Appendix 1

Rice farming and the problem of wild rice in the context of farming systems in Northern Ghana: Social and economic dimensions of control

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1. Research sites used for socio-economic data collection under the project

There were three research sites used for the purposes of collection of socio-economic data under the project: Kadia, near Tamale in the Northern Region; Gani, in the Tono irrigation scheme near Navrongo in the Upper East Region; and Fumbisi, in the Upper East Region. All three were surveyed for baseline information on farming systems, rice cultivation and the problem of *O. longistaminata* during the first part of the project in 1999 and 2000; Fumbisi went on to be the site for trialling of technologies for controlling *O. longistaminata* in 2000-2002. This was in scientist-controlled and farmer-controlled trials both on rice fields and also through a dry season vegetable growing trial.

Socio-economic data collection was carried out under the direction Osman Gyasi of SARI in Kadia and under that of Paulinus Terbobri of SARI in Tono (Gani) and Fumbisi. In addition, some data was collected through focus group discussions held by Monica Janowski of NRI. The methods used included direct field observations, questionnaires and semi-structured interviews using a checklist of questions. Individual/key informant interviews, group interviews and discussions as well as focus group discussions were also held with village elders, farmers and local assemblymen, and pairwise ranking and community mapping were also employed. Data collection was mainly carried out by research staff of the Savanna Agricultural Research Institute (SARI) and by extension staff of both the Ministry of Food and Agriculture (MoFA) and the Irrigation Company of the Upper Regions (ICOUR). These staff members work closely with the farmers and have a good understanding of farmers' circumstances. Farmers were selected to participate in the interviews based on their willingness to participate in the discussion and the presence of wild rice on their fields. Each group interview was followed upby field visits to identify species and infestation levels of wild rices. Needs assessment, using pair-wise and preference ranking (direct matrix scoring) techniques were conducted in all the communities to determine the relative priorities of the farmers.

In addition, two students at the Department of Agricultural Economics and Extension, Faculty of Agriculture, University of Development Studies, Demanya Ametepe Kofi and Nusenu Richard Yaw, carried out a survey in Fumbisi on the economic effects of wild rice on rice cultivation. In this report, this will be referred to as the survey carried out in Fumbisi, to distinguish this data from that collected through SARI. Data from all of the sources listed above has been used in compiling this report.

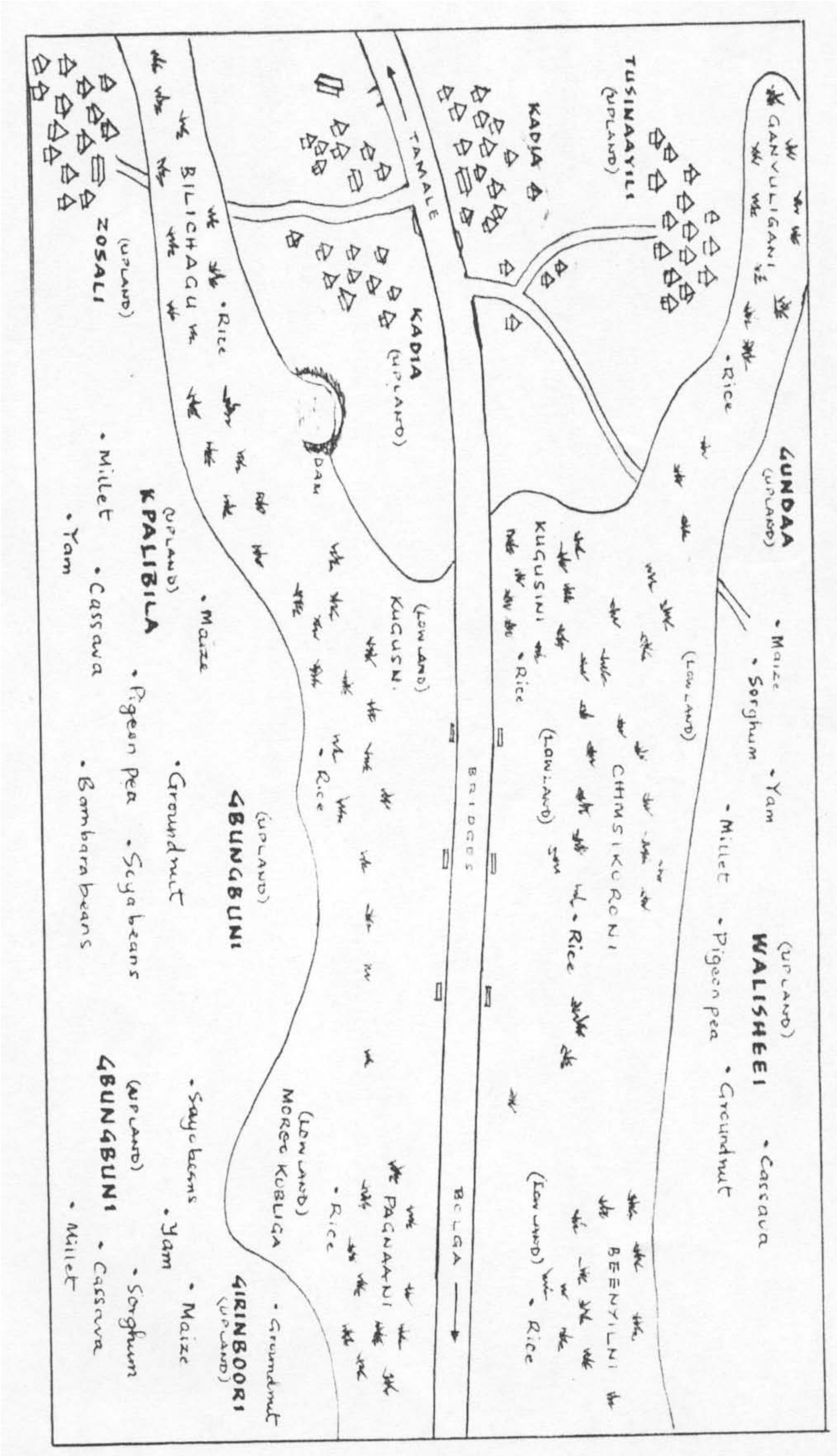


Figure 1 – Kadia village, Northern Region, Ghana, showing cropping areas for different crops. This is typical of villages in Northern Ghana, except that yams are not grown in all areas.

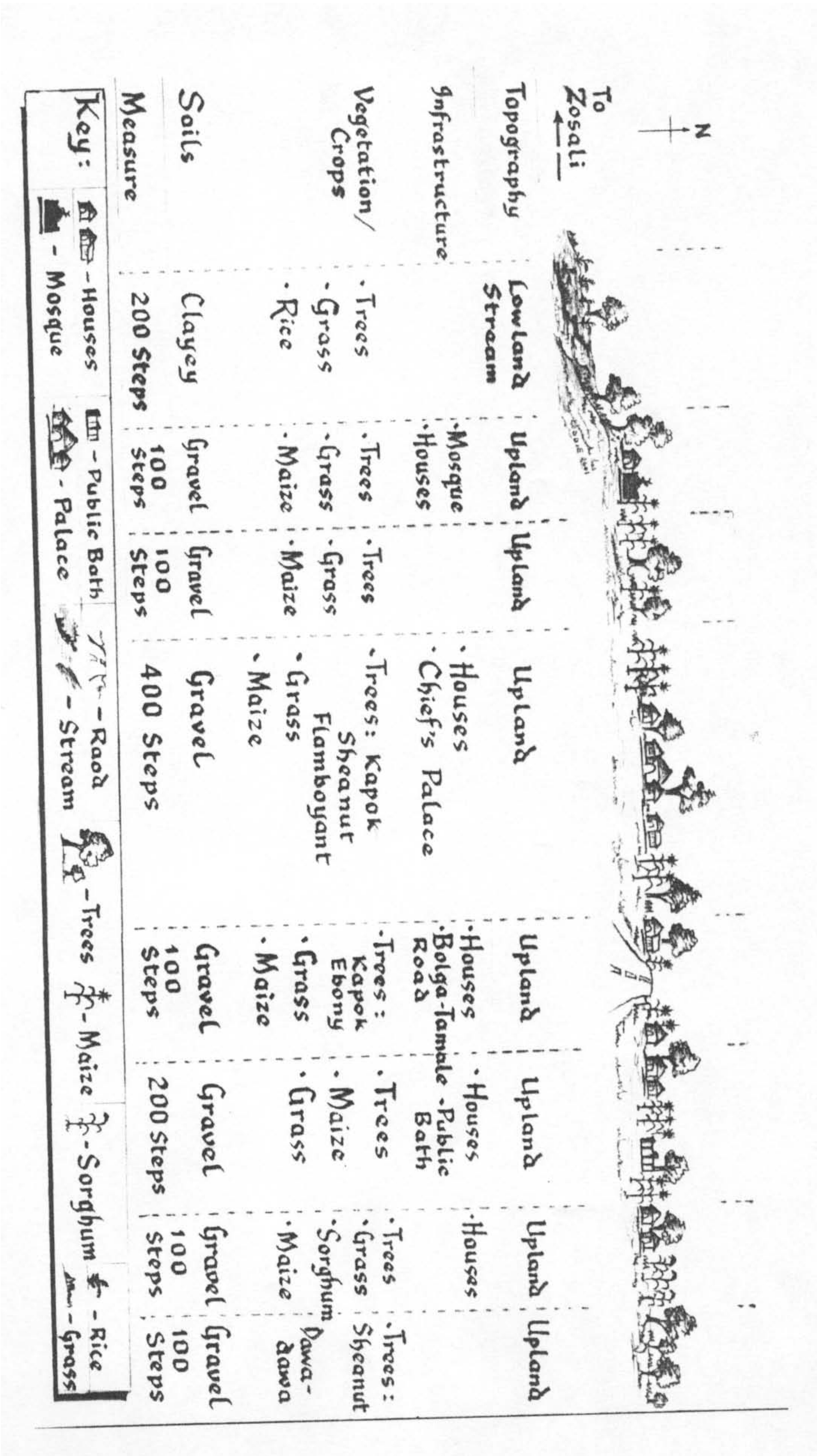


Figure 2 – Transect of Kadia village, Northern Region, Ghana, showing land use.

2. Farming systems in Northern Ghana

The northern part of Ghana is located in the Guinea Savannah Zone which is predominantly grassland with short deciduous, widely spaced, fire-resistant trees and shrubs; part of northern Ghana is also in the northern fringes of the forest-savannah transition agro-ecological zone. Northern Ghana comprises three administrative regions: Northern, Upper East and Upper West. Together, these account for the bulk of rice produced in the country. The climate in northern Ghana is characterised by unimodal rainfall which starts in April/May and lasts for five months, with the other months being hot and dry. The annual rainfall ranges between 700 and 1,200mm and it is erratic in distribution. There is only one growing season in most areas; two growing seasons are only possible where there is irrigation, as is the case in the Tono irrigation project.

In many parts of Northern Ghana, tree cutting for fuel wood and bush burning have gradually transformed the vegetation cover into secondary growth, with dawadawa and sheanut as the dominant trees. The local people attribute the rapid environmental degradation which has taken place to increasing pressure on land as a result of rising population.

Most of the peoples of northern part of Ghana speak closely related languages and have a similar social structure, although they belong to different named `tribal' groups. It is an area which has been frequently in a state of flux with a lot of population movement. First settlement confers ownership, which is held by the *tindana* – a word used both to refer to an individual who controls land use by all of a community and, in areas where later settlement has taken place by a second group of people, to the whole of the first group to settle, who have prior rights over land. Land cannot be sold but it can be leased to other groups (see Cardinall 1969).

This part of Ghana is reliant on grain crops to a much greater extent than is the case in Southern Ghana. While yams and cassava are grown in some parts of Northern Ghana, and yams have a central symbolic role (associated with men) where they are grown, there are areas where the cultivation is not possible due to the quality of the soil, and the staple starch crops here are grains alone. This is the case with the main field site for the project, Fumbisi, where trials were carried out for methods of controlling wild rice (*O. longistaminata*). Grains grown in Northern Ghana are early millet, late millet, sorghum, maize and rice.

The relative importance of the major crops grown varies depending on the part of Northern Ghana. As this relates to staple starches grown for food, the variation depends to a large extent on the quality of the land and probably also to some extent on local preference. Maize appears to have made more of an inroad on the traditional grain staples of millet and sorghum in some areas (e.g. Kadia, one of our field sites) than in others (e.g. Fumbisi). Access to the market is also relevant in relation to cash crops. In Kadia, the relative importance of the major crops grown can be seen in the following table:

Table 1 - Ranking of major crops by acreage cultivated at Kadia

	Maize	**Sorghum**	**Rice**	**G'dnut**	**Millet**	**Yam**	**C'ssava**	**Total**
Cassava	Maize	sorghum	Rice	G'dnut	Millet	Yam	---	0
Yam	Maize	Yam	rice	G'dnut	Yam	---		3
Millet	Maize	millet	rice	G'dnut	---			2
G'dnut	G'dnut	G'dnut	G'dnut	---				6
Rice	Rice	Rice	---					5
Sorghum	Maize	---						1
Maize	---							4

Source: PRA data gathered through SARI

There are two types of farms held by households in northern Ghana, the compound farm which is the area around the homestead and the bush farm which it was found in Kadia can be as much as 15 kilometres away from the home. Land degradation, declining soil fertility, plummeting crop yields and the need to increase household food production to meet the food needs of a growing population tend, in many communities, to shift the balance towards bush farming. Nevertheless, compound farms continue to play an important role in household food security. Early maturing cereals and legumes are cropped on the compound farms to help bridge the hunger gap.

There are two categories of land in this part of Ghana: `upland', which is used for grain crops and for yams and cassava where these are grown; and `lowland', which is used for rice.

Many crops are, in this region, grown intercropped with each other, in a relay intercropping system, rather than on their own. A typical intercropping system on upland areas (the list below is as found in Fumbisi) includes the following combinations:

(i) Early millet/Late millet/cowpea

(ii) Early millet/sorghum/cowpea

(iii) Late millet/sorghum

(iv) Late millet/cowpea

(v) Sorghum/cowpea

Rice, maize and soybeans are grown on their own. Groundnuts may be grown on their own or intercropped with other crops.

Crop rotation is practiced where root and tuber crops are planted. The rotation patterns are variable and include the following: yam-maize-fallow, and cassava-maize, or groundnut-cassava. There are two categories of farm: those near the home or compound, and those out in the `bush', up to 15 km away. The compound farms are cropped continuously. Bush farms are fallowed after an average of 3 years.

Livestock reared in the area are cattle, sheep, goats, fowls, guinea fowls and pigs. The purposes of keeping livestock include dowry, sacrifices, festivals, traction, and cash (to meet food consumption, domestic expenditures and to finance crop production). Another benefit derived is the provision of farm yard/organic manure. Male household heads normally own cattle but any member of the family may own any of the other kinds of livestock. During the dry season, cattle, sheep and goats are kept on a free range basis; during the cropping season cattle and sheep are herded by children. Goats are usually tethered. Supplementary feeding (groundnut and cowpea vines) is offered to draught animals and to others if available.

3. Land Tenure

Residence in northern Ghana is based on the extended patrilineal family living in the extended dwelling called the *yiri* or *yili* (see Fortes 1949). This has at its core a male head, with his sons and grandsons and their wives and children. Each man, and each of his wives, has a separate hut. Each man and each of his wives cultivates land separately, although wives help their husbands and to some extent husbands also help their wives in cultivation.

Land is not owned by the tiller, but is considered to be owned by `landowners' (*tindana*). Households belonging to `subject' ethnic groups pay tribute in kind to the *tindana* of the land they use, or to the chief (it seems that the institution of chiefship is a relatively recent creation in the area – see Cardinall 1969).

The *tindana* leases farmland to farmers, allocating it to male household heads according to their needs and land availability. Land is given free of charge to members of the same ethnic group, and reselling is therefore not allowed. Land allocated to farmers in this way is heritable and can be passed on from generation to generation, although if a family moves from the village to settle in another, their lands may be redistributed to families in need of land. Young men and women are allocated land by their parents and husbands. Young men can also request land from the *tindana* if land is available.

Land ownership at Kadia is communal, and this is typical of Northern Ghanaian communities. Land owned by the community is vested in the *tindana* (in the sense of the word referring to an individual man, descendant of the leading original founder of the community) or in the chief where there is one. Farm households have user rights (control) and cultivate communal land they have been farming, which they hand down from generation to generation. However, the power to dispose of land permanently (sell land) is the sole responsibility of the chief. Private ownership of land is nonexistent in the village.

There is a significant incidence of migration in Ghana, and migrant farmers need access to land. They can obtain land from the chief or from the *tindana*, or else from friends. Cola nuts are presented as a token payment for the land, while some farm produce is given as rent after the harvest. In the case of rice fields, tenant farmers donate up to a bag of paddy rice. The quantity of rice does not necessarily relate to the size of land or the quantity harvested. A new dimension in tenancy arrangement gaining prominence in some areas such as Kadia is that landowners may require tenants to plough a piece of land as rent for land used.

Male heads of households allocate land to other male members of the household – their sons and grandsons. Since land is cultivated separately by men and women in the region – although women help men on the land they cultivate – land is allocated by each individual man to his wife or wives in turn for her to cultivate. Women cannot be allocated land directly by the *tindana* as can men.

Although women do not, *de jure*, have control over land, a woman can have *de facto* control if, after the death of her husband, she is still living in her husband's *yir* (extended family household), and has no grown up son to take full control.

In Fumbisi, analysis of data collected in the field survey carried out by revealed that most of the respondents (81.6%) got land for farming through inheritance, hence self-owned. Renting and share cropping are not common practices. The trend might be because most of the farmers are indigents and in their active ages.

Table 2 - Frequency distribution of land tenure systems of rice farmers.

Type of land tenure	**Frequency**	**% Frequency**
Rent	5	10.2
Share cropping	3	6.1
Gift	1	2.0
Inheritance	40	81.6

Source: Field Survey by Demanya Ametepe Kofi and Nusenu Richard Yaw, 2000

4. Labour use

The main sources of farm labour are family labour, hire labour and exchange labour. All labour types are employed in all the farm operations. Hired labour is critical in land preparation and weeding, whilst exchange labour is relevant for weeding and harvesting. Family labour is involved in all the operations particularly land preparation and seeding. Family labour constitutes the most important source of farm labour in the study area whilst hired labour is the form least employed.

Table 3 - Pairwise ranking of labour types employed at Kadia

	Family labour	Hired labour	Exhnage labour	Total
Exchange labour	Family	Exchange labour	--	1
Hired labour	Family	--		0
Family labour	--			2

Source: PRA data gathered through SARI

Men use communal labour, hired labour, exchange labor and family labour in most of their farming activities. The most important of these is family labour, mainly that of their wives. Women's activities in family labour include planting, fertilizer application, weeding, harvesting, threshing, winnowing, transportation, drying and bagging.

Women, on the other hand, do not benefit from very much help in their cultivation on the part of their husbands. When a farm belongs to a woman, she does most of the work herself assisted by fellow women on an exchange basis, in addition to hired labour. Men are not obliged to help their wives on their fields. A husband may choose to prepare the land for his wife or help in the weeding or harvesting provided he has the time. Men take this attitude because they feel that farming is a masculine activity, and women are not obliged to farm at all.

A woman can assist other men in the community, including the men from her husband's family, on their farms provided she has time. She may get a share of a day's harvest for her efforts if she participates in harvesting.

All members of a household take an active part in one farm operation or the other. Men assisted by boys, for example, do land preparation whilst threshing and winnowing are often done by women and girls. The table below shows the division of labour by gender and generation in Kadia.

Table 4 - Intra-household division of labour across gender and generation in crop production at Kadia

Activity	Men	Women	Boys	Girls
Land preparation	✔	--	✔	--
Planting/seeding	--	✔	✔	✔
Manuring/fertilizer application	✔	✔	✔	✔
Weeding	✔	✔	✔	--
Harvesting	✔	✔	✔	--
Winnowing	--	✔	--	✔
Threshing	--	✔	--	✔
Haulage	✔	✔	✔	✔
Storage	✔	✔	✔	--
Marketing	--	✔	--	✔

Source: PRA data gathered through SARI

5. Crop production for home consumption and for sale by men and women

Starch-based crops which are the basis of the meal – what is locally described as `food' – are yams and cassava (where grown), millet, sorghum and maize. Responsibility for growing these crops lies with men in this part of Ghana, and a man is responsible for growing staple starch foods for consumption by all of his wives and children. While he receives a good deal of assistance from his wives in cultivating these crops, the crops are his responsibility and belong to him.

Responsibility for growing crops which provide foods eaten with `food' – what is locally described as `soup' – lies with women. This includes vegetables and pulses including cow peas, bambara beans, soybeans and groundnuts as well as vegetables such as okra, peppers and tomatoes.

6. Farm finance

Access to credit is one of the constraints identified by farmers interviewed in Kadia and Fumbisi as inhibiting their efforts at increasing production and household income. Sources of credit are limited. Farmers mostly depend on the sale of agricultural produce including livestock to finance their farming activities, where cash is needed. Livestock usually sold include small ruminants and poultry. Farmers in Kadia reported that some traders pre-finance some of their farm operations. Here no interest charges are paid directly, but the farmers are obliged to sell their produce to the financiers at prices dictated by their creditors. The farmers recognize that they indirectly pay very high interest charges since their creditors pay very low prices for their produce.

7. History of rice cultivation in Northern Ghana

Rice cultivation in Northern Ghana dates back at least to the colonial era and may well be ancient in many communities since rice is indigenous to the region and was domesticated here. However, production was, until the 1950s, on a small-scale and oriented towards household subsistence with just a little for sale. After independence public policy towards food self sufficiency tended to boost rice cultivation in the study area. New varieties were introduced and large scale production was encouraged. Government schemes to increase the area used for rice and mechanise production were introduced.

Until the 1950s rice was grown in small areas, probably mainly around the margins of valleys which flooded in the wet season. With the government schemes, much larger areas including those in the middle of valleys were cultivated.

At both Fumbisi and Gani, farmers indicated that rice cultivation started during the Gold Coast era, (i.e. before Ghana's independence in 1957). However, this was done on very small holdings. After 1957, rice cultivation became more intensive at Fumbisi. During this era, the Government supported and encouraged farmers in rice cultivation by ploughing the valley, planting and allocating the plots to the farmers to manage on their own. It was after this initiative by government that farmers went into serious rice production.

However, the government scheme to increase rice production did not last and after it collapsed, rice cultivation has mainly retreated to the margins of the valleys. This is largely due to infestation by *O. longistaminata*, which appears to have been increased through the spreading of its rhizomes by the machinery used in the government schemes. It is described locally as *yinyang* or *waba*.

8. Present-day rice cultivation; men and women

While most crops are the responsibility of either men or women, there are some crops which are grown by both men and women. All of these are grown at least partly as cash crops. Rice is one of these. Rice is important both as a food crop and as a cash crop. As a cash crop, it is an important source of cash income. In Kadia, for example, groundnuts and rice are the main cash crops. Here, rice contributes about 33% of household incomes and most rice grown is sold: 60% percent of rice grown by women and 80% of rice grown by men.

A certain amount of rice must be retained for consumption. At festivals, funerals, weddings and `out-doorings' (when a newborn baby is taken outside for the first time), rice is served. It may be prepared for communal or exchange labourers to show appreciation of satisfactory work accomplished for a farmer. It is also sometimes eaten as a starch food at the midday meal.

In Kadia, women grow rice, groundnuts, soybean, pepper and okra, and a similar pattern is found in other northern Ghanaian communities. These are all grown both for cash and for subsistence. Women use a small proportion of the rice harvest to prepare a midday meal, but most is sold for cash. 60% of rice grown by women was sold in Kadia, while 80% of that grown by men is sold.

Women informants told us in focus group discussions in Fumbisi that women grow rice to feed their families, while men grow it to sell to solve family problems outside the immediate family consisting of his wives and children.

While rice can be substituted for maize, sorghum, millet or yams in the morning, it is not considered proper to eat rice in the evening. It is largely because of the need to ensure that there is adequate maize, sorghum, millet or yams (depending on the part of Northern Ghana, which is of these is eaten most frequently varies) for the evening meal that men sell the rice which they grow. If a family eats rice in the evening, others will say that the family is not well fed, that the male head is not responsible. So men sell rice to buy maize or millet. Income from the sale of rice – by both men and women – is also used to pay medical bills, school fees and to meet other domestic expenses.

Varieties of rice grown are a mixture of traditional red varieties and improved varieties. There is a problem with the mixing of varieties, which affects the marketing of rice beyond local markets. In local markets, this poses much less of a problem.

In Fumbisi, focus group informants told us that the traditional varieties, which have longer stalks, are grown in areas which are less low-lying, although still in relatively low-lying areas which are flooded to some degree in the wet season. This is, according to informants, because the taller varieties lodge at maturity when there is a lot of water. Only improved, short varieties are grown in the most low-lying areas. Since it is in the most low-lying areas that *O. longistimanata* grows most readily, there is more of a problem with the weed when growing improved varieties than when growing traditional varieties.

9. Methods of rice cultivation

Plot sizes used for rice cultivation, in areas which are not part of irrigation schemes, are very small. In Fumbisi, the field survey indicated that 85.7% of the farmers have less than 5 acres of land under rice cultivation while only 14.3% had more than 5 acres under rice cultivation. At Fumbisi farmers generally use yield obtained from a unit area to determine the size of the fields. They estimate an average of 10 maxi bags of paddy rice as the yield obtainable from an acre. Based on this estimation the average size was estimated at one acre. Field estimation confirmed that the average holding per farmer is about 0.4ha, although farmers cultivate between 0.4–1.0ha. In Kadia plot sizes were even smaller, ranging from 0.2 - 5ha. However, this is not because of lack of land but because of lack of resources to cultivate it, particularly in relation to weeding. Women find it particularly difficult to get enough labour to cultivate bigger plots. In Kadia, very few rice farmers are women and they cultivate smaller plots than do men, with plots ranging from 0.2 - 0.8ha. At Gani women cultivate between 0.5 and one acre while the men cultivate 2 - 3 acres.

In most of the area, methods of cultivation are simple. In most of the area, no bunding or transplanting are carried out. Gani has some land in the Tono irrigation scheme (see Tonah 1993), and these plots are bunded and rice is transplanted; but plots held by farmers in Gani which are outside the scheme are cultivated without bunding or transplanting.

Out of the 49 rice farmers interviewed in Fumbisi, 16.3% broadcast their seeds and cover by tractor harrowing. This method is mainly used for larger fields because it reduces the problem of labour cost, it is faster and less expensive as compared to drilling and transplanting. This method of planting is disadvantageous in that it does not allow for easy weeding due to over-crowding and also rice plants may be mistaken for wild rice during weeding. 83.7% of the farmers interviewed use the dibbling method. This method is mostly used on small-scale farms. This ensures effective utilisation of seed. Plants are planted in rows to enhance effective weed control (hand pulling and hoeing). Also movement becomes easier on the field. This method also prevents birds from picking rice seeds from the soil after planting. However, this method when applied on a large scale would be time and energy consuming and further increases production costs.

Varieties planted include both traditional varieties derived from local indigenous rices and improved varieties. They are not always kept separate very effectively. This is accentuated by the methods of harvesting, which do not separate different varieties which may have got mixed up in the field. There is however a broad distinction between the Upper East and the Northern Regions; in the former, harvesting is done more carefully, using a sickle to harvest, which keeps varieties separate and the rice freer of straw and other contaminants.

Although farmers interviewed by SARI staff at Fumbisi indicated that they used no external inputs (agro-chemicals) for rice production, and that labour for land preparation and other cultural practices is all the input required, the questionnaire applied by Demanya Ametepe Kofi and Nusenu Richard Yaw indicated that during planting 40.8% of farmers applied fertiliser while 59.2% did not apply. Out of the 40.8% who did apply fertiliser, 38.8% applied through broadcasting and 2% used the placement method. The application methods vary from farmer to farmer.

Table 5 - Frequency distribution of fertiliser application methods

Fertiliser.Application.Methods	Frequency	% Frequency
Broadcasting	19	38.8
Placement	1	2.0
No fertiliser application	29	59.2

Source: Field Survey by Demanya Ametepe Kofi and Nusenu Richard Yaw, 2000

Farmers at Gani said that they use fertilizer (120-90-90kg of N-P-K) and herbicides in rice production. This is due to the influence of the Tono Irrigation Project.

75.5% of the farmers interviewed in Fumbisi revealed that land preparation starts mainly between May and June. 18.3% start earlier between March and April. 6.1% depend on the first rain to start land preparation for the next season. This is however contrary to literature which indicates that *Oryza longistaminata* in rice can be minimised if the field is deeply ploughed twice before the on set of the dry season preceding the next rice cultivating period. On the other hand, Saw Ler Wah (1993) indicates that if ploughing is done two weeks after first heavy rain, wild rice infestation would be minimised.

Table 6 - Periods of land preparation for rice cultivation

Month of land preparation	Frequency	% Frequency
March - April	9	18.3
May - June	37	75.5
First rain	3	6.1

Source: Field Survey by Demanya Ametepe Kofi and Nusenu Richard Yaw, 2000

Time of harvesting depends whether the variety grown is late or early maturing and also on the time (month) of planting. These determine when it will be ready for harvesting. From the survey in Fumbisi, 51% start harvesting from September – October calculating from the time of land preparation and planting, that is May-June. 49% start harvesting from November – December. This is assumed to be the late maturing variety.

Harvesting is predominantly done with the aid of a sickle on smallholdings. On large holdings (which do not exist in the communities used for study here), mechanical combine harvesters are employed. The availability of combine harvesters has dwindled in recent years and therefore even large farmers resort to employing hired labour that use the sickle. On very small holdings, some farmers in the Upper East region manually harvest "panicle-by-panicle" during which they are able to sort out varieties and therefore reduce contamination. When the rice has been “sickled” by men, women gather and heap the material. The heap of rice is then threshed either manually with the aid of sticks or mechanically using tractors that trample on the harvested material after which women winnow the grain from the trash.

Table 7 - Frequency distribution of time of harvesting rice

Time of Harvesting	Frequency	**% Frequency**
September – October	25	51
November - December	24	49

Source: Field Survey by Demanya Ametepe Kofi and Nusenu Richard Yaw, 2000

Rice seed is generally stored for the next season's production From the survey carried out in Fumbisi, it was apparent that for an acre of land half a bag of rice seed is required. 93.1% of the farmers interviewed stored their own seed rather than buying it for the next season.

Farmers sold their rice at different months for varying reasons. 51% of those interviewed in Fumbisi sold their rice between May and June. This coincides with time of land preparation, which starts between May – June for majority of the farmers. It appears that money from the sale of rice was used partly to cater for labour and land preparation expenses. .

Tab;le 8 - Frequency distribution of sale of rice (month)

Month of Sale	**Frequency**	**% Frequency**
Before planting season	10	20.4
March – April	2	4.1
May – June	25	51
Not sold (consumption)	12	24.5

Source: Field Survey by Demanya Ametepe Kofi and Nusenu Richard Yaw, 2000

10. The problem of *O. longistaminata* in rice production in Northern Ghana

The problem of weeds in rice is more pronounced in the rainfed ecologies of the area (Katanga, Gbedelbisi, Fumbisi, Nabogu and Kadia) than in the irrigated locations (Bontanga, Vea and Tono). This is probably because the majority of farmers lack the technology of bunding, adequate land preparation methods including leveling and puddling. Consequently, these farmers are not able to manage water to their advantage for the control of very common weeds (Akobundu, 1987).

From the survey carried out among 49 farmers in Fumbisi, all of those interviewed said that weeds are a significant problem. Weeds mentioned were spear grass, digitaria, 'wusagsa' (buli), 'nanyuri' (buli), wild rice and tiger nut weed. Out of these, wild rice was ranked as the most serious weed affecting rice production in the valley. This was because:

1. wild rice grows faster and more vigorously than the cultivated rice plant thereby competing with it for nutrients, water and space.
2. it colonises the field faster than any other weed thereby making its control difficult leading to retarded growth and hence yield reduction in rice.

3. it is an erect perennial rhizomatous grass and is difficult to distinguish from cultivated rice. This means that rice can be mistaken for a weed during weed control operations.

The Ghanaian MOFA (Ministry of Food and Agriculture) (1996) found a sharp decline of rice production in the entire Upper East Region, a situation chiefly attributed to wild rice infestation. The situation is similar in the Northern Region and almost certainly this is also the case in the Upper West Region. Two species of wild rices are generally recognised by farmers namely; the wild perennial rice (*Oryza longistaminata* Chev. & Roer) and the wild annual (*Oryza barthii*) from which the native rice (*Oryza glaberrima*) originated (Holm *et al*., 1997). The former is the most frequent and important/economic species. It is more easily recognised because it is tall, rhizomatous and usually grows in homogenous populations on creeks, drains and flood plains of rivers. *O. barthii* on the other hand, is usually found among crops, at the edges of rice fields and sometimes in clusters with *O. longistaminata* around water holes.

It would appear that the mechanisation of rice production in the 1960s contributed significantly to the spread of *O. longistaminata*, because the machinery used distributed fragments of the weed around valleys and spread the infestation. Informants in Fumbisi and Kadia told us that there was a very considerable increase in levels of infestation due to mechanisation. Before the 1960s they did not have such a problem with the weed.

Farmers interviewed during the survey in Fumbisi said that they were able to distinguish wild rice from the cultivated rice crop as early as the germination stage, due to past experience in rice cultivation; however, it is in fact difficult, in practice, to distinguish the wild rices from a rice crop during the early stages of growth due similar anatomical features. Some distinguishing features of wild rice were said by farmers to be:

1. wild rice is thicker, broader and is a darker green compared to true rice, which is thinner, narrower and is a lighter green
2. wild rice has a rough and thorny leaf edge while cultivated rice has a relatively smooth edge.
3. wild rice has a slender, flat stem whilst that of rice is thicker and round.
4. wild rice has a white fibrous (rhizomatous) rooting system and that of rice is yellowish and round with no rhizomatous rooting system.
5. wild rice grows taller than short varieties of cultivated rice.
6. wild rice does not tiller while the cultivated rice plant tillers.

Apart from wild rice, which was the major problem, a few farmers in Fumbisi mentioned grasshoppers, theft, lack of tractor services at the right period for land preparation, lack of money and soil infertility as minor problems associated with rice cultivation.

At Fumbisi no fertilizer is applied to a crop cultivated on a wild rice infested field for this reason. The presence of *O. longistaminata* is taken to be indicative of high fertility and suitability for rice growing. Farmers would rather use the money for fertilizer to hire labour to manage *O. longistaminata*, considering the investment on labour more rewarding than fertilizers.

Farmers at Fumbisi reported that *O. longistaminata* is not a new species to them and believe that it is a normal flora of the valley. This plant used to be found in isolated small ponds, but with the mechanization of land preparation methods, this weed has spread and colonized the valley. It is thought that ploughing the field with tractors fragments the rhizomes and spread them along the valley as the tractor moves along. It became a serious problem in 1975.

At Gani, farmers said that *O. longistaminata* was in existence even before rice cultivation. Previously, when the pressure on land was low, farmers avoided infested fields by cultivating areas which had a lower degree of infestation or which were not infested. Currently, almost all the rice fields are infested to some degree and farmers have no choice but to stay on these fields.

In Fumbisi and in Gani, farmers said that they have to do an additional weeding before they get any meaningful yields from rice fields, due to the high levels of *O. longistaminata*. The weeding process is slow and takes not less than 20 man-days to complete an area of about 0.4ha (1acre). This therefore puts pressure on the limited household labour force.

Farmers in Gani and Fumbisi reported that *O. longistaminata* restricts the area they are able to put under cultivation due to the high labour requirement. Due to labour constraints, farmers frequently abandon their cropped rice fields to wild rice infestation or restrict the area under cultivation. Severely infested fields often become unsuitable for rice production and are abandoned. All the farmers interviewed in Fumbisi indicated that they have at one time or another abandoned their rice fields. From the analysis, 49% of the farmers revealed that the number of farmers they know to have abandoned their fields to wild rice were uncountable (many). 36.7% gave the number they know to have abandoned their fields to wild rice to range from 2-10 farmers, while 14.3% do not know anybody at all.

Farmers avoid the problem of confronting *O. longistaminata* as far as possible by cultivating land around the edges of valleys, where there is less of the weed. However they would prefer to be able to use the middle of valleys for growing rice, where there is plenty of water. In Fumbisi, they experimented with using the middle of the valley in 1999, but said they were `defeated' by *O. longistaminata*. In 2000 and 2001 they only used the margins of the valley for this reason.

11. The economic cost of control of *O. longistaminata*

Wild rice infestations are a major constraint to the sustainable intensification of lowlands in West Africa. In Northern Ghana majority of the lowlands are heavily infested by wild rice, posing significant threat to smallholder rice production in the face of increasing domestic demand.

Calculating the cost of rice production as including the cost of land preparation (tractor, bullock, and manual), the cost of seed, the cost of planting, the cost of weeding (hand pulling and hoeing),the cost of fertiliser/manure, annual land rent cost and harvesting cost, 59.2% of the respondents in the survey in Fumbisi made a profit during the 1999 production season while 40.8% made or registered losses of various degrees. The highest net income per acre was Ghanaian ¢148,140 and the least net income was ¢2,800. On the other hand, the highest loss per acre was ¢45000 and the lowest loss per acre was ¢8,000

On average, an estimate of 10 maxi bags of paddy rice is obtainable from an acre of land. The survey carried out in Fumbisi revealed that 77.6% of the farmers interviewed were not satisfied with the yield they had from the land they cultivated for rice. They attributed the low yield to wild rice infestation.

It is not, on an economic level, viable or profitable to produce rice in a wild rice infested area. The low yield, (4 bags/acre) is at least partly due to wild rice infestation, which is increased through the use of contaminated seeds for planting and tractor ploughing for land preparation, which cuts the rhizomes of the wild rice into pieces and spreads these around the field.

The fact that farmers grow rice at all is due a) to their need for some rice for consumption at festivals and at home and b) to their not taking into account the cost of their own labour in producing rice.

12. Methods of control of *O. longistaminata*

According to Fischer and Antigua (1996), there are diverse strategies for controlling wild rice, which depend on the diversity of rice agro-ecosystems and socio-economic conditions in a given area. The most relevant control is the use of wild rice free seed. Other methods of control include:

- a method of land preparation,
- b time of weeding,
- c varieties of rice,
- d cropping systems and
- e chemical control.

According to Bidaux (1971), land preparation as an effective means of controlling wild rice consists of one or more ploughings. Deep ploughing and harrowing are recommended in the dry season if rhizomatous perennials are a problem (Ampong-Nyarko and De-Datta, 1991). However, farmers in Northern Ghana do not carry out two ploughings, and do not plough in the dry season.

Crop rotation has been found to be successful in controlling wild rice. However, from the analysis, 93.9% of the farmers in Fumbisi did not practice crop rotation. This was attributed to the water logged condition of the valley under which rice is grown. This makes it impossible for other crops grown in the area to be rotated on the rice fields.

Intercropping can also be an effective method of controlling *O. longistaminata.* However, 98% of farmers in Fumbisi do not practice inter-cropping. This too was attributed to the high water logged conditions during the cropping season. The continued rice mono cropping has led to the widespread infestation of wild rice.

From the survey carried out in Fumbisi, 81.6% of the farmers interviewed used a combination of hand pulling and hoeing in controlling wild rice. This can be attributed to the size of land holdings. The majority of the farmers are small-scale farmers, hence the use of this method for controlling wild rice. The method of planting also contributes to the use of these methods. The majority of the farmers use the dibbling method of planting, which is effective in controlling wild rice infestation. 18.4% used only hand pulling as a means of controlling wild rice in their fields. No farmer used hoeing alone or used any herbicides in weed control. Herbicides were said to be too expensive and farmers did not have any knowledge about how to use them. Hoeing is used to a limited extent because it is time consuming and waterlogging prevents hoeing. Farmers who used broadcasting said that during hoeing some of the rice stands tend to be cleared away together with the wild rice. . Hand pulling can be more successful, but for this method to be successfully executed the field must be flooded to ease the pulling out of the rhizomes. Under partially dried field conditions, it is very difficult to pull out the *O. longistaminata*. Hand pulling is also labour intensive and expensive - the cost of controlling once by hand pulling is estimated to be between sixty and eighty thousand cedis per acre depending on the level of infestation - and most often this intervention is untimely.

Apart from hand pulling and hoeing, the farmers interviewed in Fumbisi said that they have no indigenous ways or methods of controlling wild rice. They have no effective method of control, and it is for this reason that they consider that wild rice is the most serious problem which they face in growing rice.

Farmers at Kadia do very little to control wild rice because they reckon that little can be done to control these weeds and therefore resort to abandoning infested fields as the most economic option. Recently, pressure on land makes this option technically unfeasible and farmers now consciously remove some of the rhizomes of the weed, which they heap and burnt after during land preparation (ploughing, harrowing and leveling). Another control method practiced by farmers at Kadia is increasing the seeding rates at the infested portions during planting to give the rice a competitive edge.

13. Control of *O. longistaminata* in the Tono Irrigation Project

The Tono Irrigation Project, where Gani is located, is a very different context from non-irrigated rice-growing areas in Northern Ghana. Here, a lot of effort and money has been invested to reduce the incidence of *O. longistaminata*. In the past the project had to abandon some of its fertile and irrigable fields to wild rice. Some of the irrigation canals were choked with *O. longistaminata*. In the late eighties, the project recruited the expertise of two Koreans who recovered about 400ha of *O. longistaminata* infested fields. There remains however the perennial problem of the bunds acting as reservoirs for *O. longistaminata*, which has never been conquered. Most of the control was achieved during land preparation through the following five methods.

Nowadays, it should be noted that the dominant method of control here, as elsewhere, is hand weeding.

a) Rotovation

This method involves the use of rotary cultivators drawn by either tractor or power tiller fitted with caged wheels to prevent bogging. It is only feasible on wet soils and not dry soils. The field is first irrigated to saturation (above field capacity). The rotovation is done twice at an interval of 3-7 days. The first operation is termed "knock down rotovation" and the second is termed "smooth rotovation". The water on the field is then drained off and the rice transplanted.

b) Wet levelling

This involves the use of tines (rakes) mounted on a tractor. The field is drained of any water and the initial vegetation on the field slashed, and burnt. This is followed by routine land preparation methods of ploughing and harrowing. With some moisture in the soil, the field is then leveled using the tines, which rake out the rhizomes of *O. longistaminata*.

c) Puddling

This method is labour intensive and is used on relatively small areas. The field is ploughed with the aid of either tractor or bullock. Harrowing is optional and is often not carried out. The field is then flooded and a group of farmers in a row then go into the field with hoes to puddle the soil and rove the rhizomes of *O. longistaminata*. Rhizomes removed are used to create bunds or reinforce existing bunds.

This practice is a source of re-infestation since the rhizomes are not properly disposed off. It is therefore usual to see a high infestation of *O. longistaminata* along the edges of the field with the level of infestation decreasing as one moves towards the middle of the field.

d) Herbicides

The branded herbicide `Round-Up' (glyphosate) at the rate of 8-12 litres/ha (depending on the level of infestation) has proved successful in controlling the *O. longistaminata*. This method is most effective when the initial vegetation is slashed, burnt and the subsequent re-growth of the *O. longistaminata* is sprayed with the herbicide.

This method is the most expensive of all the existing control methods at Tono/Gani and farmers rarely use it.

e) Hand weeding

This is the dominant weed control method and is often used in established rice crops. The wild rice are pulled out and heaped on the field or dumped on the bunds.

14. Assessment of the trials of control methods for *O. longistaminata* undertaken in 2000 and 2001 by SARI and NRI

The Savannah Research Institute (SARI), based in Tamale in Northern Ghana, in collaboration with the Natural Resources Institute (NRI), University of Greenwich (UK), have been working together on a research project intended to develop methods for the management and control of wild rice. Trials of different methods of control were conducted in 2000 and 2001 at Fumbisi, in the Upper East Region. These were intended:

a) To investigate which methods produce the most promising results on a scientific level.
b) To demonstrate new methods of control to farmers
c) To find out what farmers feel about new methods and which they are likely to adopt

In both 2000 and 2001 researcher managed trials were conducted at Fumbisi, in fields loaned by one extended household (*yili*), to which all the farmers involved in the trial belonged; the researcher-managed trials were related to all the aims above, but particularly to a) and b). In 2001 farmer managed trials were also carried out, related mainly to aim c) above.

Below we present the results of the economic analysis and of the farmer evaluation of the trials that were conducted in the years 2000 and 2001.

Data were collected on the inputs and output involved in the various control methods that were implemented. This consisted of both agronomic and economic data (including labour and all physical inputs and their values as well as cost of all operations undertaken).

The control methods evaluated were as follows (it should be noted that T2 was different in 2000 and 2001):

Control methods for 2000

- T1-Stale bed sprayed with glyphosate and rice seed dibbled.
- T2-Intercrop of taro with the rice seed dibbled.
- T3-Farmer's practice: removal of rhizomes during land preparation and rice seed dibbled.
- T4-Bunding, puddling and transplanting rice seedlings.

Control methods for 2001

- T1-Stale bed sprayed with glyphosate and rice seed dibbled
- T2-Rice broadcast at double seeding rate (200kg/ha).
- T3-Farmer's practice: removal of rhizomes during land preparation and rice dibbled

- T4-Bunding, puddling and transplanting rice seedlings.
- T5-Plot fallowed previous year

T1, T3 and T4, which remained the same over the two years, were applied in both years on researcher-managed plots. In 2001 these three treatments were also applied under farmer managed conditions. The plots used for all the trials are held by one *yili*, or extended household, which is located in two physical sites although they hold the land they use, and it was farmers belonging to this *yili* who were involved in the trial. 12 farmers were involved in the trials, and each had a separate plot on which he trialled all the methods.

Farmers involved in the farmer-managed trials were male farmers; unfortunately, although it was intended that female farmers should also be involved, this did not happen. As it turned out, male members of the *yili* did not (according to the women, at a focus group discussion held in late 2001) allow the women to be involved, although the intention was that they should do so. The women expressed disappointment at this and said that they would like to have been involved. They were also not involved in the dry season vegetable trial which, in early 2001 and early 2002, was carried out as another potential method of controlling *O. longistaminata* (see below). This was, it appears, because the men, with whom researchers were negotiating directly, did not involve the women – although again it had been intended that they would be involved and this was discussed at the beginning of the growing season with the male heads of the *yili* by researchers.

15. Results of the farmer assessment

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 organized to allow farmers to critically observe each plot; farmers (including female farmers) had previously visited the field independently to observe how the trial was faring. Farmers' knowledge about the objectives of the trial and the control methods was also sought at the site. They were then allowed time to interact among themselves, after which they were asked to rank the treatments in order of preference, giving reasons for their ranking. The 12 male farmers involved in the trials were also asked, in focus groups at the end of the 2000 growing season, to rank the treatments being used.

After the 2001 growing season, questionnaires were administered to the male farmers participating in the trials and to 3 female farmers belonging to the same *yili*, who had observed the trials although they had not been involved in them, with the intention of seeing what their responses had been to the trials of farmer-managed trials and two seasons of researcher-managed trials.

The farmers involved in the trials indicated, in the questionnaires, that they understood the objectives of the trial. 86.7% said that the objective was to demonstrate to them how to control wild rice, and 13.3% said that in addition to the above it was also meant to demonstrate to them how to plant in rows and the essence of planting in rows.

93.3% of the respondents indicated that they encountered problems in carrying out the trial. The problems encountered were pests and diseases (20%), late rains (20%), late planting (20%), pests and diseases as well as mid-season drought (13.3%), mid-season drought (6.7%), pests and diseases as well as late planting (6.7%) and mid-season drought as well as late planting (6.7%).

16.1 Ranking of the different methods

The farmers were asked to rank the different treatments after the 2000 and 2001 growing seasons. As will be shown, the ranks assigned to the different treatments changed.

By assigning ranks to all the treatments in order of preference with 1 being the best and 5 being the worse, the following results were obtained through the questionnaires administered in late 2001:

Table 9 - Ranking of treatments in order of preference, Fumbisi, late 2001

Rank	**Treatment**
1	1 (chemical treatment)
2	4 (bunding and transplanting)
3	3 (farmers' own practice)
4	5 (fallowing)
5	2 (broadcasting at double the usual seeding rate)

Source:- Questionnaire data collected in late 2001 through SARI.

After both 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. In late 2001, the reason given in the questionnaires for putting it first was that it kills not only the wild rice but all other weeds. Its main constraint as given by 100% of the respondents to the questionnaire in late 2001 is the belief that the chemical causes poor germination of the crop when applied a few days before planting.

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 will not fail. Other advantages were the suppression of the wild rice by the taro and the avoidance of the high cost and unavailability of the chemical. Constraints to adoption of this method was the unavailability of the planting material which has to be imported from the southern part of the country.

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 practiced by any farmer. Its disadvantages were that weeding must be timely and it is only applicable in low-lying parts of the valley. In the questionnaire applied in late 2001, farmers additionally gave faster planting of the seed as the advantage of their own practice. Disadvantages of their own practice were seen to be poor germination due to drought after planting (93.3%) or due to drought and/or heavy rains after sowing (6.7%).

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 all this to good 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 (73.3%) in late 2001. All the farmers said that the fallow plot is more fertile. Its disadvantages were said to be hard soil + poor germination (33.3%), poor germination (20%), the need for both ploughing and harrowing (13.3%), poor germination + drought (13.3%), hard soil+ difficulty in ploughing with hoe (13.35%) and hard soil (6.7%).

Broadcasting at double the seedling rate (T2) was ranked fifth in late 2001. Its advantages were said to be faster sowing + effective weed control (73.3%) and faster sowing (26.7%).The constraint associated with this treatment was poor yield due to over crowding of the crops, as indicated by all the respondents.

The most striking change that took place between the end of the 2000 growing season and the end of the 2001 growing season 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 2001 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.

16.2 Likelihood of adoption of the different methods of control

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 (66.7%). Chemical control came second (26.7%). The remainder of the respondents said that they would continue to use their own practice (6.7%). The reasons given for adopting bunding and transplanting were the good plant stand (46.7%) and water conservation (20%); that given for adopting chemical control was the elimination of all weeds (26.7%). The reason for continuing to use their own practice was given as easy sowing as well as less labour (6.7%).

Various reasons were given for the likely non-adoption of one treatment or the other. The most important reason given (66.7%) for non-adoption related to bunding and transplanting, which was seen as being very labour intensive. About 13% said that hard soil was a reason for their likely non-adoption of fallowing.

The non-availability of finance is a major reason for the fact that such a small proportion of the farmers said that they would be likely to adopt chemical control, even though they rank it highly as a method of control. Farmers already find it difficult to manage to get the cash for inputs, and would find it difficult if not impossible to fund the chemicals needed to control *O. longistaminata*.

There is a constraint related to the adoption of bunding and transplanting - the high labour input involved. This is particularly a problem for adult men with families, who are under pressure to produce enough millet, maize (and yams, in areas where these are grown). Informants told us that adult men find it difficult to invest labour in growing rice; we were also told, as referred to elsewhere, that men will sell rice in order to buy maize in order to be able to provide their families with maize, which is `proper' food. Women too are under pressure in terms of time availability because they have household responsibilities as well as farms of their own, and because of their obligation to help their husbands on their plots. The least time-constrained group, and therefore perhaps the most likely to adopt this technology, are young men who are not yet married.

16.3 Interest in the trial on the part of non-participating farmers

All the farmers said that non-participating farmers had expressed interest in the trial, with 66.7% of these being particularly interested in bunding and transplanting and 33.3% in the chemical treatment. Reasons given for the preference for these two treatments were the good plant stand associated with bunding and transplanting (66.7%) and total weed control possible through the chemical treatment (33.3%).

The reason that non-participating farmers were not interested in the other three treatments were the difficulty of cultivating fallow land as well as lack of funds to buy seeds (60%), lack of funds to buy extra seeds (20%), lack of funds to buy extra seeds as well as insufficient seed for double seeding rate (13.3%) and difficulty in cultivating fallow land as well as insufficient seed for double seeding.

16. Results of the economic analysis

Figure 1:- Net Returns (2000, Researcher managed)

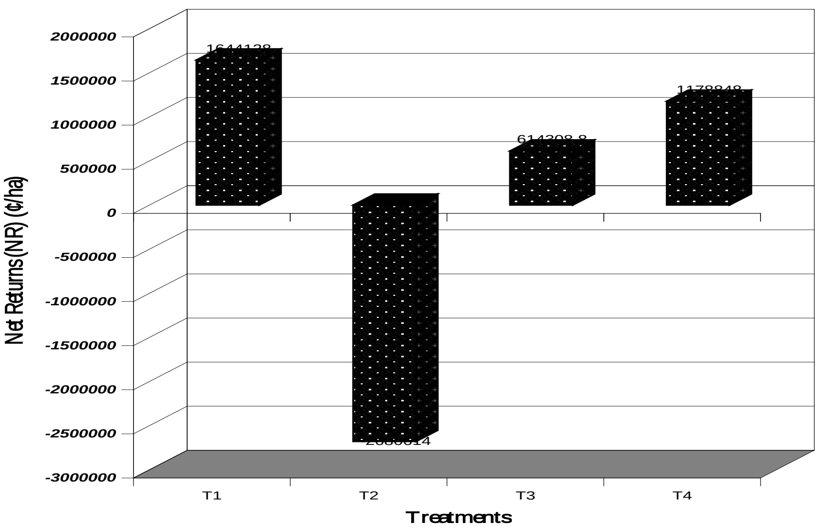


Figure 2:- Net Returns (2001, Researcher managed)

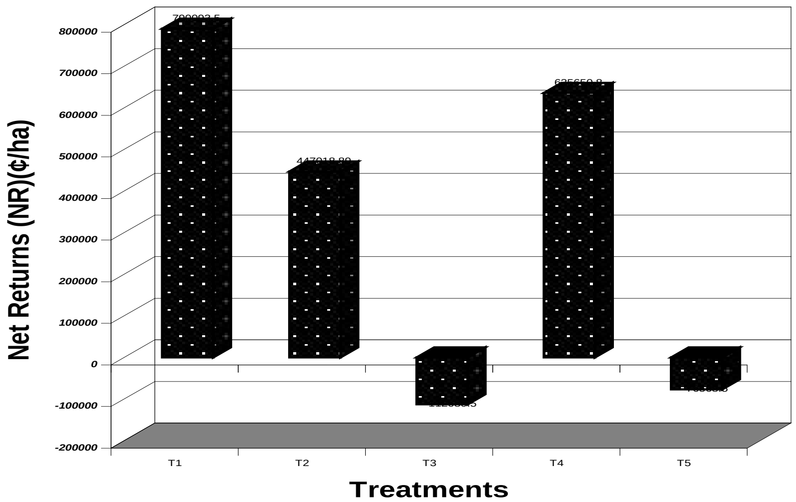
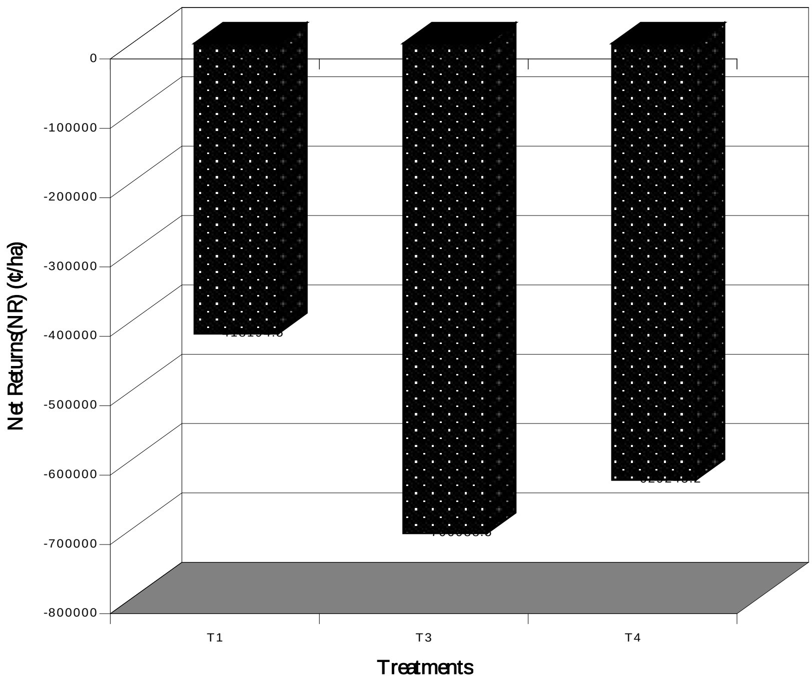


Figure 3:- Net Returns (2001 Farmer managed)



The figures above give the net returns for the researcher managed trials of 2000 and 2001 in Fumbisi, and those for the farmer managed trials of 2001 in Fumbisi, are given. Partial budgeting and simple descriptive statistics were used to provide figures for the costs of different inputs on the part of households. The benefit:cost ratio (B:C) of each treatment was also calcualted.

Treatment 1, which involved spraying with glyphosate, resulted in the highest returns in the researcher managed plots (see Figures 1 and 2). This is because a lot of the activities that involve costs in the other treatments are not undertaken in this treatment. T4, which involved bunding and transplanting of the rice, ranked second in net returns in the researcher managed cases again for both 2000 and 2001 (Figures 1 and 2). The cost involved in this treatment is relatively high, because of the costs of bunding and transplanting, which are labour intensive. However it should be borne in mind that, depending on the level of flooding during the wet season, the labour of bunding may not need to be repeated each year.

Though intercropping with taro (T2) resulted in the highest variable cost in 2000, it gave negative net returns (Figure 1) in the researcher managed plots. This is due to the fact that pigs ate up the taro after the rice was harvested. The gross income obtained was therefore from the yield of the rice alone. In addition to that the taro suckers also constituted a huge cost since they were not locally available and were therefore bought and transported up from Kumasi which is in the southern part of the country. This treatment was therefore left out in 2001 since it had very limited chances of being adopted.

Though positive net returns were obtained from the farmers' practice in year 2000, negative returns were obtained in year 2001. This is because the yield in 2000 was higher than in 2001.

For the farmer-managed fields, treatments 1, 3 and 4 gave negative net returns in 2001 (Figure 3); however, chemical treatment and bunding and transplanting were still better than the farmers' practice. However, the low net returns may be attributed at least partly to the fact that in the 2001 trial, the land used for the researcher-managed trial was the same as that used in the previous year, so that the level of infestation by *O. longistaminata* was lower. In the farmer-managed plots, the land had not been used the previous year and had a higher level of infestatation with the weed. However, the low returns are probably also due to the low management level of the (male) farmers, whose priority in terms of investment of time is their upland maize and millet fields. The farmers involved in the trial also chose not to apply some of the fertilizer which they were given by the research project for use on the trial rice fields but used this instead on their upland fields, for growing maize and millet. It is possible that had some of the farmers been women these farmers might have used the fertilizer for the rice fields, since women, unlike their husbands, do not have the obligation to grow starch staples for their families which their husbands have (see above, section 8).

The benefit-cost ratios followed a similar trend as the net returns.

17. The dry season vegetable trials

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.

The reason for conducting a trial of dry season vegetable growing was that it is potentially a way of controlling *O. longistaminata*, because it involves weeding of the land, during a period when something is being grown which is quite dissimilar to the rice crop – which makes it much easier to remove this weed.

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 practiced 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 practiced except that there is no dam here and farmers resort to sinking wells which they use for watering in the dry season.

There is a good deal of potential for sale of vegetables produced in the dry season, since there is a shortage of vegetables in this period. Thus, there is considerable motivation to grow vegetables at this time. The constraint, of course, is the lack of water. However, the water table is quite close to the surface in the valleys in which rice is grown and can be reached through sinking wells. Thus it was decided to sink a well 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 *yili* which owns the land on which the trial was being conducted. It became apparent later that the well would need to be lined; funds were provided to line the well and the members of the *yili* took responsibility for organising this work.

Unfortunately, during the dry season of 2000/2001 most of the vegetables were eaten by grasshoppers. However, during the second year of the vegetable trial (male) members of the *yili* which owns the land were still very interested in being involved in the trials. Although it had been agreed that female members of the *yili* would also be involved in this trial, in the event the men took all the land available for farmer-managed trials of vegetable growing. In early 2002 at a focus group held by researchers, the women expressed their interest in being involved in the trial and funds were left for the sinking of a second well for their use, so that the area of the trial could be extended and the women too could be involved.

At the two focus groups held at Fumbisi in early 2002 with male and female farmers belonging to the *yili* concerned, all the farmers expressed great interest in dry season vegetable growing and it was clear that they would certainly take this forward in future years. They made it clear that so long as they have a reliable and sustainable source of water supply in the dry season to do dry season gardening, they would very much want to practice this, since they are very aware of the economic opportunities which it presents in terms of marketing their vegetable crops. The women farmers involved in the trial said that they planned to open a group savings account to save the money which they get from selling vegetables grown.

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

18. Economic assessment and farmer assessment of trials: Conclusion

From the economic analysis and the farmer assessment of the various treatments, bunding and transplanting and chemical treatment were more promising than the other treatments. Financial returns were higher for these treatments. Farmers in their assessment ranked these treatments highly and even non-participating farmers also expressed their appreciation for these treatments.

Chemical control could be trialled – it is rated first in terms of effective control by farmers – but there is a very significant constraint to its adoption in the form of its cost, a constraint which farmers are very aware of and which has caused this method to be rated a low second by them in terms of its likely adoption. Chemical control is probably not suitable for adoption by most small farmers. Caution should be used in deciding to trial this method further for use by such farmers, and careful assessment made of the ability to pay for the chemicals on the part of farmers. While there may be some sites where this is feasible, there are likely to be more where it is not.

Bunding and transplanting is the most promising treatment and should probably receive most emphasis in further trialling. It was ranked first by farmers in terms of likelihood of adoption, by a considerable margin, and it seems that farmers have very quickly come to realize the benefits of this method through one year of exposure to it, given its rapid rise in ranking between late 2000 and late 2001. The very positive response to this method is because of the high levels of productivity which this cultivation method makes possible. This is not only because it controls *O. longistaminata* but because it is, in general, a more productive method of cultivating rice.

However, bunding and transplanting is a very labour-intensive method of rice cultivation. In general, labour is in short supply in the farming systems in Northern Ghana. However, within this generalization there are complex calls on the labour of different categories of people and household, which need to be understood before it can be predicted whether labour will be available for a given activity, particularly where it is a novel activity, such as that involved in bunding and transplanting. 2001 was the first year in which the people of Fumbisi were exposed to this method of faming, and research could usefully be carried out to see which categories of farmer, and which types of household, do in fact take up this method over the next few years, and why.

Dry season vegetable production could very usefully be incorporated into further trials. Farmers have already expressed considerable interest in it and it is being practiced in other parts of the region. Its combination with bunding and transplanting – the method of on-season control considered by farmers to be the most likely one to be adopted – on the same plot is likely, in the medium and longer term, to lead to the gradual, and potentially fairly rapid, removal of the rhizomes of *O. longistaminata*, through year-round working of the soil and/or weeding. It has very clear and immediate benefits in terms of vegetables available for home consumption and for sale in a very advantageous market situation. It seems highly likely that if the opportunity of being given assistance to construct further wells for use in dry season vegetable production is made available, this will be taken up with alacrity in Fumbisi and other communities in Northern Ghana.

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Appendix 2

The effect of herbicides on wild rice (*O. longistaminata and O. barthii*).

1. Effect of glyphosate on *O. longistaminata* raised from seed or cutting.

2. The effect of ALS inhibiting herbicides (imazethapyr, imazomox and imazapyr) and oxadiazon on *O. longistaminata* and *O. barthii*.

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3. The effect of age of *O. longistaminata* regrowth and glyphosate application rates in Ghana.

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4. The effect of age of *O. longistaminata* regrowth and glyphosate application rates in Tanzania.

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Report for the DFID Crop Protection Programme project - Management of Weedy Rices in Africa (R7345/A0823)

Long Ashton Research Station **June, 2002**
Long Ashton, Bristol

1. Effect of glyphosate on *O. longistaminata* raised from seed or cuttings

Discussions with farmers and research staff had suggested that there were differences in the susceptibility of different populations of *O. longistaminata* to glyphoste and that regrowth after application was a common problem. To determine whether there were difference in the susceptibility of different accessions of *O. longistaminata* a series of experiments were conducted under glass-house conditions at Long Ashton Research Station.

Materials and Methods

O. longistaminata plants were propagated in two ways, as cuttings and from seed. Cuttings were taken from stock plants and consisted of a piece of shoot attached to some root. These were potted into 9-cm-diameter pots containing a mix of loam, peat, grit and perlite at a ratio of 5:3:2:1. Pots were covered with polythene and placed in trays containing a small volume of water. After 10 d, the polythene was removed. Seed were surface-sown on modules containing Levington seed compost. The modules were covered loosely with Clingfilm and placed in a tray containing a small volume of water. After 2 weeks, seedlings were potted on usually into 9-cm-diameter pots containing the same planting medium as above.

Rice 01-1 and 01-2

The effect of glyphosate used as Roundup against Mali rice plants raised from cuttings or seeds sown on the 17/7/01 was tested on plants at one of two growth stages. Plants were sprayed either 4 (Rice 01-1) or 6 weeks (Rice 01-2) after sowing or taking cuttings and in the first test, plants had 4 – 6 leaves. In the second test, plants had 5 - 7 leaves. In each of the two tests, plants taken from cuttings also had a rhizome on the spraying day. Plants raised from seed were sprayed with 20, 40, 80, 160 or 320 g a.e. ha^{-1} glyphosate and those raised from cuttings were sprayed with 40, 80, 160, 320 or 640 g a.e. ha^{-1} glyphosate. Fresh weight of the shoots was determined at 21 DAT and shoot regrowth from roots and rhizomes was assessed 35 and 70 DAT in the first and second tests respectively.

Rice 01-3 and 01-4

As described above, plants of four biotypes of *O. longistaminata* from the Ivory coast, Mali, Tanzania and Ghana were raised from cuttings taken 16/8/01. Seven (Rice 01-3) and eight weeks (Rice 01-4) after taking cuttings, plants were sprayed with 40, 80, 160, 320 or 640 g a.e. ha^{-1}glyphosate. In the first test, plants had 3 - 4 leaves and 5 - 6 leaves in the second test. Fresh weight of the shoots was determined 20 and 21 DAT and shoot regrowth from roots and rhizomes was assessed 49 and 59 DAT in the first and second tests respectively.

Rice 01-5

Plants raised from Mali seed No 9 sown 13/8/01 were re-potted into 25-cm-diameter pots and sprayed 12.5 weeks after sowing with 160, 320, 640 and 1280 g a.e. ha^{-1} glyphosate when plants had 6-7 leaves. Fresh weight of the shoots was determined 20 DAT and shoot regrowth from roots and rhizomes was assessed 59 DAT.

Throughout these studies glyphosate formulated as Round-up was used and 0.3% of spray volume of ethoxylated tallow amine surfactant (Ethokem) was added to all doses of glyphosate.

RESULTS

In the following GENSTAT analyses, data as a percentage of untreated controls have been used for all experiments to enable direct comparisons between different methods of generating plants, between different biotypes and between experiments. LSDs are calculated at the 5 % significance level and where there is a statistically significant difference between means, letters have been placed after the means. Thus, in the analysis tables, means within a column that have different letters are statistically different. Where two treatments have been compared directly t-tests have been performed and P values provided.

The tables at the end of this summary include fresh weight data and standard errors expressed as grams as well as data expressed as a percentage of untreated controls.

Rice 01-1 and 01-2:

01-1 Herbicide application 4 weeks after sowing or taking cuttings.
Plants from seed were treated with Roundup at 20, 40, 80, 160 and 320 g a.e. ha^{-1}.
Plants from cuttings were treated with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}.
Control plants raised from seed = 53.3 ± 5.9 g; control plants raised from cuttings = 41.6 ± 2.6 g at the initial fresh weight assessment 21 DAT.
Control plants from seed = 4.3 ± 0.8 g; control plants raised from cuttings = 8.1 ± 1.2 g at the regrowth assessment 35 DAT

Table A Effect of glyphosate rate on fresh weight (% of untreated controls) 21 and 35 DAT of *O. longistaminata* plants raised from seed or cuttings.

	Plants raised from seed		**Plants raised from cuttings**	
Rate (g a.e. ha^{-1})	**Fresh weight 21 DAT**	**Regrowth 35 DAT**	**Fresh weight 21 DAT**	**Regrowth 35 DAT**
0	100a	100a	100a	100a
20	50.8b	131.3a	-	-
40	26.0c	96.7a	47.6b	88.2a
80	33.6c	2.1b	47.9b	70.1ab
160	25.7c	0.0b	33.1c	26.3bc
320	16.5c	0.0b	31.3c	13.1bc
640	-	-	9.9d	0.0c
LSD*	21.94 24.04	89.1 97.6	18.65 11.76	49.05 53.74
F-value	<0.001	0.019	<0.001	0.002

**LSD; because of higher replication in controls than for treatments there are two LSD values. The first value is for comparing controls with treated plants, second value for comparing between treatments.*

At the first fresh weight assessment 21 DAT, control plants raised from seed were heavier than plants raised from cuttings by approximately 20 %, although the difference was not statistically significant (P=0.10 in t-test). However, the regrowth from plants from both seed and cuttings was statistically different (P=0.027), but minimal in both cases at 8 g or less per pot.

All treatments with glyphosate caused some initial damage (Table A), with the lowest rate of glyphosate used against plants from both seed and cuttings reducing shoot fresh weight of by approximately 50 %. For plants from seeds, increasing the rate from 20 to 40 g a.e. ha^{-1} caused additional control, but the control was not increased further by further increases in glyphosate rate. Despite effective control at the first assessment when using 20 and 40 g a.e. ha^{-1}, regrowth was as strong as the controls, whereas higher rates reduced regrowth close to zero. It must be remembered however that the regrowth was minimal even in controls at just 4 g.

For plants from cuttings, increasing the rate from 40 to 80 g a.e. ha^{-1} caused no additional control, but it was increased by approximately 15 % by increasing the rate to 160 or 320 g a.e. ha^{-1}. Increasing the rate still further to 640 g a.e. ha^{-1} increased control significantly by a further ~20 %. Again, despite initial control by the two lowest rates, regrowth was as strong as the controls, whereas higher rates reduced regrowth, but again regrowth was minimal in controls at ~8 g.

01-2 Herbicide application 6 weeks after sowing or taking cuttings.
Plants from seed were treated with Roundup at 20, 40, 80, 160 and 320 g a.e. ha^{-1}.
Plants from cuttings were treated with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}.
Control plants raised from seed = 63.9 ± 32 g; control plants raised from cuttings = 85.9 ± 11.2 g at the initial fresh weight assessment 21 DAT.
Control plants from seed = 43.5 ± 7.0; control plants raised from cuttings = 48.5 ± 7.0 g at the regrowth assessment 70 DAT

Table B Effect of glyphosate rate on fresh weight (% of untreated controls) 21 and 70 DAT of *O. longistaminata* plants raised from seed or cuttings.

	Plants raised from seed				**Plants raised from cuttings**			
Rate (g a.e. ha^{-1})	**Fresh weight 21 DAT**		**Regrowth 70 DAT**		**Fresh weight 21 DAT**		**Regrowth 70 DAT**	
0	100a		100a		100a		100a	
20	51.6b		112.1a		-		-	
40	44.8b		10.4b		38.3b		91.3a	
80	36.7b		0.6b		20.0bc		3.5b	
160	42.6b		0.0b		20.5bc		1.6b	
320	27.8b		0.0b		14.8bc		0.0b	
640	-				11.3c		0.0b	
LSD	20.73	22.71	35.78	39.20	23.31	25.53	39.55	43.32
F-value	<0.001		<0.001		<0.001		<0.001	

Control plants were heavier in this test than in the previous test, both at the initial fresh weight assessment and at the regrowth assessment. At the first assessment, plants from seed were 10 g heavier than in Rice 01-1, although the difference was not statistically significant (P=0.148). Those raised from cuttings were twice as heavy than in Rice 01-1, and in this case the difference of over 40 g was statistically significant (P=0.003). As the difference in the age of the plants at spraying and at the initial assessment was just two weeks, the substantial extra growth of plants from cuttings occurred in the last two weeks prior to the first assessment. Thus, whilst plants from cuttings have a relatively slow start, once established they can quickly increase their weight and far outstrip the growth of plants from seed. Because the roots and rhizome system in this test would have been more advanced when the shoots were initially removed due to the two week age difference and because regrowth of plants in this test was allowed to re-establish over 49 rather than 14 days, regrowth of controls was consequently upto 10-fold heavier than in the previous test.

As with the previous test on younger plants, all glyphosate treatments caused substantial damage when shoot weight was assessed 21 DAT. The lowest rate used on plants from seed reduced fresh weight by 50 %; a similar percentage control as in the previous experiment and indeed, actual weights were also reduced to a similar level (27 g in 01-1 and 33 g in 01-2; see Tables 1 and 3 in Tables section). The percentage control of the lowest rate on plants from cuttings was more severe than in the first test although the actual weight was heavier (20 g in 01-1 and 52 g in 01-2). This discrepancy is probably caused by the increasingly more rapid growth of controls in the 21 days after spraying.

For plants from seeds, there was little merit in increasing the rate above 20 g a.e. ha^{-1}. A t-test on plants treated with 20 or 320 g a.e. ha^{-1} showed the difference in control was significant at the 10 % level but not the 5 % level (P=0.07). As in the previous test, despite the strongly significant effect the lowest rate had on fresh weight at the initial assessment, regrowth of plants treated with the lowest rate of glyphosate was very similar to that of controls. In this test, this was not because regrowth of controls was low as in contrast, in this test, regrowth of controls was substantial at ~ 45 g. However, rates higher than 20 g a.e ha^{-1}did significantly reduced regrowth and whereas 50 g of regrowth occurred with plants sprayed with 20 g a.e. ha^{-1}, regrowth on plants sprayed with 40 g a.e. ha^{-1} was under 5 g. Thus, whereas 20 g a.e. ha^{-1} had similar effect as 40 g a.e. ha^{-1} or higher rates on initial growth, higher rates are significantly better at controlling regrowth.

For plants from cuttings, a similar overall pattern emerged. The lowest rate of 40 g a.e. ha^{-1} reduced weight 21 DAT by over 60 % and any additional significant control was achieved only by increasing the dose substantially to 640 g a.e. ha^{-1}. A t-test showed the extra 27 % control was significant at the 5 % level (P=0.002). Again, as in the previous test and with plants raised from seed in this test, despite initial control by the lowest rate, regrowth was as strong as the controls. As with plants from seed, rates higher than 40 g a.e. ha^{-1} did significantly reduced regrowth and whereas the lowest rate allowed nearly 45 g of regrowth, that which occurred with twice this rate was under 2 g. Moreover, zero regrowth established if plants had been sprayed with higher rates. Thus, again although 40 g a.e. ha^{-1} had as much affect as rates as high as 320 g a.e. ha^{-1} on initial growth, the higher rates were better at controlling regrowth.

Rice 01-3 and 01-4:

01-3 Herbicide application 7 weeks after taking cuttings

Four biotypes raised from cuttings: Ivory coast, Mali, Tanzania and Ghana.
Seven-week-old plants treated with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}.
Initial fresh weight assessment 21 DAT controls = 91.4 ± 10.5, 64.2 ± 6.9, 74.2 ± 12.7 and 67.5 ± 11.0 g for plants from the Ivory coast, Mali, Tanzania and Ghana respectively.
Regrowth assessment 49 DAT control = 6.0 ± 0.8, 4.9 ± 1.4, 5.1 ± 1.1 and 5.4 ± 2.2 g for plants from the Ivory coast, Mali, Tanzania and Ghana respectively.

Table C Effect of glyphosate rate on fresh weight (% of untreated controls) 21 DAT of four biotypes of *O. longistaminata* plants raised from cuttings.

Rate (g a.e. ha^{-1})	Ivory coast	Mali	Tanzania	Ghana	LSD	F-value	All biotypes
40	43.5	65.9	44.9	41.7	26.50	0.212	49.0a
80	43.0	49.8	37.7	31.7	20.72	0.317	40.6ab
160	23.6a	48.6b	37.6ab	27.3a	18.23	0.044	34.3b
320	13.2	17.6	18.8	23.4	14.20	0.498	18.2c
640	11.7	19.3	16.5	18.8	15.19	0.694	16.6c
All rates combined	28.6	40.2	31.1	28.6	11.25	0.096	
LSD	-	-	-	-			9.50
F-value	-	-	-	-			<0.001

Table D Effect of glyphosate rate on fresh weight regrowth (% of untreated controls) 49 DAT of four biotypes of *O. longistaminata* plants raised from cuttings.

Rate (g a.e. ha^{-1})	Ivory coast	Mali	Tanzania	Ghana	LSD	F-value	All Biotypes
40	184.0	235.5	236.3	158.5	172.4	0.702	203.6a
80	107.6	75.7	24.5	9.0	81.3	0.073	54.2b
160	1.4	0.0	0.0	0.0	2.18	0.426	0.4c
320	0.0	0.0	0.0	0.0	-	-	0.0c
640	0.0	0.0	0.0	0.0	-	-	0.0c
All rates combined	58.6	62.6	52.2	33.5	61.0	0.791	
LSD	-	-	-	-			38.73
F-value	-	-	-	-			<0.001

The weight of controls at the initial assessment of plants from Mali, Tanzania and Ghana were very similar regardless of biotype (F=0.147) as were the weight of controls at the regrowth assessment (F=0.937). Moreover, the effect of glyphosate on initial fresh weight and weight of the regrowth was also similar regardless of biotype (Table C). When all rates were combined, the F-values for the effect of glyphosate on the initial fresh weight and regrowth was F=0.096 and 0.791 respectively (Tables C & D). There was a clear dose response effect when data for all biotypes were combined (F<0.001 for both initial weight and regrowth) and no significant interaction of rate with biotype (F= 0.409 for initial growth, 0.549 on regrowth). The most effective control on the initial growth was when a rate of 320 or 640 g a.e. ha^{-1} was used and these two rates reduced fresh weight by more than 80 % and successfully inhibited any regrowth. In contrast, the lowest rate of 40 g a.e. ha^{-1} caused only a 50 % reduction in the initial weight but actually stimulated regrowth by ~200 %.

01-4 Herbicide application 8 weeks after taking cuttings

Four biotypes raised from cuttings: Ivory coast, Mali, Tanzania and Ghana.
Eight-week-old plants treated with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}.
Initial fresh weight assessment 21 DAT controls 70.9 ± 16.6, 63.5 ± 9.2, 69.8 ± 9.2 and 69.8 ± 9.2 g for plants from the Ivory coast, Mali, Tanzania and Ghana respectively.
Regrowth assessment 59 DAT control = = 15.6 ± 2.7, 20.0 ± 2.7, 15.2 ± 2.2 and 16.8 ± 3.2 for g for plants from the Ivory coast, Mali, Tanzania and Ghana respectively.

In the second biotype test, plants were sprayed at a later growth stage. The difference of one week, had caused very little change in the shoot fresh weight of control plants at the initial shoot weight (P=0.48) and control fresh weights of all four biotypes were statistically similar (F=0.847). However, the regrowth in this test was approximately 3-fold stronger (P<0.001); a combination of the roots and rhizome system in this test potentially being more advanced when the shoots were initially removed due to the one week age difference and also the extra 10 d allowed in the regrowth period. Although regrowth was more advanced, as with the previous test, control fresh regrowth weights of all four biotypes were statistically similar (F=0.422). For the biotype from the Ivory Coast, the fresh weight of the older control plants appears less than in the previous test, when plants were sprayed at an earlier stage. The effect is not statistically significant (P=0.23) and stems from the relatively high inherent variation caused from using cuttings

The overall effect of glyphosate on regrowth was similar regardless of biotype (F = 0.426 when all rates are combined; Table F). Moreover, for all individual glyphosate rates there was no effect of biotype, and all regrowth was completely controlled by 320 g a.e. ha^{-1}. At half this rate, growth was completely controlled in two biotypes and was less than 5 % in the other two. However, there appeared to be some suggestion that the effect on initial growth was biotype dependent. When all rates were combined, the F-value for the effect of glyphosate on the initial fresh weight was F=0.010 (Tables E), with the Mali biotype appearing more tolerant than those from Tanzania and the Ivory coast, with the Ghana biotype intermediate in the tolerance range. The potentially slightly higher tolerance of the Mali biotype was hinted at in the previous test, but at one rate of glyphosate only (160 g a.e. ha^{-1}) and in this test this biotype appeared more tolerant of this and the next highest rate. However, at lower and higher rates than 160 and 320 g a.e. ha^{-1} the responses of all four biotypes were statistically similar. The inherent variability of the production of replicate plants from cuttings along with low biotype replication may be inducing the statistical difference.

As in the other test, there was a clear dose response effect when data for all biotypes were combined (F<0.001 for both initial weight and regrowth) and no significant interaction of rate with biotype (F= 0.216 for initial growth, 0.463 on regrowth). Again, the most effective control on the initial growth was when a rate of 320 or 640 g a.e. ha^{-1} was used and these two rates again reduced fresh weight by approximately 80 % and successfully inhibited any regrowth. In contrast, the lowest rate of 40 g a.e. ha^{-1} again caused only 45 % reduction in the initial weight but in this test the regrowth was similar to controls rather than stimulated. In this test, the regrowth was allowed to continue 10 d longer than previously and may account for the test-tot-test difference.

Table E Effect of glyphosate rate on fresh weight (% of untreated controls) 21 DAT of four biotypes of *O. longistaminata* plants raised from cuttings.

Rate (g a.e. ha^{-1})	**Ivory coast**	**Mali**	**Tanzania**	**Ghana**	**LSD**	**F-value**	**All Biotypes**
40	48.9	70.2	59.4	46.1	22.76	0.141	56.1a
80	31.5	54.5	49.6	45.4	25.40	0.280	45.3a
160	21.2ab	50.9c	15.4a	46.4bc	26.27	0.011	32.6b
320	13.3a	31.5b	13.5a	23.8ab	14.4	0.048	20.5c
640	13.3	26.4	13.4	17.0	14.38	0.211	17.5c
LSD							11.02
F-value							<0.001
All rates combined	25.6a	46.7b	30.2a	35.7ab	12.62	0.010	

Table F Effect of glyphosate rate on fresh weight regrowth (% of untreated controls) 59 DAT of four biotypes of *O. longistaminata* plants raised from cuttings.

Rate (g a.e. ha^{-1})	**Ivory coast**	**Mali**	**Tanzania**	**Ghana**	**LSD**	**F-value**	**All Biotypes**
40	106.8	117.3	81.6	24.3	121.7	0.384	82.5a
80	16.1	25.5	2.1	3.0	28.25	0.266	11.7b
160	3.4	2.1	0.0	0.0	4.53	0.321	1.4b
320	0.0	0.0	0.0	0.0	-	-	0b
640	0.0	0.0	0.0	0.0	-	-	0b
LSD							25.89
F-value							<0.001
All rates combined	25.3	29.0	16.8	5.4	30.37	0.426	

Rice 01-5:

01-5 Herbicide application 12.5 weeks after sowing

Mali plants from seed treated with Roundup at 160, 320, 640 and 1280 g a.e. ha^{-1}.
Initial fresh weight assessment 21 DAT controls = 620.7 ± 25.8 g
Regrowth assessment 59 DAT controls = 106.7 ± 25.8 g

Table G Effect of glyphosate rate on fresh weight (% of untreated controls) 21 and 59 DAT of *O. longistaminata* plants raised from seed.

Rate (g a.e. ha^{-1})	**Fresh weight 20 DAT**		**Regrowth 59 DAT**	
0	100a		100a	
160	44.0b		2.1b	
320	32.3b		0.0b	
640	18.5c		0.0b	
1280	18.2c		0.0b	
LSD*	12.10	13.97	53.17	61.39
F-value	<0.001		<0.001	

**LSD, because of higher replication in controls than for treatments there are two LSD values. The first value is for comparing controls with treated plants, second value for comparing between treatments.*

On these large plants, the lowest rate of glyphosate used i.e. 160 g a.e. ha^{-1} caused more than 50 % reductions in fresh weight. Further control was affected when the rate was increased to 640 g a.e. ha^{-1}. This rate provided more than 80 % control and increasing the rate further did not provide further control. All rates gave close to 100 % control of the regrowth, which in controls was substantial at over 100 g. Indeed, there was zero regrowth when 320 g a.e. ha^{-1} or higher rates were used.

Conclusion

Existing 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 will be completely killed. Smaller plants generating from seed or rhizomes can usually be completely controlled by a lower rate of 320 g a.e. ha^{-1}. In Table D and E there is a slight trend for the Mali accession to be more tolerant to glyphoste than the other biotypes

TABLES

Rice 01-1:

Table 1: Fresh weight (g and % of untreated controls) of *O. longistaminata* 21 days after treatment with Roundup at 20, 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seeds or cuttings started 17/7/01. Herbicide application took place 4 weeks after sowing.

	Plants raised from seed		Plants raised from cuttings	
Rate (g a.e. ha^{-1})	**Fresh weight (g)**	**Fresh weight (% of controls)**	**Fresh weight (g)**	**Fresh weight (% of controls)**
20	27.1 ± 3.9	50.8 ± 7.2	- - -	- - -
40	13.8 ± 1.1	26.0 ± 2.0	19.8 ± 2.6	47.6 ± 6.3
80	17.9 ± 4.0	33.6 ± 7.5	19.9 ± 4.4	47.9 ± 10.6
160	13.7 ± 1.5	25.7 ± 2.7	13.7 ± 3.0	33.1 ± 7.2
320	8.8 ± 1.9	16.5 ± 3.6	13.0 ± 1.6	31.3 ± 3.8
640	- - -	- - -	4.1 ± 0.6	9.9 ± 1.3
Controls	53.3 ± 5.9	100.0 ± 11.1	41.6 ± 2.6	100.0 ± 6.3

Table 2: Fresh weight (g and % of untreated controls) of regrowth of *O. longistaminata* 35 days after treatment with Roundup at 20, 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seeds or cuttings started 17/7/01. Herbicide application took place 4 weeks after sowing.

	Plants raised from seed		Plants raised from cuttings	
Rate (g a.e. ha^{-1})	**Fresh weight (g)**	**Fresh weight (% of controls)**	**Fresh weight (g)**	**Fresh weight (% of controls)**
20	5.7 ± 2.6	131.3 ± 59.0	- - -	- - -
40	4.2 ± 2.4	96.7 ± 54.4	7.1 ± 1.8	88.2 ± 21.9
80	0.1 ± 0.1	2.1 ± 2.1	5.7 ± 2.4	70.1 ± 29.4
160	0.0 ± 0.0	0.0 ± 0.0	2.1 ± 1.0	26.3 ± 12.7
320	0.0 ± 0.0	0.0 ± 0.0	1.1 ± 1.0	13.1 ± 12.2
640	- - -	- - -	0.0 ± 0.0	0.0 ± 0.0
Controls	4.3 ± 0.8	100.0 ± 18.5	8.1 ± 1.2	100.0 ± 14.9

Rice 01-2:

Table 3: Fresh weight (g and % of untreated controls) of *O. longistaminata* 21 days after treatment with Roundup at 20, 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seeds or cuttings started 17/7/01. Herbicide application took place 6 weeks after sowing.

	Plants raised from seed		**Plants raised from cuttings**	
Rate (g a.e. ha^{-1})	**Fresh weight (g)**	**Fresh weight (% of controls)**	**Fresh weight (g)**	**Fresh weight (% of controls)**
20	33.0 ± 5.5	51.6 ± 8.7	- - -	- - -
40	28.7 ± 7.9	44.8 ± 12.4	32.9 ± 4.5	38.3 ± 5.2
80	23.5 ± 2.6	36.7 ± 4.1	17.2 ± 3.5	20.0 ± 4.1
160	27.2 ± 3.9	42.6 ± 6.2	17.6 ± 3.6	20.5 ± 4.2
320	17.7 ± 4.4	27.8 ± 6.9	12.7 ± 3.1	14.8 ± 3.6
640	- - -	- - -	9.7 ± 0.7	11.3 ± 0.8
Controls	63.9 ± 3.2	100.0 ± 5.1	85.9 ± 11.2	100.0 ± 13.0

Table 4: Fresh weight (g and % of untreated controls) of regrowth of *O. longistaminata* 70 days after treatment with Roundup at 20, 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seeds or cuttings started 17/7/01. Herbicide application took place 6 weeks after sowing.

	Plants raised from seed		**Plants raised from cuttings**	
Rate (g a.e. ha^{-1})	**Fresh weight (g)**	**Fresh weight (% of controls)**	**Fresh weight (g)**	**Fresh weight (% of controls)**
20	48.8 ± 9.0	112.1 ± 20.7	- - -	- - -
40	4.5 ± 4.5	10.4 ± 10.4	44.2 ± 15.6	91.3 ± 32.3
80	0.3 ± 0.3	0.6 ± 0.6	1.7 ± 1.7	3.5 ± 3.5
160	0.0 ± 0.0	0.0 ± 0.0	0.8 ± 0.6	1.6 ± 1.3
320	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
640	- - -	- - -	0.0 ± 0.0	0.0 ± 0.0
Controls	43.5 ± 7.0	100.0 ± 16.0	48.5 ± 6.0	100.0 ± 12.4

Rice 01-3

Table 5: Fresh weight (g and % of untreated controls) of four biotypes of *O. longistaminata* 21 days after treatment with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from cuttings started 16/8/01. Herbicide application took place 7 weeks after taking cuttings.

Biotype	Rate (g a.e. ha^{-1})	Fresh weight (g)			Fresh weight (% of controls)		
Ivory Coast	40	39.8	±	7.0	43.5	±	7.7
Ivory Coast	80	39.3	±	3.2	43.0	±	3.5
Ivory Coast	160	21.6	±	4.9	23.6	±	5.3
Ivory Coast	320	12.1	±	4.1	13.2	±	4.4
Ivory Coast	640	10.7	±	1.3	11.7	±	1.5
Ivory Coast	Controls	91.4	±	10.5	100.0	±	11.5
Mali	40	42.3	±	4.1	65.9	±	6.3
Mali	80	32.0	±	3.4	49.8	±	5.3
Mali	160	31.2	±	5.9	48.6	±	9.1
Mali	320	11.3	±	2.6	17.6	±	4.1
Mali	640	12.4	±	4.8	19.3	±	7.5
Mali	Controls	64.2	±	6.9	100.0	±	10.7
Tanzania	40	33.3	±	7.8	44.9	±	10.5
Tanzania	80	28.0	±	8.2	37.7	±	11.1
Tanzania	160	27.8	±	2.9	37.6	±	3.9
Tanzania	320	13.9	±	3.5	18.8	±	4.7
Tanzania	640	12.2	±	3.1	16.5	±	4.2
Tanzania	Controls	74.2	±	12.7	100.0	±	17.1
Ghana	40	28.1	±	6.2	41.7	±	9.3
Ghana	80	21.4	±	2.9	31.7	±	4.3
Ghana	160	18.4	±	2.1	27.3	±	3.2
Ghana	320	15.8	±	3.3	23.4	±	4.9
Ghana	640	12.7	±	3.1	18.8	±	4.7
Ghana	Controls	67.5	±	11.0	100.0	±	16.4

Table 6: Fresh weight (g and % of untreated controls) of regrowth of four biotypes of *O. longistaminata* 49 days after treatment with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from cuttings started 16/8/01. Herbicide application took place 7 weeks after taking cuttings.

Biotype	**Rate (g a.e. ha^{-1})**	**Fresh weight (g)**			**Fresh weight (% of controls)**		
Ivory Coast	**40**	11.0	±	3.1	184.0	±	51.1
Ivory Coast	**80**	6.4	±	2.2	107.6	±	36.7
Ivory Coast	**160**	0.1	±	0.1	1.4	±	1.4
Ivory Coast	**320**	0.0	±	0.0	0.0	±	0.0
Ivory Coast	**640**	0.0	±	0.0	0.0	±	0.0
Ivory Coast	**Controls**	6.0	±	0.8	100.0	±	13.1
Mali	**40**	11.6	±	1.8	235.5	±	35.7
Mali	**80**	3.7	±	1.8	75.7	±	35.8
Mali	**160**	0.0	±	0.0	0.0	±	0.0
Mali	**320**	0.0	±	0.0	0.0	±	0.0
Mali	**640**	0.0	±	0.0	0.0	±	0.0
Mali	**Controls**	4.9	±	1.4	100.0	±	28.0
Tanzania	**40**	12.0	±	3.7	236.3	±	73.1
Tanzania	**80**	1.2	±	0.6	24.5	±	11.7
Tanzania	**160**	0.0	±	0.0	0.0	±	0.0
Tanzania	**320**	0.0	±	0.0	0.0	±	0.0
Tanzania	**640**	0.0	±	0.0	0.0	±	0.0
Tanzania	**Controls**	5.1	±	1.1	100.0	±	22.0
Ghana	**40**	8.5	±	3.1	158.5	±	57.5
Ghana	**80**	0.5	±	0.3	9.0	±	4.7
Ghana	**160**	0.0	±	0.0	0.0	±	0.0
Ghana	**320**	0.0	±	0.0	0.0	±	0.0
Ghana	**640**	0.0	±	0.0	0.0	±	0.0
Ghana	**Controls**	5.4	±	2.2	100.0	±	41.3

Rice 01-4

Table 7: Fresh weight (g and % of untreated controls) of four biotypes of *O. longistaminata* 20 days after treatment with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from cuttings started 16/8/01. Herbicide application took place 8 weeks after taking cuttings.

Biotype	Rate (g a.e. ha^{-1})	Fresh weight (g)			Fresh weight (% of controls)		
Ivory Coast	40	34.7	±	6.3	48.9	±	8.9
Ivory Coast	80	22.4	±	3.6	31.5	±	5.0
Ivory Coast	160	15.1	±	3.8	21.2	±	5.3
Ivory Coast	320	9.4	±	1.8	13.3	±	2.6
Ivory Coast	640	9.4	±	1.9	13.3	±	2.6
Ivory Coast	Controls	70.9	±	16.6	100.0	±	23.4
Mali	40	44.5	±	6.7	70.2	±	10.5
Mali	80	34.6	±	4.2	54.5	±	6.5
Mali	160	32.3	±	6.5	50.9	±	10.2
Mali	320	20.0	±	3.9	31.5	±	6.2
Mali	640	16.8	±	5.4	26.4	±	8.5
Mali	Controls	63.5	±	9.2	100.0	±	14.5
Tanzania	40	41.5	±	1.9	59.4	±	2.7
Tanzania	80	34.6	±	5.8	49.6	±	8.4
Tanzania	160	10.8	±	1.9	15.4	±	2.7
Tanzania	320	9.4	±	3.2	13.5	±	4.5
Tanzania	640	9.4	±	1.7	13.4	±	2.4
Tanzania	Controls	69.8	±	9.2	100.0	±	13.2
Ghana	40	34.6	±	3.4	46.1	±	4.6
Ghana	80	34.1	±	8.7	45.4	±	11.6
Ghana	160	34.8	±	6.6	46.4	±	8.8
Ghana	320	17.9	±	3.6	23.8	±	4.7
Ghana	640	12.7	±	1.1	17.0	±	1.5
Ghana	Controls	75.0	±	8.1	100.0	±	10.8

Table 8: Fresh weight (g and % of untreated controls) of regrowth of four biotypes of *O. longistaminata* 59 days after treatment with Roundup at 40, 80, 160, 320 and 640 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from cuttings started 16/8/01. Herbicide application took place 8 weeks after taking cuttings.

Biotype	Rate (g a.e. ha^{-1})	Fresh weight (g)			Fresh weight (% of controls)		
Ivory Coast	**40**	16.6	±	4.8	106.8	±	30.8
Ivory Coast	**80**	2.5	±	1.5	16.1	±	9.7
Ivory Coast	**160**	0.5	±	0.3	3.4	±	2.1
Ivory Coast	**320**	0.0	±	0.0	0.0	±	0.0
Ivory Coast	**640**	0.0	±	0.0	0.0	±	0.0
Ivory Coast	**Controls**	15.6	±	2.7	100.0	±	17.6
Mali	**40**	23.5	±	7.0	117.3	±	34.8
Mali	**80**	5.1	±	3.1	25.5	±	15.3
Mali	**160**	0.4	±	0.4	2.1	±	2.1
Mali	**320**	0.0	±	0.0	0.0	±	0.0
Mali	**640**	0.0	±	0.0	0.0	±	0.0
Mali	**Controls**	20.0	±	2.7	100.0	±	13.5
Tanzania	**40**	12.4	±	9.6	81.6	±	63.1
Tanzania	**80**	0.3	±	0.3	2.1	±	2.1
Tanzania	**160**	0.0	±	0.0	0.0	±	0.0
Tanzania	**320**	0.0	±	0.0	0.0	±	0.0
Tanzania	**640**	0.0	±	0.0	0.0	±	0.0
Tanzania	**Controls**	15.2	±	2.2	100.0	±	14.5
Ghana	**40**	4.1	±	1.6	24.3	±	9.7
Ghana	**80**	0.5	±	0.4	3.0	±	2.2
Ghana	**160**	0.0	±	0.0	0.0	±	0.0
Ghana	**320**	0.0	±	0.0	0.0	±	0.0
Ghana	**640**	0.0	±	0.0	0.0	±	0.0
Ghana	**Controls**	16.8	±	3.2	100.0	±	19.0

Rice 01-5

Table 9: Fresh weight (g and % of untreated controls) of Mali No. 9 rice 20 days after treatment with Roundup at 160, 320, 640 and 1280 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seed started 13/8/01. Herbicide application took place 12.5 weeks after taking cuttings.

Rate (g a.e. ha^{-1})	Fresh weight (g)			Fresh weight (% of controls)		
160	273.3	±	21.0	44.0	±	3.4
320	200.6	±	31.7	32.3	±	5.1
640	114.6	±	28.3	18.5	±	4.6
1280	112.7	±	8.8	18.2	±	1.4
Controls	620.7	±	25.8	100.0	±	4.2

Table 10: Fresh weight (g and % of untreated controls) of regrowth of Mali No. 9 rice 59 days after treatment with Roundup at 160, 320, 640 and 1280 g a.e. ha^{-1}. Each treatment consisted of four pots of plants raised from seed started 13/8/01. Herbicide application took place 12.5 weeks after taking cuttings.

Rate (g a.e. ha^{-1})	Fresh weight (g)			Fresh weight (% of controls)		
160	2.3	±	1.3	2.1	±	1.2
320	0.0	±	0.0	0.0	±	0.0
640	0.0	±	0.0	0.0	±	0.0
1280	0.0	±	0.0	0.0	±	0.0
Controls	106.7	±	25.8	100.0	±	24.2

2. <u>Evaluation of imazamox, imazapyr, imazethapyr and oxadiazon for control of *O. barthii* and *O. longistaminata*.</u>

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-lactat synthase (ALS)-inhibiting herbicides could allow the selective control of wild rices in the rice crop. As these IMI-tolerant rices are produced through chemically induced mutation rather than genetic modification they could be grown widely within existing legislation that prohibits the utilisation of genetically modified crops. Studies on the use of "IMI-tolerant rice" had been reported after work in the USA (Webster & Masson, 2001). 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.

[Webster, E.P.; Masson J.E. (2001) Acetolactate synthase-inhibiting herbicides on Imidazolinone-tolerant rices. **Weed Science**, 49: 652-657]

Materials and Methods

The experiments were conducted in the greenhouses at Long Ashton Research Station. Herbicides were applied as pre and post-emergence application in two separate experiments. For the post emergence applications, seeds were sown 5 seeds per pot thinned to 2 plants at 13 days and sprayed at 15 days after sowing. The pots for the pre-emergence applications were sown the day before spraying.

The doses of herbicides were are follows: imazamox 30, 60, 90, 120, and 150 g a.i. / ha, imazapyr 10, 20, 40, 60 and 80 g a.i. / ha, imazethapyr 40, 70, 100, 130, 160 g a.i. / ha and oxadiazon 250, 500, 750, 1000 and 1250 g a.i./ ha. All were applied using a precision track sprayer and in the equivalent of 200 l water.

O. barthii (Mali), *O. longistaminata* (Mali) and *O. sativa* (IDSA 6) were used in the experiment and the treatments were allocated in factorial combination, with 4 complete replicates with 8 control treatments.

Results

In the pre-emergence test, the germination rates of for all three rices, including the control treatments, were very variable and, because of the nature of the treatment, the variation could not be accounted for by oversowing and thinning back. The variation depended on the rice type and germination rates ranged from 40 – 80 % for *O. barthii*, 0 – 60 % for *O. longistaminata* and 60 – 100 % for IDSA 6, with means of 60, 35 and 70 % respectively. Thus, to compare the relative effect of treatment on the different rices, the variation in germination and any subsequent differences in vigour have been accounted for by performing analyses on data expressed as percentage of control values.

In the post-emergence test, problems with differences in germination rates were overcome by over-sowing on the 9/4/01 at 5 plants per pot and thinning back to 2 plants three days before spraying.

In both the pre and post-emergence experiments, *O. barthii* was treated with five rates of each of the four herbicides. However, because of poor germination, the other two rices were treated with only the lowest, middle and highest rate from the five rates initially chosen. To prevent potential bias that could occur if there was a non-linear dose response data for rates 2 and 4 for *O. barthii*, have been omitted from the GENSTAT analyses. However, the effect of these rates on *O. barthii* can be compared in the tables at the end of this summary, where the omitted data has been included. In the GENSTAT analyses, LSD's are calculated at the 5% significance level and where there is a statistically significant difference between means, letters have been placed after the means. Thus, in the analysis tables, means within a column that have different letters are statistically different.

<u>Pre-emergence spray</u>

A: Effect of herbicide rate (all herbicides pooled)

Generally, there was a clear effect of herbicide rate on germination, fresh weight per pot and fresh weight per plant for all three rices, with increasing rate reducing germination rate and fresh weight. However, although the pattern seen for germination of *O. longistaminata* was in the expected manner, the effect was not statistically significant even at the 10 % level.

	Germination (% of controls)		
	Oryza barthii	*Oryza longistaminata*	*Oryza cv IDSA 6*
Low	108.0**b**	60.6	91.2
Medium	68.0**a**	49.9	62.6
High	52.0**a**	42.7	59.2
LSD	**0.001**	34.1	30.9
F-value	**29.9**	0.574	0.083

	Fresh weight per pot (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Low	92.2**b**	80**b**	61.7**b**
Medium	51.6**a**	43**ab**	23.1**a**
High	20.4**a**	15**a**	9.3**a**
LSD	**38.1**	**50.4**	**26.9**
F-value	**0.002**	**0.041**	**<0.001**

	Fresh weight per plant (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Low	69.7**b**	129**b**	73.7**b**
Medium	54.3**b**	69**ab**	27.8**a**
High	18.1**a**	23**a**	8.9**a**
LSD	**31.5**	**81.6**	**30.9**
F-value	**0.006**	**0.041**	**<0.001**

B: Comparison of the effect of the four herbicides applied pre-emergence (all rates of herbicide have been pooled)

Of all the herbicides, imazethapyr affected germination of all three rices the most, closely followed by imazamox. Oxadiazon and imazapyr were the least effective inhibitors of germination. The effect of herbicide was statistically significant for two of the rices and for the third *(O. barthii)*, although the effect was not significant, the ranking of the four herbicides was similar.

	Germination (% of controls)		
	Oryza barthii	*Oryza longistaminata*	*Oryza cv IDSA 6*
Imazethapyr	56.0	14.3**a**	45.3**a**
Imazamox	80.0	38.0**a**	52.5**ab**
Imazapyr	74.7	76.0**b**	83.6**bc**
Oxadiazon	93.3	76.0**b**	102.5**c**
LSD	38.7	**33.4**	**32.6**
F-value	0.286	**<0.001**	**0.003**

Imazethapyr and imazamox also had the greatest effect of the four herbicides on total fresh weight per pot. Imazapyr was the least effective. However, the effect was only statistically significant for *O. longistaminata.*

	Fresh weight per pot (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazethapyr	40.2	17.0**a**	21.1
Imazamox	42.9	18.0**a**	14.5
Imazapyr	75.3	109.9**b**	42.1
Oxadiazon	60.5	38.6**a**	47.8
LSD	49.7	**54.1**	34.8
F-value	0.457	**0.003**	0.173

Imazethapyr and *imazamox* also had the greatest affect on fresh weight of individual plants. Imazapyr again was the least effective. Again although the patterns were similar for all three rices, for some the effect was not always statistically significant (IDSA 6).

	Fresh weight/plant (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazamox	29.2**a**	27**a**	20.1
Imazethapyr	29.1**a**	38**a**	29.8
Imazapyr	73.7**c**	165**b**	47.8
Oxadiazon	57.5**ab**	65**a**	49.5
LSD	**37.8**	**91.1**	41.7
F-value	**0.053**	**0.016**	0.426

C: Comparison of the effect of the four herbicides applied at their highest rate

In a two-way ANOVA, there was no interaction of formulation with dose for any of the parameters. However, as there was a beneficial effect of increasing the rate of herbicide the following analyses compare the efficacy of each herbicide when used at its most effective rate. Although most comparisons are not significant because of the lower replication and high inherent variability, this analysis complements the previous one where rate was not taken into account. Thus, in general, *imazamox* and *imazethapyr* are the two most effective herbicides and *oxadiazon* and Imazypyr are the least effective.

	Germination (% of controls)		
	Oryza barthii	*Oryza longistaminata*	*Oryza cv IDSA 6*
Imazethapyr	32	0.0**a**	29
Imazamox	24	14.3**a**	50
Imazapyr	48	71.2**b**	58
Oxadiazon	104	85.5**b**	100
LSD	64.4	**53.78**	66.9
F-value	0.074	**0.011**	0.183

	Fresh weight (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazethapyr	7.7**a**	0.0	0.0
Imazamox	3.5**a**	0.0	0.5
Imazapyr	12.0**a**	49.7	32.5
Oxadiazon	58.2**b**	9.0	4.2
LSD	**36.4**	46.5	33.6
F-value	**0.022**	0.111	0.163

	Fresh weight/plant (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazamox	5.0**a**	0.0	2.2
Imazethapyr	5.2**a**	0.0	0.0
Imazapyr	18.5**ab**	49.7	5.0
Oxadiazon	43.7**b**	9.0	28.3
LSD	**27.7**	65.7	25.3
F-value	**0.032**	0.107	0.106

Post-emergence spray

In the post-emergence test, all three species responded exactly similarly to dose and to the different herbicides. When data for all four herbicides were pooled, the lowest rate of herbicide caused between 40 and 45 % reductions in fresh weight. The middle rate was significantly more effective and caused approximately 80 % reductions. The highest rate was 7 – 9 % more effective although the effect was not statistically significant.

Data for all herbicides pooled

Herbicide rate	**Fresh weight (% of controls)**		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Low	58.7**a**	55.8**a**	60.8**a**
Medium	20.6**b**	20.2**b**	23.8**b**
High	13.2**b**	14.8**b**	12.8**b**
LSD	**22.86**	**23.80**	**24.47**
F-value	**<0.001**	**0.002**	**<0.001**

The post-emergent experiment confirmed the greater effectiveness of particularly *imazethapyr* and over *oxadiazon*. Moreover, as the ranking was so consistent for all three species, t-tests were performed to discriminate in more detail the relative effectivenss of the two best performers. For all three rices, t-tests confirmed *imazethapyr* was more effective than *imazamox*, but the latter was similar in performance to *Imazapyr*. Oxadiazon was statistically less effective than all the other three herbicides.

Data for all rates of herbicide pooled

	Fresh weight (% of controls)		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazethapyr	1.1**a**	3.2**a**	3.4**a**
Imazamox	26.3**b**	19.0**b**	28.0**b**
Imazapyr	32.3**b**	32.3**b**	32.3**b**
Oxadiazon	63.6**c**	66.6**c**	66.1**c**
LSD	**25.32**	**24.78**	**27.56**
F-value	**<0.001**	**<0.001**	**<0.001**

In this experiment there were significant interactions of formulation with dose for each of the three rice species. Therefore ANOVAS were performed on data for both the lowest and highest rate of herbicide, i.e., where individual performance would be most and least likely to be limiting.

This analyses shows that at both the lowest and highest rates *imazethapyr* was the most effective. In particular, at the lowest rate this herbicide clearly outperformed all three other herbicides and even at its lowest rate of 40 g ai 200 L^{-1} it reduced fresh weight by over 90 %. In comparison, the next best herbicide, *imazamox*, used at 30 g ai 200 L^{-1}, reduced fresh weight by between 30 and 60 % and the two least effectice herbicides caused only between 10 and 30 % damage despite the concentration of *oxadiazon* being 250 g ai 200 L^{-1}.

Imazethapyr at its lowest rate was clearly working close to its maximum potential and increasing the rate from 40 to 160 g ai 200 L^{-1}, increased its efficacy by only a few percent. In contrast, as the other three herbicides were not as effective at their lowest rate, increasing their rates caused a substantial increase in their efficacy. Indeed, the efficacy of both *imazamox* and *Imazapyr* increased to a level similar to that achieved by *imazethapyr*. However, even when the concentration of *oxadiazon* was increased to 1250 g ai 200 L^{-1}, the efficacy of this compound was still statistically poorer than the other three herbicides by approximately 50 %.

Lowest rate	**Fresh weight (% of controls)**		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazethapyr	1.4**a**	6.8**a**	6.9**a**
Imazamox	71.6**b**	37.9**b**	68.0**b**
Imazapyr	94.5**b**	89.1**c**	93.5**b**
Oxadiazon	67.2**b**	89.6**c**	74.7**b**
LSD	**27.44**	**43.44**	**43.39**
F-value	**<0.001**	**0.003**	**0.005**

Highest rate	**Fresh weight (% of controls)**		
	Oryza barthii	***Oryza longistaminata***	***Oryza cv IDSA 6***
Imazethapyr	1.0**a**	1.4**a**	1.4**a**
Imazamox	1.3**a**	1.8**b**	2.9**a**
Imazapyr	0.9**a**	1.2**c**	1.3**a**
Oxadiazon	49.5.2**b**	54.7**c**	45.5**b**
LSD	**5.01**	**19.37**	**16.92**
F-value	**<0.001**	**0.003**	**<0.001**

Conclusions

Pre-emergence applications of imazethapyr and imazamox had more effect on the germination of *O. longistaminata* than imazapyr and oxadiazon, 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%. The results suggest that oxadiazon could not be used as a selective herbicide for the control of *O. barthii* or *O. longistaminata* in rice.

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 indicating that it could not be used as a selective herbicide in rice.

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.

Table 1: Germination and fresh weight (g) of three rices 20 days after pre-emergence treatment with four herbicides. Each treatment consisted of four pots sown on the 24/4/02 with five seeds per pot. Herbicide application took place one day after sowing.

	Oryza barthii			*Oryza longisaminata*			*Oryza cv IDSA 6*		
Rate ($g\ 200L^{-1}$)	Germination per 5 seeds	Fresh weight (g)	Fresh weight (g/plant)	Germination per 5 seeds	Fresh weight (g)	Fresh weight (g/plant)	Germination per 5 seeds	Fresh weight (g)	Fresh weight (g/plant)
Imazamox									
30	4.25	0.94	0.20	0.75	0.13	0.09	3.00	0.43	0.16
60	2.25	0.08	0.04						
90	2.50	0.14	0.06	1.00	0.01	0.01	0.75	0.01	0.01
120	2.25	0.14	0.05						
150	0.75	0.03	0.02	0.25	0.00	0.00	1.75	0.01	0.01
Imazapyr									
10	3.25	0.99	0.29	1.50	0.34	0.22	3.50	0.84	0.26
20	1.25	0.47	0.26						
40	2.25	0.85	0.36	1.25	0.38	0.27	3.25	0.40	0.12
60	1.50	0.31	0.10						
80	1.50	0.10	0.06	1.25	0.13	0.08	2.00	0.04	0.01
Imazethapyr									
40	3.00	0.67	0.18	0.50	0.13	0.13	2.50	0.64	0.25
70	2.50	0.11	0.04						
100	1.25	0.30	0.08	0.25	0.00	0.00	1.25	0.00	0.00
130	1.25	0.09	0.09						
160	1.00	0.07	0.02	0.00	0.00	0.00	1.00	0.00	0.00
Oxadiazon									
250	3.00	0.57	0.21	1.50	0.22	0.16	3.75	0.60	0.15
500	2.25	0.44	0.19						
750	2.50	0.49	0.20	1.00	0.05	0.05	3.50	0.53	0.18
1000	2.00	0.30	0.17						
1250	3.25	0.50	0.14	1.50	0.02	0.02	3.50	0.33	0.08
controls	**3.13**	**0.86**	**0.32**	**1.75**	**0.26**	**0.12**	**3.50**	**1.02**	**0.28**

Table 2: Germination and fresh weight (% of controls) of three rices 20 days after pre-emergence treatment with four herbicides. Each treatment consisted of four pots sown on the 24/4/02 with five seeds per pot. Herbicide application took place one day after sowing.

	Oryza barthii			*Oryza longisaminata*			*Oryza cv IDSA 6*		
Rate ($g\ 200L^{-1}$)	Germination per 5 seeds	Fresh weight (%)	Fresh weight (%/plant)	Germination per 5 seeds	Fresh weight (g)	Fresh weight (g/plant)	Germination per 5 seeds	Fresh weight (g)	Fresh weight (g/plant)
Imazamox									
30	136	109	64	43	49	76	86	43	56
60	72	9	12						
90	80	16	19	57	4	5	21	1	2
120	72	16	15						
150	24	3	5	14	0	0	50	1	2
Imazapyr									
10	104	115	91	86	132	192	100	82	95
20	40	55	80						
40	72	99	112	71	148	230	93	40	44
60	48	36	32						
80	48	12	18	71	50	72	57	4	5
Imazethapyr									
40	96	78	58	29	51	113	71	63	90
70	80	13	12						
100	40	35	24	14	0	0	36	0	0
130	40	10	27						
160	32	8	5	0	0	0	29	0	0
Oxadiazon									
250	96	67	67	86	87	134	107	59	55
500	72	51	58						
750	80	57	62	57	20	43	100	52	65
1000	64	34	53						
1250	104	58	44	86	9	20	100	32	28
controls	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**	**100**

Table 3: Fresh weight (g ± s.e and % ± s.e) of three rices 20 days after post-emergence treatment with four herbicides. Each treatment consisted of four pots sown on the 9/4/02 with two plants per pot.

	Oryza barthii		*Oryza longisaminata*		*Oryza cv IDSA 6*	
Rate ($g\ 200L^{-1}$)	Fresh weight (g)	Fresh weight (% of controls)	Fresh weight (g)	Fresh weight (% of controls)	Fresh weight (g)	Fresh weight (% of controls)
Imazamox						
30	5.31 ± 0.29	72 ± 4	2.74 ± 1.15	38 ± 16	3.40 ± 1.03	68 ± 21
60	1.02 ± 0.86	14 ± 11				
90	0.44 ± 0.21	6 ± 3	1.25 ± 0.59	17 ± 8	0.66 ± 0.28	13 ± 5
120	0.118 ± 0.03	2 ± 0				
150	0.10 ± 0.02	1 ± 0	0.13 ± 0.06	2 ± 1	0.15 ± 0.01	3 ± 0
Imazapyr						
10	7.01 ± 1.16	94 ± 16	6.44 ± 1.07	89 ± 15	4.68 ± 0.77	94 ± 15
20	3.19 ± 0.46	43 ± 6				
40	0.11 ± 0.02	1 ± 0	0.48 ± 0.27	7 ± 4	0.10 ± 0.01	2 ± 0
60	0.07 ± 0.01	1 ± 0				
80	0.07 ± 0.01	1 ± 0	0.09 ± 0.01	1 ± 0	0.06 ± 0.01	1 ± 0
Imazethapyr						
40	0.10 ± 0.02	1 ± 0	0.49 ± 0.27	7 ± 4	0.34 ± 0.14	7 ± 3
70	0.08 ± 0.01	1 ± 0				
100	0.06 ± 0.01	1 ± 0	0.09 ± 0.03	1 ± 0	0.09 ± 0.02	2 ± 0
130	0.08 ± 0.01	1 ± 0				
160	0.08 ± 0.01	1 ± 0	0.10 ± 0.03	1 ± 0	0.07 ± 0.00	1 ± 0
Oxadiazon						
250	4.99 ± 0.56	67 ± 8	6.47 ± 1.27	90 ± 18	3.74 ± 0.56	75 ± 11
500	5.36 ± 1.07	72 ± 14				
750	5.50 ± 0.60	74 ± 8	4.02 ± 0.99	56 ± 14	3.91 ± 0.80	78 ± 16
1000	5.07 ± 0.75	68 ± 10				
1250	3.67 ± 0.24	49 ± 3	3.95 ± 0.91	55 ± 13	2.28 ± 0.55	45 ± 11
controls	**7.42 ± 0.48**	**100 ± 6.5**	**7.23 ± 0.68**	**100 ± 9.5**	**5.00 ± 0.20**	**100 ± 4.0**

The effect of age of *O. longistaminata* regrowth and glyphosate application rates in Ghana.

F. Tuor, S. Powers[2], D.E. Johnson

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Summary

Dose response curves were fitted to the final fresh and dry weight, numbers of plants and height data for two experiments considering the effect of herbicide on wild rice. Separate asymptotes representing the values of the variables for control for the three ages of plants were statistically significant in all cases, but only for experiment 1 fresh and dry weight were separate *LD*50s significant as well. In these two cases, the plants at the two older ages had similar LD50s, which were lower in comparison to that of the youngest aged plants.

Introduction

Herbicide was applied at each of 7 doses, and a control, to 3 ages of weed in an experiment with 4 replicates. The treatments were: control (0), 1 (0.36), 2 (0.72), 3(1.08), 4(1.44), 6(2.16), 8(2.88) and 10 l Roundup ha (3.60 kg a.e. glyphosate ha). The herbicide was applied to 3 stages of *O. longistaminata* regrowth after cutting namely, 2, 4 and 6 weeks old. The experimental design was a randomised block and the experiment was performed twice. Initial heights, numbers of plants, fresh and dry weights were recorded to ascertain the variation between plots prior to the application of herbicide. Hence, the final measurements, at the end of each experiment, of these variables, were taken as the data to be analysed.

Analysis

For each experiment and variable, dose response (logistic) curves were fitted, by non-linear least-squares regression. In each case, a parallel curve analysis was undertaken to consider the effect of weed age. Also, for each analysis, a weighting was defined as the corresponding variable of initial values of numbers, heights, fresh or dry weight for plots. Hence, a plot with a *high* initial fresh weight, dry weight, number of plants or height of plant was therefore allocated *higher* (i.e. more) weight in the analysis, so that, in fitting the model, a better fit to data with high weighting is important. This makes sense from a point of view that the effect of the herbicide is going to be of more interest in the worst weed conditions.

Due to non-constant variance, a log transformation was required for the two weight measurements, and a square root transformation for the number of plants and heights. It is noted that a log transformation would have been too strong in the case of the height data. The transform-both-sides (of the model equation) technique was used, and so the estimated parameter values are on the same scale as the raw data. ANOVAs of the transformed data, taking into account the design and treatment structure (age by dose), were also performed. Hence, for comparison of means, least significant differences (LSDs) (calculated using the residual mean square (s^2) of the ANOVAs) refer to the transformed data scale.

Results

For experiment 1 **fresh** and **dry weight**, the best logistic model was:

$$y(dose) = \log\left(\frac{C[i]}{1 + \left(\frac{dose}{\exp(M[i])} \right)^B} \right),$$

where $y(dose) = \log(freshwt)$ or $y(dose) = \log(drywt)$ respectively for replicate *j* (= 1, …, 4) of age *i* (= 1, 2 or 3). In this model, the fresh or dry weight for control is estimated by the asymptote *C*[*i*], and the dose that kills 50% (*LD*50) of control weed is estimated by *M*[*i*], for each age, *i*. The common parameter, *B*, is the effective exponential rate of decline with increasing dose for the curves.

For experiment 1 fresh weight, separate asymptotes for age and separate *LD*50s were significant ($p = 0.012$ and $p = 0.03$ respectively). For dry weight these p-values were $p = 0.002$ and $p = 0.009$ respectively.

For experiment 2 **fresh** and **dry weights** and for both experiments in the case of **number** and **height** of plants, the best logistic model was:

$$y(dose) = sqrt\left(\frac{C[i]}{1 + \left(\frac{dose}{\exp(M)} \right)^B} \right)$$

where $y(dose) = sqrt(number)$ or $y(dose) = sqrt(height)$ respectively for replicate *j* of age *i*. Here, the fresh or dry weight for control is estimated by the asymptote *C*[*i*] for each age, *i*, and the dose that kills 50% (*LD*50) of control weed is estimated by *M*. Hence, *M* and *B* are common for all ages in this model.

For experiment 2 fresh weight and dry weight, numbers of plants and height, separate asymptotes for age were significant ($p < 0.001$ for all).

For experiment 1 numbers of plants and heights, separate asymptotes for age were significant ($p < 0.001$ and $p = 0.04$ respectively).

The table below summarises the results including the estimates of random variation s^2 for each model. The full analysis results (GenStat output) are provided at the end of the report.

Table 1: Experiment 1 Parameter Estimates and Standard Errors

Variable / Parameter	Log(Fresh Weight)	Log(Dry Weight)	Sqrt(Number of Plants)	Sqrt(Height)
C[2]	576.8 (66.9)	185.0 (15.3)	372.2 (24.2)	84.49 (4.24)
C[4]	860.0 (103)	253.7 (20.2)	415.9 (23.9)	85.72 (4.02)
C[6]	880.1 (93.9)	259.1 (17.4)	498.4 (27.4)	90.50 (4.15)
B	1.854 (0.312)	1.755 (0.178)	1.344 (0.137)	0.794 (0.108)
M[2]	1.158 (0.218)	0.948 (0.131)	Common M = 0.410 (0.098)	Common M = 1.076 (0.128)
M[4]	0.585 (0.169)	0.513 (0.114)		
M[6]	0.655 (0.153)	0.600 (0.100)		
s^2	48.76 on 89 df	8.237 on 89 df	25.39 on 91 df	30.42 on 91 df

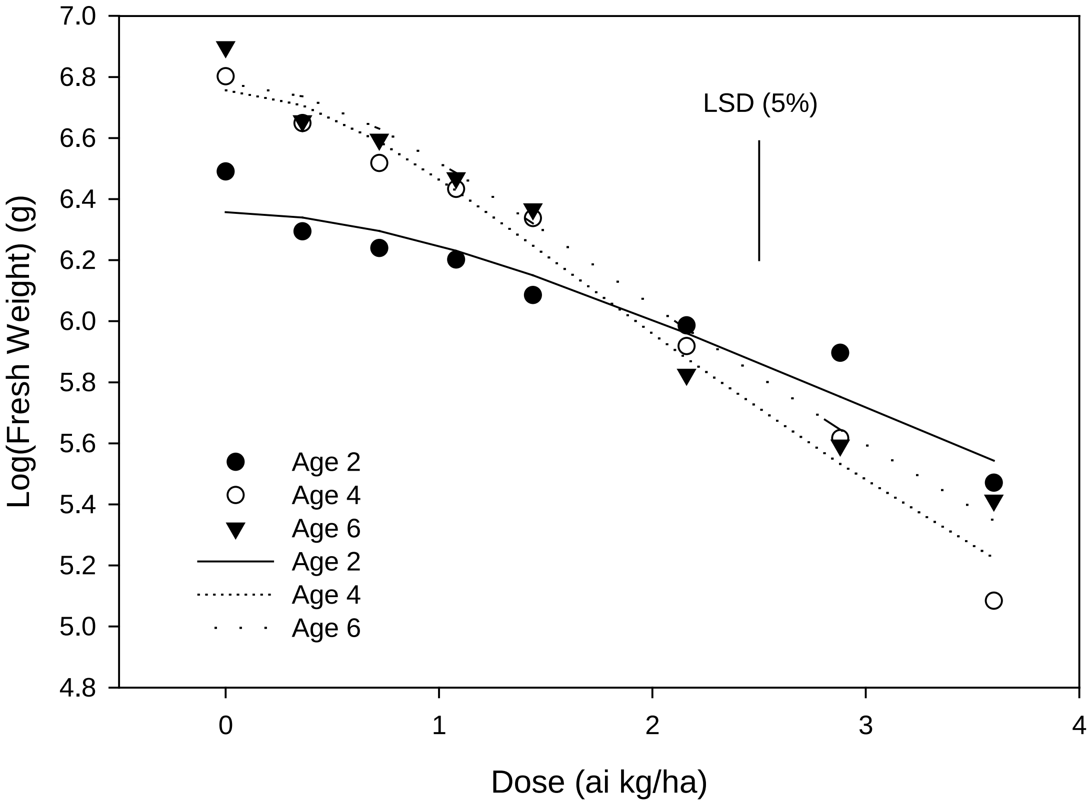
Table 2: Experiment 2 Parameter Estimates and Standard Errors

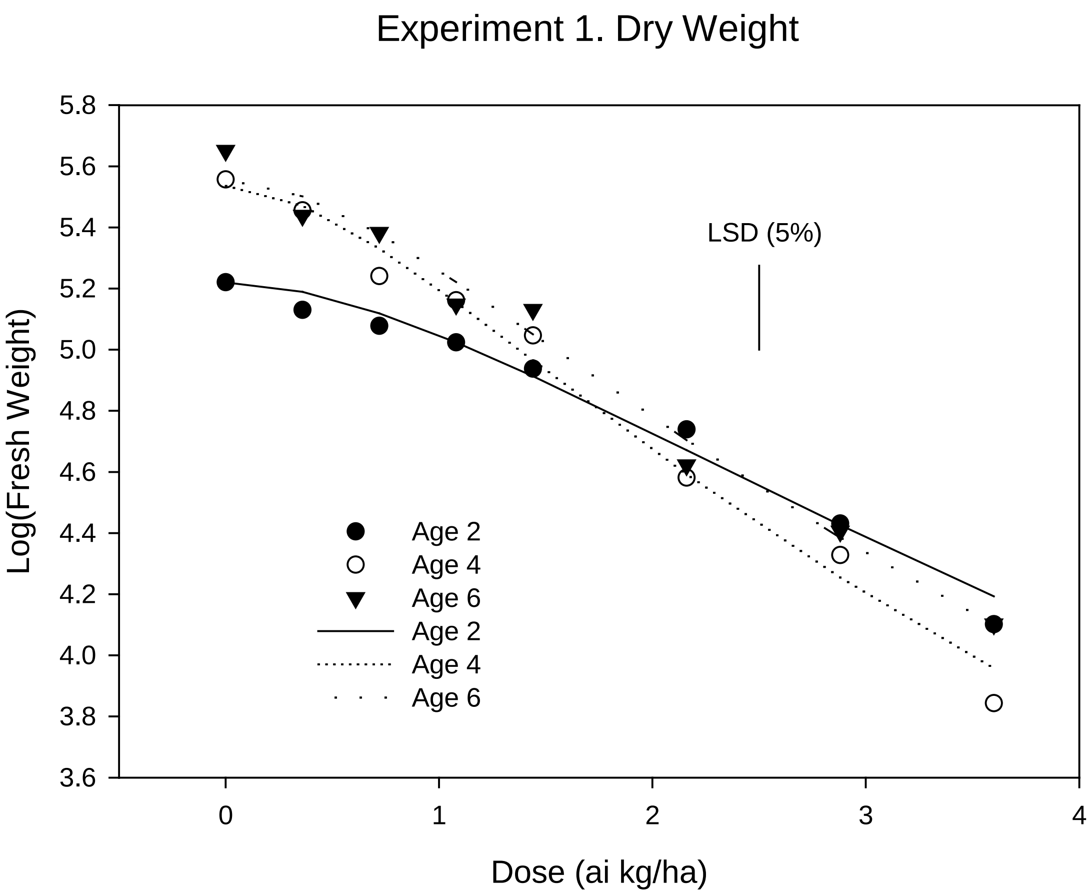
Variable / Parameter	Log(Fresh Weight)	Log(Dry Weight)	Sqrt(Number of Plants)	Sqrt(Height)
C[2]	358.4 (46.5)	133.8 (14.0)	239.0 (20.6)	67.86 (3.09)
C[4]	453.1 (48.8)	154.7 (13.9)	288.8 (20.6)	69.10 (3.08)
C[6]	703.5 (64.4)	249.0 (20.4)	363.5 (19.6)	87.53 (3.50)
B	2.123 (0.273)	1.830 (0.234)	1.847 (0.235)	1.080 (0.113)
M	0.478 (0.117)	0.517 (0.117)	0.6249 (0.0861)	0.8266 (0.0854)
s^2	30.42 on 91 df	9.376 on 91 df	655.3 on 91 df	17.49 on 91 df

The graphs below show the dose response curves for the **fresh** and **dry weights**, and the **numbers of plants** for the two experiments. The points plotted are the means of the transformed data at each dose and age combination.

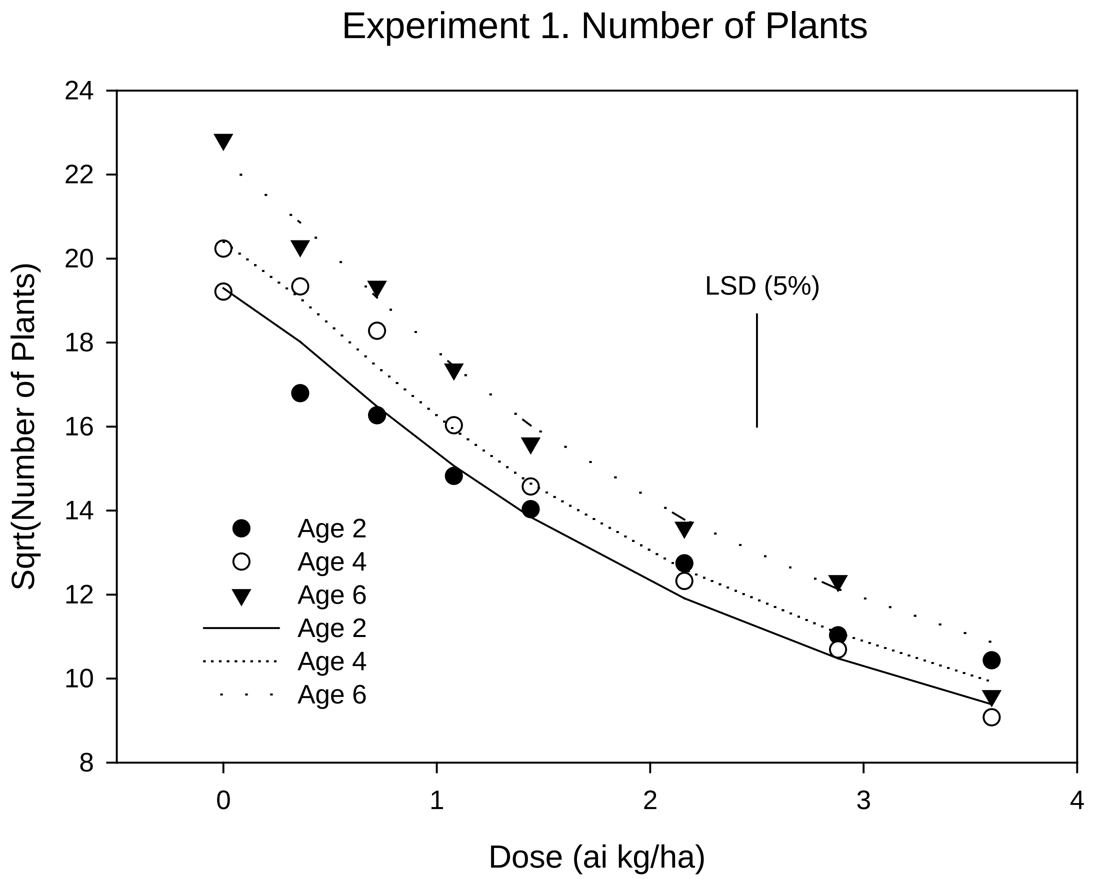
ANOVAs of the transformed variables, taking account of the experimental design and treatment structure, were also undertaken. These results are provided for completeness at the end of the report below each logistic model fit. The analyses show that there was no significant lack-of-fit when considering the replicate observations at each dose by age combination. Significant effects of Age and dose were most usually apparent (see ANOVA tables for p-values) but without a significant interaction between these two factors, as is also indicated by the parallel nature of the majority of the plotted curves below. Note that the LSDs on the graphs are calculated using the residual mean squares from these ANOVAs, having ascertained that there was no significant lack of fit given the replicate observations.

Experiment 1. Fresh Weight



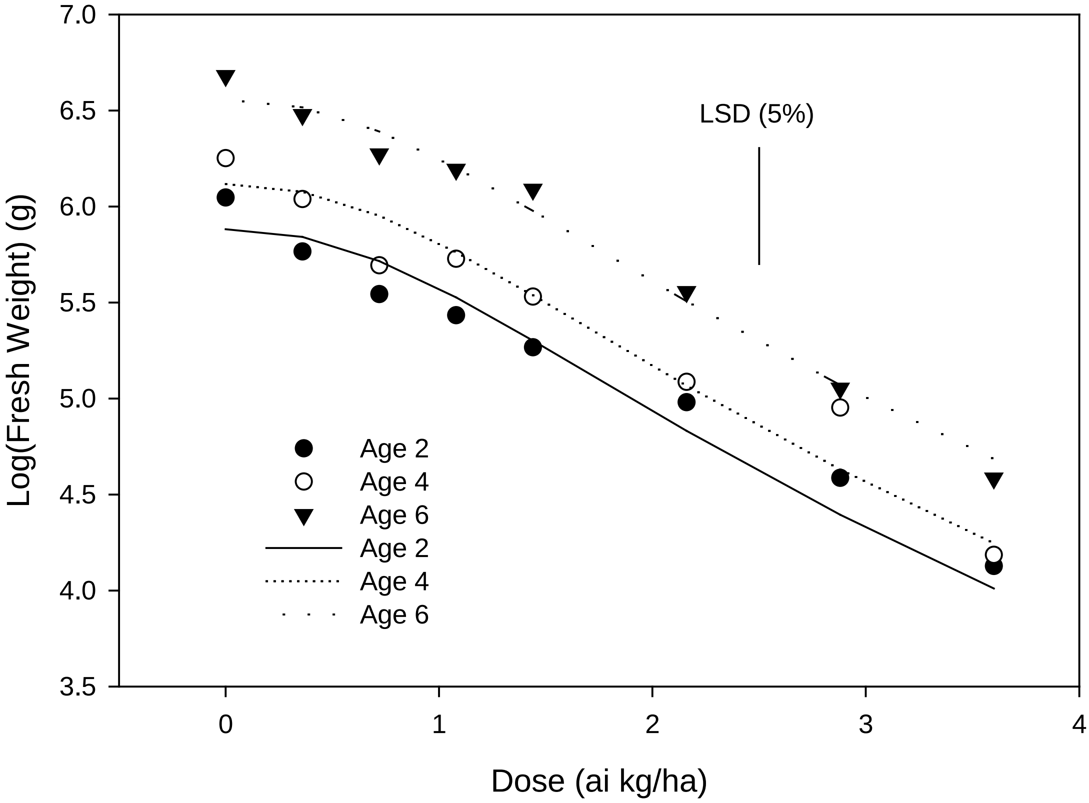


Experiment 1. Dry Weight
5.8
5.6
5.4
5.2
5.0
4.8
4.6
4.4
4.2
4.0
3.8
3.6
Log(Fresh Weight)
LSD (5%)
Age 2
Age 4
Age 6
Age 2
Age 4
Age 6
0
1
2
3
4
Dose (ai kg/ha)

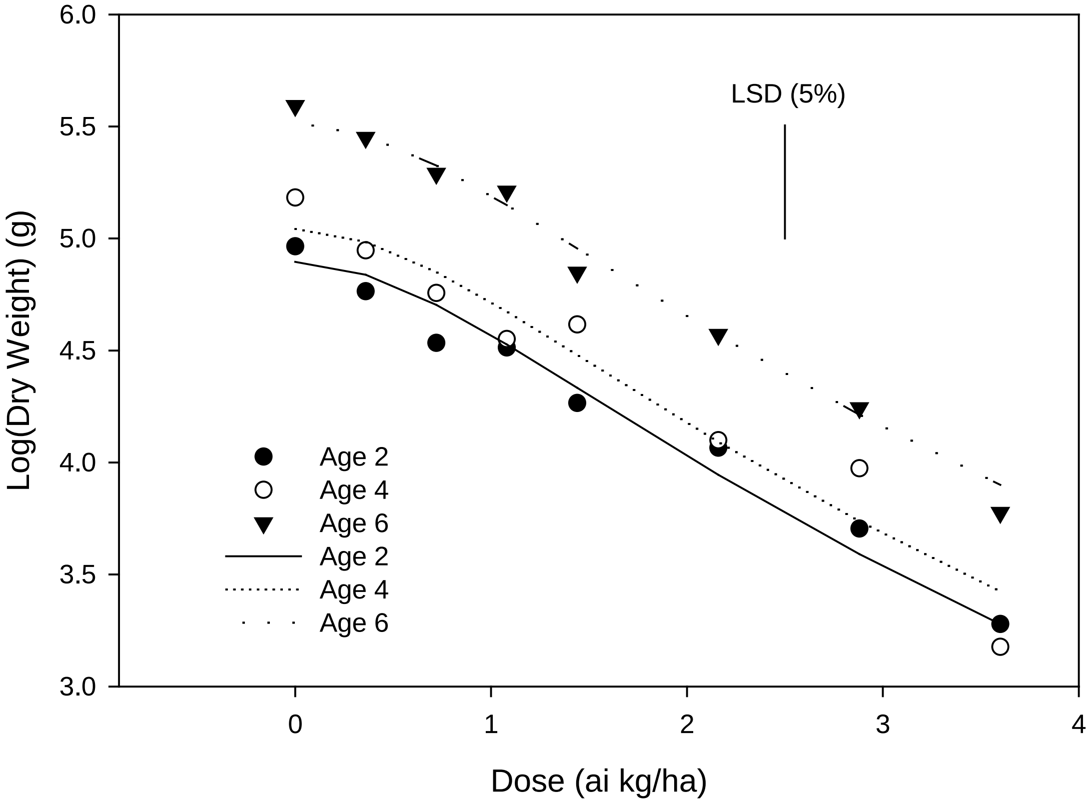


Experiment 1. Number of Plants
24
22
20
18
16
14
12
10
8
Sqrt(Number of Plants)
LSD (5%)
Age 2
Age 4
Age 6
Age 2
Age 4
Age 6
0
1
2
3
4
Dose (ai kg/ha)

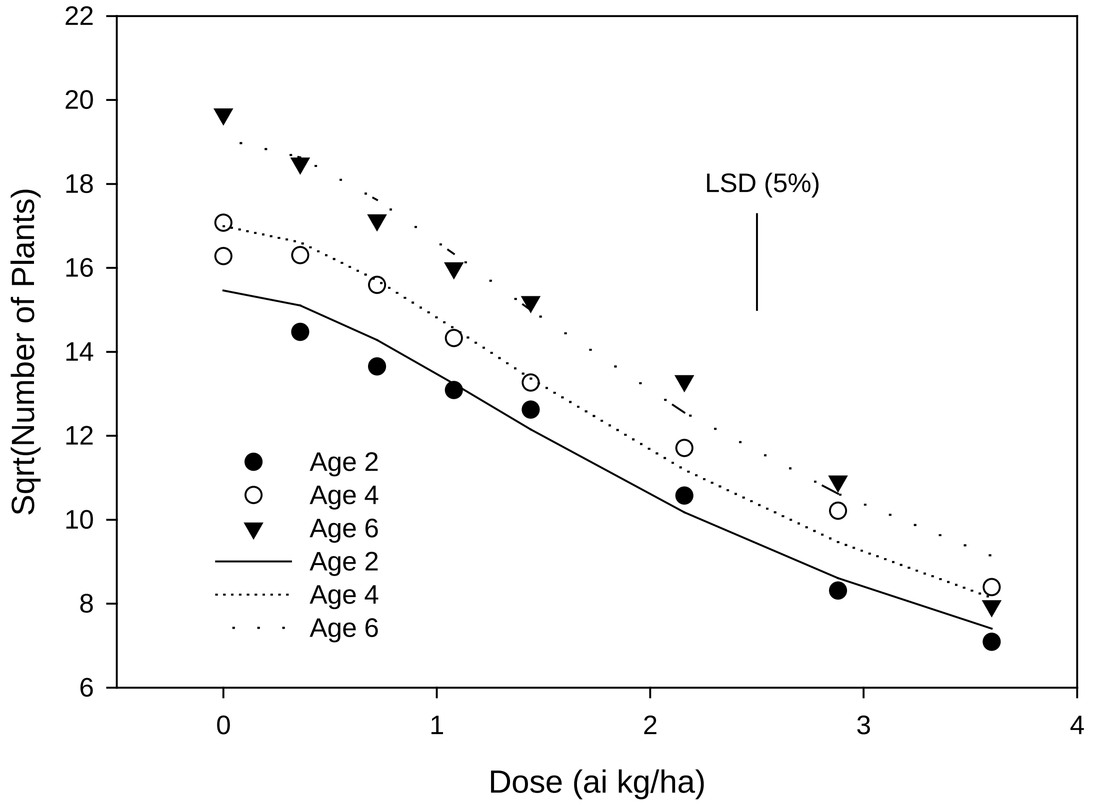
Experiment 2. Fresh Weight



Experiment 2. Dry Weight



Experiment 2. Number of Plants



The effect of age of *O. longistaminata* regrowth and glyphosate application rates in Tanzania.

J. Mbapila and D.E. Johnson

A total of 24 treatments made up of a factorial combination of eight (8) glyphosate rates [litres/ha (a.i kg/ha)]; control (0), 1(0.36), 2 (0.72), 3(1.08), 4(1.44), 6(2.16), 8(2.88) and 10(3.60). The herbicide was applied to 3 stages of *O. longistaminata* regrowth after cutting namely, 2, 4 and 6 weeks old.

The experimental design was a strip-plot design with four replications. The different ages of regrowth were achieved by cutting existing *O. longistaminata* at fortnight intervals and all the herbicide treatments are applied on the same day.

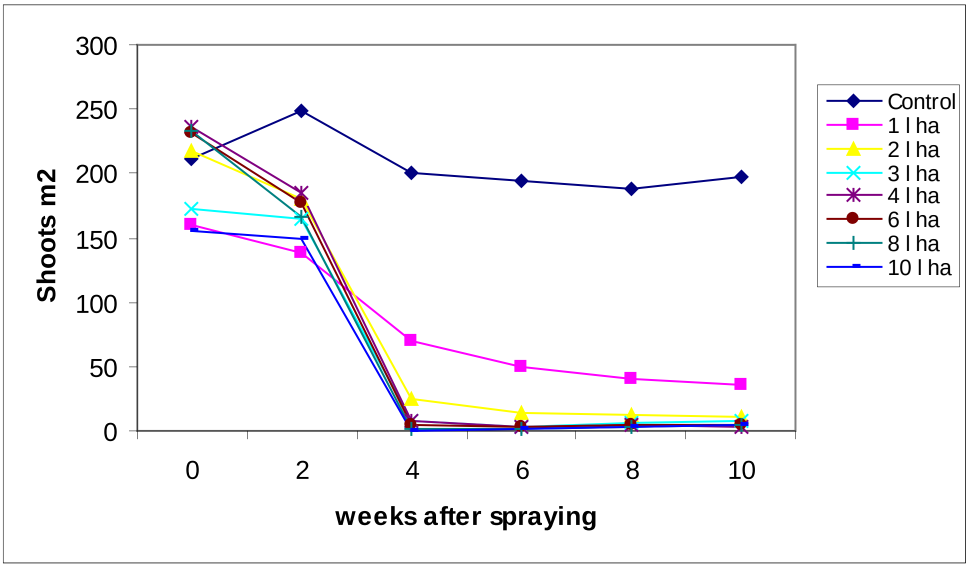


Fig. 1. The effect of glyphosate at 8 rates on *O. longistaminata* at 6 intervals after application, Ifakara, Tanzania, 2001

The shoot numbers varied between 155 and 236 m2 at the initial reading (Fig.1). By the fourth week the herbicide had a clear effect on shoot numbers, with 3 l ha or more reducing shoot numbers by more than 90%. There appeared to be no benefit in improved control by increasing the application rate above 3 l ha. There appeared to be only a small or marginal effect of the age of the regrowth at the time of spraying. At the fourth week there were fewest shoots where the wild rice had been left to grow for 4 weeks before application of the herbicide. It appeared from this study that an application at 3 l per ha to *O. longistaminata* regrowth of 4 weeks old would provide effective control.

The management of wild rices in Africa

Introduction

Wild rices are widespread in Africa and grow in wet areas such as river flood plains, swamps and lowland rice areas. They are close relatives of cultivated rice (*Oryza sativa*), and as weeds they can greatly reduce rice yields. Wild rices are often difficult to control as they are similar in appearance and biology to cultivated rice. Correct identification of the weed and a combination of preventive and control measures can greatly reduce crop losses.

Identification

There are two annual wild rice species, *Oryza barthii* and *O. punctata*, and one perennial species *O. longistaminata.* The annual species very similar in appearance to cultivated rice during the vegetative growth stages, with the clearest difference being in the **ligule** (at the joint of the stem and leaf). In *O. barthii* and *O. punctata* the ligule is much shorter than in *O. sativa*. When the head (or panicle) is formed these species can be identified as the grains are usually awned.

O. longistaminata forms a network of underground rhizomes that enable it to spread, survive the dry season, fire and disturbance. In the vegetative stages the plant also resembles cultivated rice, but the leaves tend to be broader and the plant larger. The **ligule** is long, pointed and often split, and the head (**panicle**) is usually open and the grains have awns. See table below for comparisons.

Characteristics of wild rice species

Species	Ligule length mm	Spikelet length mm	Awn length mm
O. longistaminata	15-45	7-9	40-80
O. barthii	2-6	7-11	90-160
O. punctata	3-10	5-6	10-70

Management

Effective management of wild rice weeds will usually depend on the use of a combination of measures aimed at preventing infestations becoming established and reducing or eliminating existing populations. Because of the long and variable periods of seed dormancy, control measures will usually have to be repeated over a long period to achieve complete control of established populations of wild rice

Prevention

Wild rices infest new areas as seeds that are usually carried in contaminated rice seed, in flood or irrigation water or in soil carried by machinery. Care should be taken to ensure that wild rice seeds are not introduced in this way. Use uncontaminated rice seed and ensure that machinery coming from infested areas is properly cleaned and that irrigation canals are kept free of infestations. Wild rice seeds have pronounced and variable dormancy and can remain viable in the soil for many years before germination. Great care should be taken to ensure that seed populations in the soil are not allowed to build-up.

Where infestations are only low levels, to prevent populations building-up, wild rice should be removed by hand. This should be done as soon as the infestations are identified and before grains are formed. It is important that wild rice populations are not be allowed to build-up in the fallow periods, during which large quantities of seed can be produced.

Control

- Cultural measures

O. barthii and *O. punctata*
Transplanting rather than direct seeding of rice usually greatly reduces the wild rice populations and crop losses. It is important to ensure that the nursery beds are free of wild rice (see "stale-seedbed") and that the rice seedlings are sown into a well prepared field where any existing wild rice plants have been either killed or removed.

A "stale-seedbed" technique is used before the crop is established and where the wild rice seeds in the soil are encouraged to germinate by irrigation or awaiting the first rains. Cultivation or herbicides can be used to kill the wild rice seedlings before the crop is established.

O. longistaminata
Intensified cropping, with either dry season (upland) crops or rice, can greatly reduce populations of *O. longistaminata.* The greatest control can result where rice is alternated with dryland crops such as sweet potato or vegetables, but also double cropping of rice with associated weed control measures can greatly reduce of populations.

Mechanical
Hand weeding is an important control option for annual and perennial wild rices, particularly when populations are at a relatively low level. Early interventions may prevent a rapid build-up of the wild rice populations. Hand weeding is also the most widely used control option, but because of the high labour requirement, where possible, this should be combined with other cultural, mechanical and chemical means. Hand weeding can be aided by sowing or transplanting the crop in rows.

O. barthii and *O. punctata*
Besides hand weeding, mechanical control is limited to seedbed preparation and ensuring that wild rice seedling are not already established by the time the crop is sown. This can usually be best achieved by shallow cultivation after irrigation or the initial rains.

O. longistaminata
Mechanical control is largely limited to destroying the rhizome system and this requires repeated deep cultivation during the dry season to expose and desiccate the rhizomes. Thorough puddling of the soil under flooded conditions can also greatly reduce the populations but does not result in complete control.

Chemical
Because of the similarity with cultivated rice there are no options for selective herbicides at present. The chemical control is best achieved by using glyphosate before the crop is established.

O. barthii and *O. punctata*
Glyphosate can be applied as part of "stale seedbed" technique and after the primary land preparation (ploughing/harrowing). The herbicide should be applied (c. 1.1 kg a.e. ha / 3 l ha Round-up in 150- 200 l water) 10-14 days after the first rains or after irrigation, during which time wild rice seedlings will have emerged and should be at the 2-5 leaf stage. The rice crop can be sown three days after the herbicide application following shallow or no cultivation. This method has the advantage that it also greatly reduce the numbers of other weeds, broad-leaved, grasses and sedges, in the crop.

O. longistaminata
Successful use of glyphosate on well established perennial wild rice depends on the stage of growth. It is important that the vegetation is well developed and growing vigorously to ensure that the herbicide is translocated to the rhizomes. This may be applied after harvest or before the crop, depending on adequate soil moisture. The herbicide can be best applied 4-8 weeks after the vegetation has been burnt or cut and regrowth has grown to 300-600 mm tall. Glyphosate should be applied at 2 - 3 kg a.e. ha (Roundup, 6- 8 l ha). Repeat overall or spot applications may be required to control any regrowth that occurs.

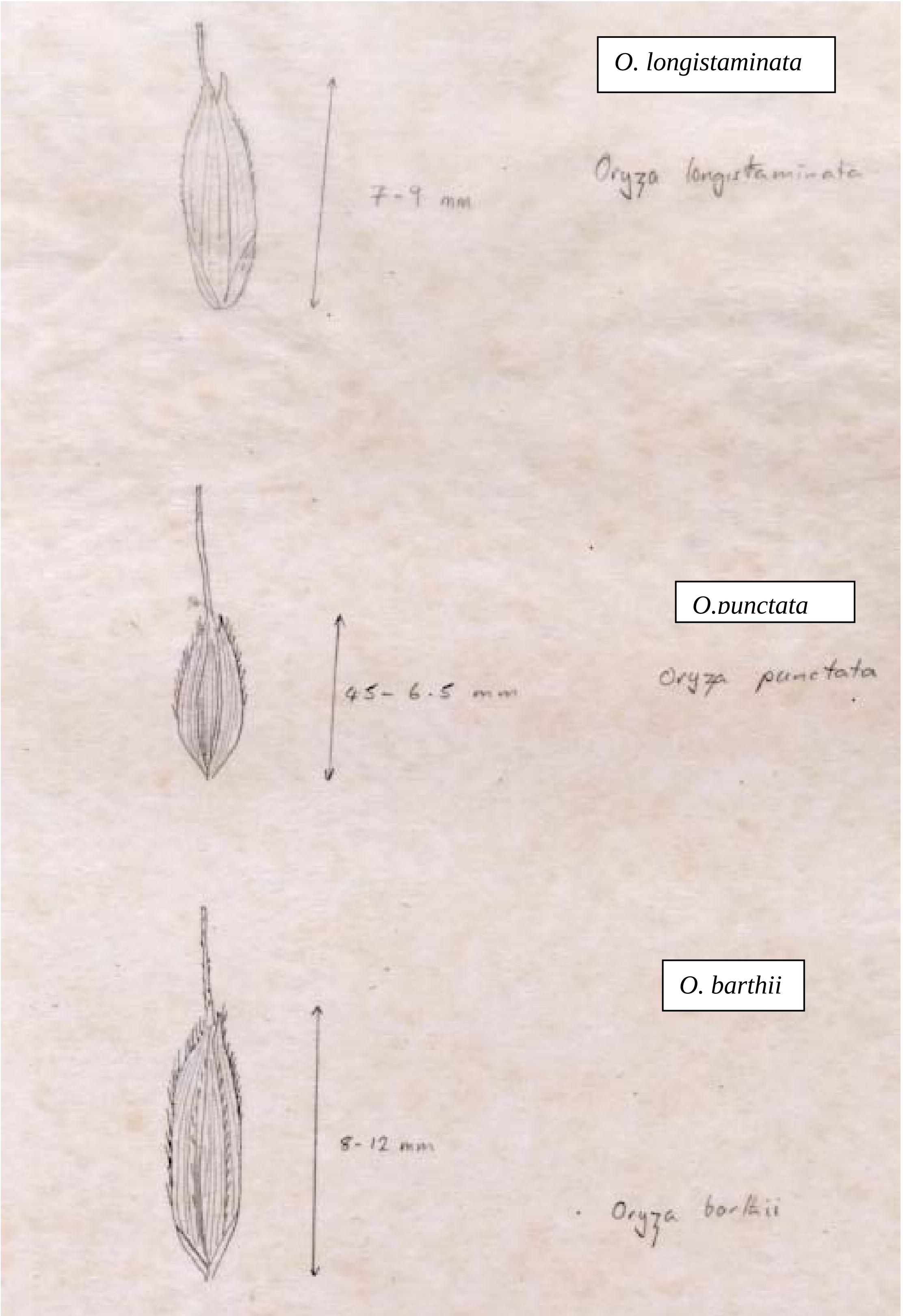
O.punctata

O. longistaminata

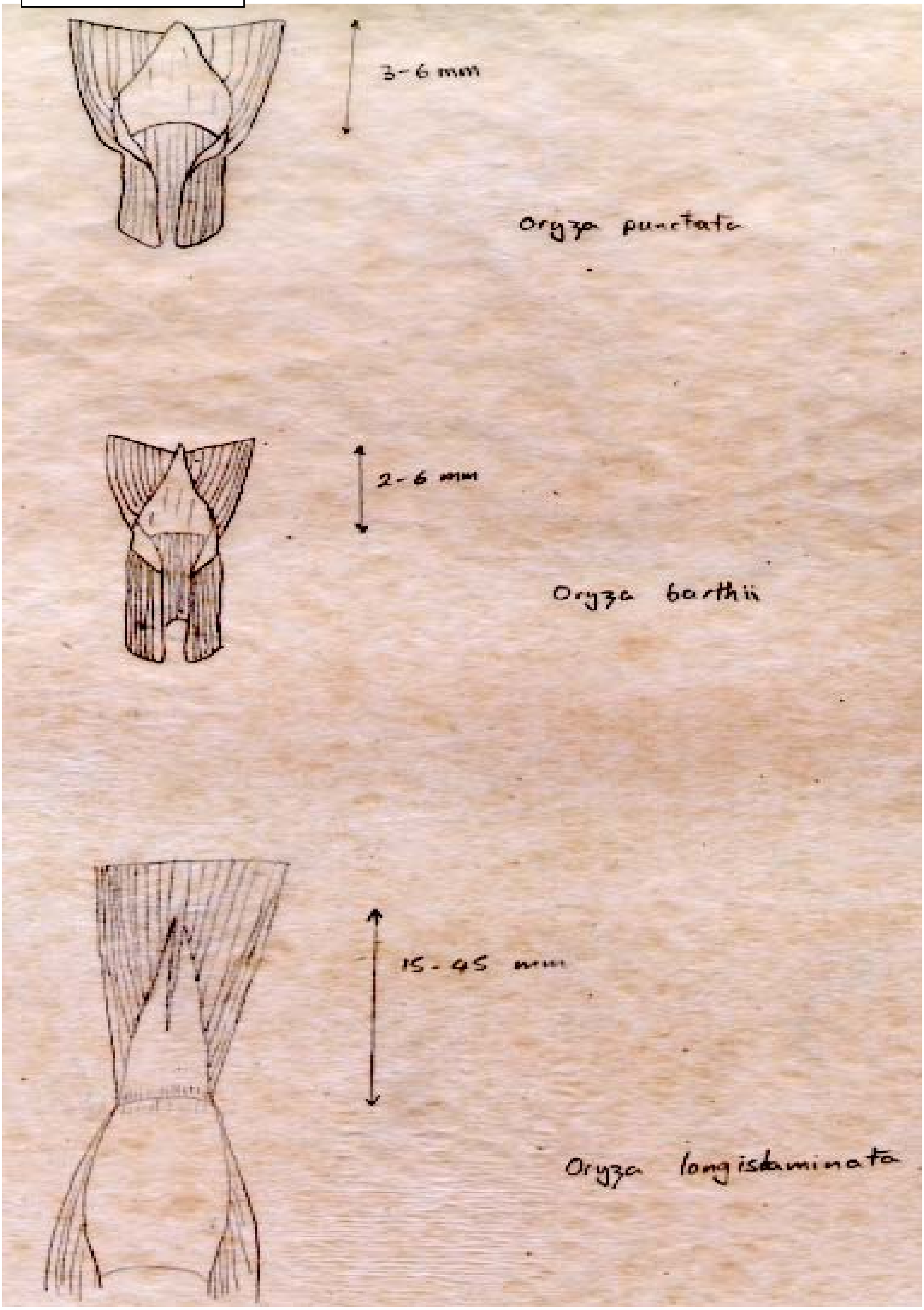
O. barthii

Grains of wild rice

Grains of wild rice



Ligules of wild rice



Appendix 4.

Wild rice Meeting

08 April, 2002
WARDA/ADRAO/Mbé, Côte d'Ivoire

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