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An ecological technology of coastal saline soil amelioration

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ABSTRACT

A field experiment was carried out in the coastal region of eastern China to determine an economic and environmentally friendly approach to saline soil bioremediation. The effects of inoculation with an arbuscular mycorrhizal fungus (AMF), *Glomus mosseae*, and a phosphate-solubilizing fungus *Mortierella* sp. on the physico-chemical and biological characteristics of coastal saline soil in the rhizospheres of castor bean (*Ricinus communis* L.) were assessed during the two-year growing season. Co-inoculation with *G. mosseae* and *Mortierella* sp. enhanced the survival percentage and growth of castor bean. AMF colonization in July and September, bacterial population in September, and actinomyces population in July were also improved by microbe inoculation. Soil electrical conductivity values and Na concentrations after microbe inoculation were significantly lower than those in non-inoculation treatments in July and September. P and organic matter content in the soil were significantly enhanced by microbe inoculation during the entire growing season. However, hydrolyzable N content increased only in June and July. No significant differences in soil pH were observed in the inoculation and non-inoculation treatments. Inoculation induced significantly stimulating effects on alkaline phosphatase and catalase activities in July as well as on urease activity in July and August. Invertase activity was stimulated in the entire growing period, except in July. The results indicate that castor bean inoculated with fungi may enlarge the C pool of the coastal saline soil.

1. Introduction

Population growth and socio-economic development has turned saline soil into an important land resource for agriculture. Saline soil from the coastal region of eastern China has received increasing attention because of its potential application in the improvement of the biological productivity of soil in bioremediation and reclamation via agroforestry (Wu et al., 2012). Vegetation has been verified as one of the most important physical, chemical, and biological methods in saline soil bioremediation (Kaur et al., 2002). Planting halophyte *Suaeda salsa* L. reportedly ameliorates coastal saline soil by decreasing soluble salt and increasing microbial content (Lin et al., 2006). In our previous study (Wu et al., 2012), we found that the planting treatment of castor bean (*Ricinus communis* L.), an oilseed plant from the family *Euphorbiaceae* with 40–50% oil concentration in commercial varieties, had significant ameliorative effects on the salinity and nutrient condition of coastal saline soil.

However, soil salinity can cause both hyperionic and hyperosmotic stress in plants and can even lead to plant demise (Evelin et al., 2009). Soil salinity can also induce a reduction in plant absorption of mineral nutrients, especially P (Grattan and Grieve, 1999). For example, the growth of castor bean seedlings has been found to be drastically inhibited by salt stress and P deficiency (Jeschke et al., 1997; Pinheiro et al., 2008). This inhibition of seedling growth weakens the impact of bioremediation via castor bean planting. Soil enzyme activity, important in the decomposition of organic residues and nutrient cycling in soil, is considered as a suitable indicator of soil quality. Urease, the most prominent enzyme involved in the soil N cycle, catalyzes the hydrolysis of urea into ammonia or the ammonium ion. Phosphatase mediates the release of inorganic P from organically bound P returned to soil. In the C cycle, invertase plays a critical role in releasing sugars with low molecular weight,

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which are important sources of C and energy for microorganisms. Catalase, an oxidoreductase that belongs to intracellular enzymes, can promote the decomposition of hydrogen peroxide and prevent cell damage caused by reactive oxygen species. However, the activities of these enzymes in the soil are adversely affected by an increase in soil salinity (Frankenberger and Bingham, 1982; García and Hernandez, 1996; Omar et al., 1994).

Bioremediation using target plant species associated with a managed community of soil microorganisms has attracted increasing attention. These microorganisms are known to benefit the physical-chemical and biological properties of soil, including its structure, nutrient availability, organic matter content, and microbial activity (Azcón et al., 2013). The arbuscular mycorrhizal fungi (AMF) are relevant members of the rhizosphere mutualistic microsymbiont populations, which are known to serve many critical ecosystem functions, including the improvement of plant establishment, enhancement of plant nutrient uptake, and plant protection against salt and other stresses (Evelin et al., 2009). Specifically, AMF can reactivate soil microbial community, enhance soil enzyme activities, and consequently improve soil quality (Kohler et al., 2009).

AMF occurs naturally in saline environments and promotes the salinity tolerance of plants by increasing the acquisition of nutrients (Ruiz-Lozano et al., 1996), decreasing the uptake of Na (Al-Karaki, 2006), and alleviating water stress (Sheng et al., 2008). However, P, one of the most essential macronutrients that limit plant growth, can precipitate with Ca^{2+}, Mg^{2+}, and Zn^{2+} ions in salt-stressed soil and become unavailable to plants (Grattan and Grieve, 1999). AMF absorbs and does not solubilize P from the soil solution (Bolan, 1991). Research has shown that P-solubilizing microorganisms (PSM) can solubilize insoluble forms of P (Azcón and Barea, 1996), especially under salt stress (Srividya et al., 2009). Therefore, co-inoculation with AMF and PSM has been applied to promote a sustainable supply of P in crops and to consequently achieve high yields under non-salt stress (Osorio and Habte, 2013) and salt stress (Zhang et al., 2011).

A significant reduction in soil salinity and electrical conductivity (EC) as well as an increase in P, organic matter, microbial activity, and diversity of coastal saline soil after two growing seasons of castor bean was observed in a previous study (Wu et al., 2012). Castor beans are known to be dependent on AMF in soil with low levels of P (Machineski et al., 2011). Inoculation with PSM and AMF had significant effects on *Kosteletzkya virginica* (L.) growth, available P concentrations in soil, pH values, soil EC, and soil enzyme activities at different salinity levels (Zhang et al., 2011). However, information on the relation between coastal saline soil and planting of castor bean inoculated with exogenous soil microbial remains unavailable. In this study, the ecological technology of coastal saline soil amelioration is investigated through field experiment to evaluate the physico-chemical characteristics and biological properties of coastal saline soil in the rhizosphere of castor bean inoculated with AMF and PSM.

2. Materials and methods

2.1. Study site

The experiment was carried out at Jinhai Agricultural Experimental Farm (32°59′–33°03′ N, 120°46′–120°52′ E) in Jiangsu Province, China, in 2010 and was repeated in 2011 (Fig. 1). At this site, the annual mean temperature is 14.7 °C, and the monthly mean temperatures in January and July are 0.8 °C and 26.8 °C, respectively. The annual mean rainfall ranges from 900 mm to 1060 mm. The area has a non-frost period of 230 d with a total sunshine radiation of 2241–2496 h annually. The main soil type is silt-puddle soil. Prior to the planting stage of the experiment, the soil had the following properties: pH, 8.22; EC, 1.32 dS m^{-1}; hydrolyzable N, 41.34 mg kg^{-1}; total K, 28.9 g kg^{-1}; available P, 15.77 mg kg^{-1};

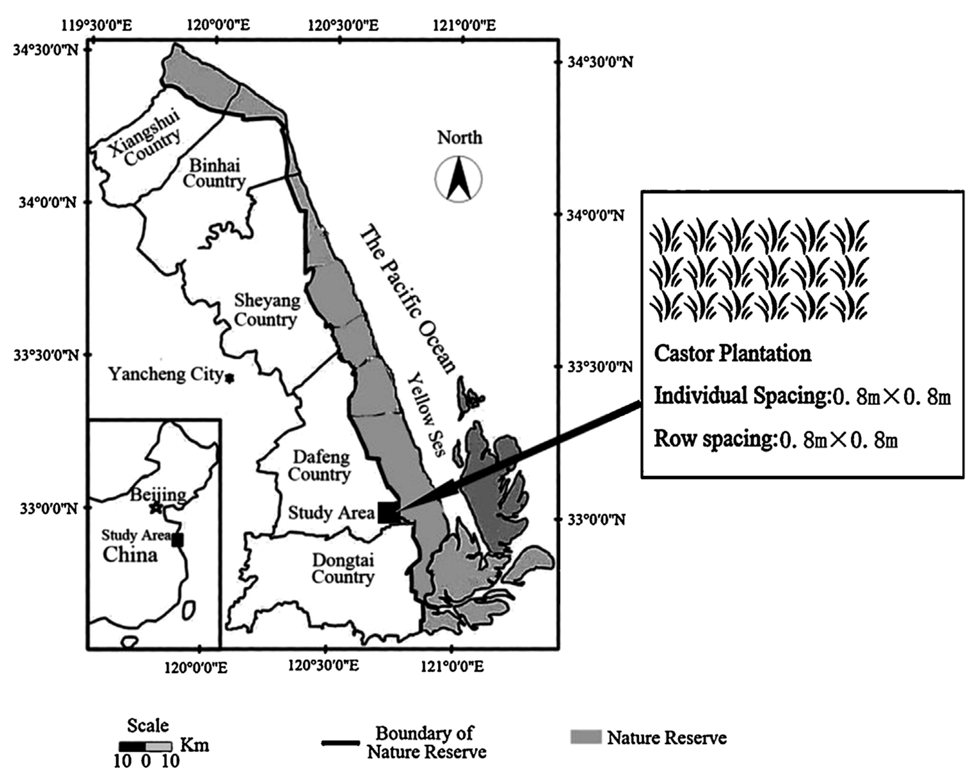

Fig. 1. Study area located at a coastal saline land in China.