Gypsum Improves Subsoil Root Growth

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ABSTRACT

In many parts of the world, crop root growth into subsoils is limited by physical (pans) and chemical barriers (toxic levels of Al and/or low levels of Ca). Plow and hard pans are usually either out of the reach of mechanical cultivation implements or require large amounts of energy for their disruption. Because lime does not readily move down the soil profile, its ameliorative effect is confined to the topsoil. On the other hand, gypsum ($CaSO_4.2H_2O$) readily moves down the profile where it supplies elevated levels of soluble Ca and precipitates Al. In addition, together with tap-rooted crops, it reduces the penetration resistance of subsoil pans allowing roots of other crops to proliferate in the subsoil. As a result, roots can access the subsoil where adequate quantities of water become available which were previously out of their reach. This additional water results in increased yields, particularly during drought periods. Many examples of the success of gypsum in overcoming subsoil physical and chemical limitations resulting in improved growth and yield of alfalfa (*Medicago sativa*), bermudagrass and fescue pastures (*Cynodon dactylon*, and *Festuca arundinacea*) and turf (*Zoysia* spp.), cotton (*Gossypium hirsutum*), maize (*Zea mays*), sorghum (*Sorghum bicolor*), and soybean (*Glycine max*) are presented.

KEYWORDS: subsoil, Al toxicity, calcium deficiency, root proliferation, gypsum, row crops

INTRODUCTION

Pans of various types and acidity-related parameters are physical and chemical barriers to the proliferation of roots into subsoils in many parts of the world resulting in lack of access to water beyond their reach and consequent drought stress. Because lime is relatively insoluble and creates variable negative charge where it is placed in the soil, little alkalinity and few beneficial cations escape from the top- into the suboil. On the other hand, gypsum being much more soluble readily moves down the profile where it has been shown to reduce levels of toxic Al^{3+}, increase soluble Ca^{2+} and reduce the strength of pans all of which encourage root coverage of the subsoil (Reeve and Sumner, 1972; Radcliffe et al., 1986). New by-product sources of gypsum (flue gas desulfurization gypsum [FGD], phospho-, citro-, titano-gypsum) are now entering the market making it much cheaper and consequently, an attractive choice as an amendment for subsoils. The objective of this paper is to summarize the wealth of information now available illustrating these positive effects of gypsum on crop rooting and growth in the hopes of promoting increased use of gypsum in crop production.

MATERIALS AND METHODS

In most cases, gypsum was surface applied or lightly incorporated into the soil at rates between 5 and 10 T/ha. Usually, these rates have been sufficient to achieve responses lasting many years. In most cases, roots were sampled at least 2 years after gypsum application to allow time for its movement into the subsoil. Roots were extracted either by taking 10 cm cores to a depth of approximately 90 cm using a Giddings truck-mounted hydraulic probe and washing out the roots on a screen after which they were dried and weighed, or by exposing a profile face, inserting a nail board and carefully washing off the soil to expose a root profile. The following soil properties were assayed by the methods indicated: Soil pH was measured in **M** KCl (1:2.5) (Thomas, 1996) and an aliquot of the supernatant was titrated with 0.005**M** NaOH to the phenolphthalein end point to measure Al+H (Thomas, 1982). Exchangeable Ca was extracted with **M** NH_4OAc and determined by ICP (Thomas, 1982). Penetration resistance was measured using a computer-controlled tractor-mounted hydraulic penetrometer (Clark and Reid, 1984).

GYPSUM AMELIORATES SUBSOIL ACIDITY

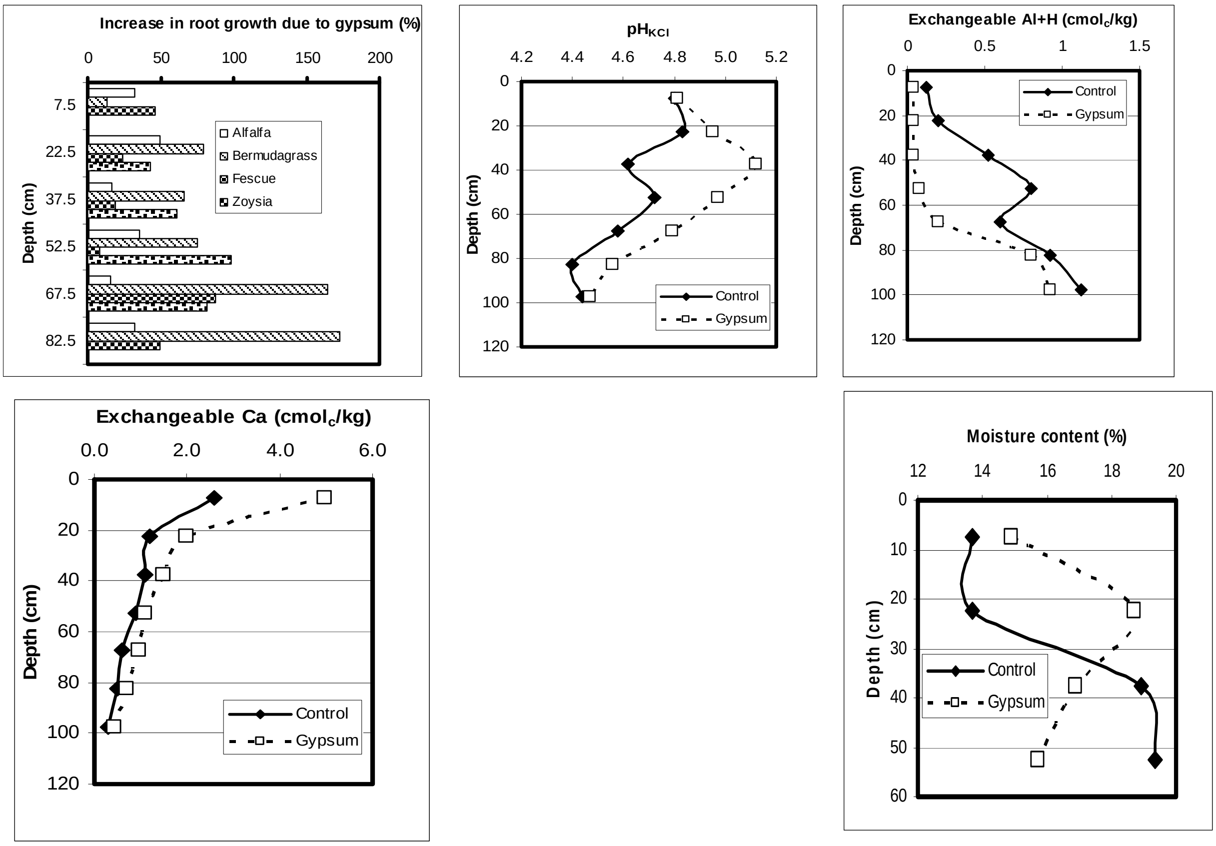

Figure 1. Root growth increases due to gypsum for alfalfa, bermudagrass, zoysia and fescue grown on Ultisols in the SE United States and soil properties associated with the bermudagrass response. The moisture extraction pattern is from the alfalfa experiment.

Following the first report showing the beneficial effects of gypsum on subsoil acidity (Reeve and Sumner, 1972), many positive responses have been obtained in South Africa, Brazil, Guatemala, Australia and the United States with a wide variety of crops as a result of the precipitation of Al^{3+} in the subsoil (Sumner, 1993, 1994). To illustrate this effect, a few new examples of root growth improvement due to gypsum together with associated changes in soil properties are presented from work currently being carried out in the SE United States in Figure1.

All 4 species showed greatly improved root proliferation in the subsoil after gypsum application with the greatest proportional increases often being observed at the greatest depths. This improved root growth is the combined result of reduced acidity, increased levels of exchangeable Ca and reduced levels of exchangeable Al+H in the subsoil all of which promote root elongation and increase water extraction from the subsoil (Figure 1). A root profile (1 m deep) of alfalfa grown in a acid clay Georgia Ultisol is presented in Figure 2. This improved root exploration of the subsoil leads to improved moisture extraction from the deeper layers of the soil as illustrated for the alfalfa crop in Figure 1. Roots in the gypsum-treated soil extract water uniformly down the profile while in the control soil, more water is extracted from the top- than subsoil. As a result, a significant yield increase due to gypsum of 32% was recorded. Similar data are available for other crops e.g., clover (*Trifolium pretense*), sorghum, and soybeans that have shown substantial yield responses to gypsum (Table 1).

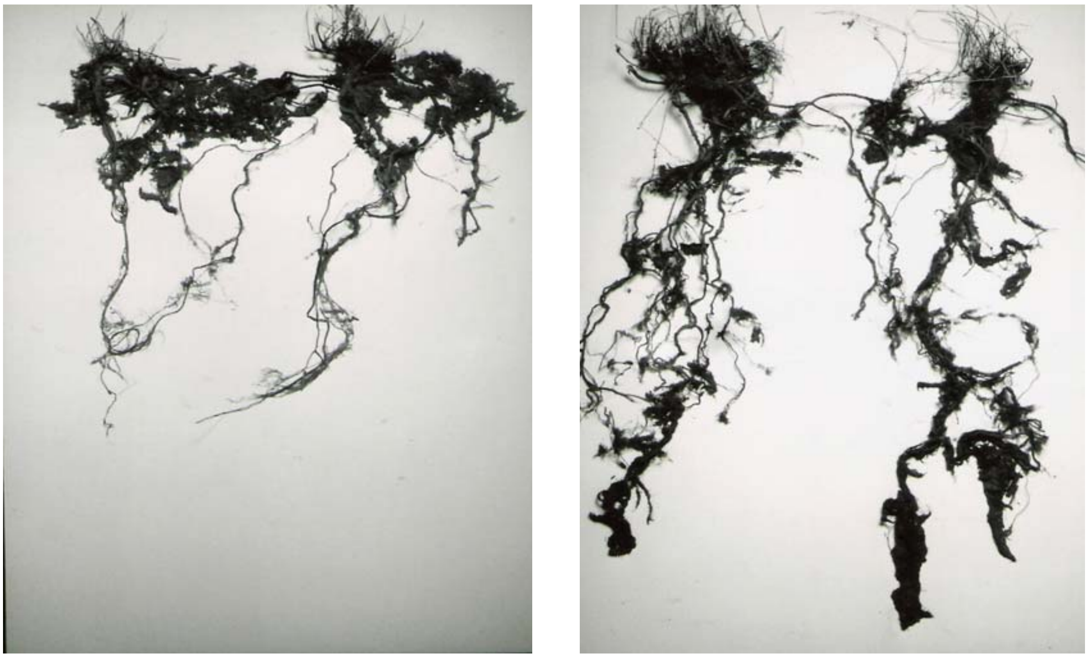

Figure 2. Alfalfa root growth in control (left) and gypsum-treated (right) clay Ultisol

Table 1. Effect of gypsum (applied 25 years previously) on crop yields grown on a clay Ultisol

	Grain yield		Forage yield			
	Sorghum	Soybean	Clover	Grass	Weeds	Total
	2006	2007	2008/9			
Treatment	kg/ha					
Control	3156a[H]	792a	63a	1588a	65a	1716a
Gypsum (10 Mg/ha)*	4952b	1201b	1749b	316b	45a	2111b

* Applied in 1981, [H] Means followed by a different letter are significantly different at $p = 0.05$

These data confirm previous work (Toma, 1999) on the same plots with alfalfa and corn which showed that the positive effect of a single application of gypsum can be long-lasting.

Table 2. Effect of a single application of gypsum on the yield of cotton lint (Kissel, 2009)

Treatment	2000	2001	2002	2003	2004	2007
	Cotton lint yield (kg/ha)					
Control	390a	968a	1122a	427a	836a	1415a
Gypsum (10 Mg/ha)*	388a	1243b	1405b	483a	973b	1786b
Difference	0	275	282	56	137	372

* Applied at planting in 2000, , [H] Means followed by a different letter are significantly different at $p = 0.05$

To further confirm this longevity, data for cotton grown on a sandy Ultisol in Georgia are presented in Table 2. Because insufficient time had elapsed between gypsum application and harvest in year 2000, no yield response was observed but in subsequent years (other crops were grown in 2005 and 2006), substantial yield responses were recorded illustrating the longevity of the effect. Over the 6 years in which cotton was grown, an increase in income over the cost of the gypsum of $1077.20, a handsome profit, was achieved.

GYPSUM AMELIORATES SUBSOIL HARDPANS

Many Ultisols and Alfisols have Bt horizons that are capable of presenting resistance to root elongation. In addition, tillage pans can also reduce root proliferation. As was originally demonstrated by Radcliffe et al. (1986), gypsum can reduce penetration resistance aided by the action of deep-rooted crops such as alfalfa as illustrated in Figure 3. This amelioration due to improved aggregation allows roots to penetrate through the pans and dense horizons to access water previously beyond their reach. There is a remarkable agreement in the shapes of the penetration resistance and root growth curves.

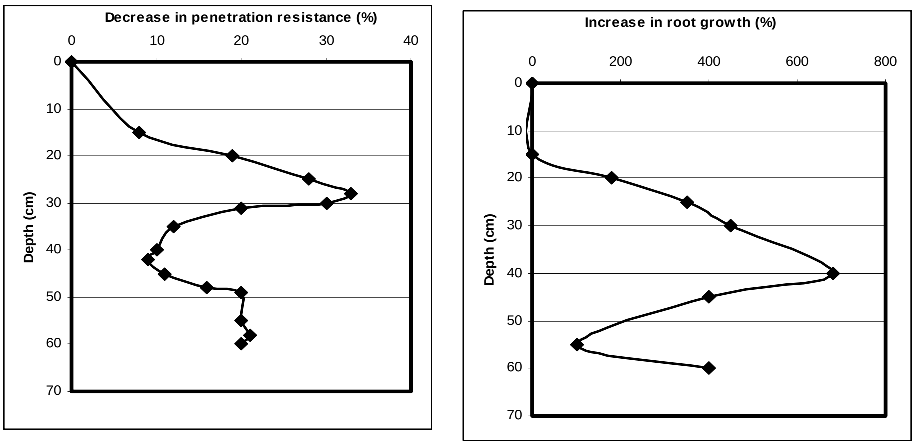

Figure 3. Effect of gypsum in reducing soil penetration resistance of an Ultisol and the associated increase in alfalfa root growth into the subsoil.

CONCLUSIONS

Gypsum ameliorates subsoil acidity by precipitating Al^{3+} and softening hardpans both of which allow roots to proliferate in the subsoil and access water previously beyond their reach. This additional water usually translates into increased yields of many crops.

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