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Participatory Development of Tillage/Weed Management Practices for Maize Farmers in Semi-arid Zimbabwe: Who benefits?

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ABSTRACT

Farmers, research and extension have been developing and testing moisture conserving tillage/weeding practices for a maize-based cropping system in semi-arid Zimbabwe which is characterised by labour and draught animal power (DAP) shortages, frequent drought and at times excessive weed growth. Using a ripper tine attached to the existing plough for planting, and weeding with the plough, practices selected by farmers from on-farm trials during this participatory exercise, are expected to benefit households who have access to DAP and labour. Some 35% of households, however, own no DAP or implements, experience severe labour constraints, generally plant late, achieve low yields, rarely produce a saleable surplus and are cash constrained. Although these households may benefit from more timely availability of hired DAP for planting, when DAP owners complete their own planting more quickly by the minimum tillage/planting technique, they are unlikely to relieve their weeding constraint by use the labour saving weeding technology, as this would incur further hire costs for DAP.

INTRODUCTION

Soil and water conservation are essential components of sustainable crop-production for the semi-arid lands of southern Africa and research on these issues is a high priority in the region. Smallholder farmers in Zimbabwe largely rely upon draught animal power (DAP) for tillage and crop establishment; the conventional practice of planting seed into the furrow made by a plough ensures that the maize crop emerges into a relatively weed-free seed bed. Farmers, however, face the problem of a peak demand for DAP early in the wet season when animals are often in short supply and are at their weakest following the long dry season (Shumba et al., 1992). Weed competition is a further constraint to improved maize productivity in semi-arid Zimbabwe, where crop water stress associated with periods of drought, is a common feature of the growing season (Chivinge, 1984). As weed management influences the availability of soil water to the crop, it needs to be incorporated as a key element of conservation tillage (Riches et al., 1997). Farmers recognise the need to weed their crops twice if possible, both to kill weeds and to maintain a rainwater retentive soil surface (Ellis-Jones et al., 1993) hence weeding can account for up to 60% of the pre-harvest labour input to maize production (MLARR, 1992), putting considerable strain on households with limited labour resources.

Although labour and DAP are the key resources which determine the area planted, timeliness of operations, and the resulting productivity of the cropping system, the likely success of a new technology has often been judged by researchers on the basis of crop yield response or water and soil conserved. Following on-station investigations, no-till tied ridging was proposed as a sustainable conservation tillage system to reduce soil and water losses (Elwell and Norton, 1988). Promotion of ridging from the late 1980s however, met considerable farmer indifference due to high-labour requirements, and the practical difficulties of planting, ridge maintenance and weeding (Vogel, 1993; Vogel, 1994), so few farmers have adopted the system (eg Sarapinda, 1989). For the past decade researchers in Zimbabwe have therefore emphasised the participation of farmers in research, in order to develop tillage and weed control practices which can reduce DAP and labour inputs while allowing timely crop establishment and weed control.

Shumba et al. (1992) demonstrated under farmer conditions that tine tillage, i.e. planting along the rip line made with a tine bolted onto the farmer's existing plough, provides a practical, low-draught system of crop establishment. The problem of early season weed growth in the untilled inter-rows can be overcome by weeding with a mouldboard plough which is owned by 76% of households in southern Zimbabwe (MLAAR, 1992). Mid-season ridging with the plough while weeding results in efficient weed control, increased rainwater retention and higher labour productivity, compared to the conventional system of hand weeding, without the additional investment associated with a DAP cultivator (Riches et al. 1997). Highest returns to labour in researcher-managed trials have been associated with planting on the flat, compared to pre-plant ridging while post-planting ridging at weeding reduces and spreads the labour demand, providing a system which in combination with planting along the rip line is more likely to be adopted (Twomlow, et al., 1997; Ellis-Jones and Mudhara, 1997).

The heterogeneity of household resource availability in smallholder farming communities in southern Zimbabwe is well known, particularly in terms of access to DAP, labour and cash for seasonal inputs (Ellis-Jones and Mudhara, 1995; Scoones, 1995). The aim of our research therefore, has been to develop and test a range of crop establishment and weeding options for farmers to choose from depending upon their biophysical and socio-economic circumstances. The most challenging phase of the work has involved community-based testing of options previously developed in researcher-managed trials. These were designed on the basis of criteria identified during rapid rural appraisal of farmers constraints, priorities and resources (Ellis-Jones et al., 1993). As our work has progressed, to adapt technology to farmers needs, we have started to question the extent to which the community can be helped by our approach. In this paper we focus on our interaction with farmers in the Zimuto Communal Area, Masvingo Province, and discuss the

extent to which the participatory methods used have resulted in technologies which can be adopted by households with very different resource endowments.

METHODS

Working in partnership, research and extension staff established a programme to demonstrate a range of tillage and weed control options in Zimuto to encourage and monitor farmer selection and evaluation of these practices. The approach of Participatory Technology Development has followed a clear, while evolving, methodology in which farmers have made an input into field trial design, site selection and evaluation. The process began with a Participatory Rural Appraisal (PRA) undertaken during 1995. This had the aims of describing existing soil and water conservation (SWC) practices, involving farmers in identification of issues group discussions with farmers, extension staff and other key informants in the community, matrix ranking of constraints and wealth ranking of households were used.

Groups of farmers reviewed trials at Makoholi Experiment Station to select technologies for on-farm evaluation. As a result, trials were implemented on six farms during 1995/96 and 1996/97 to compare combinations of three tillage/crop establishment and three weed control practices. The common farmer practice of "third furrow planting" involving sowing seed into the plough furrow to be subsequently covered by the next plough pass was compared with: 1) planting into a 30-cm deep rip-line opened with a tine attached to a plough beam or 2) "open plough furrow planting" involving sowing of seed into furrows opened with a plough at the desired inter-row space, on previously ploughed land, with seed subsequently covered by hand. The common farmer practice of hoe weeding was compared with the use of an ox-drawn cultivator or plough with mouldboard left in place. Maize was planted at each site. Rip tines were provided by the project as these are not available in Zimuto. Farmers (men and women) were selected by the community as representative of the three main wealth categories identified during the PRA. As the trials included practices not previously tested on-farm they were consultative, managed by researchers and extensionists to allow adequate demonstration of new methods, but implemented by farmers, and replicated on the three main soil catena types of the area. These represented the topland, true dryland sites of the upland ridges and valley slopes, the *vlei*-margins and *vlei* - valley bottom sites on hydromorphic soils adjacent to water courses which are subject to seasonal flooding. To reduce the risk from crop failure in this variable environment farmers aim to plant crops on each of these soil types, which require very different management. Regular meetings of farmers and other stakeholders, and field days at key stages during each crop season, allowed evaluation of the technologies according to farmer's criteria for choice of crop management practices. This more collegial form of participation allowed farmers to describe the advantages and disadvantages of each technology in the context of their own farm situation so that an assessment of likely adoption, or constraints to adoption, by households from each wealth category could be made.

RESULTS

The Environment Zimuto experiences a unimodal rainfall pattern with the bulk of rain falling as sporadic heavy convectional storms during the period October/November to March. Average rainfall for the period 1961 to 1997 at nearby Makoholi Experiment Station is 631 mm, ranging from 200 to 1200 mm, with a 30% chance of a mid-season drought occurring in January or February (Hussein, 1987). There have been seven bad droughts in the area since 1980 that have dramatically reduced livestock numbers. The on-farm trials were however implemented in wetter than average seasons (881 mm in 1995/96 and 838 mm in 1996/97), although 1995/96 was characterised- by an uneven distribution with 50% of the rain falling during January. Soils are largely derived from granite with three categories on a typical catena with soil moisture holding capacity, waterlogging during the wet season, weed burdens and soil fertility all increasing down slope from the dry topland, to the valley bottom wetlands of the *vlei*-margin and *vlei*. These are associated with different levels of risk and timeliness with which tillage operations need to be carried out. Households in Zimuto cultivated the two main land types, topland and *vlei* in the ratio

of 0.9:1, although occasionally individual households had access to only one or the other. Area cropped varied from 2-5ha per household.

Farmer resources and the cropping system Three broad farmer categories were identified during the PRA wealth ranking exercise (Mazhangara, 1995) and subsequent discussions have provided details of participation in crop production on the three soil types and of the practices used by each category (Table 1). The proportions of households in each category were estimated during farmer group meetings and in discussion with extension staff. Farmer categories have the following characteristics:

Well-resourced farmers (category 1): Households with large arable area, no DAP limitations, a full range of implements (including a plough and inter-row cultivator used for weeding) and who regularly sell agricultural produce comprise some 5% of the community.

Average resourced farmers (category 2): Households with adequate land, owning livestock but with inadequate draught power, owning only a plough, making irregular sales of agricultural produce supplemented by remittances from family members in non-farm employment are in the majority, comprising an estimated 60% of the community.

Poorly resourced farmers (category 3): Farmers with poorly developed arable lands, no DAP, inadequate implements (a hoe only), who are dependant on subsistence production in good seasons supplemented by hand outs from drought relief and recovery programmes and limited off-farm income, comprise the poorest group of some 35% of households in the community.

Three primary tillage options are available to farmers using draught animals' - winter ploughing (following the maize harvest during the dry season) and spring ploughing (prior to planting at the onset of the rains); winter plough only or spring plough only. Choice and timing of operation depends upon DAP availability and soil moisture. Category 1 farmers tend to winter and spring plough all land types, perceiving that this is advantageous for moisture conservation and weed control. *Vlei* fields may be too wet to plough following seasons of above average rainfall, but in general these are ploughed as early as possible so that a maize/rice mixed crop can be planted onto residual moisture from August. This also has the advantage of allowing the crop to become well established ahead of weed emergence, particularly of various species of *Cyperaceae* which become dominant in the *vlei* and *vlei*-margin during the rains. Planting of all sites is largely by "third furrow planting"; in this way tillage and crop establishment are combined, reducing labour requirements and ensuring the crop emerges in a weed free seed-bed. The alternative "open plough furrow planting" method is used occasionally for rapid planting of previously planted land. With no DAP constraint, and cash available to hire labour if necessary, Category 1 farmers are in a position to make maximum use of soil moisture and begin planting the *vlei* in August to September and topland with the onset of rain in November/December. Category 2 farmers tend to winter plough the *vlei* and spring plough topland, rely on third furrow planting and can usually assemble a full DAP team to begin planting early. Category 3 farmers however, who are dependant on sharing, borrowing or hiring DAP, tend to plant the *vlei* late and are rarely able to winter plough toplands. They establish maize on the topland after DAP owners have finished planting, 6 weeks or more after the onset of rain and immediately prior to the period of likely mid-season drought. These farmers often provide labour for other members of the extended family or neighbours in return for DAP and as a priority attempt to plant some *vlei* before the on-set of rain.

All farmers need to purchase hybrid maize seed and the need to replant when emergence is poor can put considerable *strain on resources of Category 3 farmers*. Animal *manure or compost is used on all soil types* by Category 1 and 2, although the area treated in any one

year is small. Likewise fertiliser, used mainly by Category 1 but also on the topland and vlei margin maize by Category 2 at rates rarely exceeding 50 kg ha⁻¹. During group discussions and the transect walks farmers regularly commented that their inability to afford significant amounts of fertiliser is a serious constraint to increasing output, particularly from the topland.

After crop establishment farmers use one of three weeding methods once or twice depending upon when they planted, availability of labour and rainfall conditions. Category 1 use the ox drawn cultivator supplemented by hand weeding within the crop row for each weeding. Category 2 tend to hand hoe but occasionally use the plough, with mouldboard removed, during the second weeding. Category 3 farmers, being short of labour and having planted late, rarely weed more than once and are restricted to using the hoe.

On-farm trials: For each season an economic analysis based on average maize yields at trial sites was undertaken. The best and worst technology options for crop establishment and weeding were identified in terms of highest and lowest productivity (Table 2). Gross margins for each system, on each soil type, were calculated using February 1997 prices for traded items and an opportunity cost for family supplied inputs of DAP and labour based on hire rates in Zimuto. The time taken for each DAP or labour operation was taken from previous on-farm work (Mudhara and Ellis-Jones, 1996) and actual measurements from the 1996/97 trials. Under the variable environmental conditions of Zimuto, the management options providing the best returns vary from season to season. Gross-margins, averaged for each soil type, were positive except on the topland in 1995/96. However, considerable variation between treatments was evident.

On topland sites productivity was highly variable depending on both total and distribution of rainfall in the season. In prolonged wet conditions, leaching of nutrients from these low organic matter soils is a major problem. With good rainfall distribution (as occurred in 1996/97) conditions of soil moisture and nutrient status are more favourable for maize growth. The rip/hand hoe combination in 1995/96 and third furrow planting/hand hoe in 1996/97 gave the higher returns on the topland.

Vleis can produce poor yields, especially when planted late or in wet years, when they become flooded early. Tillage and weeding techniques need to ensure moisture capture during dry periods and drainage during wet periods. Third furrow planting provided the optimum crop establishment method in both seasons with high returns following weeding with a cultivator in 1995/96 and the plough in 1996/97 when the increased drainage which resulted was an advantage.

Vlei-margins are likely to give the highest productivity combining the advantages of both vlei and topland. Planting in the rip line and weeding with the cultivator in 1995/96 and third furrow planting and plough weeding in 1996/97 were the best options in this ecology.

Farmer Perceptions: Farmers perceived advantages for each of the tillage/planting practices which were tested (Table 3). While considerable consensus emerged in group discussions, quite contrary views were expressed about some technologies, reflecting the range of soils and moisture conditions which farmers manage with differing access to key resources. While early season weed control is seen as an advantage of the farmers existing practice of third furrow planting, farmers are concerned that poor emergence with this method often results on topland or vlei-margins or when dry planting. This leads to the additional expense for seed as well as increased labour for replanting. The use of a ripper for planting was favoured as this is seen as a low draught, labour saving technology which, on topland and vlei margins in particular,

Although the hand hoe is widely used in other parts of sub Saharan Africa for primary tillage, its use in Zimbabwe is unpopular with farmers and rarely used

results in a good crop stand. The disadvantage is that there can be considerable weed growth in the inter-rows following crop emergence, as is perceived to be the case with open furrow planting. As few farmers own a cultivator, there was great interest in the use of the plough for weeding, as a potential improvement over labour intensive back-breaking manual weeding. Other advantages of plough weeding were thought to be moisture conservation on the topland and provision of drainage in the *vlei*. Possible crop damage was a common concern as well as the problem of removing ridges the following season. All farmers would like to use a cultivator but the expense is prohibitive for the majority.

DISCUSSION

It is not surprising that farmers have a deep understanding of the inter-relationships between the range of issues which need to be integrated for them to achieve an acceptable maize stand, and to grow a weed-free crop in synchronisation with available soil moisture. The success with which a number of trade-offs in the cropping system can be managed will depend on a household's access to resources. Many farmers seem to be prepared to accept that earlier weeding, with greater draught and labour inputs, will be needed following planting into rip lines if this consistently allows timely planting and results in a good crop stand. Timely establishment in relation to periods of good seed-bed moisture is the key farmer criteria for selection of a planting method. Although farmers are looking for technologies which ease labour and draught constraints, they are prepared to accept certain trade-offs to achieve the all important crop stand with the minimum of risk. A greater weed burden after emergence is therefore a secondary consideration. Provided farmers can find the cash to purchase a ripper tine assembly for the plough, rip planting has a role to play in improving timeliness for DAP owners, who also own a cultivator (category 1) or would be able to use their plough for weeding (category 2). It is less clear that this labour saving, low draught technology can improve the productivity for resource poor category 3 households. These farmers have little cash income, so many work for neighbours early in the season to gain access to a DAP team. A delay in planting beyond the most favourable period of November/mid-December, to just before the time when mid-season drought is common, is unavoidable for many in category 3. It will only be after the adoption of ripping by DAP owners that it will become apparent if the resulting savings in DAP increases its timely availability for households who depend on borrowing or hiring. However, the problem of being unable to winter plough topland or *vlei*-margin sites due to a lack of DAP does mean that they would experience severe weed problems soon after planting. Reduced or no tillage techniques without increasing weed burdens remains a priority for category 3 farmers.

The results of the field trials demonstrate how farmers will continue to need a choice of crop establishment and weeding options for different positions on the soil catena and need flexibility to respond to the moisture situation as the season develops. Our analysis of farmer resources and the responses they make within the current system suggests that resource poor households are unlikely to have the access to DAP, implements or labour that such flexibility in decision making demands. In particular category 3 farmers are unlikely to gain access to the labour saving technology of plough weeding as this would require them to hire or borrow DAP for a second time each season, resulting in higher input costs for households who always experience a severe liquidity problem. Our study has demonstrated that Participatory methods are extremely helpful for characterisation of existing systems and prioritising farmer problems. Working with the community has led to selection of technologies which have the potential to improve farm productivity of the majority who own DAP, but has brought into focus the limitations of trying to assist the sizeable minority of resource constrained households by introducing innovative production methods alone.

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Table 1: Existing Farm Systems for Three Farmer Categories in Zimuto Communal Area.

FARMER CATEGORY	1 Full DAP Full implements Few labour constraints Outside incomes Regular farm sales			2 Partial DAP Plough only Some labour constraints Variable outside incomes Farm sales in good years			3 Little or no DAP No DAP implements Severe labour constraints Remittances/relief Farm sales rare		
	T	VM	V	T	VM	V	T	VM	V
Soil catena	T	VM	V	T	VM	V	T	VM	V
Primary tillage									
Winter plough	*	*	*		*	*			*
Use of manures	*	*	*	*	*	*			
Crops	M;Mi; Cp;Bn	M;Gn; Bn;V	M/Ri;Gn V	M;Mi; CP;Bn	M;GN; Bn	M/Ri;Gn	M;CP; Bn	M;Gn	M/Ri
Crop establishment									
Priorities	3	2	1	3	2	1	3	2	1
Dates	Nov/Dec	Oct-Dec	Aug/Sept- Dec	Nov/Dec	Nov/Dec	Aug-Oct	Dec/Jan	Dec	Aug-Nov
Hoe	(*)		(*)		(*)		(*)		(*)
Third furrow	*	*	*	*	*	*	*	*	*
OPFP	(*)	(*)	(*)						
Weeding									
1st	II C	II C	II C (P)	II	II	H	H	H	II
2nd	II C	II C	II C	II P	II P	II	-	-	-
Use of inputs									
Hybrid seed	*	*	*	*	*	*	*	*	*
Fertiliser	*	*	*	*	*	(*)	(*)		(*)
Chemicals	*	*	*	*	*	*			
Hired labour	*	*	*						
Hired or borrowed DAP							*	*	*
Works for others at key periods							*	*	*

T - Topland, VM - Vlei-margin, V - Vlei

M - Maize; Mi - Millet; Cp - Cowpea; Bn - Bambara nuts; Gn - Groundnuts, M/Ri - Maize-rice intercrop; V - vegetables.

* - main practice, (*) - used by a few farmers, but not the dominant practice. H - hoe; P - plough; C - cultivator, DAP - Draught animal power

Table 2. Summary of Performance of Crop Establishment and Weeding Technologies at Zimuto Communal Area Zimbabwe during 1995/96 and 1996/97.

	1995/96	1996/97
Mean Maize Yield kg ha⁻¹		
Topland	852**	2164
Vlei-margins	2210	2927
Vlei	1752	1716
Best Options		
Topland	RIP/HH*	TFP/HH
Vlei-margins	RIP/P	TFP/C
Vlei	TFP/HH*	TFP/P
Worst Options		
Topland	OPFP/P**	RIP/P
Vlei-margins	TFP/C*	TFP/HH
Vlei	RIP/C**	RIP/P** - OPFP/P**

Establishment methods: TFP = Third Furrow Plant; OPFP = Open furrow plant; Rip = Ripper

Weeding Methods: HH = Hoc; C = Ox cultivator; P = Mouldboard plough.

*Negative gross-margins (when labour and DAP costs are included). Returns to labour and DAP are positive but less than the opportunity cost of labour.

**Negative gross margins (when labour and DAP costs are excluded). Returns to labour and DAP are negative.

Table 3. Farmers' Perceptions of Crop Establishment and Weeding Methods

Practice	Strengths	Weaknesses
Planting		
Rip or OPFP	Good emergence, labour saving, timeliness with moisture, better yields than farmer practice	Poor emergence with low soil moisture, early weed growth between crop rows
Third Furrow	Good emergence on poor moisture, good weed control especially in vlei	Poor emergence, uses extra seed for replanting
Weeding		
Hoc	Allows clean weeding, affordable	Labour intensive, back breaking
Cultivator	Timeliness, quick on inter-rows	Only efficient on small weeds
Plough	Smother small weeds, conserves moisture if ridges are tied, promotes drainage in vlei and vlei-margin	Crop damage, may cause erosion if ridges are not tied