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NUTRIMENTAL POTENTIAL OF RED DOLICHOS, BROWN DOLICHOS AND COWPEA FOR GREEN MANURE PRODUCED UNDER THREE TILLAGE SYSTEMS

[POTENCIAL NUTRIMENTAL DE FRIJOL DOLICHOS ROJO, DOLICHOS CAFÉ Y YORIMON COMO ABONO VERDE PRODUCIDOS BAJO TRES SISTEMAS DE LABRANZA]

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SUMMARY

The nutrimental content of N, NO_3-N, P, K, Mg, Ca, Mn, Zn, Cu, Fe, and B, was evaluated in three bean cultivars of two species with potential to be used as green manure. Cultivars were the red lab-lab bean (RL) (*Lablab purpureus*), brown lab-lab bean (BL) (*L. purpureus*) and cowpea (CW) (*Vigna unguiculata*). Three tillage systems were assayed: conventional tillage (CT), minimum tillage (MT) and optimal tillage (OT). Results showed that the nutrimental content of N, NO_3, P, K did not evidence statistical differences ($P \leq 0.05$) among bean cultivars and tillage systems. However, the greater content of N was in BL-CT with 4.85%. The content of P varied from 0.38 to 0.41% and the concentration of K from 2.40 to 2.84%. Ca showed the highest concentration in RL-OT with 2.88%, while the lowest percentage was evidenced by CW-CT, with 2.12% ($P \leq 0.05$). The highest percentage of Mg appeared in CW-OT with 0.89% and the lowest concentration was registered for BL-CT, showing 0.52% ($P \leq 0.05$). The highest Fe concentration was observed in RL-OT with 0.15% and the lowest in BL-CT and RL-CT, with 0.10%. The Mn content was significantly greater in CW without concerning the tillage system with 0.39% and the smallest concentration was obtained in RL-MT with 0.17%. The greatest percentage content of nutriment B was observed in BL-OT, RL-CT, CW-MT and CW-OT, from 0.024 to 0.030%. In contrast, the lowest content of B was found in RL-MT with 0.015%. The content of Zn did not showed statistical differences respect to the cropping system; the lowest concentration of Zn was observed in CW-OT with 0.0026% and the highest percentage in BL-OT with 0.0040. Cu was significantly highest in BL-CT, BL-MT, BL-OT, RL-CT, RL-MT, RL-OT and CW-OT, being BL-MT and BL-OT the combinations with the highest concentration (0.0061%), while the lowest concentration was observed in CW-MT and CW-CT, with 0.0048% and 0.0044%, respectively.

Key words: Soil fertility; organic manure; legume crop; plant residues; nutrients.

RESUMEN.

Se evaluó el contenido de los nutrimentos N, NO_3-N, P, K, Mg, Ca, Mn, Zn, Cu, Fe y B en tres cultivares de frijol de dos especies con potencial para ser utilizados como abono verde. Los cultivares fueron: dolichos rojo (DR) (*Lablab purpureus*), dolichos café (DC) (*L. purpureus*) y yorimon (YO) (*Vigna unguiculata*). Se utilizaron tres sistemas de labranza para la producción: labranza convencional (LC), labranza mínima (LM) y labranza óptima (LO). Los resultados mostraron que con respecto al contenido nutrimental de N, NO_3, P y K no existió diferencia estadística ($P \leq 0.05$) entre los cultivares de frijol y los sistemas de labranza utilizados; sin embargo, el mayor contenido de N se encontró en DC producido en LC con 4.85 %. El contenido de P fluctuó entre 0.38 hasta 0.41 %. Con relación al K se encontró un rango de concentración de 2.40 a 2.84 %. El Ca se encontró en mayor concentración en DR-LO con un 2.88 %, en contraste el menor porcentaje se encontró en YO-LC con un 2.12 % ($P \leq 0.05$). Con respecto a Mg se observó el mayor porcentaje en el cultivar YO-LO con un 0.89 % y la menor concentración se encontró en DC-LC presentando un 0.52 % ($P \leq 0.05$). El comportamiento de los nutrimentos menores fue diferente. La mayor concentración de Fe se encontró en DR-LO con 0.15 % y la menor en DC-LC y DR-LC con 0.10 %. El contenido de Mn fue significativamente mayor en YO sin importar el sistema de labranza utilizado con 0.39%, y la menor concentración se obtuvo en DR-LM con 0.17 %. El mayor contenido porcentual de B se localizó en DC-LO, DR-LC, YO-LM y YO-LO con un rango de entre 0.024 a 0.030 %; en contraste, el menor contenido se manifestó en el DR-LM con un 0.015 %. Se observó que con respecto al contenido de Zn no hubo diferencia estadística con respecto a los cultivares y los sistemas de labranza utilizados en su producción, el menor contenido de Zn se presentó en YO-LO con 0.0026% y el mayor porcentaje se observó en DC-LO con 0.0040. El contenido del nutrimento Cu fue significativamente mayor en DC-LC, DC-LM, DC-LO, DR-LC, DR-LM, DR-LO y YO-LO, siendo DC-LM y DC-LO en donde se presentó la mayor concentración con 0.0061% y la menor concentración se encontró en YO-LM y YO-LC con un 0.0048 % y 0.0044 % respectivamente.

Palabras clave: Fertilidad de suelos; abonos orgánicos; leguminosas; residuos vegetales; nutrimentos.

INTRODUCTION

Soil degradation is widely extended in the world's arid regions, affecting 5.5 million ha, which represent about 70% of this land's surface. This generates a loss in the annual production, which is estimated in 42,000 million dollars. To this respect, almost a million ha, from which the majority is located in the best irrigated agricultural land, are sacrificed every year as a consequence of urbanization (Altieri, 1999).

The use of highly mechanized agriculture contributes to aggravate the problem of accelerated soil degradation, even more, it lowers soil's productivity. In fact, modern agriculture tends, in general, to the simplification of the ecosystem. For example, tillage has altered soil due to the addition or removal of nutrients, had caused acidity reduction due to the addition of lime, rock removal to facilitate agricultural operation, and surface leveling up to facilitate watering and mechanization. Soil and landscape structure have been intensely modified, which is justified by the possibility of incorporating agricultural resources to the economical system (Marco y Reyes, 2003).

In the same way, the argument of conventional farmers and promoters to apply synthetic fertilizer has been the lower cost associated to the quantity of cheaper fertilizers in comparison to organic fertilizers. However, industrial chemical fertilizers unbalance the soil fertility, from the mineral point of view, and contaminate it with ions. These ions penetrate by osmosis, due to their high solubility, and hence the plant absorbs them rapidly, more frequently and in a bigger proportion than it is really needed. This is inconvenient for the consumer's health (Jiménez, 2001).

Therefore, the incorporation of organic material becomes necessary, because it brings nutrients and promotes the microorganism's activity, improving the soil's condition for plants (Beltrán-Morales *et al.*, 2004). Thereby natural and organic material based fertilization can assure a supply of the necessary elements without damaging the environment and humans (Álvarez, *et al.*, 2005).

Nevertheless, the use of organic fertilizers has gained more importance in the last decades because of different reasons (Agostini *et al.*, 2003, Blackshaw *et al.*, 2001). From the ecological view point, the concern to promote agricultural practice harmonized with the environmental profile has increased. Use of green manure contributes to the recovery of soil's fertility (Bučienė *et al.*, 2003), it can improve its physical attributes (Agostini *et al.*, 2003) and control pests (Aloyokhin y Atlihan, 2005), weeds (Blackshaw *et al.*, 2001) and nematodes (Guereña, 2006); but more than anything else, it increases the organic matter content, which in its turn modifies the cation exchange capacity and the availability of macro and micronutrients.

Other indirect effects of the green manure implementation on soil include the formation and stabilization of aggregates, and the improvement of structure, infiltration capacity and aeration (García-Hernández *et al*, 2000). When using legume as green manure, the incorporation of nitrogen to the soil is favored by biological fixation (Kristensen, 2006; Mehari *et al.*, 2005). It has been estimated that 40% of N contained in plants forming of a vegetable cover can be available in the soil during the first year, whereas the remaining 60% will be available if the remaining plant cover is incorporated as green manure (Hoyt, 1987).

Mineralization of N brought by the green manure and its utilization by subsequent crops depends on the chemical composition of the legume, the soil attributes, and how both are handled (Varco *et al.*, 1993); the interactions among such attributes and factors will enhance the synchronization among the N released by legume with the assimilation by subsequent non legume culture (Dou *et al.*, 1994; Stute y Posner, 1995).

Numerous studies have been made about drip and cover crop irrigation and green manure, associated to the content of nitrogen in soil (Onim *et al.*, 1990; Beltrán-Morales *et al.*, 2006), mainly about its importance as nitrogen-based fertilizer substitute by means of crop residue and also about the influence of residue management over the subsequent crop (John *et al.*, 1992; Smyth *et al.*, 1991). Other studies have investigated the absorption of the other main nutrients, their equivalent in fertilizers (Sharma y Sharma, 1990) and their presence subsequent to fodder cut (Shatilov y Dobrovol'skaya, 1991). The associated increase in efficiency associated to the use of drip and cover crop irrigation has been directly related to the N content of the cover and to the total dry matter produced (Amado y Wildner, 1991).

Present investigations are focused on practices which promote conservation, formation, restoration and soil improvement, inducing chemical and physical attributes favorable to the production of crops with no natural resource detriment (Colla *et al.*, 2000).

In consequence, we propose to evaluate the nutritional content represented by the nutrients N, NO_3-N, P, K, Mg, Ca, Mn, Zn, Cu, Fe y B released by three bean cultivars of two species with potential to be used as green manure produced with three tillage systems.

MATERIAL AND METHODS

This study was carried out from February to July of 2007 in the experimental farming field of the Autonomous University of Baja California Sur (UABCS), located at 5.5 Km of the Carretera al Sur in the City of La Paz (Fig. 1), at the coordinates 24° 08’ 32” NL and 110° 18’ 32” WL (INEGI, 2002).

The soil in the study area shows a sandy texture, commonly prevailing in the arid regions; the organic matter content is approximately 0.4 %. Soil in the experimental site shows 75 % sand content, 15 % silt and 10 % clay (Beltrán-Morales et al., 2006). Climate is BW (h’) h w (e), which can be interpreted as a hot desert weather, with an annual average temperature above 22 ^{o}C and predominant rain during the summer; average annual rainfall is 184 mm (Fenech-Larios *et al*., 2008).

Sowing and cropping practices

The assayed cultivars were the red dolichos lab-lab bean (RL) (Lablab purpureus), brown dolichos lab-lab bean (BL) (L. purpureus) and cowpea (CW) (Vigna unguiculata). Sowing was performed in March 2007 placing two seeds manually in each hole, at a distance of 20 cm between plants at a 5 cm depth. The experimental parcel had a size of 1080 m^2 and the sowing density was 6 plants per m; the separation between furrows was 80 cm. Irrigation was applied by a drip system, with a frequency of three watering per week, each application lasting 2 h. No pests or diseases of economical importance were observed, weeds control was performed manually, when necessary. The management of the crop was carried out in agreement with regional recommendations (Murillo-Amador *et al.,* 2003).

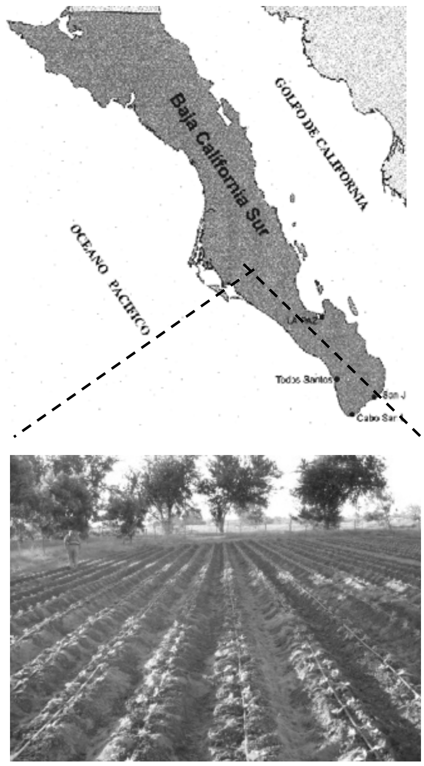

Figure 1. Location of the experimental site.

Tillage systems

Tillage systems used for the production of the three legume cultivars were conventional tillage (CT), which consisted of a 40 cm deep plough till and two 15 cm ground deep harrow tills, minimum tillage (MT), which consisted in two 15 cm deep harrow tills, an finally optimal tillage (OT), consisting in a kind of tillage in which the only tilling is to incorporate residue 15 cm deep (ASAE, 2002).

Dry matter production

Plants were harvested manually, including their roots; we collected five plants per experimental unit selecting them randomly, when plants showed an approximated grow of 30 %. The green material was placed in bags according to treatment and repetition, and taken to lab where weighted green, and later dried in a stove, under a temperature of 70 ºC for 48 hours. Then, the samples were removed from the stove and cooled to ambient temperature to be weighted and to estimate the amount of dry matter per ha. Afterwards, each of the samples went through an electrical mill to be grinded; next, through in a mortar and pestle and finally, through a 1 mm sieve; we made two reproductions of each sample.

Nutritional analysis

Foliage analyses were performed in the soil and plant lab of the Northwestern Biological Research Center (CIBNOR). Lab methods were applied for determining Nitrogen (microkjeldahl digestion), Calcium and Magnesium (atomic absorption), Potassium (atomic absorption), Phosphorus (atomic absorption), Boron (turmeric acid colorimeter method), Copper (atomic absorption), Zinc (atomic absorption), Iron (atomic absorption) and Manganese (atomic absorption), all of which are described by Alcántar y Sandoval (1999). NO_3-N was obtained by ionic chromatographic according to Marschner (1986).

Experimental design and statistical analysis

We used an experimental design of randomized whole blocks, arranged in divided parcels with three replicates, where the major parcel was the assayed tillage system. The experimental unit had a size of 6 x 10 m. Data were captured and organized in the spreadsheet Excel; the analysis of variance and resulting graphics were processed and performed using the statistical program Minitab (version 15.1.0).

RESULT AND DISCUSSION

Dry matter production

Differences for bean cultivar's average production of dry matter were not significant; RL CT produced 6.10 t ha^{-1}, in MT produced 5.09 t ha^{-1} and in OT produced 6.05 t ha^{-1}. The dry matter production of BL in CT and in MT was 5.67 t ha^{-1}, likewise, we obtained 6.08 t ha^{-1} of BL in OT. The dry matter produced by CW in CT was 5.39 t ha^{-1}, CW in MT produced 6.05 t ha^{-1} and finally the production of CW in OT was 5.83 t ha^{-1}. The nutrimental contribution of each cultivar and system is shown in Table 1.

No statistical differences were found with regard to the N content, however, tendencies show that the bean cultivar that produced the highest amount of N was BL produced in any tillage system, specifically, the highest production was obtained in OT with 278 kg ha^{-1}, which implies that if we consider the costs and benefits out of the crops with the use of optimal tillage, we would recommend this production system for BL as the best system for the production and incorporation of N as green manure (Table 1 and 2). These levels of N are similar to the ones reported with *Crotolataria* cultivation by García and Treto (1997). However, the three cultivars assayed in this study have shown to be superior in production of N, P and K with regard to the 12 cultivars studied by these researchers to be used as green manure. Similarly, results concerning the content of N, P and K are higher to the ones obtained by Barreto *et al*. (1994), who mentioned that *Mucuna* contributed 162 kg of N ha^{-1}, 11 kg ha^{-1} of P and 49 kg ha^{-1} of K. The same authors found a nutritional content of 246 kg ha^{-1} of N, 21 kg ha^{-1} of P and 105 kg ha^{-1} of K in plants of *Canavalia ensiformis*.

Table 1. Dry matter and nutrimental contribution by bean cultivar and tillage system, in Kg ha^{-1}.

		Nutrients (Kg ha^{-1})											
Bean	TS	DM	N	NO3	P	K	Ca	Mg	Fe	Mn	B	Zn	Cu
BL	CT	5.67	275	0.58	22.0	148	122.5	29.7	5.9	1.09	1.10	0.18	0.30
BL	MT	5.67	263	0.50	22.7	144	120.7	33.1	8.3	1.10	1.23	0.17	0.33
BL	OT	6.08	278	0.59	24.1	161	135.6	34.4	7.1	1.15	1.50	0.24	0.37
RL	CT	6.10	245	0.28	23.8	162	153.4	37.9	6.5	1.23	1.72	0.19	0.35
RL	MT	5.09	223	0.51	19.8	145	131.9	33.9	5.9	0.89	0.77	0.15	0.29
RL	OT	6.05	242	0.40	23.8	150	174.4	45.3	9.1	1.17	1.38	0.22	0.37
CW	CT	5.39	213	0.39	20.5	130	114.5	42.9	4.4	2.14	0.70	0.15	0.24
CW	MT	6.05	238	0.69	24.3	147	136.3	46.5	5.5	2.35	1.84	0.16	0.29
CW	OT	5.83	239	0.44	24.2	141	129.3	51.9	5.1	2.27	1.69	0.15	0.31

BL=Brown dolichos lab-lab bean, RL=Red dolichos lab-lab bean, CW=Cowpea, TS=Tillage system, CT=Conventional tillage, MT=Minimum tillage, OT=Optimal tillage, DM=Dry matter, t ha^{-1}.

Table 2. Average contents of major nutrients in three Dolichos bean cultivars produced in three tillage systems.

		Average percentage values of major nutrients					
Bean	**TS**	**N**	**NO3**	**P**	**K**	**Ca**	**Mg**
BL	CT	4.8534 *a*	0.0102 *a*	0.3890 *a*	2.6119 *a*	2.1626 *bc*	0.5258 *e*
BL	MT	4.6441 *a*	0.0088 *a*	0.4006 *a*	2.5495 *a*	2.1391 *bc*	0.5851 *dec*
BL	OT	4.5744 *a*	0.0097 *a*	0.3976 *a*	2.6437 *a*	2.2343 *bc*	0.5669 *de*
RL	CT	4.0100 *a*	0.0047 *a*	0.3903 *a*	2.6571 *a*	2.5169 *bac*	0.6225 *bdec*
RL	MT	4.3762 *a*	0.0100 *a*	0.3887 *a*	2.8469 *a*	2.5922 *ba*	0.6660 *bdec*
RL	OT	4.0022 *a*	0.0067 *a*	0.3931 *a*	2.4789 *a*	2.8829 *a*	0.7499 *bdac*
CW	CT	3.9601 *a*	0.0072 *a*	0.3813 *a*	2.4075 *a*	2.1244 *c*	0.7971 *ba*
CW	MT	3.9384 *a*	0.0114 *a*	0.4016 *a*	2.4359 *a*	2.2564 *bc*	0.7683 *bac*
CW	OT	4.0929 *a*	0.0075 *a*	0.4149 *a*	2.4130 *a*	2.2181 *bc*	0.8901 *a*

Values with the same letter in a column indicate no significant differences according to DMS Tukey ($P \leq 0.05$).
BL=Brown dolichos lab-lab bean, RL=Red dolichos lab-lab bean, CW=Cowpea, TS=Tillage system,
CT=Conventional tillage, MT=Minimum tillage, OT=Optimal tillage.

In Table 2 the average percentage values of major nutrients are shown, and in Fig. 2 the average percentage major nutrient content of the three cultivars studied. No statistical difference was found of N, P, K in the cultivars and tillage systems, however, the N lowest concentration was found in RL produced in OT, 4%; though, this value goes up to 81.8 % more than the one found in similar investigations performed by Malavolta (1989), who mentions that the ideal values with respect to the content of N in the aerial part of the bean crop oscillates between 1.8 and 2.2 %

Similarly, the nutritional content of all cultivars was higher than those reported by Herrera and Melendez in 1997, who observed that the highest content of N was produced by *Crotalaria* spp, 3.85%. Ovalle *et al.* (2007) in a study performed with plant covers in raspberry organic production found that the highest content was peorduced by white clover, with 4.49%, a value which is lower than 4.85% found in the present study.

The range found for the nutrient P fluctuated from 0.38 to 0.41 %, which is 153% higher compared to the one established by Malavolta (1989), who found in the bean crop an optimal range of P between 0.12 and 0.15 %. Also, the content of P obtained in this study was superior to 13 of the 15 crops described by Herrera and Melendez (1997). The concentration of K oscillated from 2.40 to 2.84% and resulted inferior to the reported by Malavolta (1989) in the bean crop, who mentioned that the adequate concentration of this nutriment is 3.0 to 3.5%. However, the results found are similar to those described by Herrera and Melendez (1997), who found a concentration range of 0.9 to 3.12%. In relation to the percentage content of Ca, it was higher in the bean cultivar RL when tilled with the OT system, producing 2.88 %, in contrast to this, the lowest percentage was found in CW produced under CT, with a 2.12%; this result is similar to the reported by Herrera and Melendez (1997), who determined Ca contents from 0.21 to 3.8 %, however they are lower than the 5.0 to 5.5% reported by Malavolta (1989). In relation to the Mg nutrient content, the highest percentage occurred in CW cultivar tilled in OT, with 0.89%, and the lowest concentration was found in BL produced in CT, showing 0.52%, however, this result is higher to the ones of Herrera and Melendez (1997), who mentioned that the concentration range varied from 0.20 to 0.85%; the obtained range of values corresponds to the reported by Malavolta (1989), who determined a range from 0.5 to 0.8%.

The percentage values of minor nutrient are shown in Table 3 and in Figure 3, where is graphically shown the average nutrimental percentage of the minor elements in the three cultivars produced with all the tillage systems; the lowest content of Zn occurred in CW in OT, with 0.0026%, and the highest was produced by BL in OT, with 0.0040. These results are similar to the reported by Herrera and Melendez (1997) and Malavolta (1989), who found for Zn a concentrations range from 0.0015 to 0.0050. The Cu content was found to be higher in BL with CT, BL with MT, BL with OT, BL with CT, RL with MT, RL with OT and CW with OT; RLwith OT and BL with OT showed the highest concentration, 0.0061%; the lowest concentration was produced by CW with MT and CW with CT, 0.0048 % and 0.0044 % respectively. These value ranges are higher than those reported by Herrera and Melendez (1997) and Malavolta (1989).

Table 3. Average percentage values of minor nutriments in three bean cultivars produced with three tillage systems.

Bean	TS	Average percentage values in minor nutriments				
		Fe	Mn	B	Zn	Cu
BL	CT	0.1043 *bac*	0.0193 *b*	0.0195 *ba*	0.0033 *a*	0.0054 *a*
BL	MT	0.1460 *ba*	0.0195 *b*	0.0218 *ba*	0.0030 *a*	0.0059 *a*
BL	OT	0.1173 *bac*	0.0190 *b*	0.0247 *a*	0.0040 *a*	0.0061 *a*
RL	CT	0.1068 *bac*	0.0202 *b*	0.0282 *a*	0.0031 *a*	0.0057 *a*
RL	MT	0.1177 *bac*	0.0176 *b*	0.0153 *b*	0.0029 *a*	0.0057 *a*
RL	OT	0.1504 *a*	0.0194 *b*	0.0229 *ba*	0.0036 *a*	0.0061 *a*
CW	CT	0.0813 *c*	0.0398 *a*	0.0130 *b*	0.0028 *a*	0.0044 b
CW	MT	0.0910 *bc*	0.0389 *a*	0.0305 *a*	0.0027 *a*	0.0048 b
CW	OT	0.0873 *bc*	0.0390 *a*	0.0291 *a*	0.0026 *a*	0.0053 *a*

Values with the same letter in a column indicate no significant differences according to DMS Tukey ($P \leq 0.05$).
BL=Brown dolichos lab-lab bean, RL=Red dolichos lab-lab bean, CW=Cowpea, TS=Tillage system, CT=Conventiona tillage, MT=Minimum tillage, OT=Optimal tillage

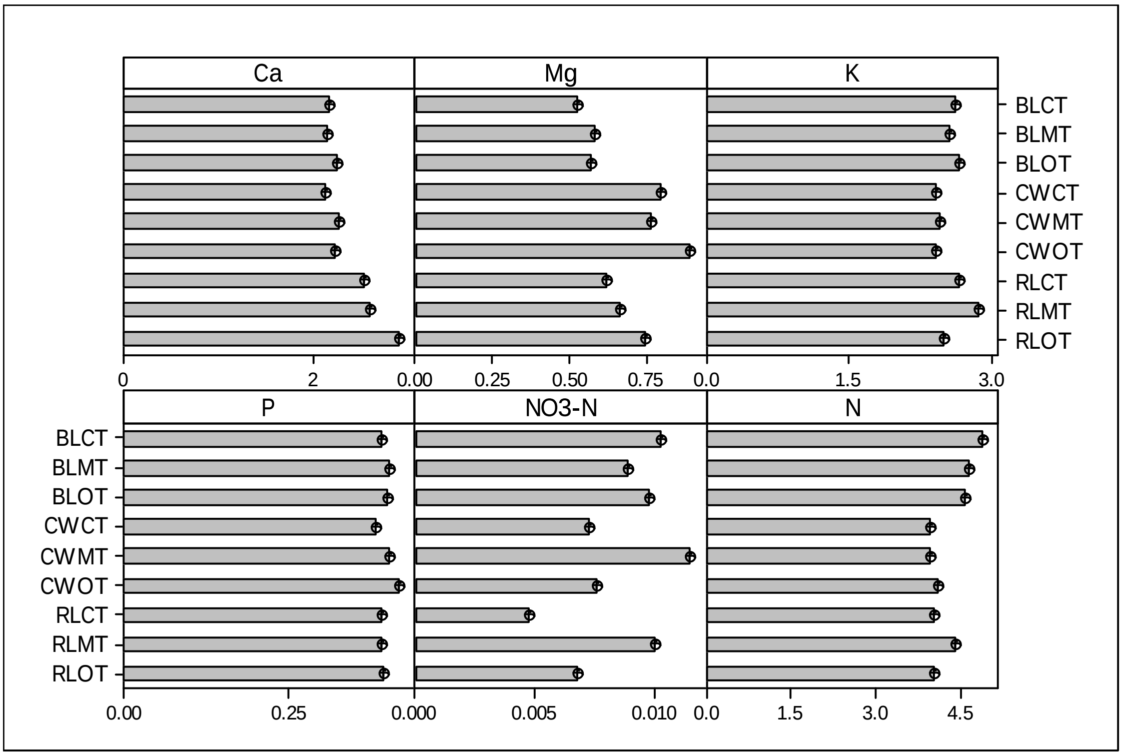

Figure 2. Percentage of major nutrients produced by three bean cultivars in three tillage systems.
BL: Brown dolichos lab-lab bean, RL: Red dolichos lab-lab bean, CW: Cowpea, CT: Conventional tillage, MT: Minimum tillage, OT: Optimal tillage

The highest percentage content of B was obtained in BL in OT, RL in CT, CW in MT and CW in OT, on the contrary, the lowest content was observed for CW in CT with a 0.0130 %. The Mn percentage content was similar for BL in CT, BL in MT, BL in OT, RL in CT, RL in MT and RL in OT, similarly, CW with CT produced the highest concentration of Mn, with 0.039 %. The highest concentration was found in CW bean produced under any tillage system and the lowest with RL in MT, with 0.0176 %. However, the Mn concentrations found in this study were higher than those reported by Herrera and Melendez (1997), who found values from 0.0059 to 0.0128%; in contrast, Malavolta (1989) showed that the adequate concentrations of Mn nutrient fluctuate between 0.04 and 0.0425%. Finally, the highest concentration of Fe nutrient was found for RL in OT, with 0.1504 % and the lowest for CW in CT, with 0.0813 %, these values are higher than those reported by Malavolta (1989), who mentioned that the optimal range of Fe concentration in bean foliage fluctuates between 0.07 and 0.09

CONCLUSION

The cultivars BL bean, RL bean and CW established in three tillage systems (conventional, minimum and optimal) in this investigation showed a higher major and minor nutriment contribution than those reported in the literature related to legumes, proposed as green manure by various authors (Herrera y Meléndez, 1997; Malavolta, 1989; Ovalle *et al.,* 2007; García and Treto, 1997).

In spite of the fact that there was no statistical difference in relation to the nutrimental content of N, NO_3, P y K, tendencies showed that the BL bean in optimal tillage represents the best condition to be added as green manure, considering the costs and benefits related to the soil preparation and the dry matter production. The lowest macronutrient concentrations were observed in CW bean produced in conventional tillage.

In relation to the minor nutrients, the cultivar RL showed the best characteristics in terms of Ca content, established in any tillage system. Mg had the highest concentration in CW bean under any tillage system and the lowest in BL bean. In relation to the minor nutrients Mn, Zn, Cu, Fe y B, the BL bean showed the highest concentrations.

We conclude that the BL bean cultivar produced in optimal tillage is the best alternative for the soil's enrichment and the maintenance of soil fertility by means of green manure.

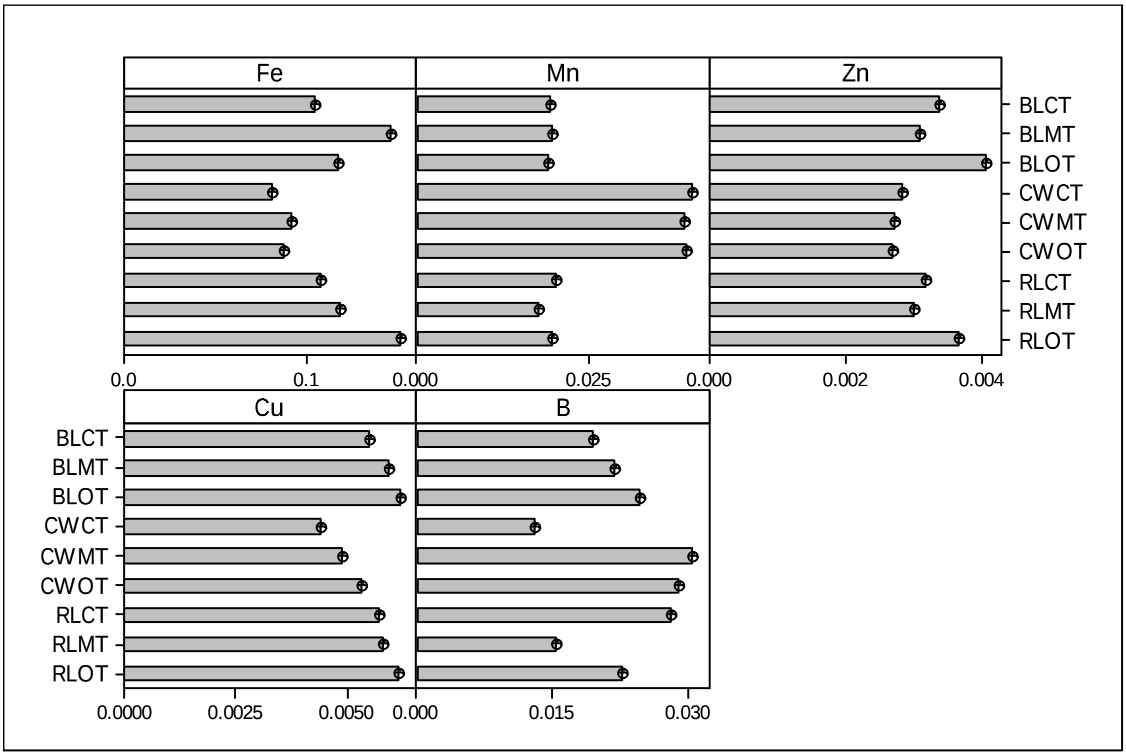

Figure 3. Percentage of minor nutrients produced by three bean cultivars under three tillage systems.
BL: Brown dolichos lab-lab bean, RL: Red dolichos lab-lab bean, CW: Cowpea, CT: Conventional tillage, MT: Minimum tillage, OT: Optimal tillage

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