Effects of conventional and conservation tillage on soil compaction in Omuntele and Ogongo constituencies of Namibia

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Introduction

This study was part of a wider study that compared the differences between two conventional tillage (CV) treatments (i.e. tractor-drawn disc harrow (TDH) and animal-drawn mouldboard plough (AMP) and two Namibia Specific Conservation Tillage (NSCT) treatments (tractor-drawn ripper furrower (TRF) and animal-drawn ripper furrower (ARF). The objective was to measure penetration resistance in the farmers' pearl millet fields in two Constituencies (Ogongo and Omuntele) in order to complement the on-station trials. Thirteen farmers were targeted because they used the NSCT technology in their fields. The NSCT technology was introduced into the Northern Communal Areas (NCA) of Namibia as a way of ameliorating the negative impacts of the conventional tillage (CV) methods traditionally used by farmers in the region. The NSCT technology is a method that uses animal-drawn and tractor-drawn ripper-furrowers to rip and make furrows in one operation and emphasizes the use of ripper furrowers in place of mouldboard and disk ploughs and also emphasizes incorporation of mulch, manure and crop rotations as explained in detail by Mudamburi (2016) and Mudamburi *et al*. (2018). Results of trials carried out by Mudamburi (2016) and Mudamburi *et al*. (2018) under on-station field conditions at Ogongo in the NCA showed that the NSCT technologies resulted in better agronomical and technical performances (higher yields, more moisture, lower penetration resistance (PR), better effective field capacities, and reduced specific draught forces) compared to the CV technologies. For this study there are significant differences (p=0.030) between NSCT and CV for Omuntele farmers' fields. NSCT actually reduced compaction in the farmers' fields.

Materials and methods

In order to be able to compare CV and NSCT technologies on soil compaction in Namibia, a study to collect penetration resistance measurements on farmers' fields was carried out in Ogongo Constituency of Omusati Region and Omuntele Constituency of Oshikoto Region between 2012 and 2013. There were nine farmers from Omuntele and 4 farmers from Ogongo. The soils in the farmers' fields were sandy soils. A cone penetrometer (hand-held, Eijelkamp) was used to measure penetration resistance following the recommendation of ASABE (2006). The cone penetrometer has a base area of 2 cm² and a diameter of 15.96 mm. Penetration resistances were measured in 10 cm increments starting at 10 cm to greater than 20cm at ten randomly selected places in the two middle rows of farmer's fields that were conventionally tilled and those where the NSCT was practiced. The resistance was read in N (Newtons) and noted for the corresponding depth in the soil profile. The penetration resistance was calculated using the following equation 1:

$$PR = \frac{\text{Manometer reading (N)}}{\text{Base area of cone (m}^2\text{)}} \quad (1)$$

Where: PR = penetration resistance in N/m^2 and reported in MPa

Analysis of variance (ANOVA) using Genstat was used to test for any significant differences in penetration resistance among NSCT and CV methods. Probability levels of 0.05 were used to determine the level of significance among the means.

Results and discussion

On-Farm Penetration Resistance in Omuntele and Ogongo Farmers' Fields

The PR measurements were taken on fields of Omuntele and Ogongo farmers. There are significant differences (p=0.030) between NSCT and CV for Omuntele farmers' fields. Only 3 of the 9 farmers (33%) had fields with PR values less than 2 MPa. The maximum penetration in the NSCT fields of two out of the nine (22%) farmers was between 15 and 16 cm, and in the CV fields of seven of the nine (78%) farmers, the maximum penetration was between 8 and 18 cm. Six of the nine (67%) farmers had fields with PR above 2 MPa under NSCT only. The PR values of the NSCT fields of eight of the nine (89%) farmers were lower than the PR values under CV. The PR values of the CV plots of all nine farmers were above 2 MPa. In Ogongo all of the four sampled farmers' fields had maximum penetration at 15 cm and less than 15 cm. Only one farmer out of the four had PR values less than 2 MPa; the other three had PR values greater than 3 MPa. This suggests that most of the farmers could have problems of root penetration in their fields, as predicted by Atwell (1993) and So *et al.* (2009). They predicted 2 MPa as the critical upper value above which root growth is severely impeded. However all four sampled fields had lower PR levels under NSCT than under CV.

The results for both constituencies were further analysed by dividing the farmers into 2 groups, one, with fields with highest maximum penetration and the other group with lower penetration depth as shown in Tables 1 and 2. Table 1 shows mean Penetration resistance for five farmers' fields with unlimited penetrometer depth that CV has significantly high mean penetration resistance (p=0.002) whilst the opposite is true for mean maximum penetration, NSCT has a higher mean. NSCT has lower PR than CV and also shows that CV contributed to increase in PR. This shows that NSCT actually reduced compaction in the fields. All the farmers in this group are from Omuntele constituency.

Table 2 shows mean penetration resistance for eight farmers' fields only with lower maximum penetrometer depth and there are no significant differences in mean penetration resistance between CV and NSCT (p=0.365) however NSCT has a significantly higher mean maximum (p=0.026). Four out of the five farmers in this category were all from Ogongo constituency and all the fields had limited penetrometer depths. It is possible that the fields of the sample of farmers from Ogongo had hard pans. It could also be because the farmers used the animal-drawn ripper furrower that does not penetrate as deep as the tractor ripper furrower.

All PR values for NSCT methods in some of the farmers' fields were less than 4 MPa. NSCT methods had lower PR than CV methods and 31% (n=13) had PR values that are less than 2 MPa showing that the fields for the rest of the farmers (69%) could have problems of soil compaction. From this study it was thus apparent that the more flexible approach of 2–5 MPa as specified by Lampurlanes and Cantero-Martinez (2003) could be used as the critical limits above which root growth is severely impeded, as roots continued to grow and high yields were achieved in the overall study for all the tillage methods. This suggests that it is important to check how far the roots of a particular crop can penetrate, so the implement depth may be adjusted to cater for the root length of the crop.

Overall NSCT methods resulted in lower PR than the CV methods showing that the NSCT methods contributed to better reduction in soil compaction. The tractor-drawn ripper-furrower can be used to reduce soil compaction better than the conventional tillage methods such as the disc harrow and mouldboard plough. The NSCT implements in this study showed some positive attributes throughout, and this conservation tillage production system therefore holds promise and has the potential to transform Namibian smallholder agriculture into a sustainable and productive crop production strategy.

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Table 1 Mean Penetration resistance for five farmers' fields with unlimited penetrometer depth

Variable Tillage method	n	Mean Penetration Resistance (MPa)	Mean Maximum Penetration (cm)	s.e ($\bar{x}$)
CV	5	2.97	23.2	6.763
NSCT	5	1.95	50.0	0.000* (all values are the same)
Overall	10	P=0.002	P=0.04	5.488

Table 2: Mean penetration resistance for eight farmers' fields only with lower max penetrometer depth

Variable Tillage method	n	Mean Penetration Resistance	Mean Maximum Penetration	s.e ($\bar{x}$)
CV	8	3.09	10.75	0.977
NSCT	8	2.74	15.75	1.750
Overall	16	p=0.365	p=0.026	1.163