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Effect of minimum tillage and mulching on maize (*Zea mays* L.) yield and water content of clayey and sandy soils

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Abstract

Rainfed smallholder agriculture in semi-arid areas of southern Africa is subject to numerous constraints. These include low rainfall with high spatial and temporal variability, and significant loss of soil water through evaporation. An experiment was established at Matopos Research Station, Zimbabwe, to determine the effect of mulching and minimum tillage on maize (*Zea mays* L.) yield and soil water content. The experiment was run for two years at two sites: clay (Matopos Research Station fields) and sand (Lucydale fields) soils, in a 7×3 factorial combination of mulch rates (0, 0.5, 1, 2, 4, 8 and 10 t ha^{-1}) and tillage methods (planting basins, ripper tine and conventional plough). Each treatment was replicated three times at each site in a split plot design. Maize residue was applied as mulch before tillage operations. Two maize varieties, a hybrid (SC 403) and an open pollinated variety (ZM 421), were planted. Maize yield and soil water content (0–30 and 30–60 cm depth) were measured under each treatment. On both soil types, neither mulching nor tillage method had a significant effect on maize grain yield. Tillage methods significantly influenced stover production with planting basins giving the highest stover yield (1.1 t ha^{-1}) on sandy soil and conventional ploughing giving 3.6 t ha^{-1} on clay soil during the first season. The three tillage methods had no significant effect on seasonal soil water content, although planting basins collected more rainwater during the first half of the cropping period. Mulching improved soil water content in both soil types with maximum benefits observed at 4 t ha^{-1} of mulch. We conclude that, in the short term, minimum tillage on its own, or in combination with mulching, performs as well as the farmers' traditional practices of overall ploughing.

Keywords: Conservation agriculture; Minimum tillage; Mulching; Planting basin; Semi-arid

1. Introduction

Ninety-five percent of the current population growth occurs in developing countries and a large proportion of these people rely on rainfed food production (Rockstrom et al., 2003). Fifty-eight percent of the world's food production comes from rainfed agriculture (Rosegrant et al., 2002). Irrigation development assistance from major international donors has been on the decline over the years as a result of high capital costs, water scarcities, limited benefits to the poor rural communities and negative environmental impacts (Postel, 1989). Thus, food production and rural livelihoods will continue to rely on rainfed agriculture in the foreseeable future. The continued development of rainfed agriculture is a potential key to increasing food production in the semi-arid areas of sub-Saharan Africa (Rosegrant et al., 2002). To achieve this, water productivity and crop yields have to be improved in rainfed farming systems. Analysis of on-farm water balances in Sub-Saharan Africa indicates that there is a great potential to improve crop and water productivity in the region. There is an opportunity to redirect unproductive green and blue water flows to productive green water (crop transpiration) (Rockstrom et al., 1999). In view of this, several studies have been conducted on water and soil management in semi-arid regions (Nyamudeza et al., 1992; Klaij and

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Vauchad, 1992; Chuma, 1993; Twomlow and Dhliwayo, 1999; Twomlow and Bruneau, 2000; Rockstrom et al., 2003; Barron, 2004). Water harvesting techniques have the potential to improve water supply to crops in rainfed cropping systems.

Rainfall in semi-arid areas of Zimbabwe occurs from November to March followed by a cool to warm period from May to October. Rainfall is erratic and highly variable both spatially and temporally. Variations in semi-arid rainfall patterns also include delayed onset and premature end of the rainy season. The rainfall often occurs as high intensity, short duration convective storms (Nonner, 1997) giving rise to severe soil erosion especially early in the cropping season when the ground is still bare. Intra-seasonal dry spells during the cropping season have become a common feature and their impact on crop production is often severe, especially if they coincide with critical stages of crop development (Oosterhout, 1996; Rockstrom et al., 2003). In the semi-arid areas severe crop yield reductions due to dry spells occur once or twice in every five years (Rockstrom et al., 2002). The long-term annual average rainfall in southern Zimbabwe is 590 mm (Ncube, 2007) with an estimated 70–85% of rainfall lost through soil evaporation, surface runoff and deep percolation (Rockstrom, 2000).

Conservation tillage (no till and reduced tillage) practices simultaneously conserve soil and water resources, reduce farm energy usage and increase or stabilise crop production. These practices lead to positive changes in the physical, chemical and biological properties of a soil (Bescansa et al., 2006). Soil physical properties that are influenced by conservation tillage include bulk density, infiltration and water retention (Osunbitan et al., 2004). Improved infiltration of rainwater into the soil potentially increases water availability to plants, reduces surface runoff and improves groundwater recharge (Lipic et al., 2005). Reduced soil cultivation decreases farm energy requirements and overall farming costs as less area has to be tilled (Monzon et al., 2006). This is crucial for the semi-arid areas of Zimbabwe where draught animals are weak at a time when land preparation has to commence.

Infiltration and soil evaporation are among the key processes that determine soil water availability to crops in semi-arid agriculture. The presence of crop residue mulch at the soil-atmosphere interface has a direct influence on infiltration of rainwater into the soil and evaporation from the soil. Mulch cover reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil. Trials conducted in the higher potential areas of Zimbabwe between 1988 and 1995 indicated that mulching significantly reduced surface runoff and hence soil loss (Erenstein, 2002). Mulch cover shields the soil from solar radiation thereby reducing evaporation from the soil. Soil biota increase in a mulched soil environment thereby improving nutrient cycling and organic matter build up over a period of several years (Holland, 2004).

This study was established to determine initial maize (*Zea mays* L.) yield and soil water responses to minimum tillage and mulching on clayey and sandy soils and identify optimum rates of mulch application for low potential areas of southern Zimbabwe. This paper focuses on the initial maize yield and soil water responses to the establishment of three tillage and seven residue/mulching treatments under two different rainy seasons.

2. Materials and methods

2.1. Experimental sites

The experiment was run at the International Crops Research Institute for Semi-Arid Tropics (ICRISAT), Matopos Research Station, during 2004/05 and 2005/06 cropping seasons on two soil types, a clay and a granitic sand. The clay soil is located at the main Matopos experimental site (28°30.92′E, 20°23.32′S, 1344 m above sea level) and is classified as a shallow siallitic soil (4E.1) and Chromic–Leptic Cambisol according to the Zimbabwean and FAO systems, respectively (Moyo, 2001). The internal drainage of Matopos clay soil indicates saturation for short periods during the rainy season and external drainage is characterised by slow runoff (Moyo, 2001). The granitic sand is located at the Lucydale experimental site (28°24.46′E, 20°25.64′S, 1378 m above sea level) and is classified in the Zimbabwean system as moderately deep to deep well-drained fersiallitic soil (5G.2). This is classified as Eutric Arenosol (FAO, 1998). Internal drainage of Lucydale sand is rapid to very rapid and external drainage is characterised by slow runoff (Moyo, 2001). The chemical and physical properties of the two soil types are described in Table 1.

Matopos Research Station is located in Natural Farming Region IV, which is characterized by semi-arid climatic conditions with annual rainfall ranging between 450 and 650 mm. Rainfall season is unimodal and begins in November/December and ends in March/April. The long-term average rainfall for Matopos and Lucydale is 590 mm. The cropping season experiences periodic dry spells particularly in January. It is followed by a cool to warm dry season from May to September.

2.2. Experimental layout

The experiment was set up with a factorial treatment structure consisting of three tillage methods (conventional ploughing, ripping and planting basins) and seven rates of residue/mulch cover (0, 0.5, 1, 2, 4, 8 and 10 t ha^{-1}). Plots were pegged out in October of the first year, and then maintained in subsequent seasons. The treatments were arranged in a split-plot design with three replications at each site. The main plot factor was tillage (63×8 m) and seven mulch levels were randomly allocated in sub-plots (8×8 m) on each tillage treatment. Each plot was separated by a 1 m pathway to avoid movement of residue from