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The introduction of animal traction into inland valley regions. 3. Different cultivation techniques for maize

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SUMMARY

Maize was grown in the upland areas surrounding an inland valley in central Nigeria in a randomized block experiment using six cultivation techniques (manual cultivation with a hand hoe (MC); ploughing in both directions to throw up a ridge (DPL); single ploughing with the seed placed on the ridge (SPL); ridging with a wooden, single tine, locally made 'bush' plough (BPL); single ploughing with the seed placed in the furrow (FPL) and ridging with a conventional ridger (RID) with or without pre-emergence herbicide (PEH) with two replicates. Initial cultivation times ranged from 29 to 70 h/ha (BPL < RID < SPL < FPL < DPL < MC). Total weeding time ranged from 220 to 512 h/ha (MC < DPL < RID < FPL < BPL < SPL) with PEH and from 431 to 763 h/ha (MC < SPL < DPL < RID < FPL < BPL) without PEH. Ox cultivation techniques were associated with higher weeding times and larger weed burdens. Total times for all field operations were 568–758 h/ha (MC < FPL < DPL < BPL < SPL < RID) with PEH and 791–870 h/ha (BPL < MC < SPL < DPL < RID < FPL) without PEH. Thus, although ox cultivation saved time at the most critical time of year (cultivation and planting), it did not save time overall.

Amongst the ox cultivation techniques, work inputs were 6·3–34·1 MJ/ha (BPL < FPL < SPL < RID < DPL) and draught forces 387–1377N (BPL < DPL < FPL < SPL < RID).

Yields of maize cobs were 2·55–4·0 t/ha (SPL < FPL < MC < RID < DPL < BPL) with PEH and 1·65–3·55 (RID < BPL < FPL < DPL < MC < SPL) without PEH. Except for SPL, PEH was associated with increased yield especially when used with ox cultivation.

As regards crop yield, time inputs and work input, there was no advantage to be gained from using a separate (and expensive) ridger for maize compared with a locally made plough or the plough also used for the main cash crop (rice).

At 1992 prices, the cost of PEH was about the same per ha as the price of labour saved on weeding, but additional benefits associated with PEH use were the avoidance of mid-season labour bottlenecks and an overall increase in crop yield.

INTRODUCTION

In the sub-humid zone of Nigeria, subsistence food crops, particularly maize and sorghum, are traditionally grown on ridges on upland soils and cultivation is carried out using a hand hoe. Previous studies have shown that the time taken for cultivation can be reduced by *c.* 75% using oxen pulling a ridger. During the same studies, however, weed burden and time spent weeding were increased on ox-cultivated plots. It was also established that, although cultivation was the most arduous task, hand seeding and weeding were the most time consuming. It was therefore necessary to try to devise alternative cultivation techniques to overcome these problems before the use of animal traction in the cultivation of upland maize could be recommended with any confidence (Lawrence *et al.* 1997). In addition, the initial cost of an ox-drawn ridger, at *c.* $US 120 (1992 prices), is beyond the reach of many farmers but pilot studies using a minimum tillage system, similar to that used in many other parts of the world, in which the furrows are made by an ox-drawn plough made of wood and a single metal tine and seeds are placed at regular intervals using a seeding tube, showed promising results (J. T. Dijkman & P. R. Lawrence, unpublished). The cost of the plough and seeding tube is

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only *c.* $US 20 (1992 prices) and the saving in time compared with manual cultivation is large. Consequently, an experiment, carried out in 1992, was set up to compare the inputs and yields given by this proposed minimum tillage method with four other ox-cultivation methods using the Emcot plough and ridger, and manual cultivation. Moreover, as the application of herbicide has been proposed to reduce weed burden (Olukosi & Ogunbile 1994), the various cultivation methods were also tested with and without the use of pre-emergence herbicide (PEH).

MATERIALS AND METHODS

A total of 24 upland plots (10 × 10 m), located on land rented from local farmers, was used in the experiment. 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 with the same degree of care as those of the other farmers in the valley, all grain not needed for scientific purposes was divided amongst the people who regularly worked on the experimental fields.

Six different tillage methods were used. These were: Manual cultivation with a hand hoe (MC), Double ploughing, i.e. ploughing in both directions to throw up a ridge (DPL), Single ploughing with the seed placed on the ridge (SPL), Ploughing/ridging with a single tine 'bush' plough (BPL), Single ploughing with the seed placed in the furrow (FPL) and Ridging with a conventional ridger (RID). The furrow contours produced by these different methods and the seed placement is illustrated in Fig. 1.

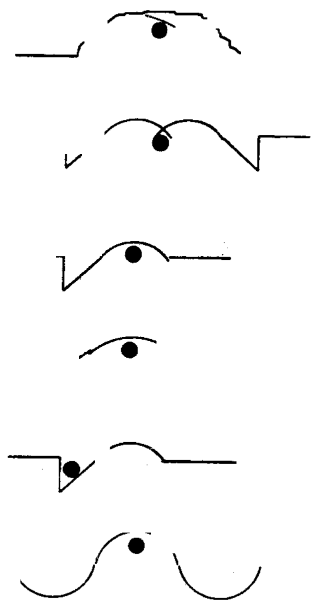

Fig. 1. Furrow contours produced by the six different cultivation methods used and seed (●) placement.

Measurements taken during ox cultivation were: Total time (h), Elapsed working time (EWT; h), Work done (J) and Distance travelled (m) for ploughing and ridging. As in previously reported work, 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.

Measurements taken during manual cultivation were: Total man hours available (h) and EWT (h). 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 records kept.

Maize seeds (TZB) were sown 25 cm apart, three at a time. After germination, maize seedlings were thinned to one per hole and transplanted to any place within the plot where seeds had failed to germinate. Immediately after sowing, two of the four plots of each separate tillage method were sprayed using Gesaprim 500fw PEH at a rate of 5 l/ha, using a hand-operated knapsack sprayer (CP15 by Cooper Pegler & Co Ltd, Sussex, UK). Experimental fields were allocated to a particular treatment using a completely randomized block design.

NPK fertilizer (27:13:13) was applied at planting at a rate of 4·0 kg per 10 × 10 m plot (400 kg/ha). In addition, the maize plots received a top-dressing of 1 kg of urea (100 kg/ha), 8 weeks after planting. Manual weeding was carried out 4 and 8 weeks after planting on all plots.

During the harvest, a 1 m strip was left around each 10 × 10 m plot and the remainder divided into four 8 × 2 m strips running parallel with the ridges. Plots were completely cleared of vegetation which was thereafter divided into cobs (maize), crop residues and weeds. Total wet weight of the individual categories were recorded. Samples of 1·0 kg were taken to determine the dry matter content of each of the categories.

Measurements taken during planting, spraying, fertilizing and weeding were as follows: Total man hours available (h), EWT (h) and Total dry weight (kg) of weeds from each subplot at both weedings, i.e. a total of 48 samples. Wet weight yields were measured as soon as possible after the weeds had been pulled out and the roots cleaned. Subsamples of 1·0 kg were

Table 2. *Mean values for elapsed working time (h/ha) using different cultivation techniques on upland maize plots in Kufana village, central Nigeria, 1992* (*n* = 2, *12* D.F.)

Operation	BPL		DPL		FPL		RID		SPL		MC		
	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	S.E.
Cultivation*	15·8		40·1		27·6		24·6		24·2		66·2		3·7
Spray/fertilizing	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	0·0
Planting	54·2	45·0	70·8	86·7	64·2	62·5	65·0	70·0	88·3	94·2	68·3	78·3	9·2
First weeding	225·8	252·5	263·3	175·0	214·2	158·3	269·2	229·2	169·2	204·2	205·0	106·7	68·9
Second weeding	276·7	162·5	250·0	153·3	325·0	140·8	227·5	100·0	230·8	165·8	179·2	81·7	70·6
Harvesting	36·5	35·2	31·3	41·7	40·4	26·0	41·7	53·4	62·5	39·1	41·7	46·9	10·5
Husking	147·1	197·9	122·4	183·6	164·1	174·5	173·2	240·9	191·4	183·6	184·9	148·4	43·7
Total time	791·1	748·9	812·9	720·4	870·5	629·7	836·2	758·1	801·4	751·1	780·3	568·2	129·5

*n = 4, 18 D.F.
BPL, bush plough; DPL, double plough; FPL, single plough, seed in furrow; RID, ridger; SPL, single plough, seed on ridge; MC, manual; NH, no herbicide; H, herbicide.

Table 1. *Mean values for total human time inputs (h/ha) using different cultivation techniques on upland maize plots in Kufana village, central Nigeria, 1992* (*n* = 2, *12* D.F.)

Operation	BPL		DPL		FPL		RID		SPL		MC		
	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	S.E.
Cultivation*	29·0		57·3		38·0		34·3		34·6		69·6		4·2
Spray/fertilizing	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	35·0	40·0	0·0
Planting	60·0	51·7	75·0	91·7	69·1	67·5	70·0	73·4	93·3	98·3	70·0	80·0	8·7
First weeding	293·3	260·0	280·0	185·0	240·8	204·8	276·7	260·0	221·7	307·5	213·3	113·3	85·3
Second weeding	469·2	201·7	286·7	193·3	456·7	211·7	296·7	127·5	260·0	204·2	217·5	106·7	67·9
Harvesting	36·5	35·2	31·3	41·7	40·4	26·0	41·7	53·4	62·5	39·1	41·7	46·9	10·5
Husking	147·1	197·9	122·4	183·6	164·1	174·5	173·2	240·9	191·4	183·6	184·9	148·4	43·7
Total time	1070·1	815·5	887·7	792·6	1044·1	762·5	927·6	829·5	898·5	907·3	832·0	604·9	121·2

*n = 4, 18 D.F.
BPL, bush plough; DPL, double plough; FPL, single plough, seed in furrow; RID, ridger; SPL, single plough, seed on ridge; MC, manual; NH, no herbicide; H, herbicide.

dried until their weight was constant to determine the dry matter content.

Experimental results were analysed using an analysis of variance on GENSTAT 5 (Lawes Agricultural Trust 1993).

RESULTS

Cultivation

Total human time inputs and EWT for cultivation were significantly higher ($P < 0{\cdot}001$) during DPL and MC in comparison to all other cultivation methods tested. The total human time inputs and EWT for MC, however, were also significantly higher ($P < 0{\cdot}05$) than during DPL (Tables 1 and 2).

Oxen

Table 3 shows the mean ox inputs during upland maize cultivation using the different tillage techniques tested. Work done and DADF were significantly lower and walking speed significantly higher ($P < 0{\cdot}001$) during the BPL cultivation technique compared to all other tillage methods tested. In addition, the distance walked during the BPL tillage method was significantly lower ($P < 0{\cdot}05$) than the distance walked during the FPL, SPL and RID cultivation activities.

Work done, distance walked, total human time inputs and EWT were significantly higher ($P < 0{\cdot}001$) using the DPL technique. Work done during the RID cultivation method was significantly higher ($P < 0{\cdot}05$) than during both the FPL and SPL tillage technique. There was also significant difference ($P < 0{\cdot}001$) between the DADF required and power output using the RID cultivation technique and FPL, DPL and BPL and SPL ($P < 0{\cdot}05$).

Planting, spraying and fertilizing

The BPL cultivation technique, which utilizes a seeding tube for planting, significantly reduced ($P < 0{\cdot}001$) the total human time inputs and EWT for planting in comparison to all other tillage methods. Conversely, the SPL cultivation technique caused a significant increase ($P < 0{\cdot}01$) in total human time inputs and EWT for planting compared to all other cultivation methods tested (Tables 1 and 2). Time needed for spraying and fertilizing were identical for all tested cultivation methods (Tables 1 and 2).

Weeding

No significant differences were found between total human time inputs and EWT during the first weeding due to tillage technique or the application of PEH (Tables 1 and 2). During the second weeding period, however, the use of PEH significantly reduced ($P < 0{\cdot}001$) the total human time inputs and EWT for all cultivation techniques with the exception of SPL. In addition, the BPL and FPL tillage techniques required significantly higher ($P < 0{\cdot}05$) total human time inputs and EWT during the second weeding in comparison to the other cultivation methods on trial (Tables 1 and 2).

Harvesting, husking and total operational time inputs

The use of PEH or type of tillage technique had no significant influence on the total human time inputs and EWT required for harvesting and husking (Tables 1 and 2). Total operational time inputs and EWT, however, were significantly reduced ($P < 0{\cdot}01$) through the application of PEH in all cultivation methods tested, with the exception of the SPL tillage technique (Tables 1 and 2).

Yields

Whereas the use of pre-emergence herbicide significantly reduced ($P < 0{\cdot}001$) cob yield for the SPL cultivation method, yields on plots using the other tillage methods tested were significantly improved ($P < 0{\cdot}001$) through the application of PEH. Moreover, the use of PEH caused a significantly higher increase ($P < 0{\cdot}001$) in yield when used in combination with the DPL, BPL, FPL and RID cultivation techniques compared to the use of MC (Table 4).

Table 3. *Mean values for ox inputs during upland maize cultivation in Kufana village, central Nigeria, 1992* (*n* = 4, 15 D.F.)

	BPL	DPL	FPL	RID	SPL	S.E.
Work done (MJ/ha)	6·3	34·1	24·7	27·3	24·8	1·0
Distance walked (km/ha)	16·1	29·9	21·2	19·8	19·8	1·2
Total time (h/team/ha)	14·5	28·7	19·0	17·2	17·3	2·3
EWT (h/team/ha)	7·9	20·5	13·8	12·3	12·1	5·7
Power (W)	218·0	475·0	497·3	618·5	571·5	22·8
DADF (N)	387·0	1137·3	1169·8	1376·8	1255·8	41·7
Speed (m/s)	0·56	0·42	0·43	0·45	0·46	0·02

BPL, bush plough; DPL, double plough; FPL, single plough, seed in furrow; RID, ridger; SPL, single plough, seed on ridge
EWT, elapsed working time; DADF, distance averaged draught force.

Table 4. *Mean values for cobs and straw dry matter yields (t/ha) for upland maize cultivation in Kufana village, central Nigeria, 1992 (n = 2)*

	Cobs	Straw
BPL		
No herbicide	2·15	2·95
Herbicide	4·00	4·90
DPL		
No herbicide	2·35	4·05
Herbicide	3·70	5·45
FPL		
No herbicide	2·30	2·95
Herbicide	3·40	4·70
RID		
No herbicide	1·65	3·25
Herbicide	3·60	5·95
SPL		
No herbicide	3·55	4·40
Herbicide	2·55	4·35
MC		
No herbicide	3·05	4·85
Herbicide	3·50	6·45
S.E. (12 D.F.)	0·37	0·86

BPL, bush plough; DPL, double plough; FPL, single plough, seed in furrow; RID, ridger; SPL, single plough, seed on ridge; MC, manual.

Yields of straw followed a similar trend, although PEH had no significant effect on straw yield for the SPL tillage method. In addition, cultivation technique had no significant effect on straw yield although, with the exception of SPL, yields were consistently higher on PEH-treated plots (Table 4).

Dry matter yields of weeds were significantly reduced ($P < 0{\cdot}01$) during the first weeding for all cultivation methods, bar MC, through the application of PEH. Manual, DPL and RID cultivation techniques produced significantly less ($P < 0{\cdot}05$) weed mass compared to BPL, FPL and SPL, however, no significant tillage method × PEH interactions were observed. During the second weeding, dry matter yields of weeds were significantly reduced ($P < 0{\cdot}001$) through the application of PEH for all tillage techniques, with the exception of SPL. Cultivation techniques MC, BPL, SPL and DPL all produced significantly less ($P < 0{\cdot}05$) weed mass than RID and FPL. The use of PEH, however, caused a significantly greater reduction ($P < 0{\cdot}001$) in weed burden when used in combination with the RID and FPL cultivation techniques. Use of PEH or cultivation technique had no significant effect on the dry matter yield of weeds during harvest (Table 5).

DISCUSSION

The use of PEH caused a significant reduction in the total human time inputs and EWT required during weeding. In general, PEH also significantly improved the yield of cobs, and was particularly effective in combination with ox rather than with manual cultivation. These results are in agreement with those presented by Olukosi & Ogunbile (1994) in one of the few strictly comparable, quantitative studies available in the literature.

In previously reported work on rice cultivation, weed infestation was heavier and weeding took longer on ox-cultivated plots (Lawrence *et al.* 1997). In the present study, a similar trend was recorded, but the differences seldom reached statistical significance. On the plots not treated with herbicide, average total weeding time for all ox-cultivation techniques was 616 h/ha and for manual cultivation 430 h/ha. Corresponding values for the treated plots were 431 and 220 h/ha respectively. In contrast to these results, Olukosi & Ogunbile (1994) reported that ox-cultivated plots required far less weeding than manually cultivated ones (134 *v.* 224 h/ha for ox and manual cultivation respectively on untreated plots and 113 *v.* 177 h/ha for treated ones). It is difficult to see how these two sets of results can be reconciled either with respect to the absolute values obtained or to the relative amounts of time spent weeding after the two types of cultivation. In the present study, almost no

Table 5. *Mean values for weed dry matter yields (t/ha) on the experimental plots during upland maize cultivation in Kufana village, central Nigeria (n = 2, 12 D.F.)*

	BPL		DPL		FPL		RID		SPL		MC		
	NH	H	NH	H	NH	H	NH	H	NH	H	NH	H	S.E
First weeding	4·00	2·32	2·00	1·14	4·61	1·21	2·25	1·09	3·89	2·68	0·93	0·66	1·04
Second weeding	1·22	0·39	0·95	0·36	2·37	0·52	1·91	0·31	0·64	0·60	0·73	0·41	0·25
Harvest weeds	2·43	1·75	1·94	1·79	1·78	1·37	2·58	1·93	1·56	1·40	1·89	1·42	0·49
Total weeds	7·65	4·46	4·89	3·29	8·76	3·10	6·74	3·33	6·09	4·68	3·55	2·49	1·34

BPL, bush plough; DPL, double plough; FPL, single plough, seed in furrow; RID, ridger; SPL, single plough, seed on ridge; MC, manual; NH, no herbicide; H, herbicide.

weeds at all were visible on plots immediately after manual cultivation by local farmers. On ox-cultivated plots, on the other hand, some weeds could always be seen especially along the ridges, no matter how well the ploughs or ridger were set. One would therefore expect *a priori* that manual cultivation would be associated with fewer weeds and less weeding time later in the season which, in fact, proved to be the case.

Yields obtained on non-PEH treated plots were generally higher than those obtained in previous years, which may have been due to the location of the experimental plots on better soil. Nevertheless, yields recorded on fields that had been cultivated with the use of the ridger were similar to those attained previously (Lawrence *et al.* 1997). Overall, the use of a separate, and expensive, ridger did not give higher yields than cultivation with the Emcot plough used for fadama rice cultivation (Lawrence & Dijkman 1997), or a locally made, cheap, wooden plough. The use of this 'bush' plough also significantly reduced the work done by oxen and the DADF required, although no significant time saving was made in comparison to most other ox-cultivation techniques tested. The reduction in work done and DADF required, however, may be important if animals are in bad condition or when cultivation needs to be carried out with a single animal.

The extra costs connected with the use of PEH were (using 1992 costs and prices) more or less equal to the labour saved on weeding. There are, however, considerable additional benefits of PEH especially in areas where the availability of labour is limiting (Phillip & Ogunbile 1993) In these situations, the use of PEH lessens the likelihood of crops becoming inundated with weeds because the farmer and his family cannot 'keep up'. Another important economic attraction of PEH is the increase in yield associated with its use, which, using 1992 costs and prices, amounted to an average increase in income of $US 220/ha.

As previously reported by other authors, the cultivation of food crops such as maize using oxen is economic only if there is a cash crop to finance the initial outlay on animals and equipment (Adesina 1992; Jansen 1993). What the currently reported experiments emphasise is that once purchased for the cash crop (in this farming system, rice) these resources can be exploited effectively for the food crop, without the need for further investment, through the use of inventive cultivation techniques. Moreover, the use of animal traction enables a substantial saving of time at the start of the growing season so that planting can be timely, thus lessening the risk of crop failure later in the year if the season proves to be short.

Whereas we were previously reluctant to recommend the use of draught animals in the cultivation of maize, the currently presented results clearly indicate that, provided the appropriate tillage techniques are used, the use of animal traction can be beneficial and can be promoted with confidence in the farming of upland maize.

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