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Assessment of Nutritional Status of Different Genotypes of Common Bean (*Phaseolus vulgaris* L.)

Luzia Pereira da Silva[1], Walter Quadros Ribeiro Júnior[2], Andre Freire Cruz[3], Sebastião Alberto de Oliveira[1] & Maria Lucrécia Gerosa Ramos[1]

[1] Universidade de Brasília, Faculdade de Agronomia e Medicina Veterinária, Brasília, DF, Brazil

[2] Embrapa –Centro de Pesquisa Agropecuária dos Cerrados, Planaltina, DF, Brazil

[3] Kyoto Prefectural University - Graduate School of Life and Environmental Sciences, Kyoto 606-8522, Japan

Correspondence: Andre Freire Cruz, Kyoto Prefectural University - Graduate School of Life and Environmental Sciences, Shimogamohangi-cho 1-5, Sakyo-ku, Kyoto 606-8522, Japan. Tel/Fax: 81-75-703-5608. E-mail: andre@kpu.ac.jp

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Abstract

The objective of this study was to evaluate the nutritional state of 20 different genotypes of common bean, which were six cultivars and 14 breeding lines. The experiment was conducted in the field, between August and November of 2002, in an Oxysoil, Cristalina – GO, Brazil. Yield and leaf diagnosis were evaluated, 45 days after the emergence of the culture (total foliar rates of N, P, K, Ca, Mg, S, B, Mn, Cu and Zn), by the DRIS method, using the nutrient concentrations, taken two by two. Nutrient absorption was different for the genotypes. In most of them, Zn was the less absorbed nutrient, while S was the nutrient in excess. DRIS correlation was different for nutrient interactions, as for a positive correlation for P x Zn (0,928), as for a negative correlation, for N × S (-0,947). DRIS shows nutrient deficiency and nutrient excess, for manure recommendations, and it can be used as a routine for bean culture, based on a leaf diagnosis.

Keywords: nutrient uptake, leaf diagnosis, DRIS, yield

1. Introduction

The common bean (*Phaseolus vulgaris* L.) represents an important protein source in Brazil. Due to its easy adaptability to many climatic conditions in this country, it can grown in different regions, and can be cultivated over the year (up to three harvests) using several systems ranging from subsistence farming in small farms to high-tech agriculture on large scale. This crop reached a year production of 3.5 million ton in 2010 (MAPA, 2012), however actually this area decreased to about 4.1 million hectares (Ruas, 2010).

The utilization of high-tech agriculture, especially with irrigation, the production becomes economically viable, including the use of lime, proper fertilization, high yield cultivars, severe control of diseases, pests and weeds (Thung & Oliveira, 1998).

The bean productivity in Brazil is considered low as compared to the potential of the varieties recommended by researchers. The explanation for this low productivity could be several factors, such as, inadequate farming management, poor soil and lack of using of improved breed varieties, and finally the inappropriate fertilization. In high-tech agriculture, fertilizer application usually occurs with large amounts, increasing production costs, which leads the necessity to optimization of this practice, in order to maximize the yield at low cost (Malavolta, 1992).

However, in cases of insufficiency, excess of imbalance of one or more nutrients the plant growth become restricted, because the nutrients coexist in complex interactions involving energy metabolism, and plant physiology. Thus, deficiency symptoms may be due to low soil nutrient supply or low plant genetic ability to uptake and transport ions, but also by their interaction with other ions (Creste et al, 1999; Schulte & Kelling, 2002).

Schulte and Kelling (2002) reported the role of plant nutrition analysis to detect the deficiency, toxicity or non-balance of nutrients, identifying especially “hidden hunger”, to assess fertilization programs. This

information determines the availability of elements not detected by other methods, the interaction between nutrients and completes the soil nutritional analysis.

To provide more data besides the chemical analysis of soil, the leaf analysis quantitatively can determine the nutrients concentration in plant tissues, which allows an assessment of plant nutritional status *in situ* (Bonilla & Bolaños, 2010; Creste et al., 1999). The plant nutrient analysis of a specific organ at a phonological stage have been used to evaluate the nutritional status and in the fertilizer recommendation (Creste & Echer, 2010; Malavolta et al., 1998).

The DRIS (Diagnosis and Recommendation Integrated System) is a method to understand leaf analysis, which takes into account all interactions between nutrients and minimize the main limiting factors for the critical level method. The DRIS method uses the ratios between the concentrations of nutrients to understand the leaves and soil (Malavolta et al, 1998; Schulte & Kelling, 2002). The utilization of DRIS can alleviate the effects of nutrients concentration or dilution on dry matter. When the DRIS value become negative, suggests that the plant is deficient in those nutrients, otherwise the positive values indicate the excess of nutrients, and near the zero means that the plants are nutritionally balanced (Lana et al., 2010).

Costa (2002) used the DRIS system in commercial bean farms in Jussara city (Goiás state, Brazil), whose preliminary results showed that the method has been effective to diagnosis the crop nutritional status. This indicates non-balance degree and the range between the excess and deficiency, which are fundamental for fertilizer recommendation.

According to Schulte and Kelling (2002), the advantage of DRIS system would be that the growth stage, plant parts and cultivars are not essential to detect the critical level of a particular nutrient. However, a research conducted by Wadt et al. (1999) and Silveira (2000) with eucalyptus and Ferreira (2003) in *Heliconia latispatha* using the DRIS demonstrated a distinct behavior according to the evaluated genotype.

The current research aimed to assess the nutritional status through the DRIS method in different bean genotypes, observing the differences between cultivars to seek a understanding of the evaluated traits. (foi isso que vc quis dizer)

2. Materials and Methods

The study was conducted at Pantanal Farm, owned by Prezzoto Sementes Company Ltd., Crystalline City, Goias State, Brazil. on an clay texture Red Oxisol. The weather was defined as Aw (Köppen), with two distinct seasons (wet and dry). The experimental area was primarily used for pasture, and for the implementation the bean was sown in 2002.

The experimental design was composed by a randomized block design with three replicates. The plot size was 5 × 3 m, with a space of 0.50 m between rows having 12 plants per m, where 0.5 m of the boarder lines was deducted, totaling 6 m^2 area per plot. The three central rows within each plot were chosen for planta analysis ahd yield.

Soil analysis was performed before the experiment: pH in water, 5,2; Organic Matter, 55 g dm^{-3}; Al^{3+}, 0.03 $cmol_c$ dm^{-3}; Ca^{2+} + Mg^{2+}, 4.29 $cmol_c$ dm^{-3}; H^+ + Al^{3+}, 8.26 $cmol_c$ dm^{-3}; P, 18,3 mg dm^{-3}; K^{2+} 0,10 $cmol_c$ dm^{-3}. The soil amendment and fertilization (600 kg / ha of NPK 7-21-16 + FTE BR-12 and 200 kg / ha of ammonium sulfate at 22 DAE) were applied based in the fifth matching and according to technical recommendations for bean from EMBRAPA-Brazil (Stone & Sartorato, 1994).

In August 17, 2002 the bean was sown and the weeds and pests control were done as usual in the farm where the experiment was located. Considering the topography and the existence of sub-soil water a sub-surface irrigation (by capillarity) was used too.

Six cultivars of beans and 14 lines were used, composing 20 genotypes as follows: FT-84-105, FT-Nobre, FT-97-512, FT-97-708, FT-91-625, FT-Soberano, FT-97-837, FT-91-3168, FT-206, FT-9768, FT-96-1117, FT-Magnifico, FT-97-176, FT-97-119, FT-84-113, FT-90-1535, FT-97-255, Carioca, Bonito and Bionobre, provided by FT - Sementes Ltda. The agronomic characteristics of these genotypes, obtained in different assays are described in Table 1.

Five plants were randomly collected from each plot for leaf analysis 45 days after crop seeding. From these plants the first young leaves from the apical part were removed (Oliveira, 2002). Then the samples were drought in oven at 70 °C for 72 hours, ground and 20 g was taken for macro and micronutrients analysis, performed at the Laboratory of Soil Fertility and Plant Nutrition of CAMPO Co., Paracatu City - Minas Gerais-Brazil.

The nutrients N, P, K, Ca, Mg, S, B, Zn, Fe, Mn and Cu were determined, whose concentrations were expressed

in g kg^{-1} and for macronutrients mg kg^{-1} for the micronutrients. The leaf tissue analysis was performed according to the methods described by Malavolta et al. (1998).

Table 1. Agronomical characteristics of the bean genotypes used in the experiment, as informed by FT- Sementes Ltda, Brazil

Genotype	Grain type	Prod(1)	Standard	kg/ha(2)	Number(3)	Stability(4)	Antrac.(5)	FS(6)	Curtobac.(7)	Type(8)
FT 91-3168	Carioca	99	Pérola	2341	26	15 in 26	R	4,4,0,0	1,2,2	SP
FT 91-625	Carioca	96	Pérola	2341	26	14 in 26	R	4,4,2,0	2,3,2	SE/E/SP
FT 97-68	Carioca	93	Pérola	2341	26	11 in26	R	4,3,2,1	2,1,1	SE -SP/SE
FT Magnífico	Carioca	116	Pérola	2341	26	25 in 26	MR	0,0,0,0	2,3,2	P/SP
FT 97-175	Carioca	116	Pérola	2341	26	25 in 26	MR	0,0,0,0	2,3,2	P/SP
FT 97-119	Carioca	99	Pérola	2341	26	16 in 26	AE	1,1,0,0	2,1,2	SE/SP
FT 90-1535	Carioca	104	Pérola	2341	17	13 in 17	MS	0,5,1,3	SI	SP
FT 97-255	Carioca	99	Pérola	2341	17	14 in 17	AS	3,1,0,1	2,3,2	E/SE
Carioca	Carioca	102	Pérola	2341	17	18 in 26	S	4,5,0,1	SI	P
Bonito	Carioca	101	Pérola	2341	10	6 in 10	MS	SI	SI	SP
FT206	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)	(9)
FT 84-105	Preto	96	Nobre	2340	19	13 in 19	AR	3,5,2,0	SI	SE - P
FT 84-105	Preto	96	Nobre	2340	19	13 in 19	AR	3,5,2,0	SI	SE - P
FT 97-512	Preto	95	Nobre	2340	19	9 in 19	MR	3,5,0,0	SI	E/SE - P
FT 97-708	Preto	97	Nobre	2340	19	10 in 19	MS	5,5,4,5	SI	E-SP
Soberano	Preto	109	Nobre	2340	19	13 in 19	AR	0,0,0,1	SI	SP/P - SE
FT 97-837	Preto	94	Nobre	2340	19	9 in 19	MR	0,2,0,0,	SI	E/SE
FT 96-1117	Preto	110	Nobre	2340	19	12 in 19	AR	2,3,2,5	SI	SP/SE
FT 84-113	Preto	97	Nobre	2340	19	11 in 19	MR	4,5,2,5	SI	SE/SP
Bionobre	Preto	101	Nobre	2341	19	12 in 19	AS	2,0,0,0	SI	SE/SP P

1) Relative productivity compared to the standard (%).

2) Average productivity (kg ha^{-1}) of the standard.

3) Total number of assays.

4) Number of assays equals of greater than the standard.

5) R(resistant), AR (strongly resistant), MS (moderate susceptible), S (susceptible), AS (strongly susceptible).

6) Soil fungus (*Fusarium* and *Rhizoctonia*) - 0 to 5.

7) Curtobactérium (0 a 5) - SI= no information.

8) Type: E (Straight), P (supported), SE-SP (semi-straight or semi-supported).

9) Data not informed.

The grain yield was determined at 90 days after seeding, when the plants reached the physiological maturity, with the grain mass moisture corrected to 13%. The concentration of the nutrients N, P, K, Ca, Mg, S , B, Zn, Fe, Mn and Cu in leaves and yield (kg ha^{-1}) were used as a database for DRIS application (Beaufils, 1973; Creste et al, 1999; Costa, 2002).

The DRIS index estimation was done by merging the genotypes based on average yield in two groups: group A (productivity less than 3000 kg ha^{-1}), and group B, with yield equal or more than 3000 kg ha^{-1}. The Group B was considered high yield ones denominated "control group" as described in Table 2.

The DRIS rates obtained from different bean genotypes were calculated using computer software developed by

Prof Sebastiao Oliveira, (University of Brasilia – Brazil) (Lana et al., 2010; Oliveira et al., 2009).

Table 2. Leaf concentration of macro e micronutrients and productivity of 20 bean genotypes (average of three replicates)

Genotypes	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	Yield
	g/kg						mg/kg					kg/ha
FT-84-105	36.30	3.40	23.10	27.77	5.23	3.00	61.7	13.0	348.7	266.3	32.7	1846.66
FT-Nobre	34.77	4.07	28.17	24.55	5.25	3.10	72.4	13.0	386.0	283.0	38.3	3714.07
FT-512	36.04	3.70	28.67	22.4	4.70	2.94	78.3	13.1	350.3	204.3	35.0	2962.00
FT-97-708	35.77	3.70	28.67	22.4	4.70	2.94	56.3	13.3	350.3	204.3	35.0	3892.65
FT-91-625	41.90	3.74	26.40	21.47	4.64	2.97	66.0	13.0	330.7	281.0	34.7	2487.77
FT-Soberano	40.34	3.85	24.30	25.57	4.87	2.74	70.7	13.0	309.0	255.3	34.3	2942.22
FT-97-837	35.04	3.54	25.20	23.06	4.03	2.74	74.7	12.0	328.0	234.7	36.0	2591.11
FT-91-3168	39.07	3.37	27.13	20.43	5.03	2.77	80.7	10.3	355.7	210.3	34.0	3436.74
FT-206	41.53	3.77	28.27	23.3	13.80	3.34	68.0	12.3	300.0	243.3	35.7	3513.41
FT-9768	37.36	3.87	28.36	21.80	5.06	2.80	63.0	14.3	303.0	214.7	34.7	4109.63
FT-1117	40.00	3.53	27.57	23.24	4.77	2.64	68.0	13.3	331.3	247.3	35.3	3024.37
FT-Magnífico	39.30	4.03	24.40	23.83	6.77	2.96	82.0	14.0	418.7	246.7	36.7	3810.81
FT-97-176	32.53	3.43	29.73	21.03	5.47	3.23	67.7	12.7	296.0	248.3	29.7	4208.15
FT-97-119	36	3.20	20.80	20.63	5.5	2.63	62.0	11.0	344.3	189.7	32.7	3757.85
FT-84-113	40.3	3.30	25.67	21.33	4.13	2.70	56.3	12.0	265.3	200.3	30.0	3690.37
FT-90-1535	34.5	3.50	25.40	21.2	5.17	2.97	65.7	12.3	310.0	192.7	29.3	2636.82
FT-97-255	34.26	3.63	27.17	20.5	4.87	3.17	70.7	12.3	519.3	235.7	33.0	1328.37
Carioca	34.8	3.53	23.36	22.8	5.40	2.83	64.0	12.7	360.7	213.3	33.0	1897.11
Bonito	36.03	3.83	24.80	23.66	5.00	2.90	73.7	14.0	247.7	261.0	33.7	3467.78
Bionobre	33.53	3.43	26.93	21.8	4.40	2.96	69.0	11.7	298.0	221.3	33.0	1767.93

3. Results and Discussion

The nutrients concentration in leaves and productivity of the genotypes are shown in Table 2. Leaf analysis genotypes corroborates with the data of macro and micronutrients which are appropriate for the beans, described by Malavolta et al. (1998). The yield ranged from 1328 to 4208 kg ha $^{-1}$ (Table 2).

The calculation of DRIS index for each nutrient in all genotypes and the series values were obtained. Then these values were ranked within each series, in order of limitation importance, the criteria in descending order (Table 3) was used. When the index was more negative, the nutrient limitation was higher, and more positive indicates less limiting and depending on the situation by limiting excess.

The results in Table 3 showed that Zn was the most limiting nutrient in 40% of the genotypes, whose yields were below than those of the Group B, in 55.5% of cases. B and K were the most limiting in 15% of cases, and 66.6% of these belonged to control group. The Fe and S had the same level of limitation, 10%, and the yields obtained were lower than the standards in 50% of the genotypes. And finally, the most limiting nutrients were N and Cu with 5% of occurrences in the control group. P, Ca, Mg and Mn had not any results in terms of limitation in any situation. In summary, the limitation sequence of nutrient scarcity in the genotypes in percentages was as follows: Zn (40%) > K = B (15%) > S = Fe (10%) > N = Cu (5%) > = P = Ca = Mg = Mn (0%).

Among 20 analyzed genotypes, 40% (eight) showed the S as the nutrient most limiting by excess. Within this group, 75% (six) had Zn as the most limiting nutrient for scarcity. And in both genotypes and FT-97-837 and FT-1117, where the S was considered the limiting by scarcity, Zn was the limiting nutrient by excess, suggesting a trend of antagonism between these two elements i.e. the S and Zn are contradictory in terms of absorption in plants. Other nutrients have been limiting for excess: Mg (genotypes), Ca (two), K (two), Mn (one), B (one) and

Cu (one) (Table 3).

Table 3. Primary DRIS index and limiting sequence of nutrients in different bean genotypes

Genotype	DRIS index											Limiting sequence
	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn	
FT-84-105	-62	-55	-55	111	33	95	-81	23	-36	59	-115	Zn>B>N>P=K>Fe>Cu>Mg>Mn>S>Ca
FT-Nobre	-32	31	7	31	12	31	32	6	32	48	42	N>Cu>K>Mg>P=S=Ca>B=Fe>Zn>Mn
FT-512	-35	-13	41	-27	-20	37	-45	-3	-17	-34	-31	B>N>Mn>Zn>Ca>Mg>Fe>P>Cu>S>K
FT97-708	-34	-11	41	-10	-24	39	-80	18	-16	-34	-32	B>N=Mn>Zn>Mg>Fe>P>Ca>Cu>S>K
FT-91-625	4	-5	36	-19	-26	67	-5	-6	-52	40	-37	Fe>Zn>Mg>Ca>Cu>B=P>N>K>Mn>S
FT-Soberano	36	17	-54	75	-5	-35	12	23	0	47	26	K>S>Mg>Fe>B>P>Cu>Zn>N>Mn>Ca
FT-97-837	29	30	-13	36	-43	-50	62	-16	32	37	96	S>Mg>Cu>K>N>P>Fe>Ca>Mn>B>Zn
FT-91-3168	1	-30	7	-87	20	-3	102	-104	29	-33	8	Cu>Ca>Mn>P>S>N>K>Zn>Mg>Fe>B
FT-206	-60	-61	78	-66	-50	157	-46	-49	-128	-3	-143	Zn>Fe>Ca>P>N>Mg>Cu>B>Mn>K>S
FT-9768	-6	19	28	-19	-10	1	-29	35	-23	-19	-7	B>Fe>Ca=Mn>Mg>Zn>N>S>P>K>Cu
FT-1117	58	28	-30	48	-21	-85	18	21	38	24	81	S>K>Mg>B>Cu>Mn>P>Fe>Ca>N>Zn
FT-Magnífico	-15	11	-81	6	119	-31	72	-9	87	-4	17	K>S>N>Cu>Mn>Ca>P>Zn>B>Fe>Mg
FT-97-176	-210	-111	152	-139	31	350	-69	-48	-210	-2	-333	Zn>Fe=N>Ca>P>B>Cu>Mn>Mg>K>S
FT97-119	0	-18	-81	8	83	-40	24	-28	80	-32	9	K>S>Mg>Cu>P>N>Ca>Zn>B>Fe>Mg
FT-84-113	-11	-57	45	-31	-54	81	-86	-11	-111	-21	-124	Zn>Fe>B>P>Mg>Ca>Mn>Cu=N>K>S
FT-90-1535	-138	-91	71	-103	42	210	-61	-44	-123	-50	-241	Zn>N>Fe>Ca>P.B>Mn>Cu>Mg>K>S
FT-97-255	-114	-47	104	-109	-2	204	-5	-45	-129	0	-164	Zn>Fe>N>Ca>P>Cu>B>Mg>Mn>K>S
Carioca	-46	-21	-34	14	61	34	-14	-2	22	-10	-47	Zn>N>K>P>B>Mn>Cu>Ca>Fe>S>Mg
Bonito	-34	12	15	13	-5	75	13	32	-96	57	-63	Fe>Zn>N>Mg>P>Ca=B>K>Cu>Mn>S
Bionobre	-72	-37	64	-51	-24	119	-2	-41	-75	3	-88	Zn>Fe>N>ca>Cu>P>Mg>B>Mn>K>S

The excess S and the Zn deficiency might be related to the soil richness in organic matter (OM), because it can induce to this situation (Fageria, 2002; Oliveira et al., 1996). The fact that in most of the genotypes the S was the limiting nutrient by excess may be due to the application of ammonium sulfate as cover fertilizer and / or because of the high amount of OM in the soil experiment. According to Oliveira et al. (1996), soils rich in OM that received high doses of P and areas that were planned or soil moved from surface may exhibit Zn deficiency. In the present experiment the P dosage used was the one recommended for the crop, but the experiment place has the same characteristics as described above. This may explain the limitation of Zn by scarcity. Thung & Oliveira (1998) reported that the S concentration in bean leaves increases until the end of crop cultivation.

The productivity of the genotypes that presented the Zn as limiting nutrient by scarcity was below to those of "control group" in five genotypes, however in three of them it was higher, suggesting that despite of DRIS analysis indicate Zn limitation by scarcity, the productivity was not affected (Table 3). According to Oliveira et al. (1996) there are varieties of bean less susceptible to Zn deficiency, which enables the beans cropping even in soil poor with Zn deficiency.

In the genotype FT-Nobre, where N was the strongest limiting factor, Mn showed the highest index, suggesting that despite of Mn to be a toxic element, when in excess, the general conditions of the plot did not show their deleterious effect (Table 2 and 3).

For the genotypes FT-Magnifico and FT97-119, it was observed that K and Mg were the most and least limiting nutrients respectively, indicating that the excess of Mg affected the uptake of K in these genotypes (Table 3). This result corroborates with Malavolta et al. (1998), who reported that excess of Mg leads to lack of Ca and K.

The Table 3 presents a scarcity of B in three genotypes (FT-512, FT-97-708, FT-9768) which can be explained by

its low mobility in plants (Malavolta et al., 1998), probably these genotypes have more difficulty to mobilize B than others. The B has a low range between sufficient concentration in substrate and toxic level, and the relative tolerance of plants to toxicity is linked to transportation rate from roots to shoots (Malavolta et al., 1998). In the case of FT-91-3168, the B excess could be attributed to the phenomenon mentioned above.

The availability of Fe is reduced in flooded soils (Oliveira et al., 1996). The genotypes FT-91-625 and Bonito, where there was scarcity of Fe, may be due to the sub-surface irrigation during the experiment and/or to big sensitivity of these materials to flood (Table 3).

Oliveira et al. (1996) reported that bean does not respond to potassium fertilization, similar situation observed in this experiment, because 66.6% of the genotypes that showed K as the most limiting by scarcity belong to the "control group".

Phosphorus has most increased the beans production compared to other elements (Malavolta, 1987; Oliveira et al., 1996; Westermann, 2011). In the currently research, the P was not limiting by scarcity nor excess, because due to fertilization applied with and appropriate P concentration, made difficult the detection of genotypes tolerant to P deficiency.

The potassium, boron, sulfur and copper showed an interesting role in this experiment, limiting by deficiency and excess, which indicates the sensitivity of these nutrients to the fertilizer management. Costa (2002), when using DRIS in irrigated commercial beans, found the following results: N, P, K and Cu as limiting by scarcity and Mn, Cu and Zn limiting by excess. Some genotypes of this study behaved similarly: N, K and Cu limiting by scarcity and Mn, Cu and Zn by excess (Table 3).

The correlation matrix between DRIS rates for different bean genotypes (Table 4) led to identify interactions between nutrients estimating the necessity for fertilizations in the future. In the genotypes could be observed that the highest positive correlations between the nutrients levels were: P × Zn (0.928), N × Zn (0.920), Fe × Zn (0.885), K × S (0.829), N × P (0.823), N × Fe (0.754) and Ca × Cu (0.735). Negative correlations were: S × Zn (-0.963), N × S (-0.947), S × Fe (-0.908), K × Fe (-0869), P × S (-0.855) and K × Ca (-0.815). However, to construct the correlation matrix between DRIS rates the data of all genotypes were used together, and would be interesting to make this correlation matrix for each genotype. Epstein (1975) pointed out that chemical analyzes of different varieties of same species grown in similar environments, can vary widely in the plant tissue nutrient concentration.

According to Malavolta et al. (1998), the excess of P can cause deficiency of heavy metals such as Fe, Cu, Zn and Mn, thus the higher level of this nutrient increase the necessity of the other, i.e. they correlate negatively. In the currently research, the P content was in the proper range thus there was a negative correlation of P with the heavy metals mentioned above. N and P are the most limiting factors in bean production, confirming the positive correlation found (Thung & Oliveira, 1998).

The values of Nutritional Balance Index (NBI) of the genotypes ranged from 192 to 1655. In DRIS applied to bean in low productivity crops (lower than 300 kg ha^{-1}), when the NBI was below 30, the limiting factor in the productivity is not nutrition, however above 60 the productivity was limited by a nutritional factors (Costa, 2002). This author had NBI values ranging between 26 and 220, lower than those in this research. The Figure 1 shows the effect of NBI on bean productivity, but there was no correlation between them. Costa (2002) demonstrated that although the correlation value has not been shown, the graph indicates a correlation between NBI and productivity. However, as the conditions of each experiment are different and the study of DRIS on bean is recent, all of comparisons of different studies should be carefully done.

Table 4. Correlation matrix between the DRIS rate in different bean genotypes

	N	P	K	Ca	Mg	S	B	Cu	Fe	Mn	Zn
N	1,000	0.823	-0,713	0,673	-0,195	-0,947	0,496	0,393	0,754	0,255	0,920
P		1,000	-0,613	0,657	-0,081	-0,855	0,586	0,568	0,745	0,416	0,928
K			1,000	-0,815	-0,455	0,829	-0,473	-0,400	-0,869	-0,267	-0,734
Ca				1,000	0,049	-0,704	0,149	0,735	0,630	0,612	0,672
Mg					1,000	-0,048	0,284	-0,104	0,378	-0,178	-0,043
S						1,000	-0,565	-0,400	-0,908	-0,153	-0,963
B							1,000	-0,242	0,634	0,199	0,649
Cu								1,000	0,246	0,475	0,372
Fe									1,000	0,059	0,885
Mn										1,000	0,269
Zn											1,000

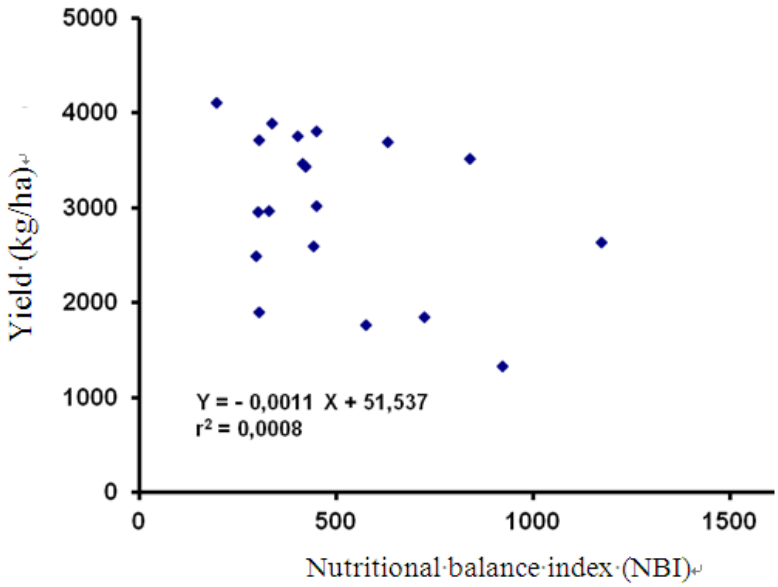

Figure 1. Correlation between yield (kg/ha) of 20 bean genotypes and the nutritional balance index (NBI)

The results of this study indicate that the DRIS is a relatively efficient methodology to determine the trustable sufficiency levels in soil, plant and in commercial crops. The DRIS performance could be explained by the fact that the forms are quite general, composed of a database with many variables, such as different genetic materials with large differences in yield potential and more (Silva et al., 2013; Wadt & Novais, 1999).

Thus, this study showed that the DRIS analysis must take into account the cultivars, because in general each genotype showed different responses to the same fertilization.

4. Conclusions

1). The nutritional status of the genotypes obtained from leaf analysis are suitable for cropping.

2). The elements with high probability of response to fertilization in descending order of percentage genotypes are Zn (40%) > K = B (15%) > S = Fe (10%) > N = Cu (5%) > P = Ca = Mn = Mg = (0%).

3). The NBI shows no correlation with productivity for the genotypes studied.

4). The DRIS can be used to select genotypes for the efficient use of nutrients in bean production.

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