Research Application Summary

Effect of integrated water and nutrient management technologies on soil profile moisture content and grain water productivity in Zimbabwe

Mhaka, L.[1,2], Nyagumbo, I.[3] & Nyamugafata, P.[1]
[1]University of Zimbabwe, Department of Soil Science and Agriculture Engineering
P. O. Box MP 167, Mt Pleasant, Harare, Zimbabwe
[2]Chemistry and Soils Research Institute Department of Research and Specialist Services
5th Street Extension, P. O. Box 550 Causeway, Harare, Zimbabwe
[3]CIMMYT-International Maize and Wheat Improvement Centre, Southern Africa Regional Office
P. O. Box MP 163, Mt. Pleasant, Harare, Zimbabwe
Corresponding author: lukemhaka@yahoo.com

Abstract

This paper reports results of an on-farm experiment done to quantify soil moisture storage, water and water productivity of maize and soybean as affected by tillage and fertility management systems during 2009/2010 and 2010/2011 cropping seasons. The aim of the study was to investigate the effect of cattle manure and inorganic fertiliser (compound D) under tied ridging, conservation farming basins, conventional mould board plough, rip and potholing on soil profile moisture storage and water grain productivity. The results showed that there is no interaction between tillage system and fertility management options on determining water productivity and soil profile moisture storage. However tillage systems and fertility management options independently had an impact on water productivity while soil profile moisture storage was affected by tillage systems alone.

Key words: Fertility management, soil moisture, soil profile, tillage, water productivity

Résumé

Cet article présente les résultats d'une expérience menée dans une exploitation agricole pour quantifier l'accumulation en l'humidité dans les sols, l'eau et la productivité de l'eau du maïs et du soja telles que affectées par le labour du sol et les systèmes de gestion de la fertilité durant les saisons culturales 2009/2010 et 2010/2011. Le but de cette étude était de rechercher l'effet du fumier des bovins et des engrais inorganiques (composé D) sous le billonnage conditionnel, les bassins de l'agriculture de conservation, la charrue conventionnelle de l'ensemble de l'humus, la déchirure et la spéléologie sur l'accumulation en humidité du profil des sols et la productivité de l'eau dans les céréales. Les résultats ont montré qu'il n'y a pas d'interaction entre le système de labour

et les options de gestion de la fertilité sur la détermination de la productivité de l'eau et l'accumulation en humidité du profil des sols. Toutefois, les systèmes de labour et les options de gestion de la fertilité avaient indépendamment un impact sur la productivité de l'eau tandis que l'accumulation en humidité du profil des sols a été affectée seulement par les systèmes de labour.

Mots clés: Gestion de la fertilité, humidité du sol, profil du sol, labour, productivité de l'eau

Background

Poor soils, erratic rainfall, frequent dry spells and lack of irrigation infrastructure among others have been cited as the major threat to the growth of a sustainable agricultural system in Southern Africa (Kahinda, 2007). Most cropping seasons in sub Saharan Africa are characterised by mid-season dry spells which seriously reduce yield potential, making water the greatest limitation to crop productivity. There has been little improvement in crop production despite efforts to conserve soil water, which has necessitated further research on tillage and better land husbandry such as no-till to tackle problems of soil water deficits and soil degradation (Nyagumbo, 2008). In addition to low rainfall, soil nutrient deficiencies account for continued decline in smallholder maize production (Woomer and Swift, 1994). Whilst, use of inorganic fertilisers as an alternative is limited by prohibitive costs and general lack of availability (Scoones *et al.* 1996), use of organic mineral amendments is in turn limited by their poor quality and insufficient amounts (Mugwira, 1995**).** A situation that has left many smallholder farmers with limited options to sustain agricultural productivity (Mapfumo and Giller, 2001). Gaps still exist to explore benefits derived from synergizing water conservation and soil nutrient management options. This study was therefore carried out to investigate the effects of integrating different moisture conservation techniques and fertility management options on crop productivity.

Literature Summary

Conventional tillage has been blamed for the decline in soil fertility in Southern Africa with estimated annual loss of 536 kg ha^{-1} organic matter, 50kg ha^{-1} of nitrogen and 8 kg ha^{-1} phosphorus through sheet erosion (Elwell *et al.*, 1988). Apart from conserving soil loss, conservation agriculture (CA) has been shown to improve soil moisture retention; soil nutrient use efficiency thus can be used to achieve sustainable agricultural productivity. Research has shown an improvement in maize yield by 20-60% as a result of use of different water harvesting

techniques such as ripping and tied ridging when used in conjunction with CA (Morse, 1987).

Study Description

The study was done in Kadoma and Domboshawa during 2009/10 and 2010/11 agricultural seasons. Four maize and 3 soybean sites were set up in Kadoma while Domboshawa had one on-station maize site. The experiment design was a split plot consisting of four tillage main treatments replicated 3 times. Each tillage plot measuring 24m x 7m was split into 4 soil fertility subplots of the size 8 x 7 m. The tillage systems consisted of Tied ridges (TR), conservation farming basins (CFB), conventional moldboard plough (CT), rip and potholing (RP) as the main treatment. Fertility management options included 200kg/ha of compound (N, P, K- 7:14:7), 5 tones/ha of cattle manure and the control (no fertility amendment). Medium seasoned maize (Seed-Co 513) and soybean (savannah) varieties were planted with the first effective rains in November in both seasons, using seed rates of 25kg/ha seed with 60 x 90 cm plant spacing and 100kg/ha with plant spacing of 4-7cm and 45cm respectively. The first weeding was done before planting using pre-emergency herbicides while the second weeding was done at 8 week stages using mechanical means. While the maize was split top-dressed with ammonium nitrate at 4 and 8 week stage, the soybean seed was inoculated with *Bradyrhyzobium japonica* at the rate of 100g per 100kg of soybean seed before planting.

Post-planting tied ridging involved planting on mould board ploughed soil followed by construction of ridges along the crop rows and tying them at 2-3m intervals to trap run-off. In rip and pot holing planting rows were made on un-ploughed land using a magoye ripper and making in-row pot holes at 3 - 4m interval to trap runoff. Conservation farming basins measuring 15cm x 15cm x 15cm were made using a hoe at a spacing of 60cm x 45cm and crop residues were then applied at a rate of 2 tones ha^{-1}. The seed rate in the conservation basins was done at 12 seeds per basin. Weeding was done manually using a hoe twice during the rainy season.

Gravimetric moisture content was determined from 3 soil profile levels (i.e. 0-15cm, 15-30cm and 30-45cm) at 3 week interval throughout the season. The soil sampling was done using a marked augur and the samples were packaged in zip plastic and immediately taken to the laboratory for analysis. Gravimetric moisture determination was then achieved by oven drying the

soil samples at 105°C for 24 hours. Maize and soybean grain yield was determined from a check plot measuring 5 rows x 5m and grain moisture was corrected to 12.5%. Grain water productivity determined by measuring grain yield from each treatment and dividing the grain yield by the annual rain fall (kg/mm).

Data were subjected to analysis of variance (ANOVA) using GenStat Discovery Edition 3. Main effects were separated by least significant differences (LSD) at P = 0.05 level.

Findings

a. Soil profile moisture content. Tied ridging under soybean was found to be superior (p = 0.03) in conserving soil profile moisture with 10.9% and 17% moisture increase compared to conventional mouldboard plough, in the first and second season

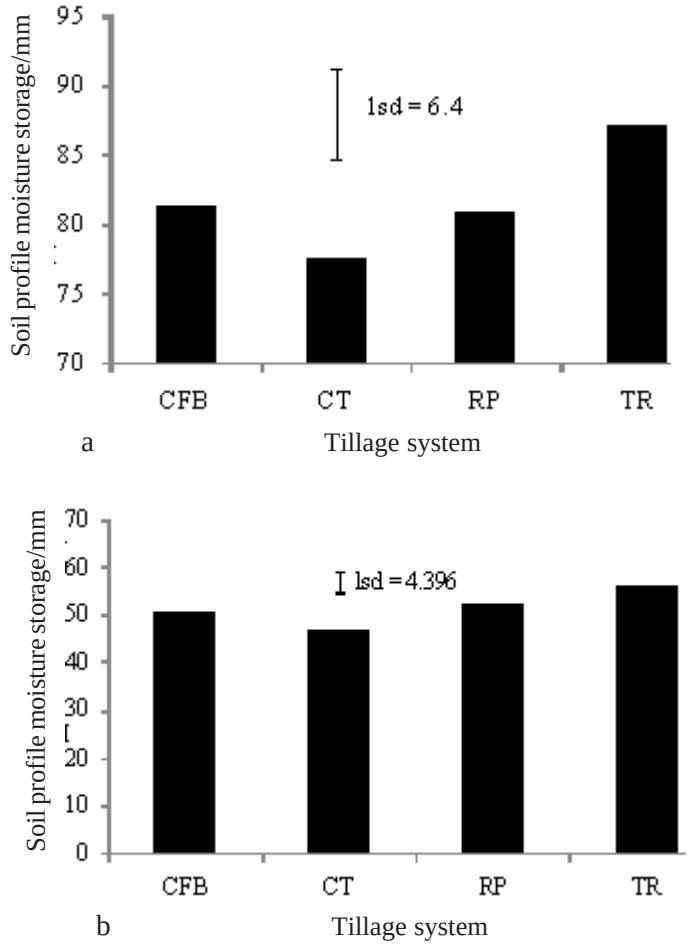

Figure 1. Effect of tillage systems under soybean on soil profile moisture storage during the, (a) first and (b) second agricultural seasons.

respectively. In addition rip and potholing had 10% and 10.8% increase in soil profile moisture content comparative to conservation farming basins and conventional mouldboard plough respectively. The high moisture content in tied ridging technique might be attributed to reduced run-off and increased infiltration due to the macro-catchment formed by the tied ridges. Conservation farming basins did not perform well as they were made late in November instead of August to make use of the early rains.

b. Grain yield water productivity. Water maize grain yield productivity was 27.2 % - 29.7% and 20.2% - 20.7% higher in combined compound D and cattle manure relative to the control and sole cattle manure. In addition inorganic compound D fertiliser recorded 19% higher grain water productivity relative to cattle manure. There was no additional grain water productivity benefit of combining inorganic and organic fertilisers from inorganic fertiliser sole application.

Soybean grain water productivity was considerably low in the control compared with compound D (N.P.K- 7:14:7) and compound D + Cattle manure across all sites in Kadoma in the 2009/10. Compound D + cattle manure had 24.5% and 38% higher grain water productivity than cattle manure and the control respectively at Jaricha site. In addition Soybean grain water productivity from conventional moldboard plough significantly decreased by 29% and 17.9% from compound D and cattle manure sole applications. Tillage also significantly affected ($p = 0.028$) soybean grain water productivity with tied ridging having 23.8% higher grain water productivity relative to conventional mould board plough.

Recommendation

The poor performance of CA might have been attributed to the late implementation of the basins which were done in November instead of August to take advantage of the first rains. Farmers are recommended to make use of the first rains by making the basins early to increase rain water use efficiency. Another observed loop hole in CA adoption is the scarcity of plant residue, hence farmers are advised to conserve crop residue for use in the conservation agriculture. Famers are also recommended to consider tied ridging as an alternative tillage practice as it proved to effectively conserve soil moisture for plant use. Given the low quality and quantity of organic manure and low capital to purchase inorganic fertilisers available to farmers; combined

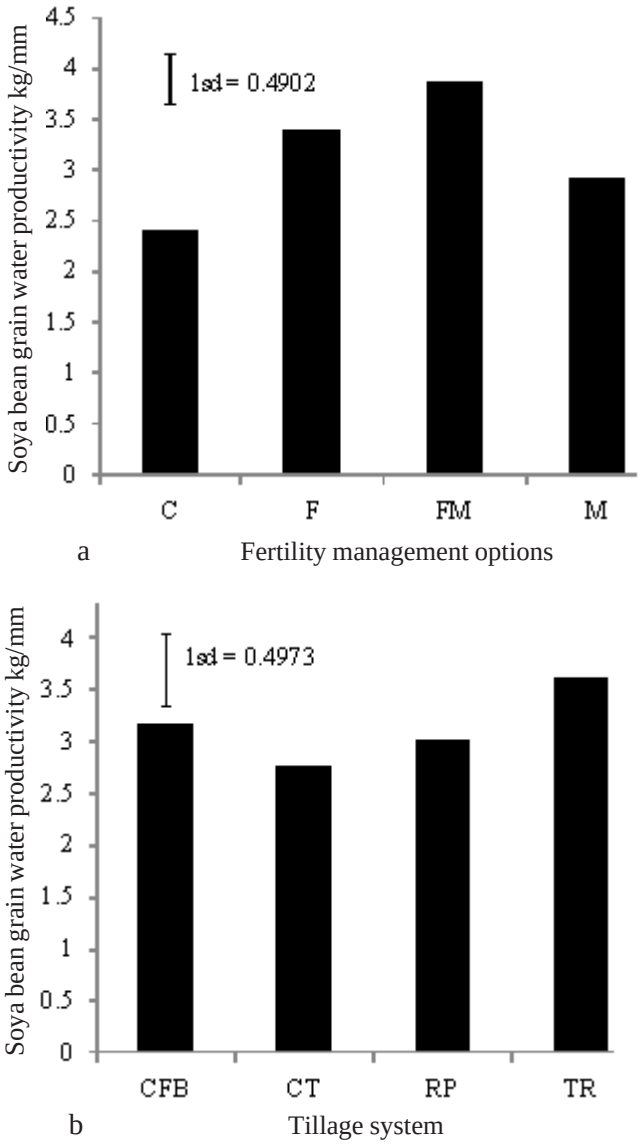

Figure 2. Effect of (a) soil fertility management systems and (b) tillage systems on soybean grain water productivity in Kadoma (2009/10 agricultural season).

C- unfertilised treatment(control), F –Inorganic compound D fertilizer, M- Cattle manure(5 t ha-1), FM- Inorganic + Cattle manure; CFB- Conservation farming basins, CT- Conventional mould board plough, TR – Tied Ridges, RP- Rip and potholing.

application of the two fertiliser resources should be recommended to smallholder farmers.

Acknowledgement

We thank farmers in Kadoma for hosting the experiments and RUFORUM for providing the funding that enabled the establishment of trials, payment of tuition, stipend and other research costs for the first author**.**

References

Elwell, H.A. and Norton. M.A. 1988. Loss of nutrients in sheet erosion in a major hidden cost. *Zimbabwe Science News* 22(7/8):83-85.

FAO, 1991. Soil Tillage in Africa: Needs and challenges. Okigwe, Nageria: College of Agriculrure and Veterinary Medicine.

Kahinda, Rockström, J., Akpofure, E., Taigbenu and Dimes, J. 2007. Rainwater harvesting to enhance water productivity of rainfed agriculture in the semi-arid Zimbabwe: International Crops Research Institute for the Semi-A Bulawayo, Zimbabwe.

Mapfumo, P. and Giller, K.E. 2001. Soil Fertility Management Strategies and Practices by Smallholder Farmers in Semi-Arid Areas of Zimbabwe. Bulawayo, Zimbabwe: International Crops Research Institute for the Semi-Arid Tropics (ICRISAT).

Mugwira, L. 1995. Effects of supplementing communal area manure with lime and fertiliser on the growth and nutrient uptake. *Zimbabwe Agricultural Journal* 105.

Morse, K. 1987. A Review of soil and water Management Research in Semi-Arid Areas of Sourthen and Eastern Africa. United Kingdom: Natural Research Institute.

Nyagumbo, I. 2002. Conservation agriculture for Sub Saharan Africa: Central Status and Trens. In: *International Workshop on Modernising Agriculture Visions and Technologies for Animal Traction and Conservation Agriculture* 23:23-25.

Nyagumbo, I. 2008. A Review of Expriences and Developments towards Conservation Agriculture and Related Systems in Zimbabwe. New York: World Association of Soil and Water Conservation.