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INTRODUCTION

Phosphorus (P) is a major limiting nutrient for plant growth. Because of the strong retention of P onto soil solid phases, its concentration remains generally low in soils (Hinsinger et al., 2011). The use of inorganic P fertilizers can increase plant P status but is not sustainable because of environmental issues and P-ore resources being finite. An improved availability of soil P resources has been observed in cereal-legume intercropping (e.g. Betencourt et al., 2012; Li et al., 2003). Such root-induced facilitation processes may be further utilized to decrease P fertilization while maintaining crop yield. However the underlying mechanisms are not fully understood as they appear to be soil dependent. The objective is to use thermodynamic modelling to investigate the root processes and mechanisms controlling available P in chickpea – durum wheat intercropping.

METHODS

Plants of chickpea and durum wheat were cultivated as sole-crop and intercrop in a rhizobox device according to a substitutive design. Unplanted soil was used as a control treatment. The soil used was a non carbonated Luvisol with a neutral pH. Plants were harvested at the chickpea flowering stage. The pH, P availability and dissolved Ca were measured in soil as extracted by water and $CaCl_2$ (1 and 10 mM). A set of thermodynamic models were used (i.e. CD MUSIC; Nica Donnan; ion exchange) to simulate and understand measured P availability variations in each treatment.

RESULTS AND DISCUSSION

(a) Durum wheat and chickpea increased significantly their biomasses and P uptake (i.e. P bioavailability) when intercropped. Such an increase suggests some positive interactions (facilitation) between the two plant species. Measured soil-available P with intercropping corresponded to intermediate value between those found for cereal and legume sole-crops as reported earlier by Li et al. (2008). Chickpea appeared to be the main driver of these P variations.

(b) Considering adsorption mechanisms, model simulations adequately reproduced the P availability and dissolved Ca measured in each treatment for water as well as for the two $CaCl_2$ extractions (Fig. 1). Mineralization mechanisms did not affect P availability under our experimental condition. However results of dissolved K suggested the potential occurrence of illite dissolution.

(c) Three main processes that alter rhizosphere P availability were suggested in the experimental data and models; Ca uptake, soil acidification and citrate release. Model outputs show that these root-induced processes led to P desorption from illite which was the main P-binding mineral in the studied soil.

CONCLUSIONS

Chickpea can increase P bio-availability for the intercropped durum wheat through the mobilization of inorganic P sources. Results showed in parallel an increase of P availability in intercropping compared to bulk soil. The set of mechanistic models used in the present study adequately simulated all the measured variations of P availability. Our results emphasize the importance of adsorption process in such phenomena. Three processes were underlined in intercropping; nutrient uptake and the release of proton and citrate. Thermodynamic models are relevant tools for a better understanding of the effect and origin of root-induced chemical changes.

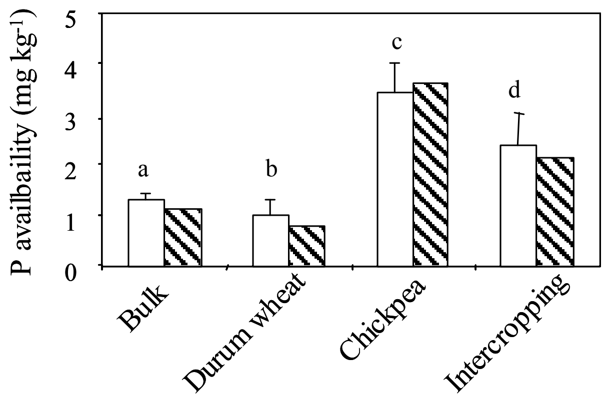

Fig. 1. Phosphorus availability as extracted by water. Bar charts stand for measured (open) and calculated (hatch) values in bulk soil and rhizosphere. The letters indicate a significant difference between crop treatments ($p < 0.05$).

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