Conversion To No Tillage Consisted In Reduced Soil Penetration Resistance Below Tillage Depth After 3 Years In A Vertisol

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Introduction

Root growth, nutrient uptake and plant yield can be negatively affected by soil compaction, which depend on the interaction of a number of environmental and management aspects. These includes soil type, texture and stabilized and non-stabilized organic matter (OM) contents and distributions in the profile, soil moisture, tillage and machine load, crop rotation, etc.. The role of tillage, especially conservation strategies, is of paramount importance in shaping soil strength at increasing depth, but it can vary depending on other management issues (Hamza and Anderson, 2005) and time length of application (Radford et al., 2007). In particular, soil tillage effects on soil strength can greatly vary depending on soil type, with special emphasis on texture and total OM, and contrasting results were found in a range of soils either with or without fluctuating soil moisture content (e.g. Lopez-Bellido et al., 2016). Aim of this work was to study and model the penetration resistance (PR) of a Vertisol at increasing depth since the application of no tillage compared to minimum tillage.

Materials and Methods

An experiment was established in the fall 2013 at the Research Centre for Cereal and Industrial crops (Foggia, Italy; 41° 28'N, 15° 32'E; 75 m a.s.l.) on a clay-loam soil (Typic Chromoxerert). Main soil traits were 30% clay, 25% sand; pH 7.5; 12.5 g kg^{-1} total C. Mean long-term rainfall of the site is 479 mm. Mean air temperatures are 12.2 ºC in fall, 8.2 ºC in winter, and 17.6 ºC in spring. The experiment was a randomized block design with 5 reps and two soil management systems (SMS), direct seeding on no tilled soil (NT) and minimum tillage (MT). MT included wheat straw removal before the tillage operation, disk cultivator at 15 cm depth and chisel at 10 cm before sowing; NT included crop residues left on soil surface, use of glyphosate at a rate of 720 g of active ingredient ha^{-1} for weed control one week before sowing. Within each replicate, measurements of penetration resistance (PR) were taken in 3 to 10 sub-replicates. In each sub-replicate, data were taken nine times throughout the experiment. In each sampling date, PR was measured by a penetration dynamic system (Rimik CP20, Agridry Rimik PTY LTD; terminal cone of 10 mm^2 area) at steps of 25 mm until a 600 mm depth. Soil moisture was computed gravimetrically after soil drying at 84°C until constant weight from soil sample at 0-20 cm and 20-40 cm depth. Data were checked for fitting a Gaussian distribution and thus transformed to square root prior the statistical analysis. Data were presented as original values in the tables and figures. A general linear mixed model of variance analysis was performed with both depth and sampling site as repeated measures. Differences among means were compared by t-grouping with Tukey-Kramer correction at the 5% probability level to the LSMEANS p-differences sliced by time. The direct role of soil moisture at varying depth and time and SMS on PR was modelled by the GLMSELECT procedure (SAS/STAT 9.2) including either interactions among effects or only the main effects of predictors. Model predictor selection method was the forward selection, with average square error (ASE) as stop criterion. Model was subjected to a 10-fold validation randomly fractioning the database in a 0.75 training set and a 0.25 validation set.

Results

Mean PR along the soil profile increased with time, with slight increases from the beginning of the experiment (fall 2013) to the 2nd of March 2017 and a sharp increase from the measurement of the 2nd of March 2017 to that of 24th of April 2017, after which it slightly decreased. Along the whole profile, the effect of the soil management system on PR was negligible from the beginning of the experiment until the measurement of the 2nd of March 2017 (Table 1). After this date, NT showed on average along the whole profile studied a PR 21% lower than MT. Mean variation between NT and MT decreased linearly with time at a rate of 0.612 N m^{-2} day^{-1} (R^2=0.63; data not shown). The role of variation of PR in NT compared to MT after the 24th of April 2017 was not constant along the profile. In particular, in the last 2 dates, NT showed a similar PR of MT from the soil surface to a depth of 250 mm. Below such depths, NT showed lower PR than MT (Fig. 1).

Few differences were found in models of PR at varying soil moisture, depth, time, and SMS with or without interactions (R^2=0.675 and 0.640, respectively). Modelling of PR by means of the main effects clearly showed that depth and time were the major contributors to the prediction (Fig. 2) with a mean effect of +0.578 kPa mm^{-1} and +0.484 kPa day^{-1}, respectively. Soil moisture reduced PR by 0.167 kPa per delta %, whereas the role of SMS was negligible in the model with no interactions. When interactions were considered, MT increased PR compared to NT in Depth*Time*SMS by 0.259 kPa.

Table 1. Results the fixed effects of the general linear mixed model of soil penetration resistance at varying soil management system (SMS), Depth (D), and Time (T)

	F	p
SMS	71.55	<.0001
D	422.54	<.0001
SMS×D	5.6	<.0001
T	63.7	<.0001
SMS×T	153.5	<.0001
D×T	20.84	<.0001
SMS×D×T	4.36	<.0001

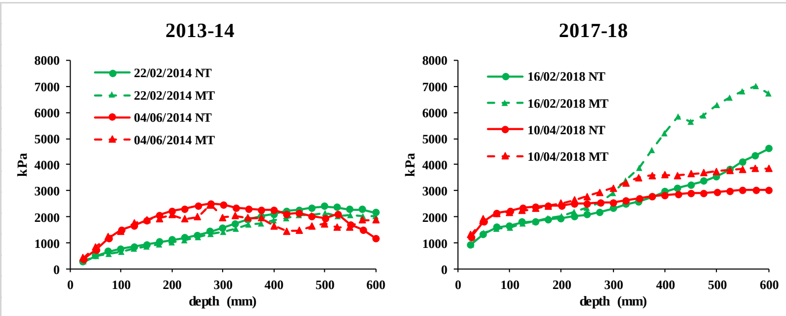

Fig. 1: Penetration resistance (kPa) in the first (2013-14) and last growing seasons (2017-18) at varying depth (mm) and sampling occasions in a Vertisol grown with durum wheat under no tillage (NT, continuous lines and circles) or minimum tillage (MT, dashed lines and triangles).

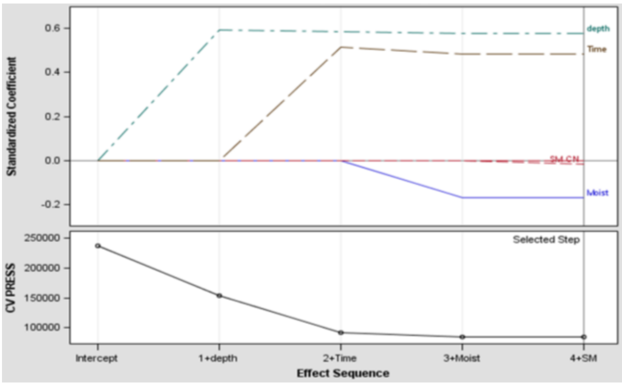

Fig. 2: Coefficients of the PR model at varying soil moisture (moist) depth and time of application of SMS (SM CN for no tillage). Cross validation predicted residual sum of squares (CV PRESS) of the model is shown

Conclusions

NT can reduce soil penetration resistance, however, such an effect occurs after a given time-lapse, estimated in 3 years. Similar results were found by Radford et al. (2007). Differences from our results and those of Lopez-Bellido et al. (2016), which worked on a soil with barely twice the clay content and half the sand and soil organic matter than the present, could have depended on the ability of the soil to form water-stable aggregates. Further studies will be aimed to study PR resistance when manipulating soil moisture content and retention of plant residues.

References

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