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Crop Residue Management Effects on Soil Mechanical Impedance

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Soil penetration resistance was evaluated in different crop residue management practices. The experimental design was a randomized complete block with five replications (block). The soil strength data, measured to a depth of 52·5 cm using a recording penetrometer, were corrected to a common water content and then submitted to a multivariate approach consisting of a combination of principal component analysis (PCA) and multivariate variance analysis, considering crop season and sampling date within season as repeated factors. The first two principal components (PC) explained 95% of the variance. The first one, related to the ~25–52 cm deep layer, accounted for 84% of total variance, while the second PC, which seems to measure the penetration resistance at 3–25 cm depth, explained more than 11% of total variance. The results of variance analysis proved that crop residue management had significant effects on soil penetration resistance only for the first PC. Crop season, date of measurement within each season, the two-way interactions: season with date, season with management, date with management and the three-way interactions: season with date and block, and season with date and management were highly significant in both PCs. This study has also shown the location effect of penetrometer measurements is fundamental when soil characteristics are altered by crop residue management.

1. Introduction

In southern Italy, the scanty use of animal manure and the cultivation of winter cereals in continuous cropping are causing, as years go by, a decrease in soil organic matter and main nutrient components, not always counterbalanced by the application of increasing levels of mineral fertilizers. Soil management procedures, that address soil chemical and organic fertility conservation on sustainable crop yield need to be developed. Among these, ploughing in of crop residue can compensate for the loss of soil organic matter content (Convertini *et al.*, 1998) and slow down the progressive deterioration of some chemical and physical soil properties. Nevertheless, stubble and straw burning is still widely practised in cropping systems in Mediterranean areas and is often utilized as a means of reducing crop residue loads on soil surface. In the light of these considerations, the Agronomic Research Institute has been carrying out a long-term study, started in 1978 and still in progress, on different straw and stubble management practices in a continuous cropping of durum wheat. The results concerning the quanti–qualitative aspects of production and some chemical characteristics of soil have been reported (Convertini *et al.*, 1985; Di Bari *et al.*, 1987; Maiorana *et al.*, 1992). This paper reports the effects over time of those treatments on one of the most important physical soil parameters, the soil strength. Its measurement is important in agriculture as it characterizes mechanical impedance to root penetration. Nevertheless, cone penetration resistance measurements have not yet been developed to such a point that a routine measurement is unambiguous enough for precise recommendations for modification of soil. An important aspect of why it is difficult to interpret resistance data unambiguously is that soil strength is a dynamic characteristic, depending on many soil physical and chemical properties, water content, position, depth and soil management procedures. Therefore, we developed a statistical analysis able to show statistically significant differences in mechanical impedance for various management practices.

2. Materials and methods

2.1. *The site and the climate*

The experiment was carried out at Foggia (41°27′ latitude N, 15°36′ longitude E, 90 m above sea level), in a typical coastal area of southern Italy, the Apulian Tavoliere, in the experimental farm of the Institute. The main crop in the area is durum wheat in continuous cropping or in rotation with industrial crops (sugar beet, sunflower, tomato), pulses and vegetables.

The soil is a silty–clay Vertisol of alluvial origin, classified as fine, mesic, Typic Chromoxerert by the USDA Soil Taxonomy, with a satisfactory content of total nitrogen (0·122%), available phosphorus (measured as P_2O_5, 41 p.p.m.) and exchangeable potassium (as K_2O, 1561 p.p.m.) and a good supply of organic matter (2·07%). In summer the soil often shows several cracks, both at the surface (4–5 cm wide) and throughout the 50 cm deep layer (1–2 cm wide).

The climate is classified as ‘accentuated thermo-mediterranean’, according to the FAO-UNESCO classification, with summer temperatures which can rise above 40°C, winter temperatures which can fall below 0°C and rains concentrated mainly in the winter months.

The weather during the period of soil strength measurements (1994–1996) was characterized by great variability. Referring to the interannual cycle August–April (ranging from the main soil ploughing to the end of penetrometer use), in the 3 trial years the rainfall was lower (416·0, 319·8 and 447·4 mm, respectively) than the long-term average 1952–1992 (461·5 mm).

2.2. *Experimental design and treatments*

The experimental field design is a randomized complete block with five replications (block) and sub plots of 80 m^2 each.

The straw and stubble treatments, namely, burning of crop residues (B) and ploughing in of crop residues (P), the latter with or without the application on the residues of three nitrogen levels (as urea) (N_1, N_2 and N_3) and of 500 $m^3\,ha^{-1}$ of water (W), are shown in Table 1.

Table 1
List of the crop residue management treatments

Crop residue treatments	*Nitrogen on residue, kg ha⁻¹*	*Water on residue, m³ ha⁻¹*	*Treatments identification*
Burning	—	—	B
Ploughing in	—	—	P
Ploughing in	50	—	PN_1
	100	—	PN_2
	150	—	PN_3
Ploughing in	50	500	PN_1W
	100	500	PN_2W
	150	500	PN_3W

The whole trial field received 100 kg P_2O_5 ha^{-1} in summer, at the time of main soil ploughing and 100 kg N ha^{-1} (NH_4NO_3) as a top dressing on the wheat, half in February (at the 5th–6th leaf stage) and half in April (at the start of booting stage).

After harvesting of wheat, straw and stubble were chopped to 10–15 cm lengths and spread back on the plot. The various doses of urea were then applied, and everything were buried with a ploughing depth of 40 cm. In the treatments requiring water, it was applied before ploughing. Finally, the residues of the B treatment were burnt.

The sowing of wheat was carried out in the last ten days of November, with a rate of 450 seeds per m^2 and a 15 cm row spacing.

2.3. *Resistance to penetration*

The measurements of soil penetration resistance (cone penetration resistance) were taken on two of the five replications four times per year, in January–April 1994–1996, the most important months of the durum wheat cropping cycle, that starts with the sowing in November and ends with the harvesting in June. In May, because of the soil dryness, most readings fell at the bottom of measurement scale (exceeding 50 MPa), then resulting not very accurate. Five random measurements were made in each experimental plot between the wheat rows.

The soil strength was measured using a Bush recording soil penetrometer (Findlay Irvine) with a 30° angle and 12·83 mm diameter cone, corresponding to the American Society of Agricultural Engineering standard.

The penetrometer resistance measurements were done at 3·5 cm depth increments up to the total depth of 52·5 cm (labelled from R_1 to R_{15}) and recorded on a data storage unit. The first depth of measurement (R_1, 0–3·5 cm depth) was excluded from the analyses, as it usually showed values near 0 MPa, owing to an incomplete contact of the penetrometer base plate on the uneven soil surface.

2.4. *Correction of resistance to penetration values for soil water content*

Since the penetrometer resistance is mainly affected by soil moisture (Perumpral, 1987; Vyn & Raimbault, 1993;