from depth were conducted. The efficacy of different rates of glyphosate was measured on different accessions of *O. barthii* and *O. longistaminata* in glasshouse studies and these were complemented with field studies in Ghana and Tanzania. Integrated control measures, including cultural and chemical interventions, were studied in four field experiments in Ghana and Mali. In Ghana the experiments were carried out within a participatory framework.

Output 4. A bi-lingual (French and English) technical leaflet covering the identification and control of wild rices.

A leaflet for production in French and English has been prepared and is being produced in collaboration with WARDA. The outline for this was developed at the end of project workshop in April 2002. It contains line drawings and descriptions of the main species occurring in Africa and the principal means of control. The leaflet will available to NARES through WARDA's documentation services and the task forces.

Output 5. Regional workshop to present project's findings on the advances in the management of wild rices.

A one-day workshop was held in Côte d'Ivoire to coincide with regional rice research workshop at WARDA. The collaborators from Ghana, Tanzania and Mali attended together with research staff from other WARDA member countries. In total of 15 participants from six African countries attended. Presentations were made on the research findings from each of the countries on the work that had been undertaken in the project. Discussions were held on the research findings, where further work needs to be conducted and the scope for the application of the findings.

Output 6. Feasibility and risk assessment for the deployment of GM herbicide tolerant cultivars for wild rice management in the context of African systems.

A desk study was undertaken to determine the potential risks related to the introduction of genetically modified rice. While these technologies may provide an effective means of controlling wild rice infestations it was concluded that the risks of gene-flow from GM rice to the wild populations is too high to make this a technology that can be recommended. Initial steps have however have been undertaken using rice resistant that to imidazolinone herbicides though not produced through GM technology. Use of this technology may be well suited for the rehabilitation of infested areas.

5.3 Contribution to DFID's development goals

The project is unlikely to have any direct and immediate impact on the poorest farmers in the community, with the possible exception of where dry season cropping has been encouraged in Ghana with demonstration plots and the construction of wells. The methods of controlling wild rice that have been tested have, however, been seen by many and these have been well received by farmers and feedback has been positive. It is expected however that some farmers will adopt control measures to control wild rice in the near future as demand for rice increases.

5.4 Promotion pathways to target institutions and beneficiaries

The project has sensitised institutions to the problems caused by wild rice in Africa and some means of improving its control. The project has worked closely with research and extension staff of the national institutions in Ghana, Mali and Tanzania. The results of the project will be made available to the target institutions enabling them to further develop these in the form of extension recommendations.

5.5 Follow up action/research to beneficiaries to promote findings

At the final workshop one of the main topics of discussion was the application of research findings. The main constraints to adoption included the lack of information at farmer, extension service and institutional levels, the non- availability of herbicides, and socio-economic constraints. Many of the proposed technologies for the management of wild rices require local adaptive research, refinement and promotion. This in turn requires an institutional framework that is not widespread. WARDA is undertaking a programme of participative research termed Participative Learning and Action Research (PLAR). This has been aimed at integrated crop management and includes a weed management component. It has been proposed that the PLAR activities are developed further to focus on reducing losses due to pests and on IPM. Where wild rices are a problem this would be an ideal medium to develop the control measures with farmers. Opportunities should be sought to undertake adaptive and promotion research in east Africa, as this area has been only a minor part of this project, and a significant wild rice problem exists in this region.

Wild rices are likely to be or become a constraint of lowland rice production wherever this is developed in Africa. Management methods aimed at prevention and the control of the wild rice problem are an important element of an integrated weed management strategy for rice. It is important that information is widely available to allow adoption and enable local adaptation of technologies. Opportunities to incorporate the findings of this project in rice development projects, particularly those funded by national, bi- or multi-lateral agencies, in Africa should be sought.

5.6 Publications

Conference proceedings

Tuor, F. A., Gyasi, K. O., Terbobri, P., Sarra, S., Hamadoun, A., Janowski, M. and Johnson, D. E. (2001) Incidence, yield losses and some control measures for wild rice in West Africa. *Proceedings of the Brighton Crop Protection Conference - Weeds*, 2001, BCPC, Farnham, UK, 889-894.

Johnson, D. E., Riches, C. R., Kayake, J., Sarra, S. and Tuor, F. A. (2000) Wild rice in sub-Saharan Africa: its incidence and scope for improved management. FAO Global Workshop on Red rice Control, 30 August - 3 September 1999, Cuba. pp 87-94

Other dissemination of results

Riches, C. R. and Johnson, D. E. (2001) Implications of the use of herbicide-resistant rice in wild rice dominated weed floras in West Africa. 15 pp. In: Use Of Transgenic Pest and Disease Resistant Crops in Developing Countries. R. Thwaites and S. Seal. Natural Resources Institute, University of Greenwich. (Institution report)

Pell, R. (2001) Characterisation of early growth and competitive interactions between cultivated rice and annual wild *Oryza* species. Project Report for MSc Degree in Crop Protection, University of Bristol. (MSc)

Demanya, A. K. and Nusenu, R. Y. (2000) Economic effect of wild rice on rice cultivation - a case study of Fumbisi rice valley in the upper east Region of Ghana. Department of Agricultural Economics and Extension, Faculty of Agriculture, University for Development Studies, Tamale. Ghana. 74 pp. (undergraduate thesis)

Mali

Farmer Field Days (c. 60 farmers) wild rice control experiments - Kogoni, Office du Niger, Institut d'Economie Rurale (Sept, 1999, October 2000 & October 2001).

IER (2000) Annual Report 1999, Institut d'Economie Rurale, Bamako
IER (2001) Annual Report 2000, Institut d'Economie Rurale, Bamako
IER (in press) Annual Report 2001, Institut d'Economie Rurale, Bamako

Comité Technique Regional (25-27 April 2000, 16-18 May 2001, 23-25 April 2002), Institut d'Economie Rurale (presentation of research results at regional level with extension staff and farmers representatives to determine topics to take forward for farm testing).

Comité Regional des Utilisateurs (7-9 March, 2000; 17-19 April 2000, 27 March 2002), Institut d'Economie Rurale Rurale (presentation of research results to extension staff and farmers' representatives to determine topics for promotion).

Ghana

SARI (in press) Annual Report 1999, Savanna Agricultural Research Institute, Tamale, Ghana

SARI (in press) Annual Report 2000, Savanna Agricultural Research Station, Tamale, Ghana

SARI (in press) Annual Report 2001, Savanna Agricultural Research Station, Tamale, Ghana

Farmers' Field Days, wet rice wild rice control measures, Kadia and Fumbisi August and October 2000 and (Fumbisi only) September and November 2001.

Farmers' Field Days, Dry season vegetables for wild rice control, Fumbisi February 2001 and April 2002

Tanzania

Farmers' Field Days in Dodoma, Iringa and Morogo 2001

Workshop Presentations

Tuor, F. "Wild rices in northern Ghana: farmers' perception, control methods and yield losses" June 2000 SARI seminar to staff , Savanna Agricultural Research Institute, Tamale

Tuor, F. "On-farm verification of options for wild rice control" December 2000 SARI seminar to staff, Savanna Agricultural Research Institute, Tamale

M'Bare, C. Lutte intégrée contre les riz sauvages au Mali. Presentation at regional meeting on weed management in Rice, April 2001, N'Diaye, St Louis, Senegal.

WARDA (2002) Workshop on "Management of wild rice in Africa", 8 April, 2002. West Africa Rice Development Association, M'be, Bouake. Presentation to regional NARES research staff.

Tuor, F. The influence of dry season vegetable cropping on the incidence of wild rice in a follow-up rice crop.

Mbapila, J. The incidence of wild rice in Tanzania and the effects of different rates and timing of glyphosate application.

Tuor, F. On-farm verification of technologies for Oryza longistaminata control.

Terbobri, P., Tuor, F. and Janowski, M. Economic analysis of alternative control methods for Wild Rice

Tuor, F. Effects of plant age and glyphosate concentration on the control of Oryza longistaminata.

Diallo, S. Les Riz sauvages dans les systèmes rizicoles au Sénégal.

Sarra, S. and Dembele, M. Mise au point d'une stratégie de lutte intégrée contre les riz sauvages

Terbobri, P., Tuor, F. A., Gyasi, O.K., Janowski, M. and Wahaga, E. Wild Rices in northern Ghana: incidence, farmers' perceptions and methods of control.
Doumbia, Y. Etude de l’effet de la Gestion des Cultures sur les riz sauvages.
Johnson, D. E. Glasshouse studies on *O. longistaminata* and *O. barthii*. i. Comparative growth studies and ii. effect of glyphosate rates and stages of application.

Internal Reports

Visit to Côte d'Ivoire for end of project workshop "Management of weedy rices in Africa - A0823" 04/04/2002 to 13/04/2002 D E Johnson
Visit to Cote d'Ivoire to participate in final project workshop in Bouake at WARDA 07/04/2002 to 10/02/2004 Monica Janowski
Visit to southern Tanzania for project A0823; Management of weedy rices in Africa 15/03/2002 to 22/03/2002 D E Johnson
Visit to Ghana 22/02/2002 to 02/03/2002 Monica Janowski
Visit to WARDA, Ivory Coast and Mali 27/01/2002 to 08/02/2002 D. E. Johnson
Visit to Ghana 06/12/2001 to 13/12/2001 Monica Janowski
Visit to Ivory Coast, Ghana and Mali. 06/09/2001 to 20/09/2001 D E Johnson
Visit to southern Tanzania 01/05/2001 to 13/05/2001 D E Johnson
Visit to SARI, Ghana 22/03/2001 D E Johnson
Visit to SARI, Ghana 22/03/2001 to 28/03/2001 Monica Janowski

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Diallo, S. and Johnson, D.E. (1997) Les adventices du riz irrigue au Sahel et leur controle. p311-323, In: Miezan, K.M., Wopereis, M.C.S., Dingkuhn, M., Deckers, J. & Randolf, T.F. (Eds.) *Irrigated rice in the Sahel: Prospects for sustainable development*. Bouake, Cote d’Ivoire: West Africa Rice Development Association.
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Holm, L., Plucknett, D., Pancho, J. and Herberger, J. (1979) *The World’s Worst Weeds:Distribution and Biology*. Honululu, Hawaii: University Press of Hawaii.
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Riches, C.R. (1989) *Weed control in Sierra Leone*. Report of FAO project SIL/85/004.
Vaughan, D.A. (1994) The Wild Relatives of Rice. International Rice Research Institute, Manila, Philippines, 137 p.