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Weed growth and labor demand under hand-hoe based reduced tillage in smallholder farmers' fields in Zimbabwe

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ABSTRACT

Conservation agriculture based on hand hoe dug planting basins has been widely promoted for the last decade or two in the smallholder farming sector of southern Africa targeting resource constrained households without access to draft power. In Zimbabwe planting basins are used by about one hundred thousand households but on small plots (<0.5 ha) although most are unable to adopt soil surface mulching and crop rotation due to competing uses for crop residues as livestock feed and poorly developed markets for other crops, respectively. We report on the effects of reduced tillage based on hand-hoe dug planting basins (PB) on weed growth (20 farms), and labor demand and returns to investment (50 farms) compared with animal-drawn mouldboard plough based conventional tillage (CONV) in maize (*Zea mays* L.) fields, across selected districts located in contrasting agro-ecological zones in Zimbabwe. Weed growth was assessed through a survey conducted at the end of the 2009/10 and 2010/11 cropping seasons. Labor demand and returns to investment were measured on 50 farms across five districts using direct observations during the 2011/12 cropping season. The survey showed that farmers on average weeded their PB plots 2.7 times per season compared to 1.7–1.9 times in CONV plots ($P < 0.001$), and timing was often delayed in the former. Reduced tillage plots had 17% ($P < 0.001$) more weed ground cover and 9% ($P < 0.05$) more weed dry matter compared with CONV plots in the 2009/10 season, and differences in 2010/11 were not significant. Weed growth was highest in semi-arid areas (natural regions III and IV) compared with wetter sub-humid areas (natural region II) and arid areas (natural region V). Farmers planted their PB plots 12–23 days earlier, weeding frequency was 42.1–58.9% higher in PB plots, compared with CONV. Labor demand was more than double under PB (84.7 man days ha^{-1}, weeding 48.1 man days ha^{-1}) compared to CONV (38.6 man days ha^{-1}). However, returns to investment were 42.7% higher under PB (U$1.77) compared with CONV (U$1.24). Weed growth and labor demand remained high under PB tillage even after several years, interventions such as the use of alternative weed control methods need to be introduced to farmers to reduce labor demand and consequently increase its adoption both in terms of number of farmers and cultivated area in southern Africa.

1. Introduction

The lack of effective weed management strategies by resource-poor smallholder farmers in southern Africa may be one of the main constraints to increasing crop productivity through conservation agriculture (CA). The CA package currently being promoted in southern Africa comprises continuous minimum tillage, at least 30% permanent or semi-permanent organic soil cover and the cultivation of a wide range of crops in a spatial or temporal crop association/sequence/rotation (Kassam and Friedrich, 2011; Nyamangara et al., 2013). Manual minimum tillage systems, such as hand hoe dug planting basins (PB), that are currently being promoted in southern Africa as part of CA have been reported to increase crop yields by 30–120% on farmers' fields in Zambia (Haggblade and Tembo, 2003) and in Zimbabwe (Mazvimavi and Twomlow, 2009). However, farmers still have a larger proportion of their planted fields under conventional mouldboard tillage (CONV) (Baudron et al., 2007; Mazvimavi and Twomlow, 2009) and purportedly under CA; only the reduced tillage principle is followed by most farmers (Mazvimavi et al., 2008).

Labor limitations, especially for weeding, and low levels of mechanization for both land preparation and weeding have been

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reported to lead to a reduction in the area under cultivation by up to 50% in sub Saharan Africa (SSA) (Kent et al., 2001; Bishop-Sambrook, 2003). It is, therefore, not surprising that minimum tillage systems such as PB are found on less than one hectare of most smallholder farming households in southern Africa (Baudron et al., 2007; Mazvimavi and Twomlow, 2009) despite their potential to increase and sustain crop yields. The PB method has been reported to increase returns to investment in labor by up to 40% compared with conventional tillage (CONV) (Mazvimavi et al., 2008). However, the use of planting basins often requires significantly higher investment in time in comparison with CONV for land preparation and hand-hoe weeding, especially in the first three years (Mazvimavi et al., 2008). In the first year, when the soil is still compacted, digging planting basins using the hand hoe has been reported to require up to 30 labor days per hectare (Mazvimavi et al., 2008) and this is coupled with over two-fold increase in weed biomass (Mashingaidze et al., 2012) compared with CONV. In the second year onwards the time required for preparing the planting basins can decrease by up to 16% probably as a result of farmers mastering the technique (Mazvimavi et al., 2008).

Without soil inversion in minimum tillage systems, most weed seeds are maintained at the soil surface where conditions are conducive for weed seed germination (Chauhan et al., 2006). However, with intensive management which includes eradicating weeds before they set seed, the weed population in CA will diminish over time as seed deposition into the seed bank lessens (Wall, 2007; Baraibar et al., 2009). The weed seed bank also declines as seed left near or on the surface is also lost through mortality caused by diseases, predators and aging (Baraibar et al., 2009; Schultz, 2011). With conventional tillage, especially mouldboard ploughing, redistribution of weed seeds occurs where they are either buried (as such the soil seed bank persists) or are brought to the surface (Baraibar et al., 2009) resulting in an initial weed flush at the start of the season. The Zimbabwean CA Taskforce recommends that fields be weeded as soon as weeds appear to prevent them from setting seeds and replenishing the soil weed seed bank (Twomlow et al., 2008). Similarly in Zambia, promoters recommend up to six operations using the hand hoes each cropping season to achieve timely weed control (Baudron et al., 2007). These operations include manual weeding before and after crop harvesting periods, during which the majority of smallholder farmers do not normally carry out weeding even if labor is available. There are, however, other options in weed management within CA such as crop rotations that suppress weed growth, smothering weeds by the use of green mulch cover crops and crop residue mulching and the use of herbicides have been used successfully in the region (Barberi, 2003; Ngwira et al., 2012).

From 2004 to 2011 the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) provided technical assistance to various non-governmental organizations (NGOs), the national extension service involved in the promotion of CA and based on the manual PB tillage system in Zimbabwe under the Protracted Relief Program (PRP). ICRISAT was also tasked by the PRP and Food and Agricultural Organisation of the United Nations (FAO) with assessing the impact of the input program. This was done by conducting annual panel surveys from 2006/7 to 2010/11 seasons and data collected included both biophysical and socio-economic challenges and opportunities faced by the households receiving inputs from the relief program. Each household was encouraged to establish paired PB and CONV plots so that they could compare the performance of the tillage systems in terms of crop establishment, growth and yield as well as qualitative weed growth and dynamics. The management of paired plots was greatly dependent on farmer resource endowments; however there were cases where farmers applied similar management to both plots and these farmers were selected for the study.

Table 1
Number of farmers with PB[a] and CONV[b] tillage fields that were under the same crop species during the 2009/10 cropping season in the 10 districts in Zimbabwe.

District	Natural region	Crop		Total number of farmers
		Maize	Sorghum	
Mt. Darwin	II	4	0	4
Chirumhanzu	III	1	0	1
Masvingo	III	3	0	3
Gokwe South	III	3	0	3
Binga	IV	0	3	3
Insiza	IV	1	1	2
Hwange	IV	2	0	2
Nkayi	IV	2	0	2
Chivi	V	3	0	3
Nyanga	V	1	0	1
Total		20	4	24

[a] Planting basin-based conservation agriculture.
[b] Conventionally tilled (animal-drawn mouldboard ploughing).

During 2009/10 and 2010/11 panel surveys, quantitative weed growth measurements in terms of ground coverage and dry matter yield were taken from the paired plots that compared the CONV and the PB systems. In 2011/12 larger plots were established in selected districts in order to measure labor demand by direct observations and returns to investment between the two tillage systems. The objective of this study was to assess weed growth between the two tillage systems in 2009/10 and 2010/11 cropping seasons, and labor demand and returns to investment in 2011/12 season using the panel survey data.

2. Materials and methods

2.1. Location

During March/April 2010 and May/June 2011, panel studies were conducted in 15 districts (450 households) in contrasting agro-ecological natural regions as part of the annual CA panel survey. In 2011, an extra five districts (150 households) were included in the survey in order to capture better endowed farmers who had been recently exposed to CA through other programs. However, because at the majority of households the paired PB and CONV plots did not have the same crops and that fertilizer rates were different, these were excluded in the weed data analysis. As maize (*Zea mays* L.) was the dominant crop grown, the study focused the weed and crop yields assessment on 20 paired plots (9 districts) in 2009/10 (Table 1) and 18 paired plots (8 districts) in 2010/11(Table 2) that were under maize.

Table 2
Number of farmers with PB[a] and CONV[b] tillage fields that were under the same crop species during the 2010/11 cropping season in 9 districts of Zimbabwe.

District	Natural region	Crop			Total farmers
		Maize	Sorghum	Pearl millet	
Guruve	II	1	0	0	1
Masvingo	III	4	0	0	4
Insiza	IV	1	0	0	1
Hwange	IV	3	0	0	3
Nkayi	IV	1	0	0	1
Zaka	IV	1	0	0	1
Mangwe	V	3	0	0	3
Nyanga	V	4	0	0	4
Chipinge	V	0	7	1	8
Total		18	7	1	26

[a] Planting basin-based conservation agriculture.
[b] Conventionally tilled (animal-drawn mouldboard ploughing).