Chemistry, Phytotoxicity and Remediation of Alkaline Soils

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Abstract

Highly alkaline soils are known to adversely affect agricultural crop productivity. Problems commonly attributed to such soils include poor structure and nutrient deficiency. Research based on solution cultures suggests that aluminium phytotoxicity may also occur at alkaline pH, however little research has been done in actual soils under controlled conditions. This new constraint needs to be verified and the nature of the aluminium responsible determined.

A potential method of remediating alkaline soils is to use acid to lower soil pH to a more neutral value. This requires an understanding of the role of carbonates in causing and maintaining high pH. Whereas the acid buffing intensity of soils has been well documented, comparatively little work has been carried out on alkaline buffering intensity. While research has been carried out on soil treatments that may be used to lower soil pH, a systematic comparison of their relative effectiveness is needed.

This study has shown that aluminium is indeed phytotoxic at high pH, significantly reducing the stem and root development of field pea test plants over and above that caused by alkalinity alone. The effects of both alkalinity in general and aluminium in particular became noticeable at a pH of 9.0 and debilitating at a pH of 9.2 or higher. As the quantity of aluminium found in test plants at neutral and high pH was similar, it is likely that it is the speciation of aluminium at high pH that is responsible for this toxicity rather than the quantity entering the plant.

Techniques including electrophoretic mobility analysis, NMR and use of aluminium precipitation characteristics and electrical conductivity were used to determine that anionic

species of aluminium are most likely responsible for aluminium phytotoxicity at high pH. At pH 9.2, negatively charged sodium aluminate became the dominant form of aluminium.

Analysis of carbonate speciation with varying pH identified that carbonate adsorbed to soil clays via exchangeable Na was responsible for soil pH greater than 8.0. Between pH 8.0 and 9.0, most of the soluble carbonates were adsorbed to clays; above pH 9.0 carbonate species dominated in solution phase.

As the effects of alkaline and aluminium toxicity diminish at a pH of less than 9.0, alkaline soils need only be lowered to less than this value to be remediated. Titration of alkaline soils showed that they had low buffering capacity against acid induced pH decrease until pH 8.0. At pH less than 8.0, the predominance of calcite minerals and their faster dissolution rate meant that buffering intensity was very high and large amounts of acid would be needed to lower pH below this value. However at a pH of more than 8.0, the slower dissolution rate of carbonate containing minerals provides little buffering intensity. Remediating alkaline soils via the use of acid to lower soil pH to 8.0 was deemed achievable because of the lower buffering capacity of soils in this pH range.

The effectiveness of gypsum, various organic amendments (glucose, molasses, animal manure, green manure, humus) and leguminous plants were trialled as a means of lowering soil pH. Plants were also trialled in conjunction with gypsum to determine if any additive benefits were evident when combining remediation methods.

Glucose, molasses, green manure and all plant root exudates proved effective at lowering soil pH to less than 9.0. The decrease in pH achieved using the additives was highly correlated with increased populations of acid-producing microbes. The effect was not long lasting however, with pH returning to pre-application levels within 6 months.

Gypsum proved most effective at lowering soil pH and, crucially, the effect was long lasting, with low soil pH maintained over the 6 month study period. When gypsum was used in conjunction with plant root exudates, the decrease in soil pH was not greater than that achieved using gypsum alone, however it was again maintained over the whole study period. It is suggested that using plant root exudates to economically lower soil pH (the plant itself can be a viable crop) and smaller quantities of gypsum (compared to gypsum used as a standalone ameliorant) to maintain the lowered pH may be an optimal method of ameliorating alkaline soils.

It is hoped that by confirming aluminium phytotoxicity in alkaline soils, determining the critical pH where aluminium and alkaline toxicity become debilitating to crops and providing a potential remediation method, the results and conclusions presented in this thesis will help improve agricultural production in alkaline soils.

Declaration

This work contains no material which has been accepted for the award of any other degree or diploma in any university or other tertiary institution and, to the best of my knowledge and belief, contains no material previously published or written by another person except where due reference has been made in the text.

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David John Brautigan **Date**

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