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Research article

Advantage of intercropping maize (*Zea mays* L.) and common bean (*Phaseolus vulgaris* L.) on yield and nitrogen uptake in Northeast Algeria

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ABSTRACT
Legume-cereal intercropping is a productive and sustainable system by its nutrient facilitation, and its effect to increase N uptake for intercropped cereal; via symbiotic nitrogen (N2) fixation. The aim of this work was to test effect of maize-common bean intercropping system on the growth, nodulation, yield and N uptake. This field of study was conducted in Setif region, North of Algeria. The study was carried out using intercropping system with one Cvs of common bean and one maize CV which were cultivated locally by the farmers of the region. The results showed a positive correlation between the nodule and shoot dry weight, this correlation is more significant in the intercropping than sole crop. However intercropping increase maize yield by more than 12.5%, the N concentration in shoot (20.8%) and seed (33.5%); as consequence N concentration in rhizosphere soil was significantly enhanced for intercropped common bean. Intercropping advantage was observed especially; at low concentration of nitrogen in indigenous soil. We conclude that nitrogen symbiotic fixation has contributed to facilitate N uptake for intercropped maize.

Keywords: Intercropping system, maize, common bean, symbiosis, nitrogen, yields, Algeria.

1. Introduction

Most studies on intercrops systems reporting legume-cereal intercropping, a productive and sustainable system, its resource facilitation which consist of growing, soil's fertility and yield (Ofori and Stern, 1987; Jensen, 1996). Nitrogen (N_2)-fixing legume is an important resource for intercropped cereal (Shen and Chu, 2004; Betencourt et al., 2012) which benefited to the nitrogen uptake and improved grain yield. This positive interaction, has been confirmed in cereal-legume intercrops, compared to sole crops, for cowpea-maize, faba bean-wheat and weath-soybean intercropping system (Zhang and Li., 2003; Li et al., 2005; Dahmardeh et al., 2010). The yield increase is not only due to enhanced nitrogen nutrition of the cereal in association, but also to other unknown mechanisms (Connolly et al., 2001). The cereal farming systems occupy an important place in the Algerian food supply, but they remains tributary in both cases; variability of soil and climate or at the pattern of farming system; which results instability in production system (Alkama et al., 2009). Actually, one role of legume crops is a fallow replacement in cereals agro-ecosystems of North Algeria. However, intercropping has been practiced in Algeria but its practices deserve to be improved, especially in the choice to the types of intercropping plant-plant and plant micro-organisms.
This work was carried on intercropping maize/common-bean under field conditions in Setif region of Algeria. Our approach was consequently based on a multi-local field trial to explore a large variability of soils in three experiments sites. Such this study implied a close participation with organized local farmers. The nodulation, shoot, root biomass and N concentration in plant of two species were measured at the flowering stage; however grain yield was estimated at harvest time for intercropping and sole crop.

2. Material and methods

2.1 Experimental sites

The multi-local field experiments were conducted in 2012. The three experimental sites; El Kharba (S1), Kasr Abtal (S2) and Baida Bordj (S3), were located in Setif region, at 300 Km North-east of Algiers. However, these sites were selected because they represent major agro-ecological conditions where intercropping maize-common bean practiced. S1 (35°57.82'N) and S3 (35°51.13'N) are located in the South while S2 (35°56.24'N) is situated in North of Setif area. The rainfall is nearly 500 mm per year. Annual mean temperature is about 14.76 °C. The Mediterranean climate of Setif is characterized by a cold winter and a very hot, long and dry summer. Indigenous soil of experimental sites was characterized by a standard sampling using a drill with a 30 cm depth, at sowing stage. Table 1 shows granulometrical and chemical soil properties for all experimental sites.

2.2. Cropping system

The experimental design was a split-split-plot with four replicates. Each sub-plot treatment included one crop modalities; common bean sole, maize sole, intercropping maize-common bean and follow (4 plots×4 modalities´4×replicates). Area of experimental design in each site was 300 m^2. Plant density was 24 plant/ m^2 for sole common bean and 15 plant/ m^2. In intercropping plots; Plant density was 12 plant/ m^2 for two species. Seeds were sown on 10 June 2012. Sowing and management of field experiment were carried by farmers with their cultural practices as a management option. Crops were harvested at complete maturity for two species; on 25 September and 10 October for common bean and maize respectively.

2.3. Data collection and statistical analysis

Data were collected at two samplings stages. In the first sampling, both maize and common bean, were harvested at the full flowering stage (55 days after sowing). The shoot was separated from the root at the cotyledonary node, and then weighed after 48 h at 70 °C. Nodules were separated from the roots, counted and weighed separately. Soil sampling included rhizospher soil for two species. Rhizosphere Soil was defined as the soil volume extending to approximately 1 mm from the root (Hinsinger, 2001). After collection, the soil samples were stored refrigerated for no more than three days before analysis. At second sampling, crops were harvested at complete maturity for each species. Nitrogen concentration in plant and soil was determined Kjeldahl procedure and P concentration by green malachite method.

One-way analyses of variance (ANOVA) with sites treatment as factor with the probability level of 0.05; were conducted on indigenous soil data for characterization of granulometrical and chemical soil properties. Two-ways analyses of variance considering site treatment and crop treatment were performed on N concentration in plants, rhzosphere soil and plant biomass dry weight. Significant difference between means was determinate by Tukey’s multiple comparison tests at the 0.05 probability level. The statistical analyses were done using the software package STATISTICA 8 for Windows (StatSoft Inc. Statistica 2007).

3. Results

3.1 Typology of experimental sites

Table 1 shows the result of variance analysis (ANOVA) on soil properties of the 3 experimental sites. Granulometrical and Chemical soil properties were significantly different between all experimental sites; for $CaCO_3$ content, total-P, Olsen-P, and total-N contents in soil. The clay represents the highest proportion in all the sites. However, the highest proportion of sand was observed in S1. $CaCO_3$ content varied between 20.6 and 23.8 % however, it should be noted that all soils were calcareous. Total-N content varied between 0.81 and 1.35 g kg^{-1}: nevertheless, total-N content was significantly lowest in S1 while the high N content was observed in S2. Total-P content was noted a large variation between sites which increased from 223.2 (S1) to 435 mg kg^{-1} (S2), it was significantly greater with S2 than those other sites treatments. In contrast the mean bio-available Olsen-P was slightly increased from 21.3 (S1) to 24.7(S2) mg kg^{-1}. Therefore it can be concluded that phosphorus availability being more optimized in S1 than S3.

3.2. Plant growth and nodulation

In the maize species, site and crop affected significantly the maize root and shoot biomass, interaction crop×site not affected significantly root biomass. For S2, intercropping increased significantly the root and shoot biomass by 31.5 and 22.2%, respectively. However, intercropping increased also the root biomass for S1 and S3 by 7.5 and 5% respectively. While in these sites, shoot biomass was noted a light increase with sole crop (Fig.1a,c). In common bean species, site and crop affected significantly the maize root and shoot biomass, interaction crop×site not affected significantly shoot biomass. For S2 and S3, both common bean root and shoot biomass were significantly decreased by more than 66 and 75 %, respectively under intercropping system. By contrast, in S1; intercropping was increased common bean root biomass by 74%. However, common bean shoot biomass was not significantly affected by crop (Fig.1b,d). In addition, nodule biomass was affected significantly by site and crop treatment; however it was not affected significantly by interaction crop×site. We observed in all sites (S1, S2 and S3) a high increase in nodule biomass (Fig.1e) by 65, 23 and 34% respectively, for common bean intercropped with maize.

In order to assess the efficiency in use of the rhizobial symbiosis (EURS), the values of common bean shoot biomass at sole and intercropping were represented as a function of those of nodule biomass in Fig. 2 with the slope of the regressions being an estimation of the EURS., a positive correlation was observed between these two parameters for all sites in sole and intercropping.

Table 1 Granulometrical and chemical soil properties of experimental sites. Values represent the mean of three replicates ± SE (standard errors). Values of probability of one-way ANOVA (Site treatment). Within a column different letters denote significant difference (P < 0.05).

Sites treatment	Clay (%)	Loam (%)	Sandy (%)	$CaCO_3$ (%)	Total-N (g/ kg^{-1})	Total -P (mg/ kg^{-1})	Olsen-P (mg/ kg^{-1})
S1	36.6 ± 0.2 c	32.4 ± 0.2 b	30.9 ± 0.3 a	20.6 ± 0.2 b	0.81 ± 0.06 b	223.2 ± 3.5 c	21.3 ± 0.2 b
S2	39.1 ± 0.1 b	34.4 ± 0.4 a	26.5 ± 0.2 b	24.2 ± 0.2 a	1.35 ± 0.08 a	435 ± 7.1 a	24.7 ± 0.4 a
S3	40.5 ± 0.4 a	33.2 ± 0.3 ab	26.3 ± 0.3 b	23.8 ± 0.2 a	1.23 ± 0.06 a	258.3 ± 5 b	21.9 ± 0.5 b
	Clay (%)	Loam (%)	Sandy (%)	$CaCO_3$ (%)	Total-N (g/ kg^{-1})	Total-P (mg/ kg^{-1})	Olsen-P (mg/ kg^{-1})
	P values	*P values*	*P values*	*P values*	*P values*	*P values*	*P values*
Sites treatment	<0.001	<0.0093	<0.001	<0.001	0.0038	<0.001	0.0013

However the high correlation was observed when common bean was intercropped with maize. S1 was observed the highest rate (17%) of the R^2 increase under intercropping, while S2 was noted the lowest rate (3%) of this increase under intercropping effect.

3.3. N concentration in plant

For N concentration in two species, site, crop and the interaction between site and crop treatment affected highly significantly the N concentration in shoot, root at flowering stages and seed in harvest stage except interaction between treatment in shoot N concentration for maize (P >0.05). In common bean, N shoot concentration was increased for S2 and S3 under intercropping treatment by 6.1 and 8.2% respectively, while it was decreased for S1 by 28.5%. The same was observed with N concentration in seed as that, under intercropping; N seed concentration was decreased by 8.7% for S1 and it was increased by 24.6 and 0.85% for S2 and S3 respectively. However the N concentration in root decreased in intercropping treatment for S3 and S1 while it was increased in the same crop for S2. In maize species, intercropping increased significantly N shoot concentration in all sites by 14.7, 18.6 and 20.8% for S1, S2 and S3 respectively. However N root concentration was enhanced under intercropping treatment for S1 and S3 while it was decreased by 31.5% for S2. Intercropping increased N seed concentration for S1 and S3 by 28.8 and 33.5/ respectively. In contrast N seed concentration was decreased by 7.7% for S2 (table 2).

3.4. Grain yield

The grain yield of common bean was not influenced by crop, but it was affected highly significantly by site and interaction between site and crop treatment. The highest value (7.5 $t.ha^{-1}$) of grain yield was observed in common bean intercropped with maize for S3.

However grain yield was increased in sole crop for S1 and S2. The maize grain yield was highly significantly affected by crop and site treatment; in contrast it was not influenced significantly by interaction between site and crop. The grain yield of maize intercropped with common bean was increased by more than 12.5% for all sites, with the largest increase being 46.6% for S1 (Table 2).

4. Discussion

4.1. Increased efficiency in use of the rhizobial symbiosis (EURS)

EURS was increased in common bean intercropped with maize for all experimental sites, this increase was highly observed with S1because total-N concentration in initial soil was the lowest value in S1 than others sites (table 1), It is well known that, both in actinorhizal plants and legumes, nitrogen decreases nodulation (Gentili and Huss-Danell, 2002, 2003; Gentili et al., 2006; Alkama et al., 2009). The increase of EURS under intercropping treatment is can be explained by interspecific competition for use of nitrogen by maize intercropped with common bean. Field studies had shown similar results for increase of N2 fixation by common bean, as a consequence of the competition with the intercropped durum wheat (Li et al., 2009; Naudin et al., 2010).

In addition, increase of N concentration observed in the rhizosphere of common bean under intercropping confirmed previous results obtained for EURS. As for that, Fig.3 shows N concentration measured in rhizosphere of common bean grown as intercrops or sole crops for the three sites treatments. Crop (p <0.001), sites (p <0.001) and interaction between treatment (p <0.05) was highly significant affected N concentration. However we observed large increase of N concentration under intercropping ; for S1, S2 and S3, Common bean increased its rhizosphere N concentration by 38.5, 25.1 and 21.7% respectively (relative to fallow) when grown as sole crop, and by 88.2, 45.2 and 56.5% respectively when intercropped (Fig. 3). The N fixed by legume can be use by intercropped cereals during their growing period and this N is an important resource for the cereals (Shen and Chu, 2004).

In our experiment, increase of EURS via N2 fixation under intercropping was associated with increases in N concentration in rhizospher of common bean. We can assume that common bean can transfer this N fixed which benefit to the intercropped maize.

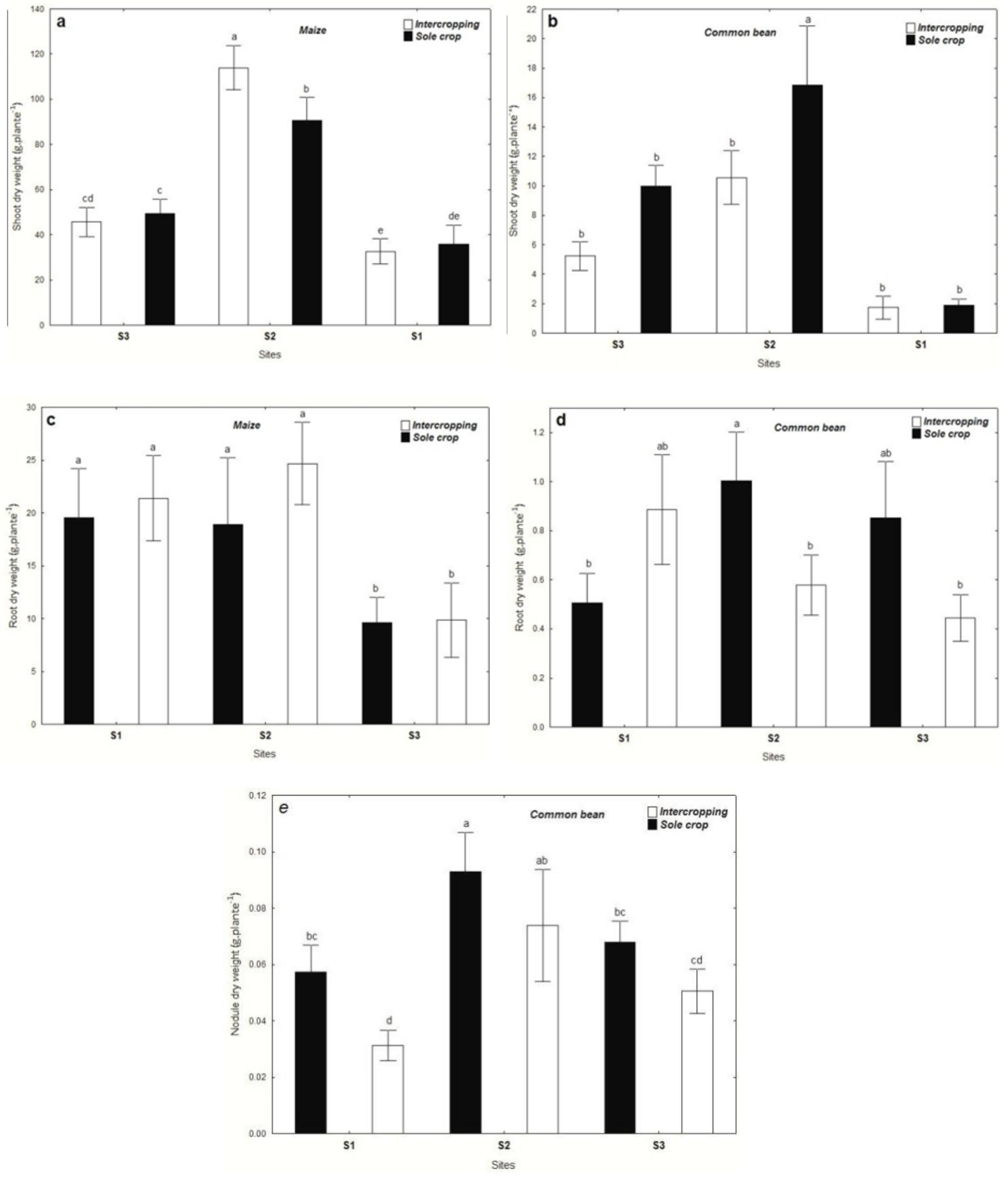

Fig. 1 Dry weight of shoot (a,b), root (c,d) and nodule (e) for maize and common bean in different crop and site treatments. Values are the mean of 5 replicates. Bars indicate standard errors. Within the columns, there are different letters which denote significant difference between treatments (site vs crop) ($p < 0.05$).

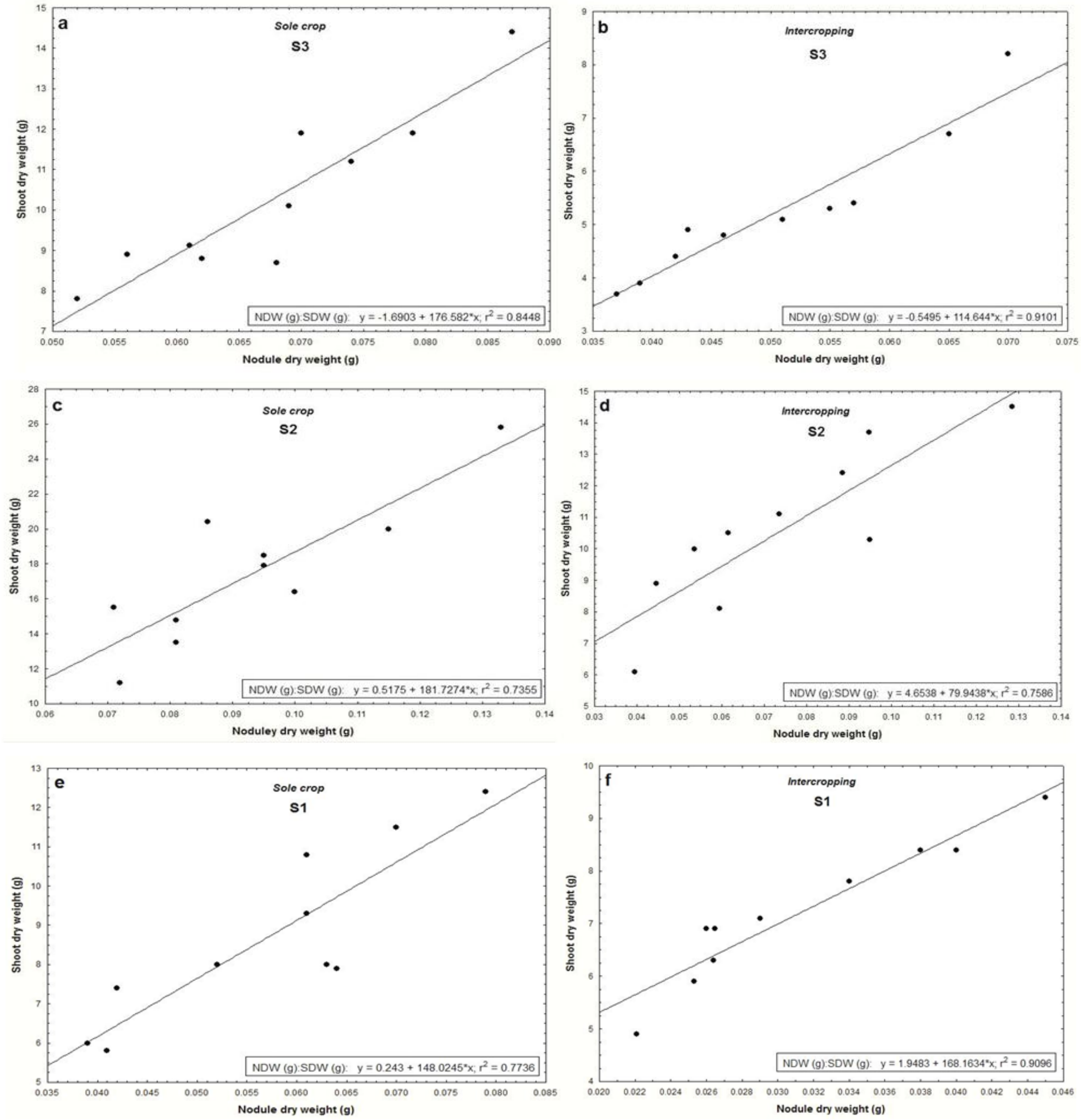

Fig. 2 Effect of intercropping on EUSR (the regression parameter of shoot as nodule) in different sites. Data are the mean of 10 replicate at full flowering stage.

Table 2 Nitrogen concentration in shoots, roots and seed for maize and common bean in different treatments. Values represent the mean of three replicates ± SE (standard errors). Values of probability of two-way ANOVA (site treatment×Crop treatment) was indicated. Within a column, there are different letters which denote significant difference ($p < 0.05$).

		Common bean			Maize		
Sites treatment	Crop treatment	Shoot N concentration (mg g $^{-1}$)	Root N concentration (mg g $^{-1}$)	Seed N concentration (mg g $^{-1}$)	Shoot N concentration (mg g $^{-1}$)	Root N concentration (mg g $^{-1}$)	Seed N concentration (mg g $^{-1}$)
S1	Intercrop	45.3 ± 0.1 b	14.2 ± 0.3 c	54.7 ± 0.4 d	29.6 ± 0.2 a	4.1 ± 0.04 c	23.7 ± 0.2 b
S1	Sole crop	58.2 ± 0.08 a	17.5 ± 0.2 b	59.5 ± 1.1 b	25.8 ± 0.3 b	3.8 ± 0.1 c	18.4 ± 0.6 d
S2	Intercrop	38.4 ± 0.4 d	15.4 ± 0.1 c	71.3 ± 0.2 a	30 ± 0.2 a	5.7 ± 0.06 b	19.3 ± 0.08 d
S2	Sole crop	36.2 ± 0.3 e	11.3 ± 0.6 d	57.2 ± 0.08 c	25.3 ± 0.2 b	7.5 ± 0.08 a	20.8 ± 0.1 c
S3	Intercrop	40.7 ± 0.06 c	17.1 ± 0.1 b	58.9 ± 0.2 bc	23.8 ± 0.4 c	3.6 ± 0.1 cd	27.5 ± 0.08 a
S3	Sole crop	37.6 ± 0.1 d	21.4 ± 0.2 a	58.4 ± 0.2 bc	19.7 ± 0.3 d	3.2 ± 0.2 d	20.6 ± 0.1 c
		Shoot N concentration	Root N concentration	Seed N concentration	Shoot N concentration	Root N concentration	Seed N concentration
		P values	*P values*	*P values*	*P values*	*P values*	*P values*
Sites		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Crop		<0.001	<0.001	<0.001	<0.001	<0.001	<0.001
Sites×crop		<0.001	<0.001	<0.001	0.34	<0.001	<0.001

Table 3 Grain yields (t ha^{-1}) of common bean and maize grown in different sites under sole crop and intercropping.

Sites treatment	Crop treatment	Common bean Grain yield ($t.ha^{-1}$)	Maize Grain yield ($t.ha^{-1}$)
S1	Intercrop	2.3 ± 0.3 c	15.1 ± 1.7 c
S1	Sole crop	2.9 ± 0.2 bc	10.3 ± 1.1 d
S2	Intercrop	7.5 ± 0.7 a	24.3 ± 1.6 a
S2	Sole crop	4.4 ± 0.1 b	21.6 ± 1.1 ab
S3	Intercrop	2.8 ± 0.6 bc	19.1 ± 1.2 abc
S3	Sole crop	4.2 ± 0.3 b	16 ± 0.7 bc
		P values	*P values*
Sites		<0.001	<0.001
Crop		0.27	0.003
Sites × crop		<0.001	0.67

This intercropping effect was confirmed for cowpea by Dahmardeh et al., (2010) who reported that intercropping increased the amount nitrogen in rhizosphere of cowpea intercropped with maize.

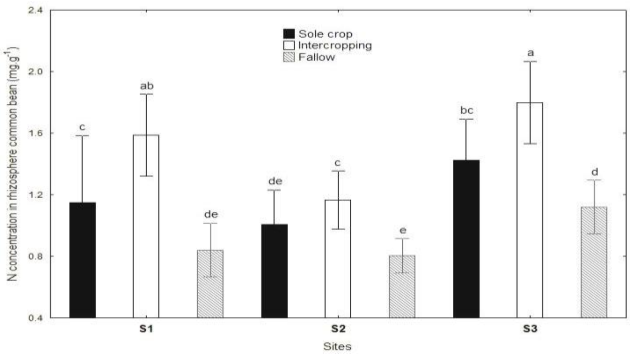

Fig. 3 Values of N concentration in the rhizosphere of common bean in different sites treatments for intercropping and sole crop. Values were compared to fallow corresponding to control soil without plant. Values are the mean of 3 replicates. Bars indicate standard errors. Different letters indicate significant difference at $p < 0.05$.

4.2. Interspecific competition and nitogen uptake by plant

Nitrogen symbiosis fixation by legume was used as important resource for intercropped cereal during growing cycle (Shen and Chu, 2004). Our result shows, that N concentration in plant was highly significantly affected by site and crop treatment. For S1, intercropping decreased N concentration in common bean shoot, root and seed, this decrease was probably due to high interspecific competition by intercropped maize, as a consequence of low N concentration in indigenous soil (table 1). On the other hand, N concentration in maize shoot and seed was enhanced under intercropping. In contrast, for S2 and S3 which N concentration in indigenous soil was highest than S1, intercropping increased N concentration in common bean shoot and seed but the high rate of increase was observed for S3 in seed (24.5%) compared to S1(0.8%) .

For S1 and S3, common bean had a positive effect on associated maize which resulted from enhanced N concentration in shoot and seed while, N concentration in seed maize was decreased by intercropping for S2, we can explain this last effect; as result of high use for N by intercropped common bean. Callaway (1995) reported that interaction between species increase resource availability of some species intercropped by facilitative mechanisms which changes environmental conditions.

In our result, common bean intercropped with maize decreased interspecific competition for nitrogen use through N2 fixation, especially at low N concentration in indigenous soil. Previous studies shows a significant effect of interspecific interactions on N uptake in wheat/soybean under intercropping (Li et al., 2003a,b). Betencourt et al., (2012) reported that intercropping durum wheat-chickpea increased N concentrations in shoot, root and N uptake for durum wheat under phosphorus sufficiency.

4.3. Yield advantages for common bean/maize intercropping systems

Increase of cereal grain yield by intercropped legume has been reported in the literature. For intercropping system, grain yield of either maize (Dahmardehet al., 2010; Li et al., 2005) or durum wealth (Zhang et al., 2003) was increased when intercropped with cowpea, faba bean and soybean. In our results crop had not a significant effect on common bean grain yield, but it was significantly affected by interaction between crop and site treatment, common bean grain yield for S2 was increased under intercropping (table 3). We can explain this effect by increased of N concentration in common bean rhizosphere with low interspecific competition by intercropped maize.

For S1and S3, intercropping decreased common bean yield which confirmed the high competition by intercropped maize on nitrogen resource. However, maize grain yield was significantly increased under intercropping in all sites. This increase was probably due to high N_2 fixation by intercropped common bean; as a consequence increase of N uptake of associated maize. Haymes and Lee, (1999) reported increase by 40% in grain yield wheat intercropped with field bean. Yield advantages in intercropping system were confirmed with wheat/maize and faba bean/maize systems (Li et al., 2005). Furthermore, Takim, (2012) reported increase of maize gain yield under intercropping with cowpea.

5. Conclusion

The aim of our study was to assess nitrogen symbiosis fixation in maize-common bean intercrop, and to test the effect of interspecific interaction between two species on N use efficiency and grain yield. Our results suggest that the efficiency in use of the rhizobial symbiosis was increased in common bean intercropped with maize. Such an increase was, to some extent, associated with enhanced of N concentration in rhizosphere of intercropped common bean, as consequence; increase for N uptake in shoot and seed of intercropped maize, especially for sites which are noted low N concentration in indigenous soil. As that, common bean had a positive effect on interspecific competition through nitrogen partitioning with the intercropped maize via increased of N2 fixation under intercropping. Consequently in our experiment maize grain yield was significantly increased by intercrop effect, we observed this result at all experiment sites. This result confirmed the advantage of intercropping maize-common bean over sole cropping system as sustainable agriculture in Setif agrosystem in the north of Algeria.

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