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Macronutrient content and accumulations in different arrangements of dwarf pigeon pea intercropped with corn

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Intercropping is a technique which consists of cultivating two or more species in the same area. In these systems, planning and management should be carried out in order to avoid interspecies competition for water, light, and nutrients. This paper aimed to evaluate macronutrient content and accumulations in corn (*Zea mays* L.) intercropped with dwarf pigeon pea (*Cajanus cajan* L.) in different plant arrangements. The experimental design adopted was one of randomized blocks, with six treatments and four repetitions. The treatments consisted of different arrangements of dwarf pigeon pea intercropped with corn: corn in monoculture, dwarf pigeon pea sown in the same rows as the corn, one row of dwarf pigeon pea sown between the rows of corn, dwarf pigeon pea sown in the same rows and in a row between the corn, and dwarf pigeon pea sown in the same rows and in two rows between the corn. The following variables were evaluated: dry matter (t ha^{-1}), macronutrient content and accumulations (g kg^{-1}), total chlorophyll in the corn leaves (FCI) and grain yield of corn, as well as dry matter production (t ha^{-1}) and macronutrient content in the aerial part of the dwarf pigeon pea (g kg^{-1}). The arrangement with dwarf pigeon pea sown in the same rows and in two rows between the corn increased N content in the corn plants, in relation to the other arrangements and the corn in monoculture. Ca content and accumulations were higher in corn in monoculture and in the arrangement with dwarf pigeon peas sown in the same rows as the corn.

Key words: *Zea mays* L., *Cajanus cajan*, interspecies competition, plant nutrition.

INTRODUCTION

In recent years, there have been great advances in corn crop management, and consequently, productivity gains in the whole country (Moreira et al., 2014). It is estimated that the crop occupies 15.9 million hectares, with 67 million tons of grain being produced (CONAB, 2016). Part of the success in the production of this cereal is due to

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the high number of commercial cultivars adapted to the different regions and cultivation systems and the possibility of intercropping with other economic and/or foraging crops (Jakelaitis et al., 2005).

Intercropping consists of the simultaneous cultivation of two or more species in one agricultural area, with coexistence space and time dimensions between the cultivated plants (Pinto et al., 2013). In intercropping, knowledge about the behavior of the species with regards to their need for water, light, and nutrients is of great importance to the system's success (Pariz et al., 2011).

The favorable characteristics of corn, such as a higher rate of dry matter accumulation in the initial stages of development, the plant's tallness, and the involvement of cobs, allow harvesting to occur without interference from intercropped plants (Busato and Busato, 2011).

The dwarf pigeon pea is one of the species intercropped with corn, since lower Fabaceae dry matter production avoids competition with the cereal and does not compromise mechanized harvesting (Cortez et al., 2009). Mixing Poaceae and Fabaceae has the following advantages: higher dry matter performance, in relation to the isolated cultivation of each species; greater stimulation of N biological fixation by fabaceae, and greater efficiency in the use of water and soil nutrients, due to the exploitation of different volumes of soil by root systems with different patterns (Collier et al., 2011).

There are various questions regarding the effects of competition between jointly cultivated crops (Richart et al., 2010). For adequate species establishment and performance, the soil needs to be in good fertility conditions; the opposite will cause competition for available nutrients, affecting the development of species (Alvarenga et al., 2011). Abilities to extract nutrients from the soil and the quantities required vary not only with the species, but also with the degree of competition (Cury et al., 2012), which can vary in accordance with the competing plant population (Silva et al., 2015).

Thus, the need arises for studies to be conducted regarding the nutritional dynamic in intercropping with the aim of finding more efficient techniques to minimize competition for nutrients (Viera et al., 2013). Competition can be minimized with the adoption of cultivation practices such as spatial arrangement and defining plant populations (Oliveira Filho et al., 2016).

In light of this, the aim of this paper was to evaluate the macronutrient content and accumulations in corn intercropped with dwarf pigeon pea in different plant arrangements.

MATERIALS AND METHODS

Site location and characterization

The study was conducted from December 2014 to July 2015, in an experimental area in the municipality of Araras – SP, at the geographical coordinates 22°17'56.9'' S and 47°22'53.80'' W, and at an altitude of 701 m. The location's soil is classified as Dystrophic Red Latosol (Oxisol), of a clayey texture, with the following chemical features in the 0.0 to 0.20 m layer: pH (in $CaCl_2$) = 5.5; P = 16.5 mg dm^{-3}; K = 4.1 $mmol_c$ dm^{-3}; Ca = 28.5 $mmol_c$ dm^{-3}; Mg = 10.0 $mmol_c$ dm^{-3}; H $^{+}$ Al = 22.0 $mmol_c$ dm^{-3}; soil organic matter = 23.5 g kg^{-1} and base saturation (V) = 65.5%. The region's climate is of the Cwa mesothermic type, according to the Köppen classification, characterized by hot and humid summers and dry winters. In Table 1, the climatic conditions observed during the course of the experiment are summarized.

Treatments and experimental design

The soil was prepared with a disk plough followed by a leveler. The experimental design adopted was one of randomized blocks with four repetitions. The treatments consisted of dwarf pigeon pea in different arrangements intercropped with corn: CM, corn monoculture; PR, dwarf pigeon pea in the same row as the corn (10 pigeon pea plants m^{-2}); P1B, one row of dwarf pigeon pea sown between the rows of corn (10 pigeon pea plants m^{-2}); P2B, two rows of dwarf pigeon peas sown between the rows of corn (20 pigeon pea plants m^{-2}); PR1B, dwarf pigeon pea sown in the same rows as the corn and in a row between them (20 pigeon pea plants m^{-2}); and PR2B, dwarf pigeon pea sown in the same rows as the corn and in two rows between them (30 pigeon pea plants m^{-2}).

Field establishment

The experimental plot was formed of five rows of corn, with 0.90 m spaces between them, and six seeds were sown per meter, aiming for a population of 50,000 corn plants per hectare, after thinning. The dwarf pigeon pea was sown in a density of 10 seeds per meter, in the same rows as the corn and between them, as in the treatments. The corn and dwarf pigeon pea were sown on 12/17/2014. The three central rows of corn in each plot were considered for the evaluation. The corn cultivar used was Al-Avaré.

Weed control was carried out manually in two periods, the first 20 days after the emergence of corn (DAE) (V4-V5 stage) and the second 48 days after the emergence of corn (V9-V10 stage). For fertilizing, 800 kg of dry organic compound was used, equivalent to 13 t ha^{-1}, and distributed homogeneously over the soil beside the planting row. The organic compound used in the study presented: pH (in H_2O) = 8.0; C = 131.0 g kg^{-1}; N = 13.0 g kg^{-1}; P = 13.65 mg dm^{-3}; K = 13.44 mg dm^{-3}; Ca = 0.19 $cmol_c$ dm^{-3}; Mg = 0.35 $cmol_c$ dm^{-3}; S = 0.49 $cmol_c$ dm^{-3}; Cu = 69.2 mg kg^{-1}; Fe = 561.4 mg kg^{-1}; Mn = 511.2 mg kg^{-1}; Zn = 766 mg kg^{-1}; organic matter = 22.58% and humidity = 37.40%.

Parameters evaluated

The following variables were evaluated: corn leaf dry matter (t ha^{-1}), 85 days after crop emergence, corn leaf macronutrient content and accumulations (g kg^{-1}), total chlorophyll content in the corn leaves (FCI), and dry matter production (t ha^{-1}) and macronutrient content in the aerial part of the dwarf pigeon pea (g kg^{-1}).

To calculate corn leaf dry matter, three plants per plot were collected randomly. The plants were separated into foliar limbs and stalks. For the dwarf pigeon pea, a wooden template was used measuring 0.25 × 0.25 m. The material collected was conditioned in paper bags and dried in a forced air circulation oven at 65°C, and when it reached constant mass, it was weighed. The green manure samples removed for dry matter evaluation were used to determine the nutrient content.

The corn leaf macronutrient content was determined by collecting the leaf opposite and below the upper cob in female flowering in all of the treatments (Cantarella et al., 1996). 10 leaves were collected

Table 1. Climate data observed during the months in which the experiment was conducted, Araras, SP, 2014/2015.

Months	Radiation MJ m^{-2}		Precipitation mm		Temperature ºC		
	Total	Average	Total	Average	Mín	Max	Average
Dec./2014	631.9	20.4	218.6	7.0	18.4	31.0	24.7
Jan./2015	691.3	22.3	121.8	3.9	19.9	33.3	26.6
Feb./2015	557.6	19.9	245.4	8.7	18.6	30.7	24.6
Mar./2015	513.4	16.6	173.4	5.6	18.1	28.7	23.4
Apr./2015	544.4	18.1	11.2	0.4	16.2	29.9	23.1
May/2015	405.2	13.1	67.0	2.2	14.1	25.8	20.0
Jun./2015	404.0	13.0	26.2	0.9	13.6	25.3	19.5
Jul./2015	355.4	11.5	12.1	0.4	13.8	24.9	19.3

Natural Resources and Environmental Protection Department/*UFSCAR*, Araras, SP. MJ·m^{-2} = mega joules per square meter; mm = millimeters; ºC = degrees Celsius.

per plot, at 85 DAE, and after excluding the central ridge, these were dried in a forced air ventilation oven at a temperature of 65°C for 48 h.

The corn and dwarf pigeon pea samples were ground in a Willey type grinder and submitted for analyses of nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), and sulfur (S) content, according to the methodology described by Malavolta et al. (1997). The corn leaf macronutrient accumulation was obtained by multiplying the level of each nutrient by the leaf dry matter.

To determine the chlorophyll content, a ClorofiLOG® (model CFL 1030) portable chlorophyllometer was used. The measurements were expressed in dimensional units called Falker Chlorophyll Index (FCI). The readings were taken in the central third part of the limb of the last expanded leaf, in ten plants (four readings per plant) in the useful area of the plots. The chlorophyll evaluation was carried out in three periods, the first 20 days after corn emergence (DAE) (V4-V5 stage), the second 48 days after corn emergence (V9-V10 stage), and the third 85 days after emergence (R3-R4 stage).

To interpret the corn leaf macronutrient contents, the deviation from optimal percentage (DOP) method was used, as proposed by Montañés et al. (1993). This method is defined as the standard deviation in the concentration of an element in relation to the optimal level taken as a reference value. It is obtained using the following formula:

$$DOP = [(C \times 100/Cref) - 100]$$

In which C is the concentration of the nutrient in the dry matter from the sample and Cref is the optimal concentration of the nutrient in dry matter.

The values that are considered optimal for corn cultivation were proposed by Cantarella et al. (1996). As the adequate macronutrient levels for the crop are mentioned in adequate value ranges, the lowest value in the range for each macronutrient was considered.

The DOP indices were interpreted as follows: the absolute values (without sign) indicate the importance or severity of the deficiency or excess of the nutrient. The negative values indicate a situation of macronutrient deficiency; the positive values reflect situations of excess: and the indices equal to zero indicate optimal macronutrient values (Damián-Nava et al., 2006).

The yield of corn grains was also evaluated. The harvest was performed manually, removing all the spikes contained in the useful area of each plot. The moisture content of the grains was determined at 13%, yielding the productivity depending on the mass of grains harvested in each plot (t ha^{-1}).

Statistical analysis

Executing the DOP indices, the results obtained were submitted for variance analysis (F test) and the averages compared using the Tukey test, with a 5% probability. To process the statistical analyses, the Assistat software was used (Silva and Azevedo, 2016).

RESULTS AND DISCUSSION

For corn leaf dry mass (LDM), no significant difference ($p > 0.05$) was verified between the treatments evaluated, as well as for phosphorus (P), magnesium (Mg), and sulfur (S) contents (Table 2). This result is partially consistent with those obtained by Heinrichs et al. (2002), who in evaluating the production and nutritional state of corn intercropped with green manure for two years, did not verify any difference for P, Mg, and S contents in the first year of study.

Regarding corn leaf N content, there was a significant difference ($p < 0.05$) between the treatments (Table 2). The PR2B arrangement was higher than the rest, which did not differ between each other. The greater number of dwarf pigeon pea plants in the PR2B treatment probably caused a greater amount of nitrogen, which could have favored absorption by the corn plants. An increase in nitrogen availability is accompanied by a positive response in N content in the leaves (Nascimento et al., 2012).

According to Barcellos et al. (2008), the transfer of N from the fabaceae to the corn may have occurred under and/or over the soil surface, directly or indirectly, whether via the excretion of nitrogenated compounds, via the decomposition of roots and nodules, via the connection between mycorrhizae of the Poaceae roots and those of the Fabaceae, via fauna action in the soil over Fabaceae

Table 2. Leaf dry matter (LDM) and average macronutrient contents in corn crops intercropped with dwarf pigeon pea in different plant arrangements. Araras, SP, 2014/2015.

Treatments	LDM	N	P	K	Ca	Mg	S
	$t\ ha^{-1}$	$g\ kg^{-1}$					
CM	1.9[a]	31.9[b]	3.2[a]	9.9[ab]	34.8[a]	3.7[a]	1.2[a]
PR	2.3[a]	31.7[b]	3.2[a]	11.3[a]	23.0[a]	3.6[a]	1.1[a]
P1B	1.9[a]	31.7[b]	3.0[a]	7.7[b]	3.7[b]	2.9[a]	1.0[a]
P2B	1.8[a]	33.1[b]	3.0[a]	7.0[b]	3.5[b]	2.9[a]	1.4[a]
PR1B	1.9[a]	29.0[b]	3.0[a]	7.1[b]	3.8[b]	2.8[a]	1.8[a]
PR2B	2.2[a]	38.4[a]	3.1[a]	6.9[b]	3.2[b]	2.5[a]	1.4[a]
VC (%)	20.72	5.59	7.32	19.06	58.96	20.35	19.32

Averages followed by the same letter in the column do not differ statistically between each other using the Tukey test with a 5% probability. CM: Corn monoculture; PR: dwarf pigeon pea sown in the same row as the corn; P1B: one row of dwarf pigeon pea sown between the rows of corn: P2B: two rows of dwarf pigeon pea sown between the rows of corn; PR1B: dwarf pigeon pea sown in the same rows and in one row between the corn; and PR2B: dwarf pigeon pea sown in the same rows and in two rows between the corn. VC (%) = Variation coefficient.

roots and nodules, via the decomposition of leaves on the soil surface, via the leaching of nitrogenated compounds in the canopy, or via leaves losing ammonia, liable to absorption by the Poaceae.

The N values obtained in all of the treatments were considered to be satisfactory for corn cultivation, since they varied between 29.0 and 38.4 g kg^{-1}. That is, monoculture cultivation or intercropping with dwarf pigeon pea in different plant arrangements presented a N content within the adequate range for cultivation (27.5 to 32.5 g kg^{-1}), according to Malavolta et al. (1997). Corn behaves well in intercropping systems, and because it is an extremely demanding crop in terms of nutrients, especially N, the cereal favors intercropping with Fabaceae.

For corn K content, a significant difference ($p < 0.05$) was verified between the treatments (Table 2). PR had higher values than P1B, P2B, PR1B, and PR2B and did not differ statistically from MC. The presence of dwarf pigeon pea in the different arrangements hampered the absorption of potassium by the corn plants, except when the Fabaceae were sown only in the same row as the cereal. Probably, fabaceae can absorb K at depths greater than the area exploited by corn roots, and thus in the same row the species did not compete for the P available in the soil. Moreover, dwarf pigeon pea dry matter production in the rows of corn was lower than in the other arrangements, which may have reduced competition for the nutrient.

In this paper, the K contents observed in corn leaves were low in comparison to the values obtained by Heinrichs et al. (2002), which reached 24.7 g kg^{-1} for corn and dwarf pigeon pea intercropping.

There was a significant difference in Ca content between the treatments (Table 2). The CM and PR treatments were statistically similar and had higher values than the P1B, P2B, PR1B, and PR2B ones, which did not differ between each other. The reduction in nutrient content in plant tissue in intercropping may have been linked to the interspecies competitive interaction exercised by one species over the other (Viera et al., 2013). The low ability to compete for Ca on the part of corn in intercropping systems was already observed by other authors (Cury et al., 2012; Silva et al., 2015). Higher populations of the intercropped plant make greater soil exploitation possible, intensifying the competitive effects over the main crop (Belel et al., 2014).

In relation to the rates of deviation from the optimal percentage (DOP), excessive N and P in corn crop leaves was verified in all of the treatments, with PR2B presenting the highest DOP index for nitrogen, and the CM and PR treatments presenting the highest DOP indices for phosphorus (Table 3).

The higher DOP index for N verified in the PR2B treatment may be attributed to the higher number of dwarf pigeon pea plants in the system, increasing the amount of N via biological fixation, thus making a higher quantity of the nutrient available for the main crop. However, in biological fixation of N, Fabaceae need high quantities of phosphorus to meet the needs of the nodules (Caldas et al., 2009). Thus, in the treatments in which there is a greater number of dwarf pigeon pea plants, greater competition for P may have occurred, which could explain the lower DOP indices for phosphorus as the Fabaceae population increased (Table 3).

For K, all of the treatments presented negative indices, which indicates a deficiency in the macronutrient in the corn crop (Table 3). The potassium deficiency in all of the treatments may be related with the excessive Ca verified in the corn leaves (Table 3). Calcium presented positive indices in all of the treatments, showing good availability of the nutrient in the soil, especially in the CM and PR treatments, which presented very high indices.

The higher availability of Ca in soil causes its approximation to roots in greater quantity, and as Ca and K are absorbed by the same mechanisms in the cellular

Table 3. Deviation from optimal percentage (DOP) of macronutrients in the corn crop intercropped with dwarf pigeon pea in different plant arrangements. Araras, SP, 2014/2015.

Treatments	Deviation from optimal percentage					
	N	**P**	**K**	**Ca**	**Mg**	**S**
CM	+18.1	+60	-41.8	+1292	+146.7	-20
PR	+17.4	+60	-33.5	+820	+140.0	-26.7
P1B	+17.4	+50	-54.7	+48	+93.3	-33.3
P2B	+22.6	+50	-58.8	+40	+93.3	-6.7
PR1B	+7.4	+50	-58.2	+52	+86.7	+20
PR2B	+42.2	+55	-59.4	+28	+66.7	-6.7

CM: Corn monoculture; PR: dwarf pigeon pea sown in the same row as the corn; P1B: one row of dwarf pigeon pea sown between the rows of corn: P2B: two rows of dwarf pigeon pea sown between the rows of corn; PR1B: dwarf pigeon pea sown in the same rows and in one row between the corn; and PR2B: dwarf pigeon pea sown in the same rows and in two rows between the corn. DOP = [(C × 100/Cref) - 100]. C: concentration of the nutrient in the dry matter in the sample; Cref: optimal concentration of the nutrient in dry matter.

membrane, its absorption was probably preferential in relation to K (Medeiros et al., 2008). According to Bissani et al. (2006), Ca is generally the macronutrient found in greatest concentration in soils, after Iron (Fe), and as there is no specific absorption mechanism, it is generally found in exchangeable form in levels above those required by plants.

For Mg, positive indices were observed in all of the treatments (Table 3), showing an excess of the nutrient in the corn leaves. The highest Mg indices were obtained by the CM and PR treatments. Similar results were verified for foliar P. This similarity may be related to the synergism between these two macronutrients. According to Malavolta et al. (1997), absorption of P is influenced by the Mg concentration in the medium, with Mg able to carry P into the plant.

In relation to S in the corn plants, a deficiency was verified in the CM, PR, P1B, P2B, and PR2B treatments. In the PR1B, there was an excess, even though it was low, of the macronutrient (Table 3). It is worth noting that the S deficiency occurred to a greater degree in the treatments with lower dwarf pigeon pea plant numbers and in the corn monoculture. However, greater competition for S was expected in plots with higher dwarf pigeon pea populations, since for Fabaceae, sulfur is required in the nodules for symbiotic fixation of nitrogen, given that this nutrient is an element which constitutes nitrogenase, an N fixing element (Paiva and Nicodemo, 1993).

In the PR1B treatment, which was the only one that presented excessive S in the corn leaves, the lowest foliar content and lowest DOP index for N was verified (Tables 2 and 3). From this result, it can be inferred that in the treatment less fixation of N occurred via biological means. Thus, there was less absorption of S by the dwarf pigeon pea, allowing for greater use of the macronutrient on the part of the corn plants.

Concerning the nutrient accumulations in the corn leaves, no significant differences ($p > 0.05$) were verified between the treatments for N, P, Mg, and S (Table 4).

This result can be attributed to the absence of a significant difference for dry matter in corn leaves (Table 2). Indeed, according to Moreira et al. (2014), variations in foliar nutrient accumulations are due to variations in dry matter production by corn plants.

For K and Ca accumulations, significant differences ($p < 0.05$) were verified between the treatments adopted (Table 4). In relation to K, the PR treatment had higher values than the P1B, P2B, PR1B, and PR2B arrangements, and did not differ from the corn monoculture. For Ca, the PR arrangement and the corn monoculture were statistically equal, and had higher values than the other arrangements, which did not differ between each other. This result is related with the foliar content of these nutrients in both treatments (Table 2). Despite no statistical difference having been observed for corn leaf dry mass, the CM and PR treatments had much higher values than the other arrangements in the intercropping with regards to K and Ca content, which was reflected in the greater accumulation of these macronutrients in the corn leaf dry mass.

For the Falker chlorophyll index, no significant difference ($p > 0.05$) was verified between the treatments studied in any of the evaluation periods (Table 5).

There was no significant difference ($p > 0.05$) between the treatments for dry mass of the aerial part of the dwarf pigeon pea, as well as for the N, K, Ca, and K content of the Fabaceae (Table 6).

In relation to the P in the aerial part of the dwarf pigeon pea, a significant difference ($p < 0.05$) was verified between the treatments (Table 6). The P1B had higher values than the PR, and did not differ statistically from the PRB, PR1B, and PR2B. From this result, it can be inferred that the dwarf pigeon pea presented a greater ability to compete for this nutrient. This occurs due to the fact that Fabaceae roots, as well as being differentiated and deep, exude organic acids, especially citric ones, which act in solubilizing the P linked to the Ca, which

Table 4. Accumulation of macronutrients in corn intercropped with dwarf pigeon pea in different plant arrangements, Araras, SP, 2014/2015.

Treatments	N	P	K	Ca	Mg	S
	kg ha^{-1}					
CM	63.3[a]	6.5[a]	20.1[ab]	69.0[a]	7.3[a]	2.3[a]
PR	73.8[a]	7.6[a]	25.9[a]	49.1[a]	8.1[a]	2.6[a]
P1B	61.2[a]	5.8[a]	14.8[b]	7.2[b]	5.6[a]	2.0[a]
P2B	60.9[a]	5.5[a]	12.8[b]	6.4[b]	5.2[a]	2.6[a]
PR1B	56.2[a]	5.9[a]	13.8[b]	7.5[b]	5.5[a]	3.5[a]
PR2B	85.3[a]	6.9[a]	15.3[b]	7.2[b]	5.5[a]	3.2[a]
VC (%)	21.23	21.21	23.30	54.69	23.29	21.01

Averages followed by the same letter in the column do not differ statistically between each other using the Tukey test with a 5% probability. CM: Corn monoculture; PR: dwarf pigeon pea sown in the same row as the corn; P1B: one row of dwarf pigeon pea sown between the rows of corn: P2B: two rows of dwarf pigeon pea sown between the rows of corn; PR1B: dwarf pigeon pea sown in the same rows and in one row between the corn; and PR2B: dwarf pigeon pea sown in the same rows and in two rows between the corn. VC (%) = Variation coefficient.

Table 5. Average content of chlorophyll in the leaves of corn depending on consortium with dwarf pigeon pea in different arrangements of plants. Araras, SP, 2014/2015.

Treatments	Foliar Chlorophyll		
	20 DAE	48 DAE	85 DAE
	FCI		
CM	50.4[a]	52.9[a]	55.0[a]
PR	51.5[a]	52.6[a]	57.9[a]
P1B	51.4[a]	54.4[a]	56.5[a]
P2B	50.1[a]	51.8[a]	57.7[a]
PR1B	47.6[a]	52.1[a]	54.9[a]
PR2B	48.2[a]	50.9[a]	56.4[a]
VC (%)	6.64	3.46	6.35

Averages followed by the same letter in the column do not differ statistically between each other using the Tukey test with a 5% probability. CM: corn monoculture; PR: dwarf pigeon pea sown in the same row as the corn; P1B: one row of dwarf pigeon pea sown between the rows of corn: P2B: two rows of dwarf pigeon pea sown between the rows of corn; PR1B: dwarf pigeon pea sown in the same rows and in one row between the corn; and PR2B: dwarf pigeon pea sown in the same rows and in two rows between the corn. DAE = Days after emergence; FCI = Falker Chlorophyll Index; VC (%) = Variation coefficient.

favors the absorption of this macronutrient (Ae et al., 1990).

The values verified in this study were lower than those obtained by Ferrari Neto et al. (2011), in dwarf pigeon pea and millet intercropping systems. In the PR1B and PR2B treatments, the P content was higher than that observed by Heinrichs et al. (2005), in the simultaneous intercropping of corn and dwarf pigeon pea, the other treatments presented lower values, although they were very close to those verified by the authors (Table 6).

There was a significant difference ($p < 0.05$) between the treatments for S content (Table 6). The P2B intercropping presented a lower average in comparison to PR, and did not differ statistically from the other arrangements. This result shows that the dwarf pigeon pea plants competed more with the corn for this nutrient. It is important to highlight that the S content was lower in the treatment in which the pigeon pea accumulated more dry matter (Table 6). Therefore, the reduction in absorption of the nutrient could be attributed to possible interspecies competition.

The levels obtained in the study are below those verified by other authors in intercropping systems (Heinrichs et al., 2005; Ferrari Neto et al., 2011). The low S content in the aerial part of the dwarf pigeon pea may be related to the reduced availability of this nutrient in the soil. This was a factor that also caused its deficiency in the corn plants, according to the DOP indices (Table 2).

For grain yield, significant difference was found among treatments (Figure 1). The maize in a consortium with seedlings seeded on the line and two lines in the interline (PR2B) was superior to maize in monoculture and to

Table 6. Dry matter in the aerial part and average macronutrient content for dwarf pigeon pea in different plant arrangements intercropped with corn, Araras, SP, 2014/2015.

Treatments	DMAP	N	P	K	Ca	Mg	S
	$t\ ha^{-1}$	$g\ kg^{-1}$					
PR	0.9^{a}	38.8^{a}	1.0^{b}	15.9^{a}	7.6^{a}	2.4^{a}	0.24^{a}
P1B	0.7^{a}	32.2^{a}	1.7^{a}	14.2^{a}	7.8^{a}	2.2^{a}	0.18^{ab}
P2B	1.8^{a}	29.0^{a}	1.2^{ab}	16.4^{a}	8.3^{a}	2.5^{a}	0.15^{b}
PR1B	0.8^{a}	33.5^{a}	1.5^{ab}	16.1^{a}	8.4^{a}	2.3^{a}	0.16^{ab}
PR2B	1.2^{a}	28.4^{a}	1.5^{ab}	14.1^{a}	8.7^{a}	2.6^{a}	0.20^{ab}
VC (%)	22.62	15.59	19.06	14.59	17.94	12.58	18.71

Averages followed by the same letter in the column do not differ statistically between each other using the Tukey test with a 5% probability. PR: Dwarf pigeon pea sown in the same row as the corn; P1B: one row of dwarf pigeon pea sown between the rows of corn: P2B: two rows of dwarf pigeon pea sown between the rows of corn; PR1B: dwarf pigeon pea sown in the same rows and in one row between the corn; and PR2B: dwarf pigeon pea sown in the same rows and in two rows between the corn. VC (%) = Variation coefficient.

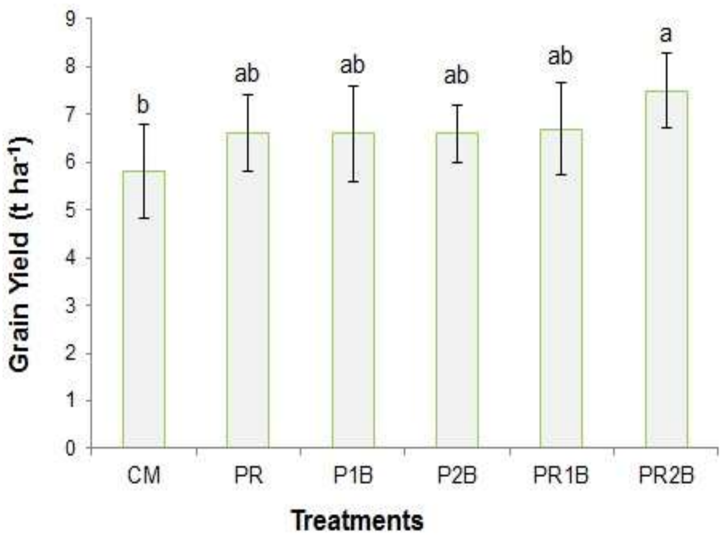

Figure 1. Corn grain yield depending on the consortium with pigeon pea in different plant arrangements, Araras, SP, 2014/2015.

other plant arrangements, which did not differ among each other.

This result corroborates in part with those obtained by Rao and Mathuva (2000), who verified higher yield of corn intercropped with pigeon pea compared to corn in monoculture, reaching 24% increase in the intercropping system.

The superiority of PR2B in relation to the other treatments can be attributed to a larger population of pigeon pea plants in the system, increasing the N uptake through biological fixation, benefiting the nutrient absorption by maize plants. This occurrence can be confirmed by the higher N content observed in maize leaves (Table 2) and higher DOP index for N (Table 3) in the PR2B system. In addition, the larger population of green manure may have contributed to the maintenance of soil moisture and greater organic matter addition in the system, improving soil nutrient cycling (Arantes et al., 2016), resulting in increased corn grain yield.

Conclusion

The different dwarf pigeon pea arrangements did not have any influence on P, Mg, and S absorption by the corn plants. When sown in rows between corn and/or in greater plant populations, Fabaceae compete more for K and Ca.

The arrangement with larger population of pigeon pea plants provided increase in corn leaf N content as well as grain yield of the crop.

The accumulations of macronutrients in corn were negatively affected by the different dwarf pigeon pea arrangements in the intercropping, with the exception of Ca, which was favored in the corn monoculture and in the arrangement with dwarf pigeon pea sown in the same row as the Poaceae.

CONFLICT OF INTERESTS

The authors have not declared any conflict of interests.

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