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# Soil moisture content and maize grain yield under conventional and conservation agriculture practices - results of short term field tests in Iiselo, Namibia

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**This article focuses on the results from trials developed to monitor the short-term effects of conventionally tilled systems versus CA on soil quality and crop productivity under conditions of the major cropping systems in central, north-central and north-eastern regions of Namibia. Conventional tillage (CT), Minimum tillage (MT), Minimum tillage, mulch (MT-M), Minimum tillage, rotation (MT-R) and Minimum tillage, mulch and rotation (MT-MR) were the primary treatments tested. Significant differences ($p \leq 0.000$) among the treatments were observed in the 0-60 cm soil profiles where MT-M plots had the highest soil moisture content (39.8 mm, Standard Error of Mean 0.2815) over the study period. A significant difference ($p=0.0206$) in grain yield was observed in the second season with CT plots yielding the highest grain yield (3852.3 kg ha$^{-1}$, standard error of mean 240.35). Results suggest that CA has the potential to increase water conservation and contribute to reduction of the risk of crop failure. Climate change driven degradation under conventional tillage necessitate alternative sustainable tillage methods. Conservation tillage methods and conservation agricultural practices that minimize soil disturbance while maintaining soil cover need to be adopted more locally as viable alternatives to conventional tillage.**

**Key words:** Conservation agriculture, conventional tillage, grain yield, soil moisture content.

## INTRODUCTION

It is reported that in eastern and southern Africa, between 10 to 25% of rainwater is lost to runoff, and another 30 to 50% is lost through evaporation from unprotected soil surfaces (Rockström et al., 2001). Purcell et al. (2007) highlighted that soil moisture stress resulting from drought, dry spells and high moisture loss through

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**Table 1.** Site characteristics for Liselo research station.

| **Liselo research station** | |
|---|---|
| Elevatio (m asl): 964 | Climate: Hot, semi-arid |
| Annual mean temperature: 21.3°C | Annual mean rainfall: 600-700 mm |
| Soil texture class: Loamy sand to sand | |

Source: L.P Kudumo (2019); After CYMMIT (2016)

evaporation is one of the primary limiting factors in crop production as it affects many plant biochemical and physiological processes. Due to climate change, mitigation has become more of a need in agriculture as erratic weather patterns are projected to become increasingly worse (Rowswell and Fairhurst, 2011). Tillage is the preparation of the soil for the production of crops for human consumption, animal feed and/or for the improvement of the soil. It is known to influence soil physical properties such as soil hydraulic properties, change flow path, rate of water infiltration and percolation and the stability of the biotic factors (Dexter, 1988). Tillage methods (Fuentes et al., 2003) and climatic factors, especially rainfall distribution and reliability (Fowler and Rockstrom, 2001) influence available soil moisture which is key for plant growth, development and soil physical properties. Conventional tillage (CT) is the most common practice used among small holder farmers and has been practiced for a long time (Chen et al., 2011). However, CT is reported to be unsustainable over the long term in more intensive production setup as it contributes to inefficient natural resource use, poor soil water retention, soil degradation and global warming (Ferna´ndez et al., 2009). Conservation agriculture (CA), on the other hand is a crop management system based on three principles of minimal soil disturbance, crop rotation or intercropping and permanent soil cover with crop residues or growing plants (Friedrich et al. 2012). CA is a less energy intensive system as compared to CT and can improve crop yields while conserving water/moisture, eliminate organic matter loss, and reduce erosion among others (Dumanski et al., 2006). For sustainable and increased agricultural crop productivity, it is critical that good maintenance and improvement of soil quality is undertaken (Fourie et al., 2007) and thus the conservation of natural resources in recent decades has developed into a key global objective and a major national aim for Namibia as well. The objective of the study was to document and compare the effects of different tillage systems (CT and CA) and the influence of the individual CA principles on soil moisture and crop yield. The hypotheses tested were that (a) CA treatments have significant higher water infiltration and soil moisture content (b) the CA principles (minimum tillage, soil cover and crop rotation or intercropping) have significant influence on soil moisture content eventually leading to greater crop productivity.

## MATERIALS AND METHODS

### Site characteristics

Liselo Research Station (17.524745°S; 24.238707°E) located in the Zambezi Region of Namibia was the site of the experiment. The station is situated 7 km west of Katima Mulilo, 964m above mean sea level in a hot, sub-humid region with mean annual temperature of 21.3°C and mean annual rainfall of 600-700 mm. The site predominantly has loamy sand to sand with pH of 5.3 (Table 1).

### Experimental design

The experiment consisted of eight treatments in a Randomized Complete Block Design (RCBD) set-up with four replications on a 2016 $m^2$ trial plot (50.4m x 48m). Treatments tested were; Conventional tillage only (CP), Convectional Tillage with Mulch (CP-M), Conventional Tillage with Rotation (CP-R), Conventional Tillage with mulch and Rotation (CP-MR), Minimum tillage (MT), Minimum tillage, mulch (MT-M), Minimum tillage, rotation (MT-R) and Minimum tillage, mulch and rotation (MT-MR). Each plot was composed of 7 rows (90 cm row spacing and 35 cm within row) by 12 m and plots with rotation were split into subplots each with 7 rows by 6 m. CT plots were tilled with an animal drawn mouldboard plough, while CA/minimum-tillage plots were tilled with an animal drawn Magoye ripper, opening narrow furrows about 5-10 cm deep.

### Soil fertility test

Soil samples were taken at the onset of the study and tested the levels of nitrogen and phosphorous, Organic C, estimated SOM and pH for comparison against suggested nutrient ranges suitable for grains. Soil samples were tested using spectral analysis by a mobile Soil Lab stationed at the Directorate of Agricultural Production, Extension and Engineering Services (DAPEES) office Of the Ministry of Agriculture, Water and Land Reform (MAWLR) of the Republic of Namibia in the town of Rundu in the Kavango East region.

### Seeding and weed management

Maize (*Zea mays*, Commercial hybrid maize variety Zamseed 606) was the principal crop and cowpea (*Vigna unguiculata* L. Walp.) an important secondary crop used in rotation with maize. The maize and cowpea crop varieties were manually seeded in November during both cropping seasons. Maize was seeded in rows spaced 90 cm apart with inter row spacing of 35 cm using two seeds per planting station, later thinned to 1 plant (31,746 plants/ha target

**Table 2.** Site characteristics for Liselo research station.

| Characteristics | Suggested range for grains | Found at LRS |
|---|---|---|
| N (g $kg^{-1}$) | 1.0- 2.0 | 0.48 |
| P (g $kg^{-1}$) | 0.2 - 0.6 | <0.1 |
| K (g $kg^{-1}$) | 1.5 - 3.0 | 2.2 |
| Organic C (g $kg^{-1}$) | 17 - 50 | 6.9 |
| Estimated SOM (%)* | 2.9 - 8.6 | 1.2 |
| pH | 4.9 - 6.4 | 5.3 |

Soil Cares (2007, www.soilcares.com) provided the suggested range for grains is based on soil analysis. N = NItrogent; P = Phosphorus; K = Potasium; C= Carbon; SOM = Soil Organic Matter. N= 24 at Liselo Research Station. *Soil Organic matter is estimated based on a conversion factor of 1.72 [Soil organic matter=58%C].
Source: Soil cares (2007)

population). Rotational crop, commercial cowpea variety BIRA was manually seeded in rows spaced 45 cm apart and inter row spaced 25 cm, with two seeds per planting station thinned to 1 plant. Basal fertilizer, NPK (2:3:2) was applied at a rate of 150 kg/ ha to only maize plots. A Split application of Urea at a rate of (150 kg $ha^{-1}$) was applied as top dressing to only maize plots.

Treatments with cowpea rotation were mulched with 2.5-3 t/ha of grass at the onset and all crop residues retained on the soil surface in the subsequent seasons after harvesting. Weed control was achieved by disturbing only the top soil using a hoe at 30 day intervals and when necessary. At harvest, cobs were removed from the plots and crop residues (Stover) was retained on the respective CA and CT treatments.

### Data collection

#### *Soil moisture content data collection*

Access tubes were installed in all plots for the purpose of soil moisture data collection, one tube installed per plot and readings taken using a capacitance probe (PR-2 probes, Delta-T Devices Ltd., UK) to the depth of 1 m. Soil moisture measurements were taken once a week during the dry season (May – October) and twice per week during the rainy season (November – April) and calculated as mean soil moisture content in millimeters (mm). Data from the 0-10, 10-20, 20-30, 30-40 and 40-60 cm horizons were recorded over the study period, calculated and presented as mean soil moisture content (mm) in the 0-30cm and 0-60 cm soil depths.

#### *Harvest data collection*

Maize was harvested at physiological maturity and total above-ground biomass and grain yield determined on each plot. Sub-samples of 20 cobs per plot were taken as samples and used to determine maize grain moisture.

#### *Statistical data analysis*

Linear model, Analysis of variance (ANOVA) using Statistical analysis software 'Statistix 9' for personal computers was used to test for normality and test for any significant difference in moisture content and grain yield. Probability levels of 0.05 were used to determine the level of significance among the means. LSD All-Pair wise Comparisons Test was used to compare soil moisture and grain yield for treatment effect. The next section presents the results.

## RESULTS AND DISCUSSION

### Soil nutrient levels

Soil testing results showed low levels of nitrogen and phosphorous, organic carbon, and estimated SOM, readings far below the suggested range for grains. Only potassium and Soil pH fell within the suggested range for grains (Table 2).

### Soil moisture content

Rainfall in the 2016/17 cropping season was erratic with a short rainy season with the site receiving a total of 499.9 mm/a. A two week and six day dry spell was experienced during the first season between February 2nd and 22nd, 2017.

In the subsequent season (2017/18), a higher total rainfall of 521 mm/ was recorded although the rainfall events during the season were similarly erratic with especially low rain incidences at the onset of the season (Figure 1). Over the study period, MT-M continuously had the highest soil moisture content, particularly in March (69.0 mm), while MT-MR was almost consistently the least soil water storing treatment over both the rainy and the dry seasons in the two years (Figure 1). Conservation agriculture is reported to be most effective when all its three operational principles are put into practice accompanied by good timing of all operations (ZCATF, 2009). Although all CA principles were applied in MT-MR, the results in terms of soil moisture conservation are at variance with expected impact of this treatment. CA is taken to be a long term intervention, as most benefits especially improvement of the soil's physical properties

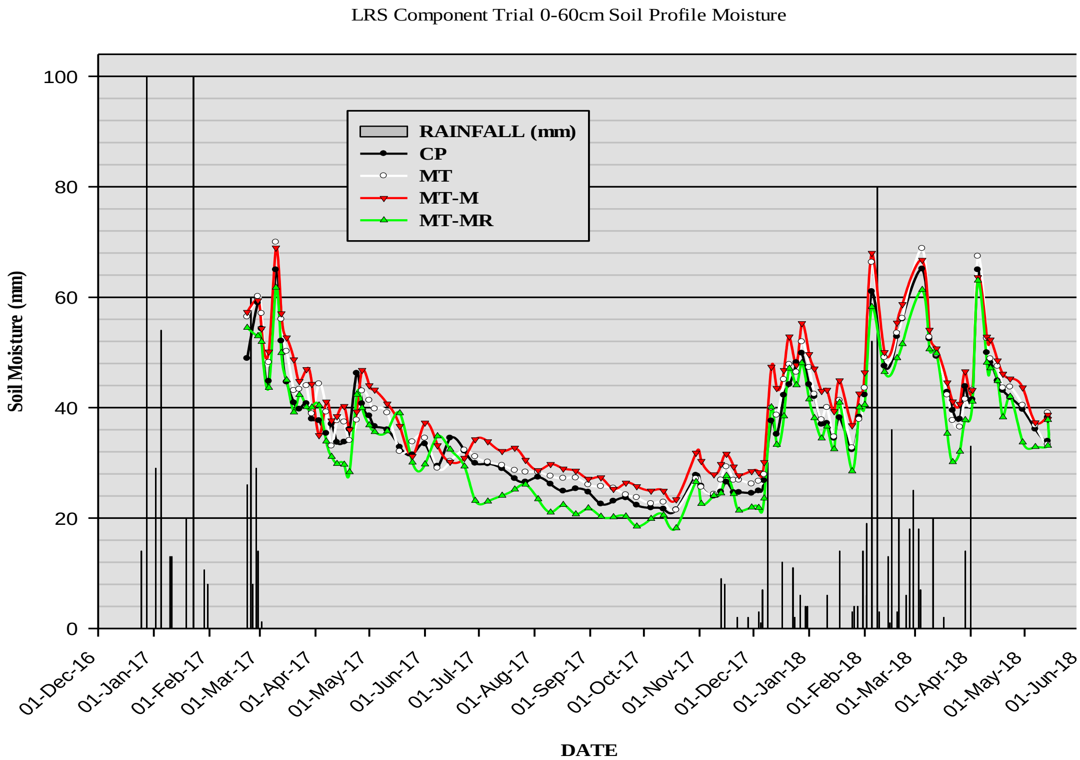



**Figure 1.** Seasonal soil moisture content comparison of treatments in the 0-60cm soil depth of the Component Trial at LRS.
Source: L.P Kudumo (2019)

are though only enjoyed in the longer term (Derpsch, 1999), 4-5 years after application of such soil tillage system (Thierfelder et al., 2015). It is probable that the two years implementation of CA treatments was insufficient to reverse effects of many years of conventional tillage on the land. The fact that MT-MR showed differences from other CA plots could possibly be due to a reduction in soil water holding capacity of non-tilled plots induced by openings in the soil left by decaying roots of crops and weeds or the effective extraction, use and evaporation of water by crops in the MT-MR plots.

Significant differences (p=0.000) were observed between combinations of tillage systems and CA principles in relation to soil moisture content, in agreement with findings by Fuentes et al. (2003) and Gicheru et al. (2004). Mean soil moisture content ranged from 34.1 to 39.9 mm, with minimum tilled plots higher in moisture content than CT plots. The observed differences may be attributed to the water saving techniques incorporated in the treatments particularly in MT-M (39.8mm) and MT (37.7mm) plots while CT only plots were on the lower end as the second least water conserving treatment (36.1mm). A CA treatment with all principles incorporated, MT-MR, was the least water storing treatment of all plots (Table 1). McVay et al. (2006) and Thierfelder and Wall (2010) reported that conservation agriculture plots generally have greater water content in years with low precipitation, as was recorded in this study carried out in years in which rainfall below the annual mean was recorded. In years of high precipitation, no greater differences are found between CA and CT plots (Thierfelder and Wall, 2010). While it's unexpected, plots where all CA principles are incorporated are sometimes found to retain lower soil moisture content than a field ploughed, not mulched and with no crop rotation. No-till treatments may reduce water-holding capacity leading to reduced moisture (Liu et al., 2013).

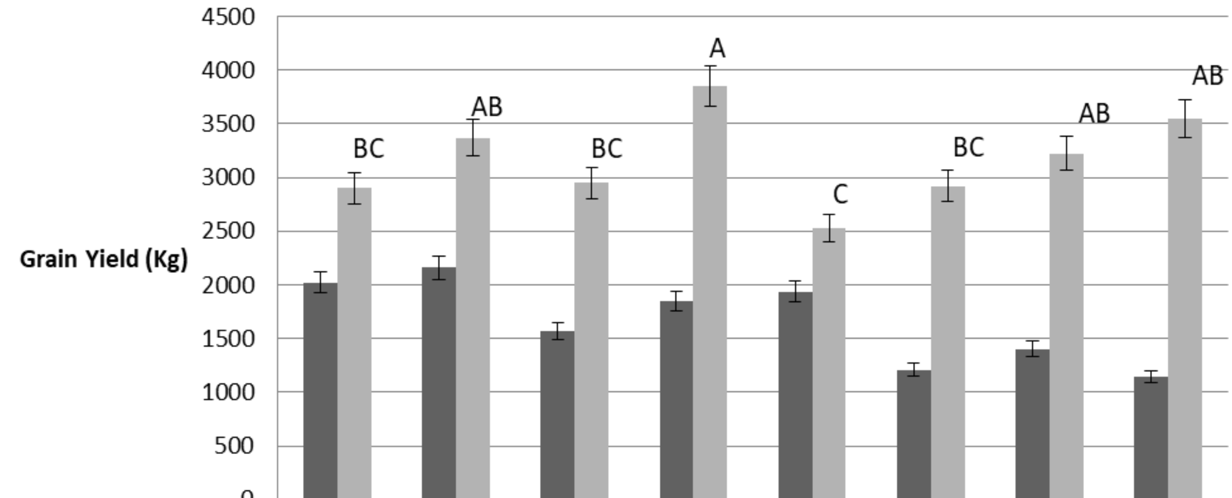
## Maize grain yields

Maize grain yield in the first season was not significantly affected (p=0.0884) by tillage systems and CA principles, however significant difference (p=0.0206) was recorded in the subsequent season (Table 3). CT-MR plots recorded the highest grain yield with MT being the least productive. Minimum tillage with selective incorporation of CA principles increased maize grain yields. It appeared

**Table 3.** Soil moisture in the 0-60 cm deep soil profile at Liselo.

| Treatment | CT | CT-M | CT-R | CT-MR | MT | MT-M | MT-R | MT-MR | P |
|---|---|---|---|---|---|---|---|---|---|
| Mean soil moisture content (mm) | 36.1$^{D}$ | 37.2$^{BC}$ | 35.1$^{E}$ | 36.9$^{CD}$ | 37.7$^{B}$ | 39.8$^{A}$ | 36.9$^{BCD}$ | 34.1$^{F}$ | 0 |

Source: L.P Kudumo (2019)




| Treatments | CT | CT-M | CT-R | CT-MR | MT | MT-M | MT-R | MT-MR |
|---|---|---|---|---|---|---|---|---|
| 2016/17 | 2023.5 | 2160.3 | 1570 | 1846.5 | 1937.3 | 1206.8 | 1404 | 1142.3 |
| 2017/18 | 2899.5 | 3371.8 | 2948.3 | 3852.3 | 2524 | 2920 | 3225 | 3550.8 |

**Figure 2.** Maize yield at Liselo Research Station for 2016/17 – 2017/18 cropping season.
Source: L.P Kudumo (2019)

that incorporation of mulch or rotation to minimum tillage leads to increased maize yields as observed MT to MT-M and MT to MT-R, respectively (Table 3). It was also observed that incorporation of both mulch and rotation led to the highest increase in yield from MT to MT-MR.

Maize grain yields were found to follow no particular order over the two seasons. Minimum tillage treatments averaged less than 1500 kg ha$^{-1}$ maize grain yield in the first season and more than 2500 kg ha$^{-1}$ in the second season (Figure 2).

Although no significant difference (p=0.0884) was observed in the first season, conventional tillage treatments were found to have yielded more maize grain than minimum tillage treatments, indicating the benefit of CT in the first season.

Maize grain yield followed the order CT-MR > MT-MR >CT-M > MT-R >CT-R > MT-M >CT>MT in the second season during which soil moisture was not very different between treatments (Figures 1 and 2). Higher soil moisture due to mulch appears to have positively influenced maize grain yield, as seen in the second season, where MT-MR delivered the highest maize grain yield of all the CA treatments and second highest overall in contrast, to the first season. MT-M and MT in that order had higher soil moisture content than conventional tillage treatments, but their maize grain yields were generally lower than that of CT (Figures 1 and 2). Mulched plots, CT-MR, MT-MR, CT-M and MT-M generally had higher maize grain yields than plots not mulched. Thus, whereas MT-MR may have recorded lower soil moisture content relative to all other treatments, this did not translate into lowered maize grain yield. This may point to effective and efficient use of soil moisture by maize under MT-MR where the crop extracted more soil water and converted it into higher yield.

## Conclusion

The results indicated that minimum tillage systems conserve more soil moisture in the 0-60 cm deep soil profile and can improve maize grain yield as compared to traditional tillage. Even where soil moisture may have not been conserved in CA plots, the grain yield was superior.

Generally, CA (Minimum tillage) treatments had higher mean soil moisture as compared to CT (conventional tillage) treatments throughout the study period, especially over dry season.

Application of mulch and crop rotation appeared to positively influence both mean soil moisture and maize grain yield over the study period compared to no mulching and, not practicing rotation.

Yields followed the order CT-MR > MT-MR >CT-M > MT-M >CT>CT-R >MT-R >MT clearly showing mulch's influence on crop yield. This study has in part shown that reduced soil disturbance and residue mulch application can conserve soil moisture, and when implemented together with crop rotation practices enhance crop performance and improve maize production in the north-eastern regions of Namibia.

## CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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