Europ. J. Agronomy 72 (2016) 80–90

Contents lists available at ScienceDirect

European Journal of Agronomy

journal homepage: www.elsevier.com/locate/eja

Review

The intercropping common bean with maize improves the rhizobial efficiency, resource use and grain yield under low phosphorus availability

Mourad Latati[a,*], Adnane Bargaz[b], Baroudi Belarbi[a], Mohamed Lazali[c], Samia Benlahrech[a], Siham Tellah[a], Ghiles Kaci[a], Jean Jacques Drevon[d], Sidi Mohamed Ounane[a]

[a] Ecole Nationale Supérieure Agronomique, Département de Phytotechnie, Hassan Badi 16200 El Harrach, Algiers, Algeria
[b] Swedish University of Agricultural Sciences (SLU), Department of Biosystems and Technology, Box 103, SE-23053 Alnarp, Sweden
[c] Université Djilali Bounaama Khemis Miliana, Faculté des Sciences de la Nature et de la Vie & des Sciences de la Terre. Route Theniet El Had, Soufay, 44225 Ain Defla, Algeria
[d] INRA, UMR Eco&Sols, 2 Place Pierre Viala, 34060 Montpellier, France

ARTICLE INFO

Article history:
Received 25 June 2014
Received in revised form
23 September 2015
Accepted 29 September 2015
Available online 22 October 2015

Keywords:
Algeria
Legumes
Nodulation
Phosphorus
Symbiosis
Intercropping
Rhizosphere

ABSTRACT

In order to better understand how mixed crop cultures mitigate stressful conditions, this study aims to highlight the beneficial effect of the intercropping legume-cereal in enhancing soil phosphorus (P) availability for plant growth and productivity in a P-deficient soil of a northern Algerian agroecosystem. To address this question, common bean (*Phaseolus vulgaris* L. cv. El Djadida) and maize (*Zea mays* L. cv. Filou), were grown as sole- and inter-crops in two experimental sites; S1 (P-deficient) and S2 (P-sufficient) during two growing seasons (2011 and 2012). Growth, nodulation and grain yield were assessed and correlated with the rhizosphere soil P availability. Results showed that P availability significantly increased in the rhizosphere of both species, especially in intercropping under the P-deficient soil conditions. This increase was associated with high efficiency in use of the rhizobial symbiosis (high correlation between plant biomass and nodulation), plant growth and resource (nitrogen (N) and P) use efficiency as indicated by higher land equivalent ratio (LER > 1) and N nutrition index (for maize) in intercropping over sole cropping treatments. Moreover, the rhizosphere P availability and nodule biomass were positively correlated ($r^2 = 0.71$, $p < 0.01$ and $r^2 = 0.62$, $p < 0.01$) in the intercropped common bean grown in the P-deficient soil during 2011 and 2012. The increased P availability presumably improved biomass and grain yield in intercropping, though it mainly enhanced grain yield in intercropped maize. Our findings suggest that modification in the intercropped common bean rhizosphere-induced parameters facilitated P uptake, plant biomass and grain yield for the intercropped maize under P-deficiency conditions.

Published by Elsevier B.V.

Contents

* Corresponding author. Postal address: Rue de la Revolution, Collo, Skikda, Algeria. Fax: +213 21822729.
E-mail addresses: m.latati@yahoo.com (M. Latati), bargazadnane@yahoo.fr (A. Bargaz), bbelarbidz@yahoo.fr (B. Belarbi), m.lazali@yahoo.fr (M. Lazali), benlahrechsamia@gmail.com (S. Benlahrech), sihemtellah@yahoo.fr (S. Tellah), kaci.ghiles@gmail.com (G. Kaci), drevonjj@supagro.inra.fr (J.J. Drevon), ounane2@yahoo.fr (S.M. Ounane).

http://dx.doi.org/10.1016/j.eja.2015.09.015
1161-0301/Published by Elsevier B.V.

1. Introduction

Phosphorus (P) is an important nutrient which improves crop production (Raghothama, 1999; Vance, 2001). However, P is present as a finite resource in the lithosphere (0.1%), and varies with the type of soil and farming system (Thompson and Troeh, 1973). The input of P via mineral fertilizers has been practiced to improve yielding of agroecosystems (Dawson and Hilton, 2011), but the availability of P fertilizers is increasingly limited by the depletion of P mineral reserves simultaneously with increased food needs during the near future (Dyson, 1999). A situation that calls for increasing the soil P availability, which is often limited by adsorption on surfaces of mineral phases and fixation to cations (Ca^{2+}, Al^{3+} or Fe^{2+}) in acidic and alkaline soils (Hinsinger, 2001; Richardson et al., 2009). Therefore, adopting sustainable technologies to better exploit soil nutrients resources such as P has been an interesting research challenge to be resolved. For instance, the intercropping cereals with legumes has been considered as one of the efficient cropping systems that increase use of nutrients such as nitrogen (N), P and micronutrients (Lambers et al., 2006; Hauggaard-Nielsen et al., 2007; Betencourt et al., 2012). Indeed, the intercropping is defined as the growth of more than one crop species or cultivar simultaneously in the same field during the same growing season (Ofori and Stern, 1987; Hauggaard-Nielsen et al., 2007). Several studies reported that legume-cereal dual intercropping systems compared to corresponding sole cropping systems result in environmental sources use efficiency for plant growth and thus stable yields due to interspecific complementarily, facilitation and competition (Jensen, 1996; Hauggaard-Nielsen et al., 2001; Corre-Hellou and Crozat, 2005). Furthermore, the association of cereals and legumes at the same space and time led to higher yields and improved N (via biological N_2 fixation for the legume) and P nutrition (Li et al., 2005; Betencourt et al., 2012; Latati et al., 2013, 2014). In a field experiment, maize yield increased by intercropping with either cowpea (Latati et al., 2014) or faba bean (Li et al., 2003), and was associated with enhanced P uptake.

Legume-grass intercrops are known to over yield because of the stimulation of legume biological N_2 fixation. However, many agricultural soils are deficient in P. While, a new mechanism of over yielding, in which P mobilized by one crop species improve the growth of the associated crop grown in alternate rows, led to large yield increases on P-deficient soils (Li et al., 2014). Recent studies have observed an enhancement in P availability in the rhizosphere for cereals and legumes in intercropping in low P soils (Devau et al., 2011; Betencourt et al., 2012; Latati et al., 2014). Authors of the latter study confirmed the advantage of intercropping for cereal through facilitation mechanisms made by legume, which was responsible for increasing inorganic P availability by rhizosphere acidification during N_2 fixation. Such positive interactions are particularly valuable when resources are limited, as occurs in low-input agroecosystems. For example, beneficial effects of intercropping have been observed at lower rates of P fertilizer application but were no longer significant at higher rates (Li et al., 2007). This study on cereal-legume interactions with regard to soil P has attracted new interests with the reported evidence of enhanced P acquisition (Li et al., 2007). This is of particular importance of legumes such as common bean, which is known to be a P-deficiency sensitive crop worldwide and so more in the Mediterranean and tropical regions (Graham and Vance, 2003; Alkama et al., 2012). This is also the case in northern Algerian soils that are P-deficient with high pH (7.5–8), and elevated calcareous content ($CaCO_3$; 60–180 g kg^{-1} soil) (Djilli and Daoud, 1999). In these soils where fallow-cereal-rotation is the common cropping system for cereal production, there is a need for replacing fallow by legumes as a strategic necessity for food security in a context of rising prices of food products (Alkama et al., 2009).

To cope with this low P availability, we first suggest that intercropping legume-cereals might be an alternative agronomical practice that is scarcely adopted in Algerian agriculture so far. Consequently, this two-year field study aimed to highlight whether the intercropping maize (*Zea mays* L.)-common bean (*Phaseolus vulgaris* L.) might alleviate the negative effect of P-deficient in northern Algerian soils. We hypothesize that the presence of common bean as intercrop with maize will enhance N nutrition of the latter cereal crop and the biological N_2 fixation for the legume. This will also result in a greater P uptake capacity for the intercropped maize when its N nutrition is enhanced. Finally, we tested whether the advantage of intercropping common bean–maize influenced plant biomass, yield and uptake of N and P. To address these hypotheses, two experiments sites (S1 and S2 located in so called "Setif region" in northern Algeria) contrasting in their soil P available were used to assess above- (plant biomass, grain yield and nutrient uptake) and below-ground (nodulation, rhizobial symbiosis efficiency and soil P availability) parameters for both maize and common bean as sole- and inter-crops.

2. Material and methods

2.1. Experimental sites

The field experiments were carried out over two cropping seasons (2011 and 2012). The two experimental sites namely; Kasr Abtal (S1) and Baida Bordj (S2) were located in the agroecosystem of Setif region (North-east of Algiers, Algeria) where cereals and legumes are widely practiced as monocrops, but also as intercrops (to a lesser extent) such as the intercropping of maize and common bean. These two experimental sites were chosen at the basis of their soil P availability (low P level of 5.5 mg P kg^{-1} in S1 and adequate P level of 21.8 mg P kg^{-1} in S2, Table 1) as to study whether intercropping "maize-common" may alleviate the low P availability in soil.