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INTERCROPPING MAIZE — COMMON BEAN ENHANCES MICROBIAL CARBON AND NITROGEN IN LOW-PHOSPHORUS SOIL UNDER MEDITERRANEAN CONDITIONS

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Abstract. The positive effect of intercropping under low phosphorus (P) conditions has already been reported in previous works. The aim of this study was to test the hypothesis that intercropping (common bean — maize) in P deficient soil, can enrich carbon (C) and nitrogen (N) of the microbial biomass (MB) through a transfer from root nodules of the plant and rhizospheric microbial flora in a field located in "Setif region" in northern Algerian agroecosystem(Mediterranean climate). The rate of nodular N sequestered in intercropped common bean was higher compared to sole crops and fallow. However, under intercropped and low P conditions, the rate of nodular N sequestered is highest over two years. Carbon of the microbial biomass (MB-C) is higher in the intercropping compared to sole crops and fallow but it is even higher in P deficient soil. Moreover, a strong correlation is established between nodular C and MB in intercropping under low P conditions. In these same conditions, the total soil respiration was the highest and the lowest C:N ratio of MB was recorded. These results showed that in low P soil, intercropping is a good solution to enhance the rhizospheric MB that can fertilize the soil and recycle mineral elements.

Keywords: Intercropping; P-Deficiency; Microbial biomass; Carbon; Nitrogen; agroecosystem

INTRODUCTION

A soil's quality affects the agroecosystems services and sustains biological productivity to promote plant growth and increase bio-availability of the essential nutrients [1, 2]. However, the effect of intercropping system on agroecosystem productivity on C and N sequestration have been well documented in either short- or long-term duration [1, 3]. The increase of C input into the soil through root residues has been confirmed for both legumes and cereals in intercropping compared to mono-cropping systems [4]. Indeed, recent studies suggest greater N storage in legumes-cereals intercropping as a result of enhancing in efficiency in use of rhizobial symbiosis (EURS) in low P soil compared to high P soil conditions [2]. On the other hand, variation in C:N ratio of soil microorganisms (fungi and bacteria) has been attributed to evaluated relative demand of soil microbes for C and N [5]. The changes of C:N ratio in MB may have important effect for N and C cycling. Considering the interspecific interaction (complementarily and facilitation) of legumes on rhizosphere MB in intercropping system, a hypothesized effect of cereals-legumes intercrops on investigating of the MB C:N and its relationship with rhizobial N_2 fixation would be tested.

Our previous studies reported that intercropping common bean-maize might be an alternative agronomical practice that is scarcely adopted in north-east Algerian agroecosystem under low P conditions [6]. In the studies reported here, we hypothesize that the presence of common bean as intercrop with maize will enhance both MB-C and MB-N through greater input of nodules C and N into the soil rhizosphere in either P deficient or P sufficient conditions. This will also result in a significant change in the C:N ratio and MB respiration. To address these hypotheses, both the intercrop and sole crop were grown in two years rotations in the same experiment sites studied in our last research experiment [2] located in Setif region in northern Algerian agroecosystem.

MATERIALS AND METHODS

The study was performed during 2012—2013; the field experiments were carried out over the same two experimental sites S1 (35°58, 11'N and 5°14, 90'E) and S2 (35°53, 37'N and 5°37, 01'E) studied in our last research [2]. Sites are located in the agroecosystem of Setif (300 km north-east of Algiers) where maize and common bean are widely cultivated as intercropping. An experiment designed to fulfil the aim of this study was carried out with one common bean cultivar (*Phaseolus vulgaris* cv. El Djadida) and one maize cultivar (*Zea mays* cv. Filou) cultivated by most farmers' fields in Algerian agroecosystem. Split-plot was used as an experimental design with four replicates. Seventy days after sowing (DAS) that corresponds to a full flowering stage, soil samples were taken from the rhizosphere of each species and fallow plot. The rhizosphere of both maize and common bean roots was bulked for each replicate in all crop treatments. The rhizosphere samples were then stored at 4°C for 72 hours before analysis. Indeed, the nodules were separated from the common bean roots, dried and weighed separately.

The soil MB-C and MB-N have been measured in physico-chemical laboratories at the national institute of agronomy research (Montpellier, France). MB-C and MB-N were determined by chloroform fumigation-extraction method modified and adjusted from Brookes and Jenkinson methods. The MB-C and MB-N were determined by calculating the difference between TOC and TN of chloroform-fumigated and unfumigated soil samples. However, the final values of microbial biomass were divided by conservation factors: KC = 0.45 and KN = 0.54 for MB-C and MB-N, respectively.

To account for problems associated with data estimation, all C and N concentrations (g plant and μg ml1 for plant and soil, respectively) in either rhizospheric soil or nodule were converted and calculated to stock (g C and N m^2).

RESULTS AND DISCUSSION

The results of this study showed that the rate of nodular N sequestered by intercropped common bean is significantly higher compared to the correspondent sole crop as well as in 2012 and 2013 seasons (Fig. 1). This joins the works of [2, 7—9]. Furthermore, our results showed a higher nodular N sequestration rates under P deficient soil relative to P sufficient soil. This suggests a more important symbiotic N_2 fixation under these conditions.

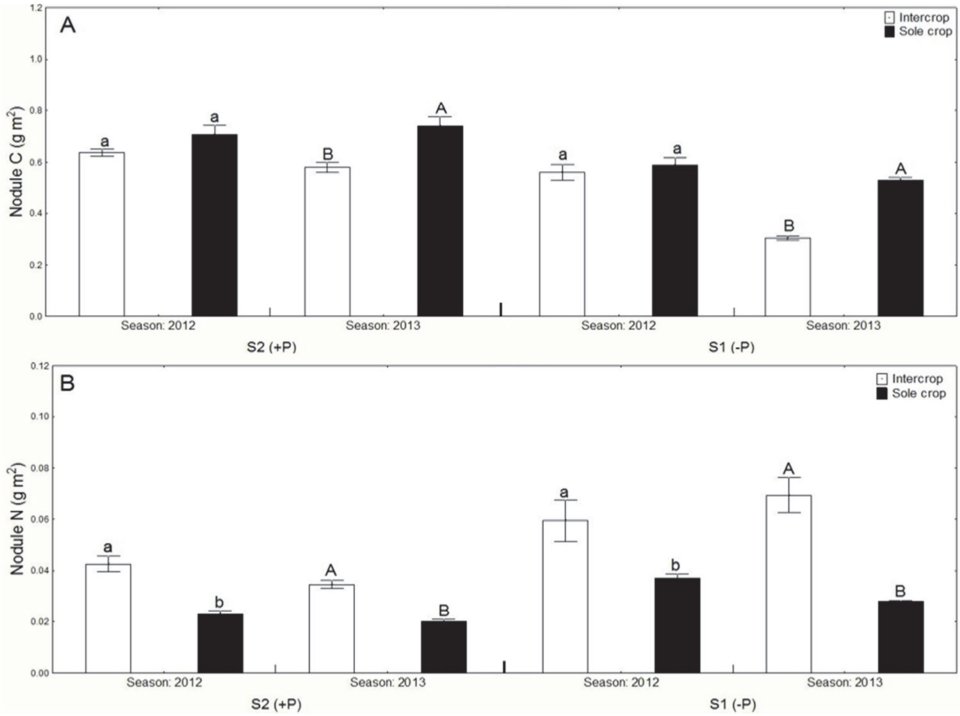

Fig. 1. C (A) and N (B) stock (g m^{-2}) in the nodule of common bean as sole crop and intercrop under S2 and S1 conditions.
Values correspond to the mean calculated with 5 replicates. Bars indicate standard errors.
For each crop,letters show significant differences between cropping systems ($p < 0.05$)

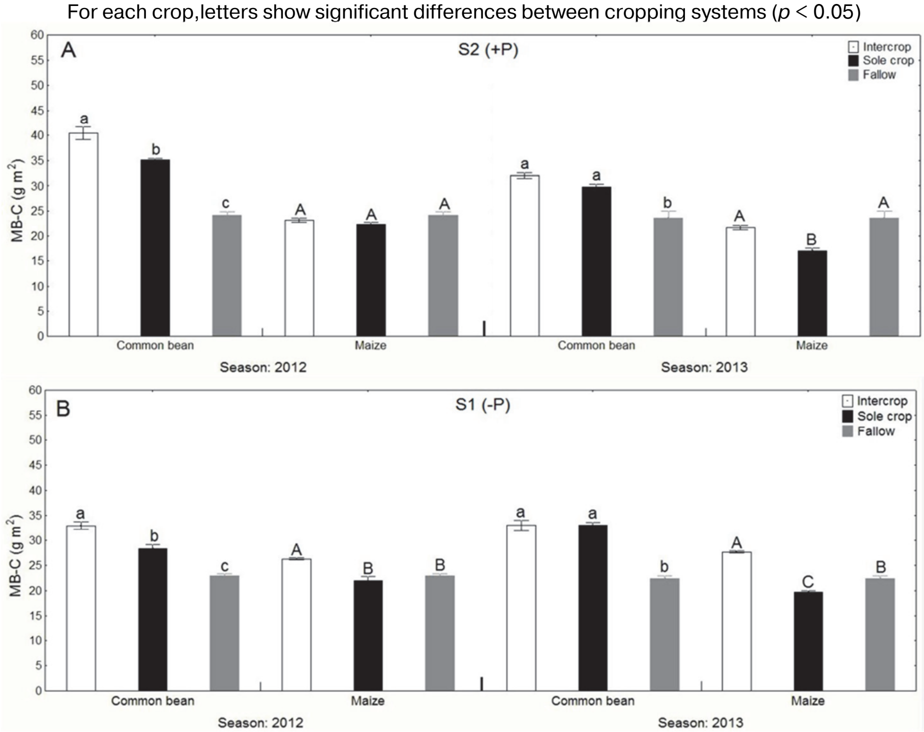

Fig. 2. MB-C (g m^{-2}) in the rhizosphere of common bean and maize as sole crop and intercrop and in the fallow under S2 (A) and S1 (B) conditions.
Values correspond to the mean calculated with 5 replicates. Bars indicate standard errors.
For each crop, letters show significant differences between cropping systems ($p < 0.05$)

The results show also that the N content in the rhizospheric MB is much higher under intercropping compared to their respective sole crop and fallow (Fig. 2). This result is very interesting more especially as fallow crop is currently a widespread practice in Algeria. The increase of N content in microbial biomass is highly positively correlated with N and C respectively sequestered in nodules under intercropping and P deficiency conditions (Fig. 3). That suggests a transfer of nodular nitrogen to the rhizosphere in favour of rhizospheric microorganisms after senescence of the nodules. The rate of N in rhizospheric MB is significantly higher in intercropping under low P conditions as well as in 2012 and 2013 seasons. This is confirmed in this study by the effect exerted under intercropping in low P soil on MB.

Indeed, the increase of nitrogen content in microbial biomass is highly positively correlated with nitrogen sequestered in nodules under intercropping and P deficiency conditions (Fig. 3). This suggests a transfer of nodular nitrogen to the rhizosphere in favour of rhizospheric microorganisms after senescence of the nodules. The rate of N in rhizospheric MB is significantly higher in intercropping under low P conditions as well as in 2012 and 2013 seasons. This is confirmed in this study by the effect exerted under intercropping in low P soil on MB. The study of Tang et al. has already highlighted the increasing of carbon in rhizospheric microbial biomass of intercropping compared to monocultures. As it was notified previously, under low P conditions, the plant is subjected to a stress that induces it to increase the rate of symbiotic fixation of atmospheric nitrogen. This enriched the soil microbial biomass after senescence of nodules.

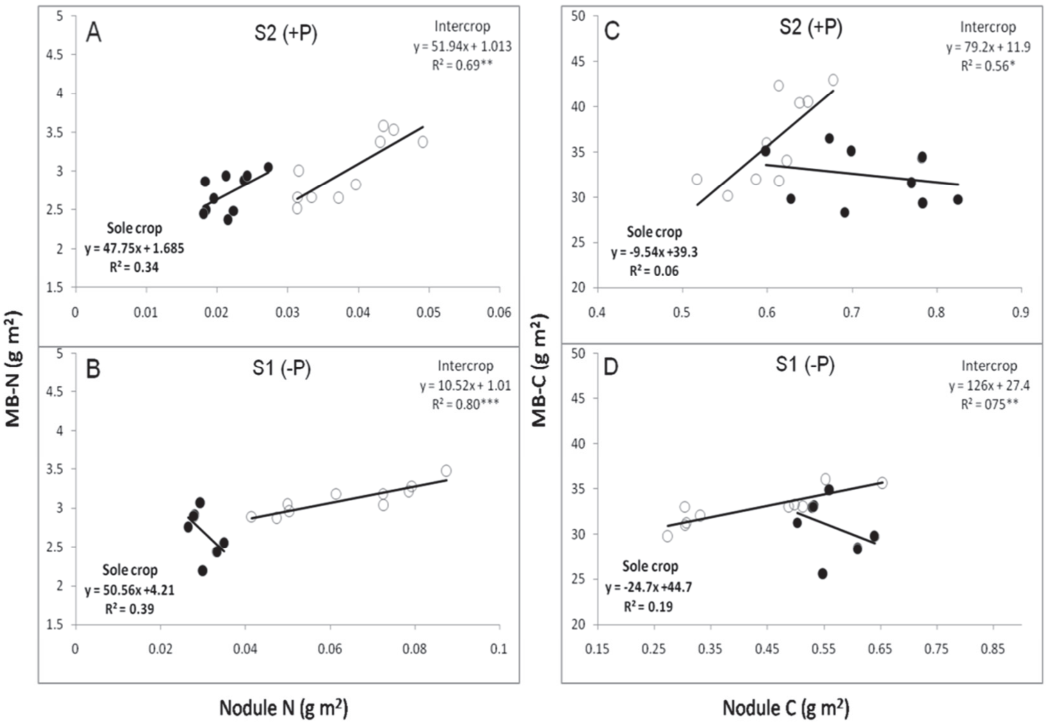

Fig. 3. Relationship between N stocks in common bean nodules and MB-N (A and B) and between C stock in nodules and MB-C (C and D) in either intercropping (opened circle) or sole crop (filled circle) under S1 and S2 conditions. All regression functions (intercropping: light gray text; and sole crop: dark gray text,respectively) were linearly established from 10 replicates and asterisks; *, **, denote significant difference at $p< 0.05$, $p< 0.01$ and $p< 0.001$, respectively

Furthermore, evolution of the microbial soil respiration is proportional and positively correlated with nodule C stock in intercropping under P deficient soil (Fig. 4B). This can be justified by the fact that the intercropping in low P soil allows efficient use of environmental resources which stimulates plant growth on the one hand. Several studies have concerned the interaction between the permeability to oxygen nodular (nodular permeability) and nodular biomass [10, 11]. On the other hand, it stimulates the growth of rhizospheric microorganisms and thus enhancing their respiration [12]. They were able to show, the nodular permeability to oxygen is increased under P deficiency in controlled environment in hydroaeroponic [6, 13]. On the other hand, it stimulates the growth of rhizospheric microorganisms enhancing their respiration. Several studies have concerned the interaction between the permeability to oxygen nodular (nodular permeability) and nodular biomass.

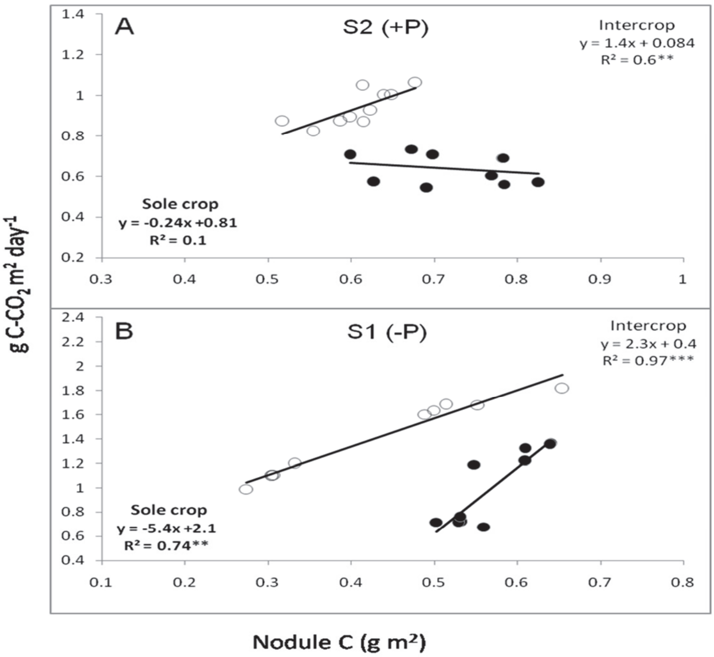

Fig. 4. Relationship between C stocks in common bean nodules and soil in either intercropping (opened circle) or sole crop (filled circle) under S1 (B) and S2 (A) conditions. All regression functions (intercropping: light gray text; and sole crop: dark gray text, respectively) were linearly established from 10 replicates and asterisks; **, ***, denote significant difference at $p< 0.05$, $p< 0.01$ and $p< 0.001$, respectively.

CONCLUSION

An increase of MB-C and MB-N was highlighted in common bean — maize intercrop under low P conditions. P deficiency causes a stress in the plant that induces an increase in symbiotic nitrogen fixation which allows increasing P availability in the soil. This increase of symbiotic N_2 fixation enriches the rhizosphere with organic matter, which has accordingly enhanced MB-C and MB-N. Enriched rhizospheric microbial flora contributes to mineralization of SOM, which stimulates rhizodeposition and growth of the plant.

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СОВМЕСТНЫЕ ПОСЕВЫ КУКУРУЗЫ И ФАСОЛИ ОБЫКНОВЕННОЙ УВЕЛИЧИВАЮТ МИКРОБНУЮ БИОМАССУ АЗОТА И УГЛЕРОДА В ПОЧВАХ С НИЗКИМ СОДЕРЖАНИЕМ ФОСФОРА В УСЛОВИЯХ СРЕДИЗЕМНОМОРЬЯ

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В предыдущих работах уже сообщалось о положительном влиянии смешанных посевов в условиях низкого содержания фосфора (P). Цель данного исследования заключалась в проверке информации о том, что смешанные посевы (фасоль обыкновенная — кукуруза) на почвах с низким содержанием P могут увеличить долю углерода (C) и азота (N) микробной биомассы (МБ) путем их перемещения из корневых клубеньковых растений и ризосферной микрофлоры на поле, расположенном в регионе Setif на севере Алжира (средиземноморский климат). Количество N, сосредоточенного в клубеньках фасоли обыкновенной, было выше при выращивании в поликультуре по сравнению с монокультурой и паром. Тем не менее, несмотря на низкое содержание P в почве, при смешанном выращивании уровень N в клубеньках оказался самым высоким за два года. Содержание C в микробной биомассе (МБ-C) было выше при поликультуре по сравнению с монокультурой и паром, однако этот показатель увеличивался в почвах с дефицитом P. Кроме того, установлена сильная корреляция между клубеньковым C и МБ при поликультуре в условиях низкого P обеспечения. В тех же условиях показатель общего «дыхания почвы» имел самое высокое значение и отмечалось самое низкое соотношение C: N МБ. Полученные результаты свидетельствуют о том, что при низком содержании P в почве смешанные посевы являются продуктивным способом увеличения ризосферной МБ, которая способна повысить плодородие почвы и рециркулировать минеральные элементы. Ключевые слова: Поликультура; низкое содержание P; микробная биомасса; углерод; азот; Агроэкосистема.

Ключевые слова: глубокая обработка почвы, антропогенное воздействие, технология стриптил, полосная обработка почвы

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