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Balance among calcium, magnesium and potassium levels affecting Asian Soybean Rust severity

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ABSTRACT

This work aimed to analyze the effect of the variation of the proportions of calcium in relation to the contents of magnesium and potassium in the cationic capacity of change (CCC) of the soil, seeking to propitiate the appropriate balance of bases, so that the soybean plants presented good nutritional state and had conditions of resisting to the attack of *Phakopsora pachyrhizi* Syd. & P. Syd. The experiment was driven in randomized blocks with eight replications and the treatments consisted of doses of Ca:Mg:K in relation to CCC of the soil being:1) without correction of the bases (original soil with 3,8%:6,6%:2,4%); 2) 35:15:5; 3) 45:15:5; 4) 55:15:5; 5) 65:15:5; 6) 75:15:5. The soybean cultivar used in the experiment was BRS 184, sowed in mud vases containing dystrophic Red Latosol (Oxisol) as substrate. The inoculation was realized in the fenologic stadium V4. The disease severity was determined through visual notes considering the percentage foliate area with visible symptoms of the disease, being calculated the Area Under Disease Progress Curve (AUDPC). The data were submitted to the variance analysis ($p<0.05$) and fitting to regression models. The balance among the nutrients was analyzed being calculated the index DRIS. The contents of nutrients, the matter dry indexes (MDI) and nutritional balance index (NBI) were inserted in the program ChecarDris for obtaining of the index DRIS. The results appeared that the percentages of 55% of calcium, 15% of magnesium and 5% of potassium, increase larger nutritional balance in the soybean providing to smallest area under disease progress curve (AUDPC), reduction in the severity of the rust (%), besides increase the largest productivity.

Keywords: *Phakopsora pachyrhizi*, plant nutrition, nutritional balance, DRIS.

INTRODUCTION

Asian rust (*Phakopsora pachyrhizi* Syd. & P. Syd.) has increased production costs due to the need of fungicides spraying, considered, until now, together with resistant varieties, the most efficient among control measures.

Plants disease severity depends on environmental factors, including the essential level of nutrients. Fageria, Baligar and Jones (1990) shows that a balanced nutrition plays an important role in determining plants resistance or susceptibility to diseases. Ito et al. (1994) adds that a balance among several soil nutrients, much more than each one in isolation, can bring a reduction in the incidence of diseases. Some authors (Mclean, 1984; Albrecht, 1996) have concluded that to reach an ideal balance of cations in the complex of change, it must be occupied by 50 to 65% of Ca, 15 to 20% of Mg and 3 to 5% of K, in relation to the CTC (pH 7).

Balardin et al. (2006) observed that Asian soybean rust severity decreased with fertilization balanced between P and K associated with the partial resistance of cultivars to this fungus. Oliveira, Carmello and Mascarenhas (2001) also verified that whenever the relation (Ca + Mg)/K in the soil was greater than 36, and the same relation was greater than 36 in the foliar tissue, plants showed K-deficiency symptoms. However, whenever the relation in the soil was between 20 and 30, plants showed greater yields.

Santos et al. (2008) explains that calcium in the plants tissue affects the incidence of parasitic diseases, since it is essential to the stability of bio-membranes. According to Rahman and Punja (2007), calcium may be the most important nutrient in plant disease management since the adequate level of this nutrient in the soil and in the plant can reduce the incidence and the severity of several diseases of economic importance.

In regards to magnesium, an excess of this mineral may increase the incidence of diseases caused mainly by bacteria such as *Xanthomonas campestris* pv. *vesicatoria*, which causes defoliation in green peppers and tomatoes (2007). According to Fageria, Baligar and Jones (1990), an excess of magnesium may reduce calcium concentration in peanut pods, making them more susceptible to *Rhizoctonia* and *Pythium* attacks.

The objective of this work was to analyze the effect of variations in calcium proportions in relation to magnesium and potassium contents on the cationic capacity of change (CCC) of the soil. It aimed at verifying the adequate balance of bases so that soybean plants could present good nutritional state and develop conditions to resist to the attack of the Asian soybean rust fungus.

MATERIAL AND METHODS

The experiment was carried out at Universidade Estadual de Londrina (UEL) during the 2008/2009 agricultural year, in mud vases with the capacity for 5 kg (Figure 1a). Low fertility Psamitic Dystrophic Red- Latosol was collected from 20-40 cm (original soil), in the region of Faxinal -PR (Table 1).

For the treatments, Mg and K contents were corrected at 15% and 5%, using $MgCO_3$ (p.a.) and KCl (60% K_2O) as source, respectively. Additions were also realized in calcium which altered the Ca Percentage in the CTC (PCaC) and affected the relations among Ca:Mg:K, using Calcite limestone ($CaCO_3$) as source. The following treatments were adopted: 1) without correction of the bases (original soil with 3.8%:6.6%:2.4%); 2) 35%:15%:5%; 3) 45%:15%:5%; 4) 55%:15%:5%; 5) 65%:15%:5%; 6) 75%:15%:5%. The experiment was driven by a randomized block experimental design with eight replications.

Manually homogenized and moistened with distilled water soil samples, enough to reach 80% of field capacity, were incubated for a period of 30 days. Eight soybean (BRS 184) seeds per vase were sown and later thinned, leaving four plants per vase.

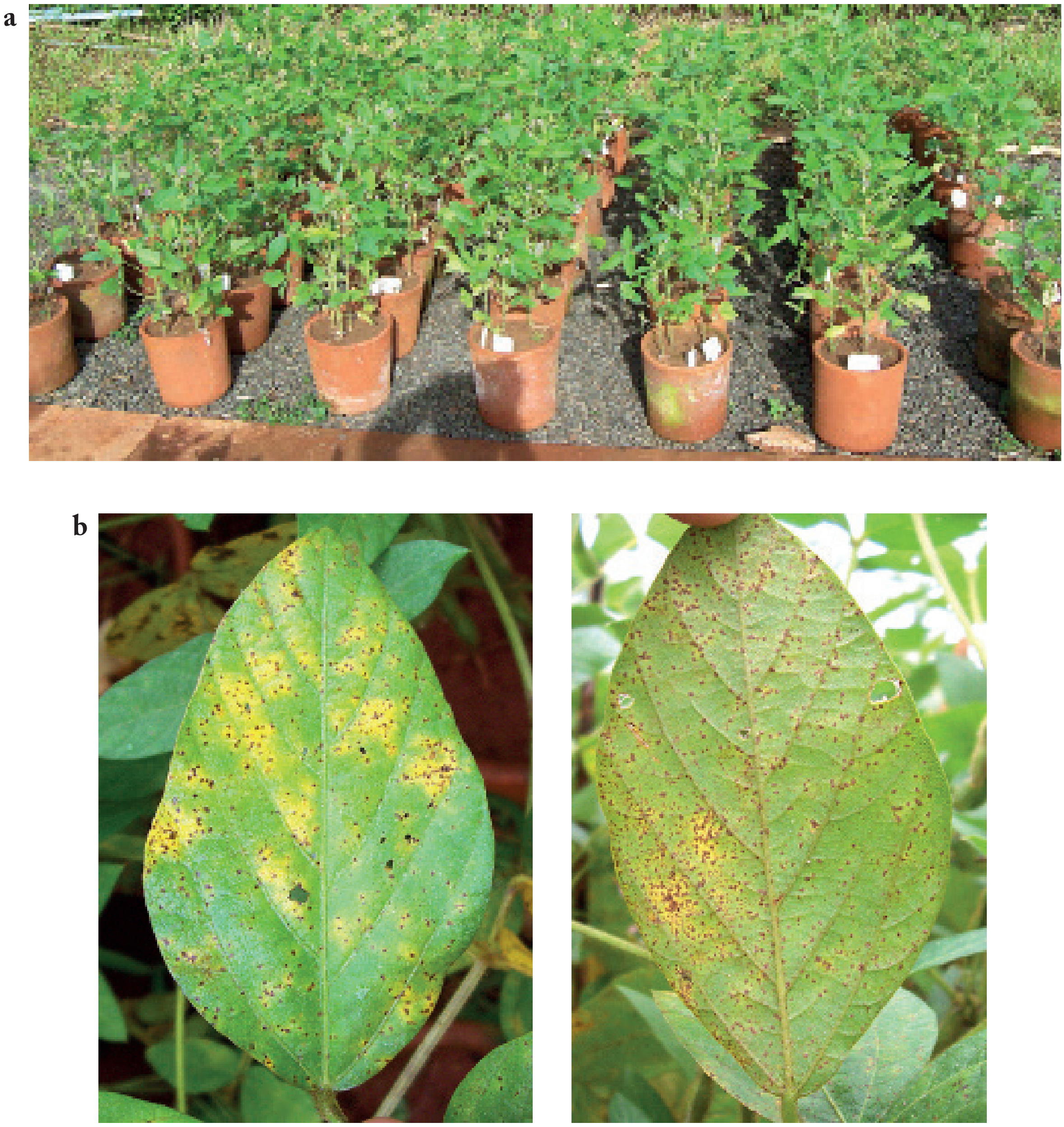

Figure 1. Partial view of the randomized design in clay pots with (**a**). Asian soybean rust symptoms in the axial and abaxial faces (**b**) in soybean leaves collected to estimate the average disease severity.

Table 1. Chemical and granulometric characteristics of the original soil.

	pH	Ca	Mg	K	pH (H+Al)	Al	H	CTC	V(%)	MO	P
	H2O		---------------------		Cmolc/dm3		----------------------			(%)	mg/dm3
Chemical	5.32	0.15	0.26	0.09	3.42	0.53	2.83	3.93	0.5	0.26	1.93
% of bases in the CTC		3.82	6.63	2.41			72.12		12.9		
	Sand	**Silt**	**Clay**								
Granulometry		(%)									
	81.5	7.1	11.5								

Pavan et al. (1992).

Experiment irrigation was done manually with distilled water, maintaining 80% of field capacity, using a tensiometer. Plant inoculation with *Phakopsora pachyrhizi* uredospore was carried out at the V4 vegetative state, 64 days after germination. Solution with spores was prepared with water, spreading adhesive (Tween 80) and *P. pachyrhizi* uredospore at the 50000 spores.ml^{-1} concentration. Inoculations were realized at night with the help of a coastal and sprayed until leaves are fully wet, without running off. After inoculation, the vases were covered with a plastic bag for 24 hours, creating a humid chamber for the plants.

Disease severity was estimated using the diagrammatic scale proposed by Godoy, Koga and Canteri (2006), taking into consideration foliar percentage with symptoms of the disease (Figure 1b). The Area Under Disease Progress Curve (AUDPC) was calculated based on the assessments carried out 14, 18, 22, 26 and 30 days after inoculation (Campbell and Madden, 1990). Assessments were done on all trifoliate leaves emerged from the main stem of the four plants present in each vase. Macro and micronutrients content determination was done by collecting the third and fourth trifoliate, starting counting from the top of the plant, in one soybean plant by replication, in the flowering period. Material was dried in a greenhouse, with forced air circulation, until constant weight at 60°C, weighed or grinded. The method described by Silva (1999) was adopted to determine content. Soybean production was determined in grams per plant and extrapolated to kilogram per hectare (Kg/ha).

The balance among the nutrients was analyzed by calculating the DRIS index. The DRIS index for each chemical element uses binary relations with the content of other chemical elements in the sample and is used to analyze plant nutritional balance (Silva, Nogueira and Guimarães, 2003; Martins et al., 2005). Binary relations among nutrients are expressed by indexes that vary from positive to negative. If negative, the nutrient will be limiting by deficiency and when positive, more excessive is the nutrient (Guindani, Anghinoni and Nachtigall, 2009).

Nutrient contents in the samples were inserted in the ChecarDRIS program, developed by LABORSOLO, in order to get the DRIS (Diagnosis and Recommendation Integrated System) for each nutrient. Dry matter (DMI) and nutritional balance index (NBI) values for each treatment were also inserted in the program.

The sum of the DRIS index values for each nutrient, in a module, provides the nutritional balance index (NBI) thus allowing the comparison of the plant's global nutritional balance where the lower the NBI the more balanced is the plant (Silva, Nogueira and Guimarães, 2003). Data collected were submitted to an analysis of variance to compare AUDPC means and to adjust the polynomial regression models ($p<0.05$) for the treatments. The Tukey test ($p<0.05$) was used to compare means.

RESULTS AND DISCUSSION

The different relations among Ca:Mg:K in the CTC affected significantly the Area Under Disease Progress Curve (AUDPC), severity and yield, with a tendency to reduce AUDPC and Severity, and increase yield as Ca contents nears a balance in relation to other bases (Figure 1) . The AUDPC presented the lowest value when the Percentage in the CTC (PCaC, Ca Percentage in the CTC) was 55% with values of 15% for Mg and 5% for K, reducing the AACPD by 54%, (Figure 2a), and severity by 10 pp (Figure 2b) , i.e., bases balance in the soil reduced disease severity being able to also reduce the number of fungicide applications and production costs. According to McLean (1984) and Albrecht (1996), to be well balanced nutritionally and healthy, the plant must be cultivated in soil or substrate whose cation exchange complex must be filled with 50 to 65% of calcium, 15 to 20% of magnesium and 3 to 5% of potassium, proportions that, according to this results, presented lower disease severity levels.

Some papers show the effect of Calcium on rust severity, as those reported by Debona et al. (2008), in which an increase in calcium dosages in the soil up to 200 Kg/ha contributed to the reduction of rut severity in soybean by 7 pp.

Soil PCaC also affected plants yield (Figure 2c). The largest yield was found in treatment 4 (55%Ca:15%Mg:5% K), representing an increase of around 3 Ton per hectare in relation to the control. This treatment showed lesser soybean rust severity progress (Figure 2a). It was also observed that the same treatment provided a foliar area increase by 37%, which interferes directly in the yield by an increase in the photosynthetically active area (Figure 2d). This finding is in agreement with those described by Watanabe et al. (2005) and Carneiro et al.(2006) who affirmed that in soils where there is a balance of bases proportions, plants become more resistant to diseases and, consequently, more productive.

The PCaC affected soybean foliar calcium contents (Figure 3), reaching a maximum Y of 20.5 g Kg^{-1}, i.e., 9.7 g Kg^{-1} more than the control. Although the calcium provided a more developed, thicker, cell wall and confer better cell membrane structuring (Epstein and Bloom, 2004; Marschner, 1995; Santos et al., 2008), there was an increase in disease levels with treatments with PCaC above 55%, considered treatments with unbalanced soil nutrients.

The increase of PCaC in the soil causes a quadratic increase in foliar calcium (Figure 2) with excellent adjustment (R^2=0,91**). These findings are in agreement with thos obtained by Fenille et al. (2000). On the other hand, foliar potassium contents showed a slight reduction when calcium contents increased in the soil, a situation similar to the that reported by Kurihara et al. (1993). With the increase in calcium percentages in the soil foliar magnesium content varied slightly in the several cationic proportions studied (Table 2).

Working with coffee plants, Santos et al. (2008) concluded that the lowest concentrations of potassium and the highest concentrations of calcium in the leaves, during the granulation phase, deliver greater nutritional balance to the coffee plants, increasing resistance to blotches and rust and reducing defoliation and the biannual effect on production.

Garcia Júnior et al. (2003) verified that an increase in calcium in the nutrition solution caused a linear decrease in the area under disease progress curve (AUDPC) of *Cercospora coffeicola* in the coffee plant. However, according to the same authors, the calcium increase would only be beneficial to diseases reduction if the amounts of potassium in the solution were respected. In this same work, excessive dosages of potassium caused an increase in the AUDPC of *Cercospora coffeicola,* according to the authors, due to the fact that potassium competes with calcium for the absorption sites.

This way, the importance of providing balanced nutrients to plants in the soil or in the nutrition solution is verified, so that one cannot affect the absorption of the other. Foliar calcium increase provided an increase in boron absorption by plants (Table 2). A PCaC below 45% provides lower calcium foliar contents thus reducing foliar boron contents. According to Marschner (1995), calcium helps boron absorption by plants since it fills negative charges in the root apoplasm (root CTC), facilitating the passage of the $H_4BO_4^-$ anion.

Manganese contents dropped as calcium percentages increased in the soil CTC. These findings are in agreement with those found by Heinrichs et al. (2008), who verified that the increase in soil bases percentages together with the increase in pH, caused a reduction in manganese foliar contents in bean plants. The increase in calcium percentage in the CTC increased the levels of calcium in radicular zone, reducing manganese absorption due to competition for the same absorption site (Malavolta, Vitti and Oliveira, 1997). The pH favors the reduction of manganese absorption since it alters the chemical composition of this soil,

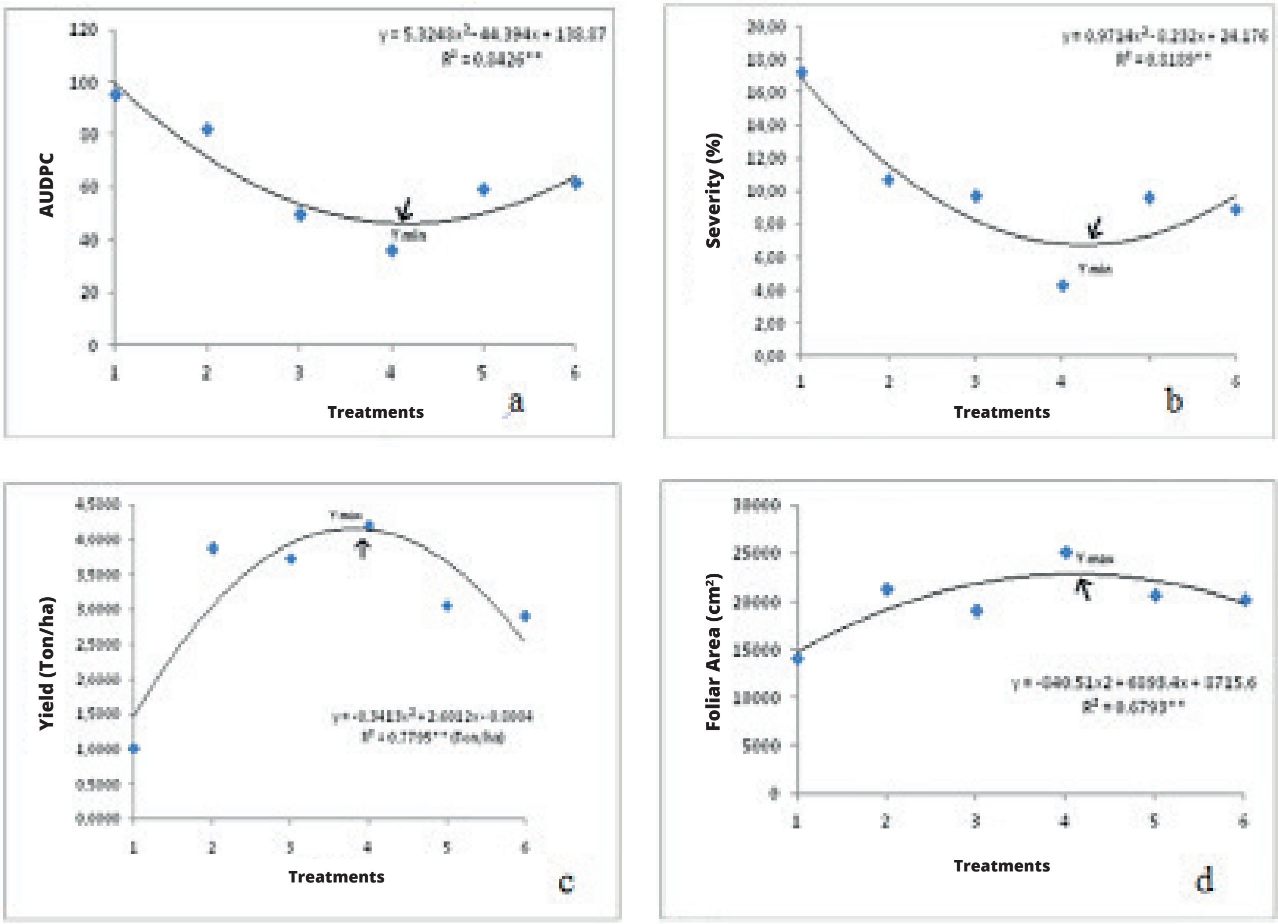

Figure 2. Area Under Disease Progress Curve (AUDPC) – a – Asian rust severity (b) soybean yield (Ton ha^{-1}) – c – at stadium R6 (%) in relation to calcium percentages in the soil CTC. T 1: 3,8:6,6:2,4 ; T 2 -35:15:05 ; T3 - 45:15:05 ; T4 - 55:15:05; T5 - 65:15:05 ; T6 - 75:15:05

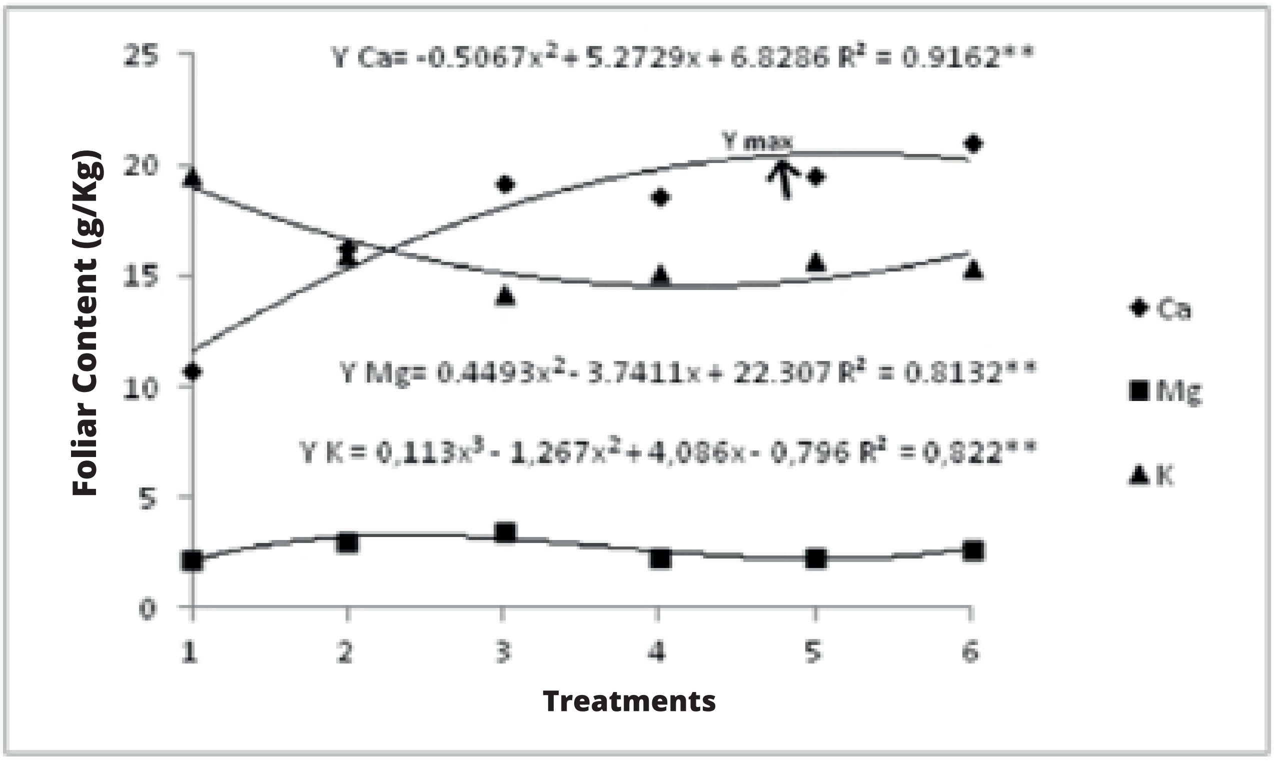

Figure 3. Calcium, magnesium and potassium contents in soybean index leaves, collected at flowerin due to calcium percentage in the CTC applied to the soil. *, ** significant at 5 significant at 1% by the F. T 1: 3,8:6,6:2,4 ; T 2 -35:15:05 ; T3 - 45:15:05 ; T4 - 55:15:05; T5 - 65:15:05 ; T6 - 75:15:05.

avoiding absorption by plants. According to Heinrichs et al. (2008), an increase by one unit in the soil pH reduces manganese concentration by 100 times.

According to the DRIS indexes (Table 2) of each nutrient, PCaC below 45% presented the boron a negatively limiting nutrient, i.e., more deficient, and the manganese as a positively limiting nutrient, i.e., in excess. The PCaC above 45% has sulfur as the most deficient nutrient and zinc (55:15:5), borous (65:15:5) and manganese (75:15:5) as excessive.

The correlation among NBI and AUDPC, severity, yield and foliar area (Figure 4) shows a direct interaction, i.e, as the NBI reduced , disease severity also reduced and there was na increase in yield, probably associated with a better plant nutritional balance. These findings are in agreement with those found by Ito et al. (1994), Balardin et al. (2006) and Santos et al. (2008), who reported in their works that a nutritionally balanced became plants more resistant to pathogens attacks.

Treatment T4 55:15:5 provided the best nutritional balance index (NBI) of 16.2 (Table 2). This finding shows that a plant cultivated in a chemically balanced soil absorbs nutrients correctly without competing among them, and presenting greater nutritional balance (Carneiro et al., 2006; Kurihara et al., 1993).

The importance of the balance among nutrients in the soil CTC in relation to Asian rust in soybean plants was detected by the DRIS method through the nutritional balance index variation (NBI). Another factor is that calcium contents below 45% in the total CTC offered greater risk of a rust epidemics and values of 55%:15%:5% providing better nutritional balance and, consequently, a reduction in disease severity and greater yield for this crop.

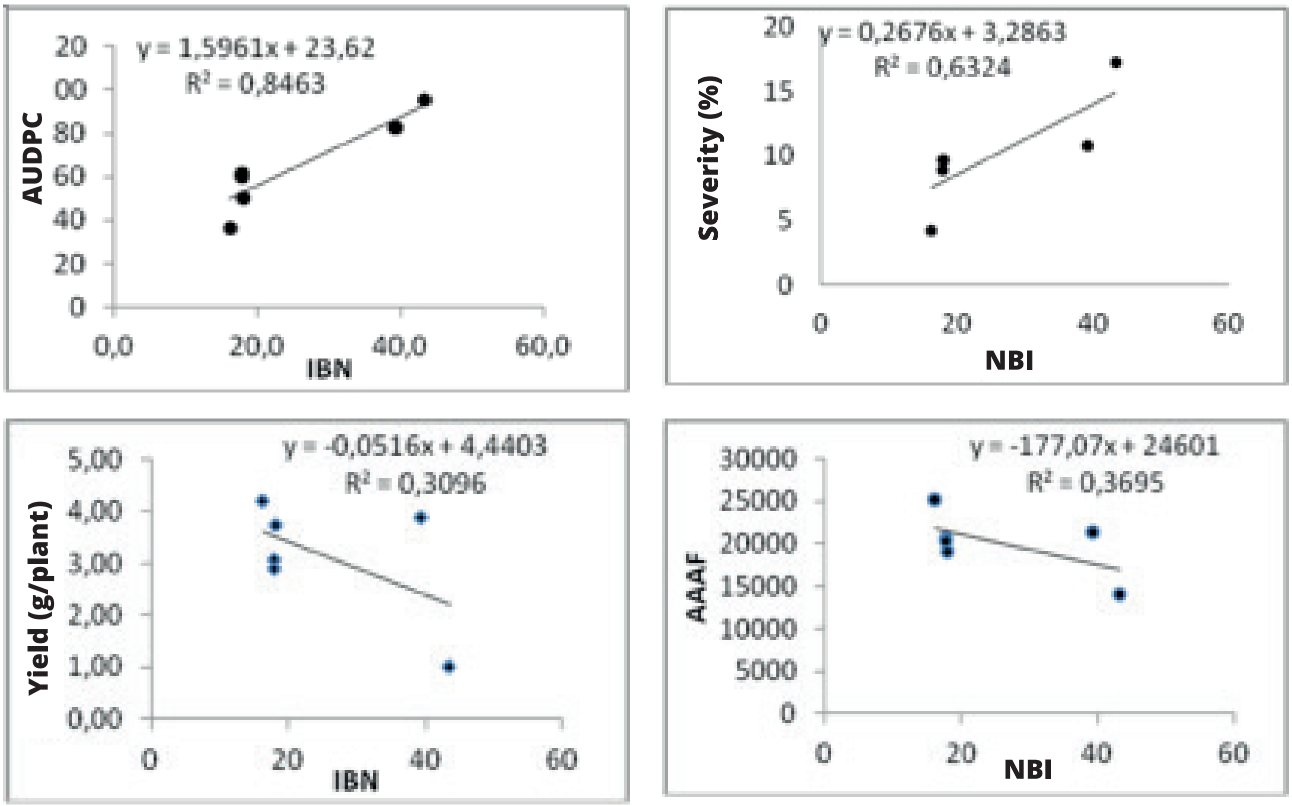

Figure 4. Area Under the Disease Progression Curve (AUDPC) for soybean rust severity due to the nutritional balance index (NBI) calculated by the DRIS index. Lower NBI values show a more balanced plant. T 1: 3,8:6,6:2,4 ; T 2 -35:15:05 ; T3 - 45:15:05 ; T4 - 55:15:05; T5 - 65:15:05 ; T6 - 75:15:05

Table 2. Foliar contents of soybean nutrients (BRS 184) with their respective nutritional balance indexes (NBI),dry matter index (DMI) and nutritional balance index (NBI) due to percentages of calcium applied on the soil.

	N²	P²	K²	Ca²	Mg²	S²	B³	Fe³	Mn³	Zn³	Cu³			
% Ca:Mg:K¹	*ID*	*ID*	*ID*	*ID*	*ID*	*ID*		*ID*	*ID*	*ID*	*ID*	*ID*	**IMS**	**IBN**
3,8:6,6:2,4	*0,5*	*1,6*	*3,9*	*0,6*	*-0,7*	*-4,3*		*-14,9*	*0,7*	*11,2*	*3,0*	*-1,9*	**0,5**	**43,4**
35:15:05	*0,1*	*1,5*	*4,0*	*1,4*	*1,0*	*-3,8*		*-13,4*	*1,2*	*6,7*	*3,0*	*-2,5*	**0,8**	**39,3**
45:15:05	*-0,5*	*-1,8*	*0,2*	*1,6*	*0,9*	*-4,9*		*-0,2*	*0,6*	*2,7*	*2,6*	*-1,7*	**0,4**	**18,1**
55:15:05	*-1,0*	*0,2*	*0,3*	*1,7*	*-0,8*	*-4,2*		*0,8*	*0,0*	*2,3*	*2,4*	*-2,1*	**0,4**	**16,2**
65:15:05	*-0,5*	*-0,2*	*0,5*	*1,8*	*-0,9*	*-4,0*		*2,4*	*-0,2*	*1,8*	*2,1*	*-3,1*	**0,3**	**17,9**
75:15:05	*0,0*	*-0,6*	*1,0*	*2,0*	*0,1*	*-3,6*		*-2,5*	*0,4*	*2,4*	*1,9*	*-1,9*	**0,9**	**17,9**

[1] Porcentagens de Ca, Mg e K na CTC.
[2] g/Kg of dry matter;
[3] mg/Kg of dry matter;
[4] T: determined nutrient content;

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