The use of animal-drawn cultivators for maize production in the southern highlands of Tanzania

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Abstract

Experiments on weed management techniques for maize production were carried out at the Uyole Agricultural Centre and on farmers' fields in Mbozi District, Tanzania. The treatments involved hand weeding and the use of the Cossul inter-row cultivator and of the over-the-row cultivator developed by the Mbeya Oxenization Project.

There were no marked differences in field capacities between the two cultivators, although the over-the-row cultivator tended to have slightly higher capacities. Field capacities tended to be higher when the maize was 45 cm high.

The use of cultivators alone reduced labour inputs for weeding by up to 80%, and the use of cultivators combined with hand weeding reduced labour inputs by 40%, compared to manual weeding alone.

Manual weeding, and a combination of manual and cultivator weeding, gave the best control of weeds, and similar high yields (5 t/ha compared to 2 t/ha with no weeding). The use of cultivators alone gave significantly poorer weed control and reduced yield advantages (3.3 t/ha).

The results emphasise the importance of weeding for high maize yields in the southern highlands of Tanzania. Farmers who cannot afford, or do not have access to, ox-drawn systems can obtain high yields by manual weeding alone, but at the cost of high labour inputs, representing high levels of family drudgery or high labour hiring costs. Those farmers who have access to ox-drawn systems are advised to do additional within-row manual weeding to ensure high yields. Ox-drawn cultivation alone for weeding is suitable only where labour is scarce.

Introduction

Weeds are unwanted and undesirable plants which interfere with the utilisation of land and water resources, adversely affecting human welfare (Rao, 1983). Their vegetative habits and demand for resources are usually similar to those of desirable plants, and so there is competition for nutrients, water, space and sunlight. There is also growing evidence for allelopathic effects of some weeds which exude chemical compounds harmful to crops, human beings and livestock (Rice, 1984). The overall effect of weeds is reduced yields of desirable plants.

Estimates of yield losses due to weeds vary greatly depending on the magnitude of the weed population, the weed species and the fertility level of the soil. It is accepted that about 10% loss of agricultural production in the world can be attributed to the competitive effect of weeds. In 1975 it was estimated that the loss of food due to weeds worldwide was 287 million tonnes, or 11.5% of total food production (Parker and Fryer, 1975).

Mani, Gautam and Chakroborty (1968) reported maize yield reductions due to weeds of about 30–74%. At Morogoro, Mugabe, Sinje and Sibuga (1980) have shown that yields of maize, sorghum, soya beans and greengram were, respectively, about 61, 96, 97 and 97% lower in unweeded fields compared with weed-free ones. At Uyole it was reported that if weeds grow unchecked maize yields can be reduced by over 70% (UAC, 1989). In The Gambia early control of weeds by either hand hoeing or hand application of low rates of *atrazine* or *propazine* increased maize yields by more than 50% in 1985 and by more than 30% in 1986, compared with farmers' normal practice (Carson, 1987).

Weed control is therefore one of the main factors determining crop production by smallholder farmers. Improved weed control often leads to substantial yield increases, even in the absence of other improvements in farming practices (Armitage and Brook, 1976). Indeed, improvements such as the introduction of improved varieties and increased fertilisation rarely increase yields if weed control is not also improved (Croon, Deutsch and Temu, 1984; Matthews, 1984).

According to Acland (1971) and Terry (1984), maize should be kept free of weeds for the first month after emergence and weeding should be done three times—when the maize is 5–10, 45 and 90 cm high. Moreover, if maize growth is checked by weeds shortly after emergence it never fully recovers. Croon, Deutsch and Temu (1984), in their experiments in the southern highlands of Tanzania, found that one weeding of maize at 10 cm resulted in an average yield of 4.2 t/ha compared to 2.3 t/ha in unweeded plots. They concluded that poor weeding of maize is the biggest constraint to maize production in this area. They went on to suggest that timely weeding was itself more important than the use of improved varieties, fertilisers or insecticides, or timely planting. In a survey of 320 farmers in 20 villages in Mbeya Region, late weeding was identified as one of the many constraints to crop production (Loewen-Rudgers et al, 1990).

In the whole cropping cycle, weed control is often the operation with the highest labour demand. The amount of land a farmer can plant is often restricted to the area that can be kept free of weeds. Improved and efficient weed control may therefore enable a farmer to cultivate more land and hence increase total yield. In addition, the time the farmer gains from improved weed control may be devoted to the cultivation of additional crops or to more profitable off-farm employment (Lewis and Watson, 1972).

Although animal-drawn weeders are available in most African countries, only 5% of farmers who use animal traction for plowing also use the weeders on row crops (Starkey, 1986; 1988). The figures vary from almost zero in Botswana, Mozambique, Tanzania, Uganda and Zambia to between 10 and 20% in Cameroon and Mali and to as much as 40% in South Africa and Zimbabwe (Kjærby, 1983; ILO, 1987). Rain (1984) identified the lack of good animal-drawn weeders as the main constraint to crop production by those farmers who plowed with animals.

Because of the benefit of timely weeding through the use of animal traction, it is important to develop appropriate animal-drawn weeders for small-scale farmers in Tanzania. The overall objective of this research was to develop effective and economical mechanical weed control methods based on animal-drawn implements.

Materials and methods

Location

The study was carried out in 1988 and 1989 at five locations in Mbeya Region, Tanzania—Uyole in Mbeya District, and Wassa, Iyula, Isangu and Igunda villages in Mbozi District.

Soils at Uyole are young, volcanic and of Tertiary to Recent origin, with top soils consisting of haplic phaeozem overlying pumice gravel. Those at Iyula and Wassa are gravelly, moderately deep cambisols while those at Isangu and Igunda are deep granular ferralsols (Rombulow-Pearse and Kamasho, 1981).

Mbeya Region is located between latitudes 7 and 9° S and longitudes 32 and 35° E. Rainfall ranges between 600 mm in the lowlands and 3600 mm in the highlands. The rainfall pattern is monomodal, with the rainy season between November and May. The altitude of Mbeya Region ranges between 400 and 2700 m above sea level: Uyole is 1800 m above sea level. The agricultural production potential of Mbeya Region is high with maize, wheat, beans, rice, coffee, tea, cotton, pyrethrum and tobacco as the major food and cash crops.

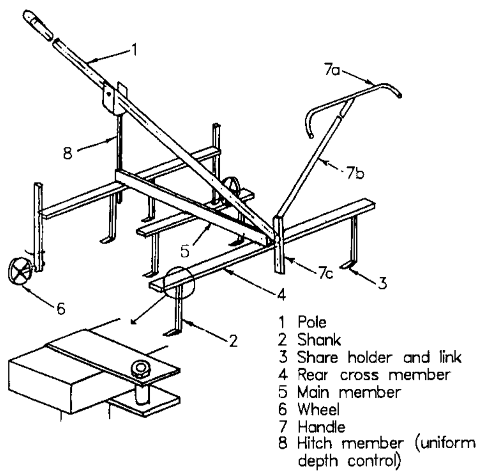
Although Mbeya Region has a high cattle population, with over 900 000 head, including 33 000 oxen, hand labour is still the major source of farm power (Shetto and Kwiligwa, 1988). However, in Kyela and Mbozi Districts draft animals are extensively used for plowing and for pulling sledges.

Implements and experimental design

Two animal-drawn cultivators were used. The over-the-row cultivator designed and fabricated by the Mbeya Oxenization Project (MOP) consists of a long pole attached to a rigid frame (Figure 1). Shanks are attached to the rigid frame by clamps so that the width of operation can be adjusted by simply sliding them on the frame. Several soil engaging parts, ranging from simple tines to duck-foot sweeps, can be attached to the shanks. The two wheels on the cultivator enable the depth to be adjusted on either side of a crop row so that an ordinary length yoke can be used (Mkomwa, 1992).

The Cossul inter-row cultivator (Figure 2a), designed in India by Cossul Company, consists of a flexible frame on which shanks are permanently fixed. The cultivator is hitched to the yoke through a trek chain. The wheel on the cultivator is used to adjust depth, and the width of cut is controlled by a

Figure 1: Prototype over-the-row cultivator, developed by Mbeya Oxenization Projet (MOP)



lever. It is designed to weed between the crop rows, so a long yoke is required. The Cossul ridger used in some treatments is a large and heavy implement (Figure 2b).

The experimental design was a randomised complete block with three replications. The plot size was 20 x 3 m. Hybrid maize H6302 was used with a spacing of 75 x 30 cm. Fertiliser and insecticide were used as recommended.

Treatments

The study investigated the following weeding systems:

1. Hand hoe weeding at 10–15, 45 and 90 cm maize height (the recommended practice).
2. Weeding with the MOP over-the-row cultivator at 5, 25 and 45 cm maize height.
3. Weeding with the MOP over-the-row cultivator at 10–15 and 45 cm maize height and ridging at 90 cm maize height.
4. Weeding with the MOP over-the-row cultivator, followed immediately by hand hoe weeding, at 10–15 cm and again at 45 cm maize height, and finally ridging at 90 cm maize height.
5. Weeding with the Cossul inter-row cultivator at 5, 25 and 45 cm maize height.
6. Weeding with the Cossul inter-row cultivator at 10–15 and 45 cm maize height and ridging at 90 cm maize height.
7. Weeding with a Cossul inter-row cultivator, followed immediately by hand hoe weeding, at 10–15 cm and again at 45 cm, and finally ridging at 90 cm maize height.
8. Hand hoe weeding at 30–40 and 90 cm maize height (normal farmer practice).
9. No weeding.

Procedure

Oxen were used for land preparation of the experimental plots (two plowing and harrowing operations). Planting was done by hand, using a rope and hand hoe to ensure uniformity in spacing. After germination and just before imposing the treatments, the plants were counted (they were counted again at harvesting to check if any serious crop damage had been done by the weeding operation). The treatments were then imposed at the appropriate weeding heights. The time taken to complete a particular operation was measured using a stop watch, and the field capacities and labour requirements were then calculated. Samples of weeds within and between the maize rows were taken using a 0.25 m quadrat just before the ridging operation (at 70 days after planting), then dried and weighed. The most common weeds at each site were identified. The middle three rows of each treatment were harvested and the yield recorded. After statistical analysis of the data, partial budget, return to labour and marginal analysis calculations were performed (Perrin et al, 1979: CIMMYT, 1988).

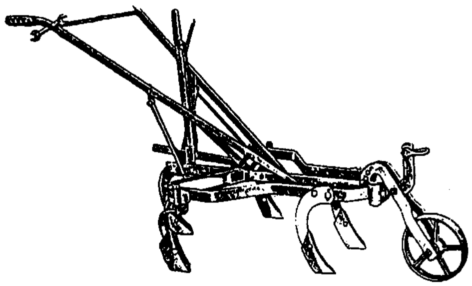


Figure 2a: Cossul inter-row cultivator

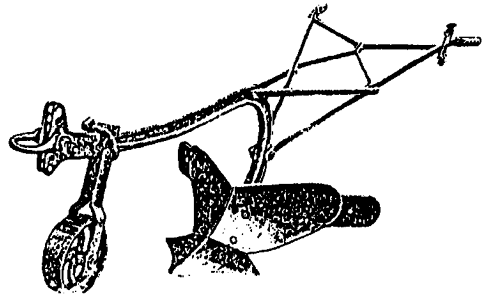


Figure 2b: Cossul ridger

Results and discussion

The common weed species at each experimental site are shown in Table 1. Chinese lantern (*Nicandra physalodes*) was very vigorous at Uyole, Iyula and Igunda whereas *Commelina benghalensis* was common at Wassa, Igunda and Uyole. Grasses were not very common at any site, probably because the fields chosen for the experiments were those cultivated annually.

Table 2 shows the effective field capacities of the animal-drawn cultivators. No marked differences in field capacities were observed between the two cultivators, although the MOP over-the-row cultivator tended to have higher capacities. The long yoke used for the Cossul inter-row cultivator may have decreased the oxen pair's "spirit of teamwork" leading to slightly lower field capacities. There was a tendency for the field capacities to increase as the maize height increased. This is probably due to the fact that the animals could easily move between the clear maize rows.

The use of animal-drawn cultivators reduced the labour input by between 50 and 80%. When

Table 1: The most common weeds on the experimental sites

Weed	*Uyole*	*Wassa*	*Iyula*	*Isangu*	*Igunda*
Galinsoga parviflora	yes	yes	yes	yes	yes
Nicandra physalodes	yes	yes	yes	no	yes
Commelina benghalensis	yes	yes	no	no	yes
Eleusine indica[1]	yes	no	yes	no	yes
Bidens pilosa	no	no	yes	no	yes
Digitaria milanjiana[1]	yes	no	no	no	no
Cyperus spp[1]	no	no	yes	no	no
Leucaus spp	no	no	no	yes	no
Setaria spp	no	no	no	yes	no

[1] *These are considered to be among the "top ten worst weeds in the world" by Holm et al (1977)*

Table 2: Effective field capacities of animal-drawn cultivators at different maize heights

Maize height (cm)	*Effective field capacities (ha/hour)*													
	Uyole		*Wassa*		*Iyula*		*Isangu*		*Igunda*		*Mean and standard error*			
	IC	*OC*	*IC*	*OC*	*IC*	*OC*	*IC*	*OC*	*IC*	*OC*	*— IC —*		*— OC —*	
5	0.11	0.12	0.11	0.10	0.12	0.13	0.12	0.11	0.09	0.08	0.11	0.010	0.11	0.019
10–15	0.11	0.14	0.13	0.12	0.13	0.15	0.10	0.14	0.08	0.09	0.11	0.021	0.13	0.024
25	0.14	0.12	0.13	0.12	0.12	0.16	0.18	0.13	0.13	0.13	0.14	0.023	0.13	0.017
45	0.18	0.16	0.14	0.14	0.24	0.24	0.16	0.14	0.12	0.14	0.17	0.046	0.16	0.044

IC: Inter-row cultivator; OC: Over-the-row cultivator

Table 3: Labour input for the various weeding systems at different experimental sites

Treatment	*Labour input (hours/ha)*					
	Uyole	*Wassa*	*Iyula*	*Isangu*	*Igunda*	*Mean*
1	281.2	213.4	159.9	230.9	288.4	226.7
2	46.1	51.8	40.0	57.5	38.2	49.9
3	50.1	51.2	31.0	55.0	55.4	47.9
4	181.9	128.0	111.6	129.3	125.7	135.4
5	46.4	48.5	39.1	48.7	64.8	49.2
6	26.1	47.9	41.5	41.1	59.8	41.8
7	136.4	117.8	106.4	112.8	134.5	119.6
8	241.2	218.3	141.7	130.3	203.0	184.1
9	0	0	0	0	0	0
Mean	126.2	109.6	83.9	100.7	121.2	106.8
LSD (0.05)	19.7	17.7	20.3	25.4	18.4	10.2
CV%	8.9	9.2	13.8	14.4	7.2	13.7

animal-drawn cultivators were supplemented by hand hoe the labour input reduction was about 40% (Table 3).

The weed dry weights for the different weeding systems at different sites are shown in Table 4 and Figure 3. Despite the good land preparation at all sites, Wassa, Igunda and Uyole had highest weed infestations. High overall weed intensity was associated with the presence of *Nicandra* and *Commelina* species. Results indicate that using animal-drawn cultivators alone (treatments 2, 3, 5 and 6) was not effective in controlling weeds within the maize rows. Supplementing animal-drawn cultivators with the hand hoe effectively controlled weeds both between and within the maize rows (treatments 4 and 7). This trend was the same within and across sites. The differences in weed dry weight between treatments 4 and 7 were not significant.

Table 4: Total weed dry weight (g/0.25 m^2) for different weeding systems at each site

	Weed dry weight (g/0.25 m^2)					
Treatment	*Uyole*	*Wassa*	*Iyula*	*Isangu*	*Igunda*	*Mean*
1	82.5	112.2	62.2	108.6	107.8	94.7
2	170.0	365.2	153.7	154.2	336.1	235.9
3	184.9	372.7	142.8	161.0	314.2	235.1
4	95.3	256.0	95.7	121.0	118.3	137.3
5	164.4	295.5	182.1	137.0	221.3	200.1
6	233.3	238.9	189.4	190.5	235.5	217.5
7	90.3	166.5	99.5	97.6	120.1	114.8
8	150.4	221.7	135.0	149.8	146.8	161.1
9	443.2	474.3	295.5	240.4	391.4	369.0
Mean	179.6	278.1	150.7	151.1	221.3	196.2
LSD (0.05)	84.1	161.5	123.0	40.1	88.7	49.1
CV%	27.1	33.5	47.2	15.3	23.2	34.5

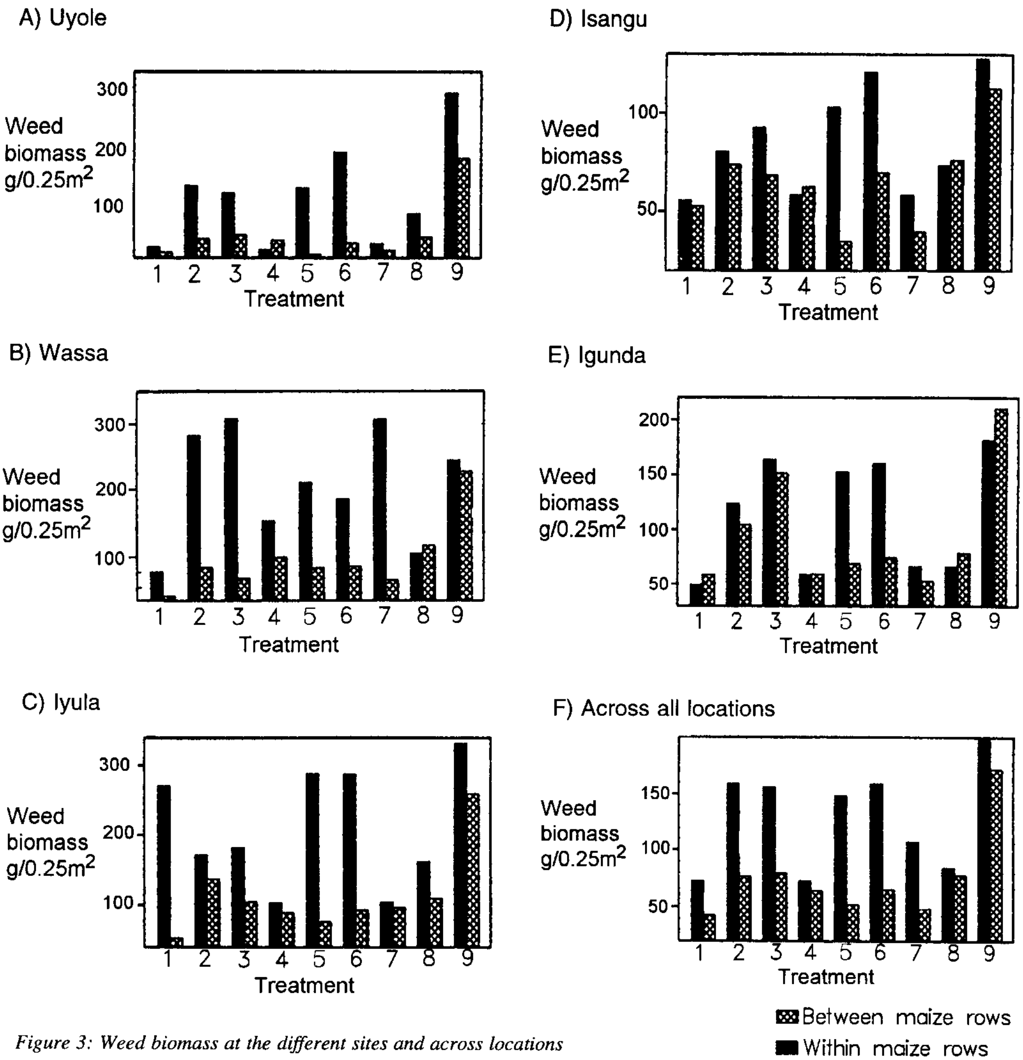


Figure 3: Weed biomass at the different sites and across locations

Table 5: Effect of weeding systems on maize yields at each site

	Yield (tonnes/ha)					
Treatment	*Uyole*	*Wassa*	*Iyula*	*Isangu*	*Igunda*	*Mean*
1	6.0	4.2	5.8	6.6	5.2	5.4
2	2.5	3.7	4.8	5.7	2.0	3.6
3	3.2	3.3	4.5	5.3	2.1	3.6
4	5.5	3.8	5.1	5.8	4.5	4.9
5	1.9	2.8	3.3	4.6	2.3	3.0
6	3.0	2.9	3.7	5.5	1.4	3.3
7	5.3	4.1	5.1	7.5	3.9	5.2
8	5.8	2.8	6.1	6.2	4.2	5.0
9	1.3	1.4	2.5	3.9	0.1	1.9
Mean	3.9	3.2	4.4	5.7	2.9	4.0
LSD (0.05)	1.3	1.0	1.7	1.6	1.4	0.6
CV%	19.6	18.5	22.9	16.5	28.5	21.2

This shows that animal-drawn cultivators when supplemented with a hand hoe can control weeds effectively. Moreover, both the MOP over-the-row and Cossul inter-row cultivators performed equally well in controlling weeds.

Weeding with a hand hoe three times, and using cultivators supplemented with hand hoe (treatments 1, 4 and 7) effectively controlled weeds both between and within the maize rows in all sites. The consistency of these weeding systems in different environments allows the techniques to be recommended to farmers with some confidence.

Some weeding techniques, especially those involving animal-drawn cultivators, did not control weeds effectively at Wassa and Igunda. The dominant weed species at these sites are stoloniferous types which are difficult to control.

The plant stand was good at all sites and ranged between 37 000 and 45 000 plants per hectare. Table 5 shows the maize yields for different weeding systems at different sites. Weeding by hand hoe and by cultivators supplemented with a hand hoe (treatments 1, 4, 7 and 8) gave the highest yields. This supports the effectiveness of these treatments on weed control, as shown by the correlations in Figure 4. Generally there was a good negative correlation between yields and weed dry weight within the maize rows (the correlation coefficient is –0.757). This shows that weeds within the maize rows affect crop production more than those between. Hence the importance of supplementing animal-drawn cultivators with the hand hoe.

Table 6 summarises the costs and benefits of the different weeding systems. Hand weeding three times gave the highest yields, but at a considerable

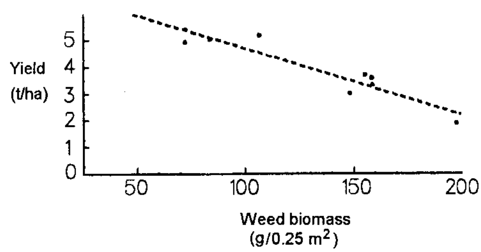


Figure 4a: Yield versus weed biomass within rows

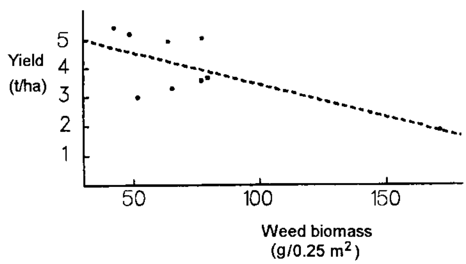


Figure 4b: Yield versus weed biomass between rows

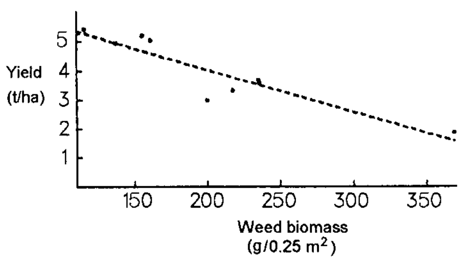


Figure 4c: Yield versus total weed biomass

Table 6: Partial budget and returns to labour of averaged data for the weeding system trial

Treatment	*1*	*2*	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Labour (hours/ha)	227	50	48	135	49	42	120	184	0
Yield (t/ha)	5.4	3.6	3.6	4.9	3.0	3.3	5.2	5.0	1.9
Gross profit (TSh/ha) [1]	57 024	37 594	38 650	51 955	31 469	34 848	54 701	53 011	19 536
Implement costs (TSh/ha) [1]	62	279	289	299	300	273	309	55	0
Net profit (TSh/ha) [1]	56 962	37 315	38 361	51 656	31 169	34 575	54 392	52 956	19 536
Net benefit (TSh/ha) [1]	37 426	17 779	18 825	32 120	11 633	15 039	34 856	33 420	–
Return to labour (TSh/hour) [1]	165	356	392	238	237	358	290	182	–

[1]The figures are given in Tanzanian shillings (Tsh) which have changed greatly in international value in recent years. In 1991 US$ 1 ≈ Tsh 100, but in this and other tables, comparision of treatments is more important than the absolute values

cost in labour requirement, while ox weeding gave the lowest yields, but with much reduced labour requirements. Ox weeding, with a ridging operation replacing the third weeding (treatments 3 and 6), gave similar yields and labour requirements to ox weeding alone. The combined operations, ox and within-row hand weeding, gave yields not significantly different to hand weeding alone, but with a considerably reduced labour input, resulting in considerably increased returns to labour.

Hiring labour for weeding can represent a major cost in maize production. Tables 7 and 8 summarise partial budgets for the various weeding systems, including costs of hiring labour for weeding, using both official and open-market prices and costs. Table 9 presents a rate of return analysis of the partial budgets. At official prices for labour, it pays to weed, with very high average rates of return for all weeding systems, although use of cultivators and ridgers alone, without supplementary hand weeding, gave reduced rates of return compared to the other systems. Using free-market prices for labour shows a rather different picture, however. Hand weeding alone gives rates of return of less than one, indicating a poor return on the cash investment, and suggesting that few, if any, farmers should consider hiring labour for hand weeding. Use of cultivators and ridgers gave an average rate of return of one, as did the use of cultivator plus supplementary hand weeding. A value of two is generally considered to represent the minimum for farmer acceptance of a technology.

Conclusions

This study emphasises the importance of weeding in obtaining satisfactory maize yields in the high altitude regions of the southern highlands of Tanzania. Those farmers who cannot afford or obtain ox plowing and weeding equipment can still achieve high yields if they can arrange the high labour inputs for manual weeding, but this would be at a disadvantageously high cost if the labour has to be hired rather than supplied from within the farm family. Those farmers who can afford/obtain ox plowing and weeding equipment can only obtain high yields if they can arrange manual inter-row weeding to supplement ox cultivator weeding. In the context of smallholder farming in the southern highlands of Tanzania, where maize is an important staple for home consumption, as well as a cash crop, and where most labour inputs are supplied from within the family, ox weeding, combined with manual within-row weeding, offers a significant reduction in drudgery, while maintaining high yields for food security and cash production. In the context of those farmers able to hire labour, this system offers one of the better rates of return to weeding.

Acknowledgements

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Table 7: Partial budget of averaged data from the weeding system trial (information based on government official prices and costs)

Treatment	*1*	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Yield (kg/ha)	5 400	3 560	3 660	4920	2 980	3 300	5 180	5 020	1 850
Adjusted yield[1] (kg/ha)	4 320	2 848	2 928	3 936	2 384	2 640	4 144	4 016	1 480
Gross field benefit[2] (TSh/ha)	57 024	37 594	38 650	51 955	31 469	34 848	54 701	53 011	19 536
Labour for weeding[3] (TSh/ha)	2 028	992	976	1 642	1 025	902	1 589	1 810	0
Implement costs (TSh/ha)	62	279	289	299	3 00	273	309	55	0
Total variable cost (TSh/ha)	2 089	1 272	1 265	1 941	1325	1 175	1 895	1 865	0
Net benefit (TSh/ha)	54 935	36 321	37 385	50 014	30 144	33 673	52 805	51 146	19 536

[1] *Adjusted by 20% (10% for the low management level of farmer and 10% for the small plot size)*
[2] *Official price: 15 TSh/kg less 1 TSh/kg for harvesting, 0.5 TSh/kg for transport and 0.3 TSh/kg for shelling and bagging*
[3] *Ox operator cost at 20.5 TSh/hour and hand hoeing at 9.0 TSh/hour (official government figures)*

Table 8: Partial budget of averaged data from the weeding system trial (information based on open market prices and costs)

Treatment	*1*	2	*3*	*4*	*5*	*6*	*7*	*8*	*9*
Yield (kg/ha)	5 400	3 560	3 660	4 920	2 980	3 300	5 180	5 020	1 850
Adjusted yield (20%) (kg/ha)	4 320	2 848	2 928	3 936	2 384	2 640	4 144	4 016	1 480
Gross field benefit (TSh/ha)	57 024	37 594	38 650	51 955	31 469	34 848	54 701	53 011	19 536
Variable costs[1] (TSh/ha)	32 400	8 640	8 640	17 086	8 640	8 640	16 265	21 600	0
Net benefit (TSh/ha)	24 624	28 954	30 010	34 870	22 830	26 208	38 436	31 411	19 536

[1]*Labour hiring average 10 000 TSh/ha in weeding and 30–39% of this cost when hand hoe supplements cultivator*
Cost of hiring oxen with cultivator/ridger plus two operators is 2600 TSh/ha

Table 9: Rate of return analysis of the various weeding systems

Treatment	*Costs*	*Net benefit*	*Additional costs*	*Additional net benefit*	*Average rate of return*
Official prices and costs					
No weeding (9)	0	19 536	0	0	–
Two hand weedings (8)	1 865	51 146	1 865	31 610	16.9
Three hand weedings (1)	2 089	54 935	2 089	35 399	16.9
Cultivator (2/5)	1 299	33 233	1 299	13 697	10.5
Cultivator/ridger (3/6)	1 220	35 529	1 220	15 993	13.1
Cultivator/hand (4/7)	1 918	51 410	1 918	31 874	16.6
Free market figures and costs					
No weeding (9)	0	19 536	0	0	–
2 hand weeding (8)	21 600	31 411	21 600	11 875	0.5
3 hand weeding (1)	32 400	24 624	32 400	5 088	0.2
Cultivator (2/5)	8 640	25 892	8 640	6 356	0.7
Cultivator/ridger (3/6)	8 640	28 109	8 640	8 573	1.0
Cultivator/hand (4/7)	16 676	36 653	16 676	17 117	1.0

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