ANNEX 3

The effects of tine design on the performance of animal-drawn rippers and cultivators

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Abstract
Six designs of ripper and eight configurations of tine types (based on four designs of cultivator) were tested on-station in Zimbabwe. The experimental designs included other treatments, representative of smallholder farmer practices, to act as controls to enable a thorough comparison to be undertaken. Each set of experiments was conducted in both sandy loam and clayey loam soils, the former being more representative of smallholder conditions, but the data have been kept separate for analysis.

Performance criteria included draught requirement, field or weeding efficiencies, crop (maize) yield and economic return. Within each soil type, the effects of tine design itself were found to be small but other factors were found to be important. The implications for smallholder farmers are discussed.

Introduction
The range of soil-engaging implements available for cultivation is wide and varied. The implements may be described in a variety of ways including major categories such as equipment for primary or secondary cultivation, or equipment that is powered by motorised, draught animal or human energy. In general, equipment catalogues suggest that there is a wider range of designs available for secondary cultivation than for primary, the latter being effected usually by either mouldboard or ard ploughs. The subject of this paper is animal-drawn equipment for secondary cultivation, in particular weeders and rippers, although it could be argued that the practice of ripping, which may displace primary cultivation, is not strictly secondary cultivation. Nevertheless, in both cases, the aim is to manipulate the soil by use of a tine.

The research trials reported below focused on the effect of tine design on the ability of the implements to achieve their purposes, in terms of associated crop performance factors.

Methods and equipment
All the trials were carried out in Zimbabwe at agricultural research establishments on sandy loam and clayey loam soils. The research station environment was favoured because of the relatively high level of management needed to ensure all the treatments were administered appropriately. The experimental details for the ripping and weeding trials are summarised in Table 1. Research station draught oxen were used to provide the tactive power in all cases.

Table 1 Experimental designs for ripper and weeder trials

	Rippers	Weeders
Purpose	To assess the performance of a range of rippers for crop establishment, in terms of draught power requirements, depth of work, field efficiency, crop quality and yield.	To assess the performance of a range of cultivators, in particular the effect of tine design, in terms of draught power requirements, depth of work, field efficiency, weeding efficiency and yield.
Trial design	Split plot design with primary land preparation as the main plot factor; ripper designs as sub plot factors with at least three replications. Each sub –plot size 10m wide x 20m long.	Fully randomised plot design with three replications for simple one-way analysis of variance. Plot size for weeding treatments 10m wide x 25m long; block size for replications 40m wide x 25m long.
Methods	a) Land preparation:– no-till or pre-ploughed (by winter- or spring-ploughing) b) Soil types:- sandy loam[1] and red clay loam[2] c) Preparation of planting lines (see Table 2):- eight methods of opening planting lines including (TFP) as a control d) Crop:- maize	a) Weeding treatments (see Table 3):- 11 types of weeding treatment, including use of hand hoe as control b) Soil types:- sandy loam[1] and red clay loam[2] c) Crop:- maize d) Land preparation:– pre-ploughed (by winter- or spring- ploughing)

The eight methods of preparing the planting lines in the ripper trials are shown in Table 2.

Table 2 Preparation of planting lines

	Method of opening planting line	Abbreviation
1	BSP Ripper	BSPR
2	Zimplow Ripper	ZR
3	Magoye Ripper	MR
4	Palabana sub-soiler	PS
5	Contil Knife Ripper	CKR
6	Contil Tool Bar	CTB
7	BSP light-weight plough	BSPP
8	BSP standard plough for TFP	TFP

Designs 1 to 5 were all marketed as simple tines which could be attached to a standard plough body and are shown in fig 1. The CTB tine was integral with the tool bar body. Because previous work with rippers had suggested that the condition of the soil prior to ripping could have a major influence on crop performance (e.g. see Shumba, 1984, Twomlow and O'Neill, 1994), winter ploughing (or not) was adopted the main plot factor. Third furrow planting (TFP), widely practised by smallholders in Zimbabwe, was included as a treatment to provide an indication of how the crop would have performed under typical smallholder conditions.

[1] Domboshawa
[2] Hatcliffe

Fig 1 Designs of ripper tine
(left to right: MR, BSPR, ZR, CKR, PS)

The eleven treatments in the weeding trials are shown in Table 3

Table 3 Treatments used in the weeding trials

	Weeding implement (treatment)	Tine configuration	Abbreviation	Notes
1	BS221 Cultivator	2 reversible tines, 2 hilling blades, 1 duck foot tine	BS2212R2H1D	
2	BS221 Cultivator	2 hilling blades, 3 duck foot tines	BS2213D2H	
3	BS41 Cultivator	5 reversible tines	BS415R	Standard set-up
4	BS41 Cultivator	4 reversible tines, 1 duck foot tine	BS414R1D	
5	BS41 Cultivator	5 duck foot tines	BS415D	
6	Zimplow light-weight cultivator	2 reversible tines, 1 duck foot tine	ZLW2R1D	Light-weight model has only 3 tine attachments
7	Zimplow light-weight cultivator	3 duck foot tines	ZLW3D	As above
8	Contil Tool Bar	with duck foot sweep tine attachment	CTB	Light-weight unconventional design primarily for donkeys
9	Standard VS8 Plough without mouldboard	plough share	SHARE	A fairly common practice amongst smallholders
10	Standard VS8 Plough	share and mouldboard	MB	For post-emergent ridge weeding
11	Hand hoe	-	HH	The basic practice included as a control

Four commercially available weeders were used (BS221[3], BS41, Zimplow light-weight cultivator and Contil Toolbar) with different configurations of tines as indicated in Table 3. Typical designs of reversible and duck foot tines are shown in fig 2. Because smallholders in Zimbabwe rarely use cultivators, the experimental design incorporated weeding with a plough as well as with a hand hoe, the last being the control. The plough provided two treatments – with and without the mouldboard. Weeding with the mouldboard removed and using just the share is quite widely practised by Zimbabwean smallholders.

Fig 2 Reversible (l) and duck foot tine (r)

Results and discussion

Ripper trials

The draught force requirements in the sandy soil (chosen for presentation because this soil type is more representative of smallholder conditions than the clayey soil) are given in fig 3, and show the no-till plots to be significantly more demanding ($p<0.001$) than the winter-ploughed plots. However, because of the variability in the results, there is no significant difference between treatments within each factor.

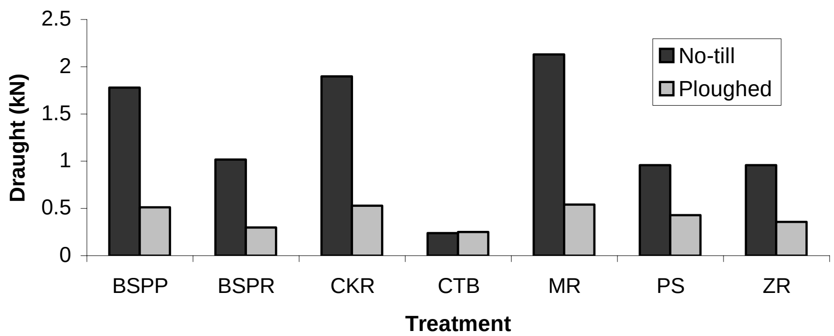

Fig 3 Draught requirements for rippers on sandy no-till and winter-ploughed plots

[3] BS indicates manufactured by Bulawayo Steel Products Ltd. BSP Ltd and Zimplow Ltd have now merged and all equipment is now marketed under the Zimplow brand.

Table 4 summarises the other two key ripper operating performance parameters, depth of work and work rate, again on sandy soil. Again, there are significant differences between no-till and ploughed but no significant differences between designs of ripper tine. Note, however, that third furrow planting is significantly slower ($p<0.001$), by a factor of about three, than rip-line planting. The benefits of winter ploughing also included significantly lower ($p<0.023$) weed densities than on the no-till plots. This may contribute to overcoming the serious weed problem associated with minimum tillage practices.

Table 4 Performance characteristics for rippers on sandy soil

Implement	**Depth of work (mm)**		**Work rate (h/ha)**	
	No-till	Plough	No-till	Plough
BSPP	119	158	4.2	4.8
BSPR	115	138	4.3	4.4
CKR	132	187	4.4	4.5
CTB	52	82	4.6	4.6
MR	145	182	4.7	4.5
PS	96	154	4.4	4.7
ZR	110	145	4.3	4.5
TFP	-	-	13.7	14.16
Tillage SED	0.295 (1 df)		0.047 (1 df)	
Implement SED	0.552 (6 df)		0.094 (7 df)	
T by I SED	0.780 (6 df)		0.134(7 df)	

Yields were also significantly affected by winter ploughing, as shown in fig 4, but again no significant differences could be attributed to tine design.

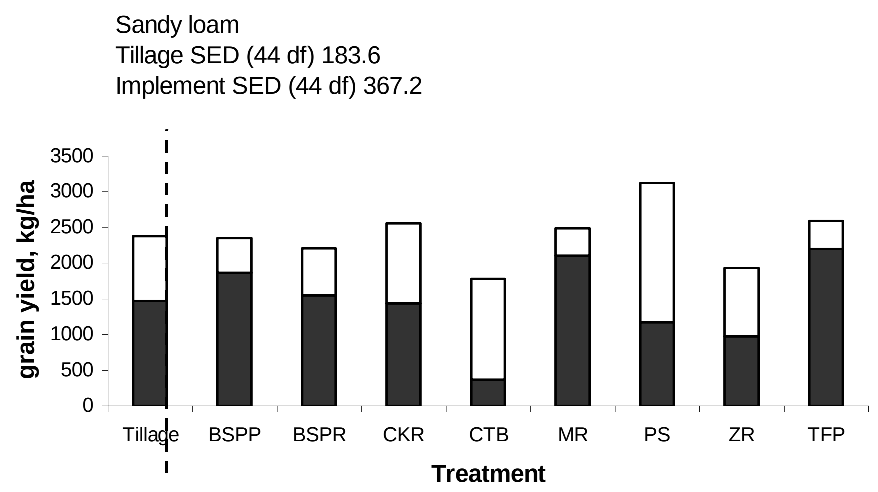

Figure 4 Yields according to rippers and tillage (2000/1 season)

■ yields for no-till plots; □ incremental yield increase due to winter ploughing

Fig 4 shows the average yield increase to be more than 900 kg/ha ($p<0.001$). At Hatcliffe, on the clayey soil, a similar response was observed, although less pronounced (increase of just under 700kg/ha, $p<0.005$).

Weeding trials

Figure 5 shows the draught requirement results, except for the hand hoe (control) treatment for which it is not applicable. There was no consistent difference attributable to soil type and very little between designs, except for the Contil Toolbar showing the lowest requirement.

Figure 6 shows the weeding efficiencies associated with each of the treatments. Again, there were no consistent differences, but the results on the clay loam were less variable. Hand weeding on clay was the most efficient.

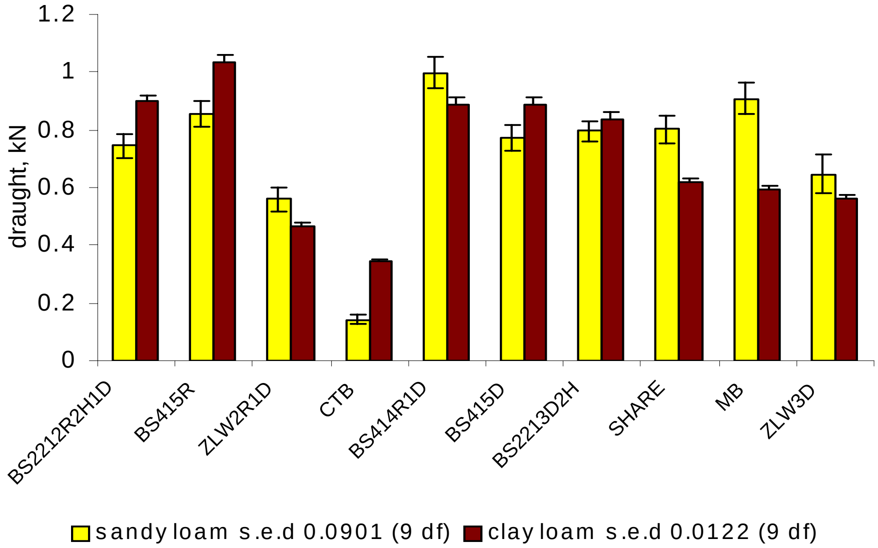

Fig 5 Draught requirement for each weeding treatment

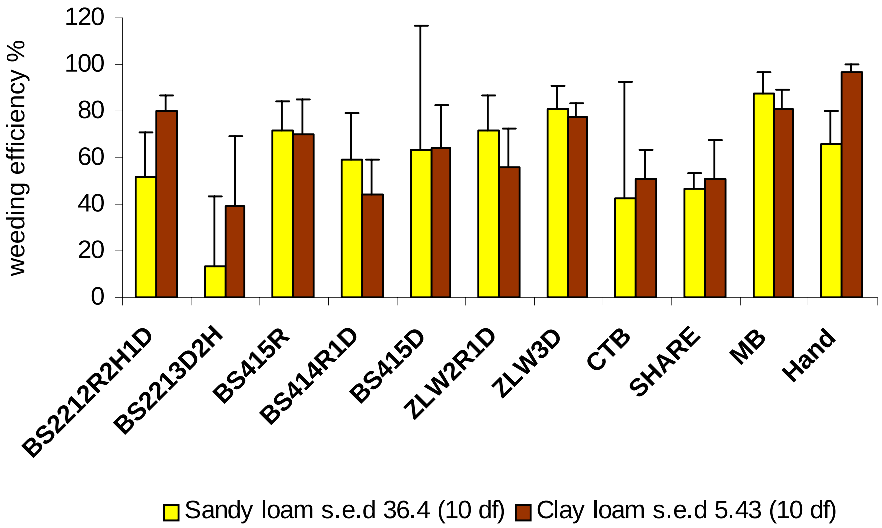

Fig 6 Weeding efficiencies for each treatment

Figure 7 shows the grain yield for each treatment. The yield on clayey soil was generally higher than that on sandy soil. However, the only cultivator to give a higher yield on sandy soil than on clayey soil was the light-weight Zimplow fitted with duck foot tines (ZLW3D).

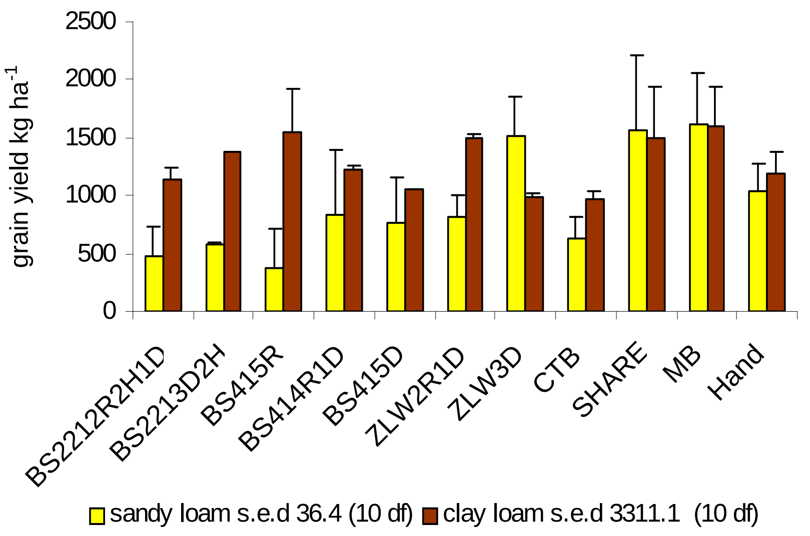

Fig 7 Grain yield for each treatment

In terms of draught requirement and weeding efficiency, there were very few differences between the treatments for a particular soil type. On these bases, therefore, no one particular design of implement or tine configuration could be recommended. Yields were generally higher on the clayey soil, but this would be expected from the differences in soil quality and properties. Of the higher yields in the sandy soil compared to clay (see figure 7) with the three animal-drawn implements, only one was achieved with a cultivator (ZLW3D), the other two arising from plough use. On the other hand, all the cultivators except this one (i.e treatment numbers 1 to 6 and 8) gave higher yields on the clay. This included the same basic cultivator (ZLW) but fitted with a different tine configuration.

Although, overall, the differences are not statistically significant, there seems to be a trend that the cultivators giving the higher yields (say > 500 kg/ha) on sandy loam soil were those fitted with more duck foot tines, whereas those giving the higher yields (say > 1200 kg/ha) on clayey loam were fitted with reversible tines. Furthermore, reversible tines seem to perform relatively poorly on sandy soil. This implies a possible interaction between tine design and soil type, which can examined further by considering the grain yields with the Zimplow Light Weight Cultivator (ZLW), as shown in Table 5.

Table 5 Yields (kg/ha) for ZLW on the two soil types

Weeder	Sandy loam	Clayey loam
ZLW3D	1520**	990
ZLW2R1D	816	1502**

** significantly greater, $p<0.01$

It would, therefore, seem on this evidence, at least, that duck foot tines are better suited to the more sandy soils, whilst reversible tines would be better suited to the more clayey soils. The implication for smallholder farmers, who have access to predominantly sandy soil, is that duck foot tines should be fitted to their cultivators. Observations suggest that this is rarely the case and, hence, the farmers do not get good results from using their cultivators and so rarely do use them (Chatizwa and Ellis-Jones, 1997).

Although the results are not presented here, the economic analysis shows that the only cultivators to give net economic return better then hand hoeing (the control) were the ZLW2R1D and the ZLW3D in clayey and sandy soil respectively. This finding results mainly from the higher yields on these plots. However, neither was as favourable as the plough-based practices.

Conclusions

- The design of the tines fitted to the rippers and cultivators was found to not significantly affect crop yields within each soil type tested (sandy and clayey loams).
- Farmers' criteria for the selection of rippers should be based more on the durability and cost of the implement than on its tine geometry.
- Crops planted in ripper lines perform significantly better if the plot has been winter-ploughed beforehand.
- Smallholder farmers on sandy soils should fit duck foot tines to their cultivators but their yields would not necessarily be better than from weeding with their plough shares.

Acknowledgements

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