METHODS TO ASSESS SOIL CHEMICAL PROPERTIES AND THEIR RELATIONSHIP WITH FIELD MEASUREMENTS OF INFILTRATION AND EROSION.

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Summary. This paper compares the distribution and concentration of total nitrogen between different treatments, from a long-term experiment at Halbury in SA, down to the 10 cm soil layer assessed by 1 cm intervals. It also reports correlations between total nitrogen content of cropping red-brown earth measured by two methods and simulated rainfall infiltration and erosion.

Thirteen years of no-till produced significantly ($p<0.001$) higher total nitrogen concentration in the top 0-4 cm soil compared with conventional cultivation. The greatest difference occurred when comparing the rotations between pasture-wheat and wheat-barley-grain legumes where a difference of 0.05% concentration occurred in the first 3 cm of soil amounting to an increase of 25%. The total nitrogen concentration, however, decreased from 0.15%, 0.17%, 0.19% and 0.2% from the surface soil for conventionally cultivated wheat-barley-grain legume, no-till wheat-barley-grain legume, conventional cultivated pasture-wheat and no-till pasture-wheat respectively to 0.11% at 10 cm depth for all treatments. High correlations were found between total nitrogen (TN) content of the 0-3 cm soil layer (the soil affected by rain drops impact) and infiltration to first runoff, percent infiltration and nitrogen loss. This layer is relevant to the behaviour of surface soil under simulated rain. No significant correlation was obtained with soil of the 0-10 cm soil layer obtained using a soil sampling tube. These differences indicate that TN, which is normally highly correlated with organic carbon, of the surface soil is a major determinant of the rate at which soil detach.

INTRODUCTION

The contents of organic carbon (OC) and total nitrogen (TN) in soils such as the red-brown earths are known to be associated with their structural properties (1), but comparable associations with infiltration capacity have not been obvious. Samples for soil nutrients and soil physical assessments have been commonly taken to depths of 5-10 cm (2, 3, 4, 5). This method gives an average value of a given parameter within the depth of sampling. While profile development within this depth would be minimal in soils being prepared by traditional cultivation methods for cropping, a more definite profile would be expected to develop under no-till or minimum tillage systems.

Since the initial adverse effects of rain drops on soil structure (e.g. slaking, sealing and crust formation) are on or near the soil surface, it was hypothesised that TN values (and comparable chemical data) for this surface soil should be more closely related to infiltration capacity and soil loss parameters than average values within the 0 to 5-10 cm depths. Results from two methods of soil sampling together with those from infiltration studies using simulated rain storms on a red-brown earth subjected to rotation and tillage treatments since 1978 at Halbury, South Australia, have been used to test the hypothesis.

MATERIALS AND METHODS

Details of the field experiment

The experiment comprised 9 rotation-tillage treatments x 2 nitrogen levels x 2 replicates x 2 phases. Treatments chosen for testing the hypothesis were (1) pasture-wheat (PW) and wheat-barley-grain legume (WBGL) rotations, each with a no-till (NT) and a conventional cultivation (CC) system, and (2) the plus N sub-plots (40 kg N/ha with the cereals).

Nutrient measurements

Two soil sampling methods were used to obtain soil samples for OC, TN and available phosphorus (AvP) in 1991. Method A was that developed by Malinda (6) to take 10 successive layers of soil, each 1 cm deep and 5 x 30 cm in area, at 3 locations per plot (a total of 4500 cm^3 per plot), from the no-till and conventional tillage treatments only from each rotation. Method B was the common method of soil sampling using a 4.5 cm ID tube. Eight cores were taken per plot giving a 509 cm^3 of soil per plot. An average of the 0-3 cm data from method A for a given nutrient was used for comparison with those from the method B. Only results using the TN data are presented in this paper, as the overall trends in simple correlations with comparable sets of infiltration and soil loss values were similar for the 3 nutrients.

Rainfall simulation and data analysis

Data for runoff/infiltration and soil loss were acquired using the Northfield rainfall simulator (7) with an energy of 29 J/m^2/mm of rain and an intensity of 100 mm/hr for 18 minutes in March 89 before the initial cultivation, and July 91 after seeding. This energy was used in order for the data to be relevant to field conditions as the energy is similar to that of natural rain. The target areas for simulation comprised two adjacent subplots, each 50 x 100 cm in area. During simulation, the existing cover (XSCOV) was retained on one sub-plot and on the other was either removed (0% cover; 3/89) or removed and covered with 3 layers of 70% shade cloth to protect the soil from raindrop energy (100% cover, 7/91). Data used in simple correlations reported in this paper were infiltration to first runoff (IRO; mm), infiltration as a percentage of the total rainfall applied (PI), total soil loss (SLS, t/ha), soil nitrogen loss (SNLS, kg/ha), cumulative tillage passes from the start of the experiment to the time of simulation (CUMTP), and XSCOV prior to simulation (t/ha, oven dry matter). It was expected that, providing soil properties and experimental procedures were comparable for a given pair of target areas, the ratio of infiltration values for alternate cover/XSCOV would be ≥ 1 with 0% cover and ≤ 1 values for 100% cover; and *vice versa* for the soil loss values. In practice, there were some exceptions and these were deleted where the PI ratios with 0% cover were > 1.04 and those with 100% cover were < 0.95. It is recognised that the sample size of the sets within this study are limited - 6 cases for WP, 3/89; 7 cases for each of the remaining sets.

RESULTS AND DISCUSSION

Distribution of TN within the 0-10 cm layer of cropping land

In the 0-2 cm depths (Method A, sampling soil in 1 cm layer intervals), the TN in the NT are clearly > than CC treatments for both rotations. Below 3-4 cm depths the trend is reversed with CC > NT (Fig. 1). It was not possible to identify a depth in which TN concentration reversed with method B as it had only one depth of soil sampling (0-10).

Figure 1. Typicalprofilefor TN for NTPW (?), CCPW (•), NTWBGl (?) and CCWBGl (?) for Halbury Tillage x rotation experiment (May 1991). The bar indicates l.s.d. p<0.001.

These measurements were done after 13 years of experimentation. Thirteen years of no-till pasture-wheat (NTPW) produced significantly (p<0.001) higher TN in the top 0-3 cm soil compared with WBGl. The greatest difference occurred when comparing the rotations especially between NTPW and conventionally cultivated wheat-barley-grain legumes (CCWBGL). The TN however decreased from 0.15%, 0.17%, 0.19% and 0.2% from the surface soil for CCWBGL, NTWBGL, CCPW and NTPW respectively to 0.11% at 10 cm depth for all treatments. Retention of surface cover using a no-till system, and less disturbance of soil could be responsible for the significantly higher TN within the top few cm of soil for NTPW. In tilled soils, aggregates are formed and fragmented by the physical process of tillage. The increase in TN at lower depths of CCPW could be partly due to distribution of finer particles and organic matter into deeper depths by the cultivation process.

Rainfall simulation

Data in Fig. 2 taken from bared soil surface in March and reduced surface cover in July indicate that irrespective of the time of simulation, the NT and PW regimes reduced both runoff and soil loss compared with the CC and WBGL respectively. The individual values of runoff and soil loss comprising the means (Fig. 2) were used to compare two methods of soil sampling.

Figure 2. Runoff and soil loss measured in March 1989 (from bare soil) and July 1991 (from reduced existing cover plots) at Halbury long-term experiment.

Comparison of the two methods

To assess relationship between the two methods of soil sampling, Table 1 shows correlations between TN and IRO, PI, SLS, and SNLS. Correlations are also reported for some factors that influence physical and chemical properties of A horizon i.e. CUMTP, XSCOV.

Using the 1-3 cm soil of method A, higher relationships were obtained compared with the 10 cm soil of method B. These results show that the shallower the soil sampled, the stronger is the relationship between chemical properties and IRO, PI, SLS and SNLS. A significant correlation was also found between CUMTP, XSCOV and IRO, PI, SLS, and SNLS but only with the sampling method A. The poor relationship for WBGL in July 1989 was a result of interactions between factors such as fresh cultivation and cover. Regressing values from a depth that is not directly affected by raindrops (Table 1, Method B, 0-10 cm) has produced negative **r** values instead of positive ones and vice versa.

The results support the hypothesis in 11 out of the 16 sets of comparisons (Table 1) and also show the importance of tillage and surface cover in many of the sets. The results indicate that further research is justified regarding the value of shallow sampling for soil nutrients when studying their relationships with infiltration and soil-loss parameters. In this study, the total number of samples taken with Method A was limited because the method was relatively slow compared with Method B. However the area sampled with Method A was significantly greater. The technique would therefore have to be modified to allow faster taking of samples and the sampling of more treatments. The low **r** values in many of the sets would be the result of variability within the site, the range and consistency of both the independent variables, and the complex interactions between the many factors governing infiltration and soil loss parameters.

Table 1. Simple correlation coefficients (**r**) between TN (obtained using two methods of soil sampling), CUMTP, XSCOV and simulated rainfall parameters. There were 6, 7, and 7 cases for PW, WBGL, WP/WBGL for March, March and July/July respectively.

Date	Surface condition	Rotation	Ranges of variables Low, Mean, High	Variable	Depth (cm)	IRO (mm)	PI (%)	SLS (t/ha)	SNLS (kg/ha)
March 89	Bare	PW	0.17, 0.19, 0.23	%TN	0-3	.77*	.76*	-.76*	-.77*
			0.11, 0.12, 0.13	%TN	0-10	-.14	-.01	.20	.12
			8, 12, 29	CUMTP		-.64	-.46	.54	.44
			0.50, 3.70, 6.70	XSCOV		.88**	.80**	-.8**	-.82**
March 89	Bare	WBGL	0.14, 0.15, 0.17	%TN	0-3	.19	.56	-.55	-.54
			0.08, 0.10, 0.12	%TN	0-10	.22	.50	-.47	-.47
			9, 23, 46	CUMTP		-.56	-.9**	-	.87**
			0.70, 1.40, 2.80	XSCOV		-.42	-.05	.87**	.02
								.01	
July 89	With cover	PW	0.17, 0.19, 0.23	%TN	0-3	.58	-.9**	-	-.86**
			0.09, 0.10, 0.13	%TN		.16	-.47	.84**	.43

			8, 29, 34	CUMTP	0-10	-.14	-.04	.44	.05
			0.40, 1.90, 3.60	XSCOV		.89**	-.65	.06	.58
								.55	
July 89	With cover	WBGL	0.14, 0.15, 0.17	%TN	0-3	.1	.08	-0	-.09
			0.08, 0.09, 0.10	%TN	0-10	-.67*	-.12	.23	.22
			10, 32, 49	CUMTP		.35	-.35	.19	.24
			0.20, 1.39, 3.60	XSCOV		.77*	.02	-.31	-.29

CONCLUSIONS

Surface soil is very critical in determining the hydraulic and erosion processes. Soil surface properties which can be related to simulated rainfall infiltration and soil loss e.g TN and OC content (8) of the 0-3 soil layer can be used to predict infiltration capacity of different (heavier) soils. Very weak or no relationship is likely if soil sampling is taken using small diameter tubes to a depth exceeding the depth of soil which is affected by raindrop impact. There are two reasons for this; i) OM/OC/N is not homogeneously distributed and the greater the area sampled the smaller the coefficient of variation would be, ii) averaging two different profiles of concentration may significantly reduce the correlation coefficients.

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