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Soil tillage effects on monovalent cations (Na^+ and K^+) in vertisols soil solution

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ABSTRACT

Potassium is an essential macronutrient for plants; it is characterized by increased photosynthetic activity by ensuring a better utilization of light energy, also acts as a regulator of cell osmotic pressure, decreasing transpiration and helping to maintain cell turgidity. However, the sodium is not an essential element for plants, although it is beneficial to certain crops, in some instances can replace the potassium and osmotic regulation making and turgidity of the cells, this effect is greatest when the supply of potassium is deficient (Wild, 1992). Both elements, in periods of aridity, delayed the wilting of plants to maintain cellular osmotic potential and in cold periods, they lower the freezing point of sap (Navarro and Navarro, 2000).

This is an experiment to study the influence of soil management techniques on the monovalent cations in soil solutions at different depths. The cropping systems studied are conventional tillage, minimum tillage and direct drilling.

Conventional tillage releases more Na^+ and K^+ to the soil solution than the conservative techniques. In the case of Na^+, the conventional tillage soil solution has an average concentration of 0.563 meq/L compared to 0.303 meq/L of minimum tillage and 0.340 meq/L of direct drilling. As for the K^+, the soil solution concentration of conventional tillage is 0.097 meq/L, compared to 0.079 meq/L of the solution of minimum tillage and 0.056 meq/L of direct drilling.

The behavior for the two cations studied is distinct at different depths. The Na^+ is more abundant in water samples of soil taken in depth. Therefore, the salinization risk may take place in the subsoil, especially in conventional tillage where the Bw_1 horizon values are three times higher than in the Ap horizon, while the K^+ is more abundant in the surface horizon. Conventional tillage and minimum tillage techniques, in the Ap horizon have a similar pattern with a K^+ concentration average of 0.15 meq/L and 0.14 meq/L, respectively, resulting in lower values for direct drilling.

Studies on clay soils have not been performed previously because of the difficulty presented by these soils when soil solution extracted for analysis. We analyzed the monovalent cations (sodium and potassium) from soil solution; because the soil solution is the immediate source of sodium and potassium for plants.

1. Introduction

The loss of soil productivity through the accumulation and leaching of salts is a global problem in arid, semiarid and subhumid regions (Szabolcs, 1989).

The accumulation of salts in the profile is mainly controlled by the amount of salts that are released from the soil and the amount of salts leaving the soil by percolation (U.S. Salinity Laboratory Staff, 1954; Ayers and Westcot, 1987).

Likewise, in the case of clay soils, water infiltration through cracks can cause lateral displacement of salts due to the influence of the horizontal component of infiltration.

With respect to production, there are many authors that highlight the benefits of conservation agriculture versus a conventional one, as in the case of the Experimental Farm Tomejil (Carmona, Sevilla) in which this work has been carried out (Perea, 2004; Muriel et al. 2005).

Studies such as Ordoñez et al. (2007) show an improvement in the physical and chemical properties of the soil under conservative techniques. Jiménez et al. (2005) reveals that the soils under direct drilling, contribute a greater amount of water to cultivation especially in the first 20 cm of the profile.

The influence of the management technique on the monovalent cation contents in different soil types has been identified. The results for the case of sodium indicate a greater content when the cultivation techniques are traditional. Thomas et al. (2007) in an Australian luvisol, and Dalal (1989) and Loch and Coughlan (1984), in vertisols, have detected smaller amounts of exchangeable sodium when the cultivation techniques are conservative than when conventional tillage is used.

For potassium, the results are not so unanimous. Thomas et al. (2007) claimed that the exchangeable potassium is greater in direct drilling than in conventional tillage in the first 10 cm of the soil surface.

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Table 1
Physical characterization of the soil.

Horizon and depth (cm)	Sand (%)[a] >50 μm	Silt (%)[a] 50–2 μm	Clay (%)[a] <2 μm	Bulk density (g.cm^{-3})	Macroporosity (%)	Microporosity (%)	pF 1/3 atm[b]	pF 15 atm[b]
Direct drilling profile (DD)								
Ap (0–24)	3.0	18.3	78.7	1.27	61.4	38.6	59.0	47.2
Bw_1(24–64)	3.2	21.9	74.9	1.30	56.4	43.6	57.4	45.0
Bw_2k (64–140)	3.5	19.1	77.4	1.32	55.7	44.3	58.3	46.3
Ck (>140)	1.3	20.4	78.3	1.36	–	–	58.7	46.7
Minimum tillage profile (MT)								
Ap (0–24)	3.4	20.4	76.2	1.29	58.1	41.9	57.9	45.7
Bw_1 (24–64)	4.1	21.3	74.6	1.30	56.0	44.0	57.2	44.7
Bw_2k (64–140)	3.7	19.3	77.0	1.32	55.3	44.7	58.2	46.1
Ck (>140)	1.6	20.4	78.0	1.37	–	–	58.6	46.6
Conventional tillage profile (CT)								
Ap (0–24)	5.7	18.2	76.1	1.27	60.0	40.0	57.6	45.4
Bw_1(24–64)	2.4	22.4	75.2	1.29	57.4	42.6	57.5	45.1
Bw_2k (64–140)	0.7	21.2	78.1	1.32	56.1	43.9	58.7	46.8
Ck (>140)	0.1	22.7	77.2	1.37	–	–	58.8	46.9

[a] Métodos Oficiales de Análisis (1994).
[b] Richard's membrane method (1947).

Table 2
Chemical characterization of the soil.

Horizon and depth (cm)	pH (H_2O)[a]	O.M. %[a]	Exchangeable macroelements (cmol (+)/kg)[a]		Assimilable macroelements (cmol (+)/kg)[b]	
			Na^+	K^+	Na^+	K^+
Direct drilling profile (DD)						
Ap (0–24)	7.5	1.54	1.46	1.31	8.46	1.69
Bw_1(24–64)	7.3	1.21	1.24	1.07	1.59	1.46
Bw_2k (64–140)	7.6	0.83	1.96	0.42	2.39	0.88
Ck (>140)	7.7	0.15	3.64	0.39	5.70	0.74
Minimum tillage profile (MT)						
Ap (0–24)	7.5	1.32	0.74	1.81	1.26	2.71
Bw_1 (24-64)	7.3	1.21	0.62	1.22	1.59	1.71
Bw_2k (64–140)	7.6	0.82	1.83	0.56	2.40	0.98
Ck (>140)	7.6	0.03	2.93	0.42	6.10	0.62
Conventional tillage profile (CT)						
Ap (0–24)	7.3	1.69	0.98	1.10	1.23	3.27
Bw_1 (24–64)	7.3	1.38	0.90	1.15	1.51	1.58
Bw_2k (64–140)	7.6	0.80	1.10	1.00	1.89	0.92
Ck (>140)	7.7	–	2.89	0.49	2.21	0.87

[a] Métodos Oficiales de Análisis (1994).
[b] G.T.N.M.A. (1976).

In the same way, Martín-Rueda et al. (2007) found that the potassium content is higher in direct drilling than in the other systems in the first 15 cm of the soil surface. But Guzmán et al. (2006), DeMaría et al. (1999), Franzluebbers and Hons (1996) and Hunter and Cowie (1989) found more potassium contents in the systems of conventional tillage than in DD, although these results are only in the surface horizon.

There are also studies which determine the nutrient content at different depths. In this sense, Franzluebbers and Hons (1996) found that the exchangeable sodium increased with the depth in the two techniques that were studied (conventional tillage and direct drilling) in a Fluventic Ustochrept in Texas. With regard to potassium, Thomas et al. (2007) in an Australian luvisol, Guzmán et al. (2006) in a clay soil of Manhattan and Asghar et al. (1996) in a vertisol in Queensland showed that the concentration of potassium is higher in the surface horizon. Also, Lal et al. (1990) and Ismail et al. (1994) found that potassium increased in the surface horizon, even in the case when the management practices diminished. However, Orihuela et al. (2001) found no influence of depth on the amount of potassium when they

Table 3
Long-term climatic conditions for Tomejil, Sevilla (1979–2007).

Climatic parameter	January	February	March	April	May	June	July	August	September	October	November	December	Annual
T (°C)[a]	9.4	10.5	12.6	14.8	18.5	21.5	26.8	26.7	22.7	17.4	13.4	10.3	17.1[d]
P (mm)[b]	75.4	74.8	65.3	57.8	28.8	24.5	5.1	6.9	19.6	60.8	63.8	78.0	560.8[e]
PET (mm)[c]	18.2	21.6	36.8	52.3	86.6	114.2	172.2	160.1	105.4	61.7	33.9	20.6	883.6[f]

[a] Mean monthly temperature (°C).
[b] Mean monthly precipitation (mm).
[c] Mean monthly potential evapotranspiration (mm) (Thornthwaite, 1948).
[d] Yearly mean temperature (°C).
[e] Total precipitation (mm).
[f] Total potential evapotranspiration (mm).