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The introduction of animal traction into inland valley regions. 2. Dry season cultivation and the use of herbicides in rice

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SUMMARY

Rice was grown in an inland valley (fadama) region of central Nigeria. Plots were cultivated using oxen either in the dry season or at the beginning of the wet season. Around 25% more time was required for dry season cultivation but this enabled an average saving of 53·5 h/ha during the most critical time of the year at the beginning of the wet season. Total time for all operations during the year was similar (2075 and 2150 h/ha for dry and wet season respectively) of which most was spent on weeding (1388 and 1527 h/ha). Weeding time could be reduced by the application of pre-emergence herbicide to 1042 and 1247 h/ha for dry and wet season cultivation respectively. Grain yields were 4·0, 4·8, 4·2 and 4·6 t dry matter/ha for dry season/no herbicide, dry season/herbicide, wet season/no herbicide, and wet season/herbicide respectively. Similarly, straw yields were 4·8, 7·0, 5·7 and 7·4 t/ha. None of the differences in yield was statistically significant.

INTRODUCTION

Work at the International Livestock Research Institute (ILRI) has shown that the introduction of animal traction into the sub-humid zone of Nigeria can be beneficial, especially for the cultivation of rice in inland valleys or fadamas (Jansen 1993). Experiments comparing animal traction and manual cultivation showed that substantial time savings are made at the most critical period of the year, so that crops can be planted in time (Lawrence *et al.* 1997). However, for many farmers, especially those who share animals and equipment, the pressure of time and shortage of labour at the start of the rainy season can still delay planting. Pilot trials (P. R. Lawrence & J. T. Dijkman, unpublished) showed that it was possible to plough and harrow a large proportion of the fadama area during the dry season using ox-drawn implements, whereas in all but a few places the soil was too hard for manual cultivation until the onset of the rains. Ox-drawn cultivation at this time of the year has several advantages. Time is not a constraint and cultivation can be done more thoroughly. Working conditions are less stressful because it is dry and cool. The exposure of the soil to the winter sunshine kills many of the pests and weeds. Most important of all, the rice crop can be sown as soon as sufficient rain has fallen and the farmers can devote all their time and energy to the cultivation of their upland food crops.

Trials conducted in 1991 also showed that weed infestation was heavier when using animal traction as compared to manual cultivation (Lawrence *et al.* 1997). Whereas this did not significantly affect the yields on weeded plots, weeding was by far the most time consuming operation and on unweeded plots rice yields were nearly halved, emphasising the necessity of this operation. One of the proposed ways to reduce weeding time is through the use of herbicides.

This paper describes the results of an experiment, carried out in 1992, set up to enable comparison of the inputs and yields associated with rice cultivation when using dry and wet season cultivation with or without the use of pre-emergence herbicides (PEH).

MATERIALS AND METHODS

Four wet season cultivated and four dry season cultivated fadama plots (30 × 10 m), located on land rented from local farmers, were used in the experi-

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ments. All experimental observations were made at Kufana village, 80 km south east of Kaduna, central Nigeria in 1992. As in previously reported work (Lawrence *et al.* 1997), crops were raised under the same conditions as those of local farmers except where experimental procedures dictated otherwise. To ensure that the growing crops were tended to the same extent as those of the other farmers in the valley, all grain not required for scientific purposes was divided amongst the people who regularly worked on the experimental fields at harvest.

One half of each fadama plot was allocated to either the 'herbicide' (H) or the 'no herbicide' (NH) treatment, resulting in a split-plot design for the experiment. Fifteen days prior to cultivation, the H subplots were treated with glyphosate (Round-up) pre-emergence herbicide at a rate of 10 litres/ha, using a hand-operated knapsack sprayer (CP15 by Cooper Pegler & Co Ltd, Sussex, UK)

Cultivation of the wet season plots consisted of slashing (cutting any large weeds with a machete and leaving them to wilt before ploughing), ploughing once and harrowing once. The dry season plots were slashed, ploughed once and harrowed twice, once during the dry season and once just before sowing. Ploughing was carried out using an Emcot plough. Harrowing was done using a disc harrow (all implements by John Holt Company, Zaria, Nigeria).

Measurements taken during cultivation were: Total time (h), Elapsed working time (EWT; h), Work done (J) and Distance travelled (m) for ploughing and harrowing. Measurements of EWT, work done and distance travelled were made using an ergometer (Lawrence & Pearson 1985). Distance averaged draught force (DADF) was calculated by dividing the work done by the distance walked. Ox cultivation was carried out by two men and a pair of oxen.

Fadamas were sowed at the rate of 1·75 kg per 15 × 10 m plot (110 kg/ha), using a 48 h pre-germinated local KUF II rice variety, broadcasting the seed as evenly as possible.

NPK fertilizer (27:13:13) at a rate of 8·5 kg per 15 × 10 m plot (550 kg/ha) was applied at planting. In addition, 10 weeks after planting 1·75 kg of urea per 15 × 10 m plot (110 kg/ha) was applied to the rice. Weeding on all plots was done manually 4 and 8 weeks after sowing. Measurements taken during spraying, sowing, fertilizing and weeding were as follows: Total man hours available (h), EWT (h) and Total wet weight (kg) of weeds from each subplot at both weedings, i.e. a total of 32 samples. Measurements were made as soon as possible after the weeds had been pulled out and the roots cleaned. Subsamples of 1·0 kg were dried until their weight was constant to determine the dry matter content.

As in previous experiments, to measure the EWT during manual cultivation all operations were done by a group of four workers. A fifth person kept a record of the number of people in the group working at the start of each minute. Individual workers could thus work at their own speed and rest when they needed to. The total man hours worked by the group during any working session was later calculated from the record kept.

During the rice harvest, each subplot was divided into four 0·5 × 3 m plots, leaving 3 m borders around each harvested area. Plots were completely stripped of vegetation which was divided into grain (rice), crop residues (straw) and weeds. Total wet weights of the individual categories were recorded. Samples of 1·0 kg were taken to determine the dry matter content of each of the categories. Harvesting of the crop was carried out over 2 days. In previously reported work, no human time inputs were recorded during the harvesting as the system of selective cutting of weeds bore little resemblance to the harvesting methods normally used by farmers (Lawrence *et al.* 1997). During this experiment, however, weeds were separated from the rice crop after harvest, which allowed human time inputs for harvesting to be recorded. Experimental results were analysed using an analysis of variance on GENSTAT 5 (Lawes Agricultural Trust 1993).

RESULTS

Cultivation

Total human time inputs and EWT during dry season ploughing were significantly higher ($P < 0.001$) than the total human time inputs and EWT during wet season ploughing of the fadama fields (Tables 1 and 2). EWT or actual time spent working of the total human time inputs during ploughing was 87·3 and 85·2% during dry and wet season cultivation respectively. Total human time inputs and EWT for dry season harrowing, which consisted of harrowing once immediately after ploughing and harrowing once at the beginning of the rains prior to planting, were also significantly higher ($P < 0.001$) than the total human time inputs and EWT during wet season harrowing (Tables 1 and 2). EWT averaged 89·3 and 81·4% of the total human time inputs during dry and wet season harrowing respectively.

Oxen

Tables 3 and 4 show the mean ox inputs during wet and dry season cultivation. Work done, distance walked, total time and EWT were all significantly higher ($P < 0.001$) during dry season ploughing. No significant differences were observed in power output, DADF and speed during dry and wet season ploughing of fadama fields. Total work done, distance walked, time spent and EWT during the two harrowing periods for the dry season cultivated plots were all significantly higher ($P < 0.001$) than the

Table 1. *Mean values for total human time inputs (h/ha) for wet and dry season cultivated fadama rice plots in Kufana village, central Nigeria, 1992 (n = 4, 6 D.F.)*

	Dry season cultivation		Wet season cultivation		
Operation	NH	H	NH	H	S.E.
Ploughing	67·8		53·5		3·0
Harrowing*	56·0		33·4		0·8
Slash/spray†/fertilizer	22·2	32·0	36·0	32·0	0·0
Planting	47·8	40·0	44·4	47·5	6·9
First weeding	635·3	519·0	819·5	610·8	119·2
Second weeding	752·8	523·0	707·5	636·0	74·3
Total weeding	1388·1	1042·0	1527·0	1246·8	154·7
Harvesting	318·3	300·0	306·5	280·3	49·7
Threshing	175·5	206·8	148·8	151·8	29·6
Total	2075·7	1744·6	2149·6	1845·3	81·6

* Harrowing for the dry season cultivation treatment consisted of harrowing once in the dry season immediately after ploughing and harrowing once at the beginning of the rains prior to planting.
† Spraying was only carried out on the H plots.
NH, no herbicide; H, herbicide.

Table 2. *Mean values for elapsed working time (EWT) inputs (h/ha) for wet and dry season cultivated fadama rice plots in Kufana village, central Nigeria, 1992 (n = 4, 6 D.F.)*

	Dry season cultivation		Wet season cultivation		
Operation	NH	H	NH	H	S.E.
Ploughing	59·2		45·6		2·2
Harrowing*	51·0		27·2		2·5
Slash/spray†/fertilizer	22·0	32·0	36·0	32·0	0·0
Planting	47·7	40·0	44·5	47·7	7·0
First weeding	602·8	467·5	765·3	582·8	119·8
Second weeding	655·3	475·0	638·0	519·8	72·1
Total weeding	1258·1	942·5	1403·3	1102·6	136·9
Harvesting	292·0	276·5	279·3	264·5	39·4
Threshing	175·5	206·8	148·8	151·8	29·6
Total	1905·5	1607·0	1984·7	1671·4	70·0

* Harrowing for the dry season cultivation treatment consisted of harrowing once in the dry season immediately after ploughing and harrowing once at the beginning of the rains prior to planting.
† Spraying was only carried out on the H plots.
NH, no herbicide; H, herbicide.

corresponding values for the wet season cultivated plots. Power output and DADF were consistently higher for harrowing on the wet season cultivated plots, although no significant differences were observed.

Slashing, spraying, planting and fertilizing

Total combined human time inputs and EWT for slashing, spraying and fertilizing were significantly lower ($P < 0{\cdot}001$) for dry season cultivated NH plots. No significant differences were observed for the total combined human time inputs and EWT for these operations between dry and wet season cultivated H plots. Wet season cultivated NH plots, however, required significantly ($P < 0{\cdot}001$) more combined total human time inputs and EWT for slashing, spraying and fertilizing than all other treatments (Tables 1 and 2).

No significant differences were found between the total human time inputs and EWT required for planting on the four different treatments (Tables 1 and 2).

Weeding

The use of pre-emergence herbicide significantly ($P < 0{\cdot}01$) reduced total human time inputs and EWT

Table 3. *Mean values for ox inputs during dry and wet season ploughing for fadama rice plots in Kufana village, central Nigeria, 1992 (n = 4, 6 D.F.)*

Work done (MJ/ha)	60·0	46·8
Distance walked (km/ha)	55·7	38·6
Total time (h/team/ha)	33·9	26·8
EWT (h/team/ha)	29·6	22·8
Power (W)	564·0	571·0
DADF (N)	1083·0	1212·0
Speed (m/s)	0·53	0·47

EWT, elapsed working time; DADF, distance averaged draught force.

Table 4. *Mean values for ox inputs during dry and wet season harrowing for fadama rice plots in Kufana village, central Nigeria, 1992 (n = 4, 6 D.F.)*

	Dry season*	Wet season	S.E.
Work done (MJ/ha)	33·9	24·4	2·3
Distance walked (km/ha)	39·9	20·0	2·2
Total time (h/team/ha)	28·0	16·7	0·4
EWT (h/team/ha)	25·5	13·6	1·2
Power (W)	383·0	500·2	74·5
DADF (N)	851·5	1245·5	174·7
Speed (m/s)	0·44	0·43	0·03

* Harrowing for the dry season cultivation treatment consisted of harrowing once in the dry season immediately after ploughing and harrowing once at the beginning of the rains prior to planting.
EWT, elapsed working time; DADF, distance averaged draught force.

during the first and second weeding for dry and wet season cultivated fields (Tables 1 and 2). Whereas no significant interactions were observed between the use of herbicide and season of cultivation when the results of the first and second weeding were analysed separately, total combined human time inputs and EWT showed that pre-emergence herbicide were significantly ($P < 0{\cdot}05$) more effective when used in combination with dry season cultivation (Tables 1 and 2).

Table 5. *Mean values for grain and straw dry matter yields (t/ha) on dry and wet season cultivated fadama rice plots in Kufana village, central Nigeria, 1992 (n = 4)*

Treatment	Grain	
Dry season		
No herbicide	4·00	4·80
Herbicide	4·78	7·00
Wet season		
No herbicide	4·20	5·65
Herbicide	4·62	7·40
S.D. (6 D.F.)	0·51	1·11

Table 6. *Mean values for weed dry matter yields (t/ha) on dry and wet season cultivated fadama rice plots in Kufana village, central Nigeria, 1991 (n = 4, 6 D.F.)*

	Dry season cultivation		Wet season cultivation		
	NH	H	NH	H	S.E.
First weeding	1·44	0·84	1·54	0·58	0·35
Second weeding	2·18	1·60	1·99	1·17	0·41
Harvest weeds	1·90	0·54	1·36	0·40	0·53
Total weeds	5·52	2·98	4·89	2·15	0·87

NH, no herbicide; H, herbicide.

total combined human time inputs and EWT for all operations when used in combination with wet season cultivation (Tables 1 and 2).

Yields

The use of pre-emergence herbicide or season of cultivation had no significant effect on grain or straw yield (Table 5). The use of pre-emergence herbicide, however, did significantly ($P < 0{\cdot}05$) reduce the weed dry matter yields during the first and second weeding during both dry and wet season cultivation. In addition, harvest weeds were also significantly ($P < 0{\cdot}01$) reduced through the use of herbicide (Table 6).

DISCUSSION

Rice yields for all treatments were similar to those obtained in previous years. In addition, time and ox inputs required during wet season cultivation were comparable to observations made during previous experimental work (Lawrence *et al.* 1997). In contrast, work inputs and time taken for cultivation in the dry season were *c.* 25–30% higher. The extra work, however, can be carried out at leisure over a period of 5 months during the coolest part of the year. Furthermore, oxen generally are in a better condition at the beginning of the dry season compared to the start of the wet season, when they are normally called upon to work (Pearson & Dijkman 1994). It should be noted that dry season cultivation should only be done in places that remain dry enough to inhibit weed growth. Areas near stream beds, for example, often retain some moisture and can become overgrown before planting time.

The use of pre-emergence herbicide significantly reduced weed burden and time spent weeding on both dry and wet season cultivated plots, but no significant differences were found due to season of cultivation. The costs associated with the use of herbicide, however, were about as much, using prevailing costs and prices, as the labour saved on weeding. Although grain and straw yields were consistently higher, the use of pre-emergence herbicide had no significant influence on yields on either the dry or wet season cultivated fields.

The current experiments clearly indicate that the introduction of dry season ox cultivation would help ensure timeliness of planting for fadama rice cultivation without adversely affecting yields. In addition, although no significant economic or yield advantages were observed, the use of pre-emergence herbicide in fadama rice cultivation results in significant labour savings. Labour has long been recognised as the major limiting resource within Nigerian farming systems especially during operations which require a high degree of timeliness such as weeding (Phillip & Ogunbile 1993). Herbicide use could, hence, have considerable benefits.

In some farming systems it has been shown that weeds from the field are a useful source of animal feed (Lamers *et al* 1996). If this were so in the present case then the use of herbicides would be contra-indicated. However, most of the weeds in the fadama fields proved to be unpalatable and were produced at a time of year when grazing was abundant. In fact, herbicide increased the amount of palatable feed available after harvest because of the increased production of straw (Table 5).

Growing population and a shortage of cultivable land has led to the realisation that the utilization of inland valleys will have to be optimized (ILCA 1991; Jansen & Lawrence 1991). Dry season cultivation could be part of this strategy. One of the main drawbacks to dry season fadama cultivation, however, is its potential conflict with transhumance livestock production as it would deprive itinerant Fulani herdsmen of winter grazing for their cattle. Any further promotion of this type of technology would, therefore, have to be preceded by appropriate systems impact studies and be accompanied by additional developments to ensure that the advances benefit all the people who depend on fadama resources for their livelihoods.

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