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Effect of tillage and application of gypsum In a No-Till field under supplementary irrigation with sodium bicarbonate waters

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ABSTRACT

Supplementary irrigation is widespread in the Humid Pampa of Argentine, where the main source of water for irrigation has elevated content of sodium bicarbonate. The combination of irrigation and rain increases the sodium absorption ratio of soil (SARs), consequently raising the clay dispersion and reducing infiltration. The water quality standards for irrigation indicate that SARs values should remain below 3.5. An alternative to mitigate these disadvantages is the application of a gypsum amendment. This study targeted the following objectives: measure the impact of tillage and the addition of gypsum on: infiltration, bulk density, sodium content and crop yield in a soil (Argiudoll and petrocalcic Paleudoll association) under no-till with supplementary irrigation. One treatment consisted of applying a gypsum liming of particle size less than 3 mm. After application, the plots were tilled to a depth of 15 cm. Sunflower (*Helianthus annuus L.*) was seeded 30 days after the completion of the amendment. Applying gypsum improved water infiltration into the soil. Tillage treatment without adding gypsum reduced SARs and increased infiltration the same way as tillage and gypsum treatment. This can be attributed the dissolution of native or precipitated carbonate by irrigation water. Tilled treatments, with or without amendment, had higher yield compared to no-till treatment.

1. Introduction

The Humid Pampa of Argentine (HP) includes 6 million hectares, of which 90% are suitable for agriculture. No tillage (NT) and supplemental irrigation are soil and water management tools increasingly used in HP to enhance grain production. Added to this, the Argentine agribusiness strategic plan aims to increase by 14% the area of grain production in the country (PEA, 2010). This objective will lead to expand the area under supplementary irrigation which is currently 166,483 ha in the province of Buenos Aires (Genova, 2011) and it is estimated that more than 110,000 ha are concentrated in the southeast of the province (Storti 2014 personal communication). The main source of water for irrigation in this region is the Pampeano aquifer (Genova, 2011), these being sodium bicarbonate waters with values of sodium adsorption ratio (SAR) from 6 to 20 (Costa, 1999). This range of SAR in irrigation water depends of the relative position in the landscape. In the region of study there are three different areas: the recharge area with SAR below 7; the transit area with SAR of 7–10 and the discharge area with SAR values greater than 10. The variations in Ca^{+2} and Mg^{+2} concentrations suggest process of magnesium and calcium exchange for sodium, in the areas above classified as recharge and transit, respectively. The continuity of this process between transit and discharge areas remains unclear, since the latter shows a gradual increase in Na^{+} and Mg^{+2}, but a decrease in Ca^{+2} (Quiroz Londoño et al., 2008). If the irrigation water has a significant amount of sodium (Na^{+}) compared with calcium (Ca^{+2}) and magnesium (Mg^{+2}) and especially in the presence of bicarbonate, the colloidal complex can be saturated with Na^{+} generating an unproductive sodic soil (Brady and Weil, 1999).

The climate regime is subhumid-humid (Thornthwaite, 1948) and has three seasons: a) rainy season from October to March, b) moderately rainy in the months of April, May and September and c) little rainy from June to August (Suero et al., 2001).

The combination of sodium bicarbonate water irrigation with rain water causes the expansion of the soil clay mainly affecting the macro-pore system (Costa et al., 1991; Costa and Aparicio, 2015). The use of water with high content of Na^{+} reduces soil hydraulic conductivity (K), significantly reducing infiltration (Pupisky and

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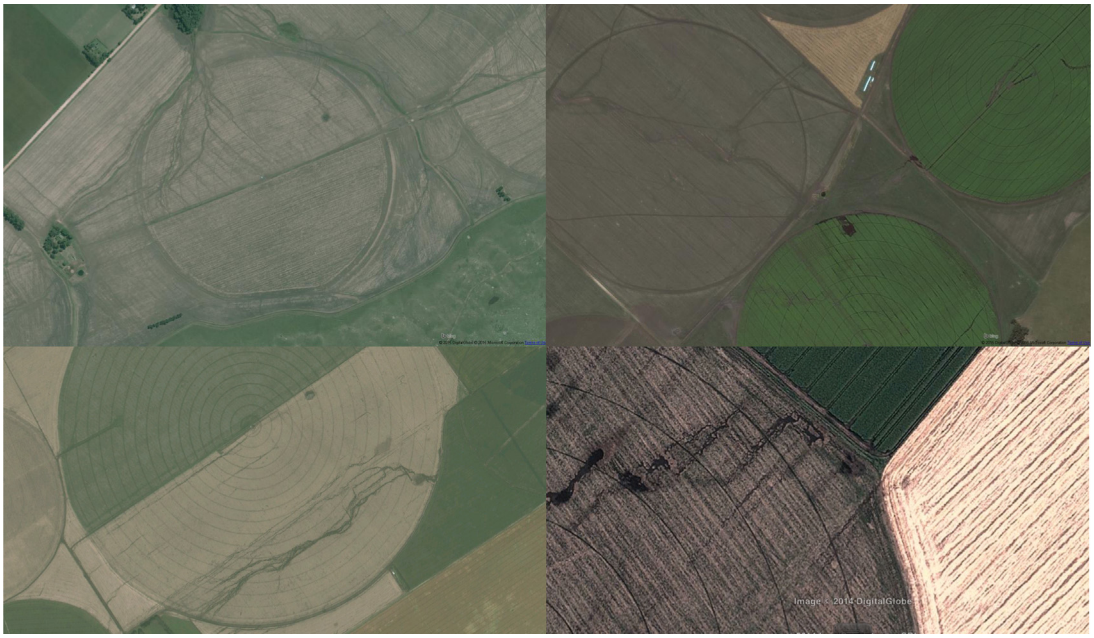

Fig. 1. Bin® and Google Earth® images, where rill erotion in plots with supplementary irrigation is observed.

Shainberg, 1979). A low K combined with heavy rainfall, produces surface runoff which can cause erosion of the topsoil, producing rill erosion (Casalı et al., 1999). These rills are kept because most of the irrigated plots are made under no-till and subsequent rains continue deepening them (Øygarden, 2003) (Fig. 1). Because rainwater is low in electrolytes, it causes the expansion of clays when it enters soils with low SAR (> 3.5), reducing infiltration and highlighting adverse physical conditions for crop development (Costa and Aparicio, 2015). An alternative to keep the SARs low is to apply a liming that provides Ca^{+2} to the soil, while removing Na^{+} of the exchange complex. Gypsum is the source of Ca^{+2} mostly used to recover sodic soils (Shainberg et al., 1989; Zhang and Miller, 1996). Conventionally, the recovery of a sodium soil comprises the application and incorporation of gypsum to the soil followed by irrigation or rainfall (Oster, 1993). The dissolution of gypsum is most effective when mixed with the entire depth of the soil to be recovered (Frenkel and Gerstl, 1989). Gypsum applications to Natracuol soils (Guido series) of 35 and 60 Tn ha^{-1} significantly reduced the content of Na^{+} in the underlying horizons where gypsum was not mixed with soil, being the depth of the recovery of the soil greater with higher doses of gypsum (Costa and Godz, 1999). When a gypsum application is made to a soil, the dilution-exchange reaction takes Ca^{+2} of the soil solution causing an additional dissolution of gypsum. The dissolved gypsum is linearly related to the Na^{+} content of the soil and it produces an increment of the ECs (Oster, 1982; Costa and Godz, 1998). Gypsum application decreases the SARs, improves infiltration, reduces soil compaction and consequently improves crop production (Abdel-Fattah et al., 2015). The application of gypsum as liming has been widely reported for recovering sodic soils with cattle aptitude (Lazovich et al., 1985; Costa and Godz, 1998, 1999) while little information is generated in soils suitable for agriculture. To our knowledge, there is no published information on the accumulation of Na^{+} in soil suitable for agriculture under no tillage and supplementary irrigation with sodium bicarbonate waters. Therefore, in this study we consider the objective of measuring the impact of tillage and the addition of gypsum to soil in no-till under supplementary irrigation with sodic bicarbonated waters on: I) soil infiltration, II) content of Na^{+} and III) the crop yield of sunflower (*Helianthus annuus L.*) in dry land sown after a maize (*Zea mays L.*) with irrigation.

Table 1
Irrigation and rainfall in the different campaigns.

Campaign	Irrigation (mm)	Rainfall (mm)
2014–2015	0	943
2013–2014	150	1108
2012–2013	40	890
2011–2012	0	889
2010–2011	220	772
2009–2010	100	928
2008–2009	340	596
2007–2008	110	1105

Table 2
Irrigation water quality of the site under study.

EC	pH	HCO^{-}	Cl^{-}	$SO4^{=}$	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	SARa
dS m^{-1}					$mmol_{(+)}$ l^{-1}				
0.80	7.7	7.9	0.8	0.1	0.5	0.6	7.4	0.3	10.0

2. Materials and methods

2.1. Experimental site

The trial was installed on a 12 ha no-till plot in *El Verano* (-37.619943 −58.524239) with a 7 years sodium bicarbonate water irrigation history (Tables 1 and 2, Fig. 2). The soil belongs to the MP11 mapping unit (INTA, 1970, 1989) corresponding to an association between *Mar del Plata* (Argiudoll (fine loamy, mixed, thermal)) and *Balcarce* (petrocalcic Paleudoll (fine loamy, mixed, thermal)) series.

2.2. Experimental design and treatments

The experimental design is based on a randomized complete-block design with three replications and four treatments. The experimental units were of 62 × 190 m to allow the use of a harvester equipped with a performance monitor. The treatments were: no-till without application of gypsum (NT), tilled soil without application of gypsum (T) and tilled soil with two doses of gypsum: 1 Mg ha^{-1} (TG1) and 2 Mg ha^{-1} (TG2).