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Research Article

Fertilization factor associated with nitrogen sufficiency index for nitrogen topdressing fertilization in common bean[1]

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ABSTRACT

The current recommendations for nitrogen (N) doses may not contemplate the complex dynamics of N in the soil, what may imply in insufficiency to the crop demand. This study aimed to evaluate the use of two portable chlorophyll meters (Minolta SPAD 502 and ClorofiLOG model CFL 1030), after defining the nitrogen sufficiency index (NSI), to estimate the nitrogen fertilization factor in modern bean genotypes. A block design was used, with four replications. Each experiment consisted of four treatments, with doses of 0, 5, 10 and 20 kg ha^{-1} of N for each 1 % considered below the NSI defined as adequate for each cultivar. At the end of the cycle, the production components and yield were evaluated. It was not possible to obtain precise adjustments in the methodology for the TAA Gol cultivar. The fertilization factor of 12.5 kg ha^{-1} of N for each 1 % below the NSI of 90 % proved to be efficient for the Pérola cultivar, when the SPAD-502 chlorophyll meter was used. In genotypes with size and cycle characteristics similar to those of the BRSMG Uai cultivar and the VR 20 strain, using a fertilization factor between 14 and 16 kg ha^{-1} of N, the NSI of 95 % must be reduced, in order to increase the efficiency of the nitrogen fertilization.

KEYWORDS: *Phaseolus vulgaris* L., nitrogen management, chlorophyll meter.

RESUMO

Fator de adubação associado ao índice de suficiência de nitrogênio na adubação nitrogenada em cobertura de feijão-comum

As atuais recomendações de doses de nitrogênio (N) podem não contemplar a dinâmica complexa do N no solo, o que pode implicar em insuficiência à demanda da cultura. Objetivou-se avaliar o uso de dois medidores portáteis de clorofila (Minolta SPAD 502 e ClorofiLOG modelo CFL 1030), após a definição do índice de suficiência de nitrogênio (ISN), para estimar o fator de adubação nitrogenada em genótipos modernos de feijão. Utilizou-se delineamento em blocos, com 4 repetições. Cada experimento foi composto por quatro tratamentos, com doses de 0; 5; 10; e 20 kg ha^{-1} de N para cada 1 % considerado abaixo do ISN definido como adequado para cada cultivar. Ao final do ciclo, foram avaliados os componentes de produção e a produtividade. Não foi possível a obtenção de ajustes precisos na metodologia para a cultivar TAA Gol. O fator de adubação de 12,5 kg ha^{-1} de N a cada 1 % abaixo do ISN de 90 % mostrou-se eficiente para a cultivar Pérola, quando utilizado o clorofilômetro SPAD-502. Em genótipos com características de porte e ciclo semelhantes às da cultivar BRSMG Uai e linhagem VR 20, com a utilização de fator de adubação entre 14 e 16 kg ha^{-1} de N, o ISN de 95 % deve ser reduzido, visando aumentar a eficiência da adubação nitrogenada.

PALAVRAS-CHAVES: *Phaseolus vulgar*is L., manejo de nitrogênio, clorofilômetro.

INTRODUCTION

Nitrogen (N) is the nutrient most required by common bean plants (Cantarella 2007, Perez et al. 2013, Magalhães et al. 2017). However, the recommendation of fixed N doses present in fertilizer recommendation bulletins may be difficult to achieve, due to the complex dynamics of N in the soil (Silveira et al. 2003). This may imply in recommending doses lower than the crop demand, thus limiting grain yield, or excessive doses, which increase the risk of nutritional imbalances and environmental contamination.

These facts show the importance of studies on new management techniques that make it possible to maximize the efficiency of N utilization by common bean plants. Thus, the use of chlorophyll meters may be an important tool to aid in the decision-making

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process on when and how much N to provide as topdressing for different crops (Maia et al. al. 2013, Cavalli et al. 2016, Maia et al. 2017, Fiorentini et al. 2019, Fernandes et al. 2021).

The use of these devices has the main advantage of obtaining relative chlorophyll indexes instantly, with the possibility of taking as many samples as necessary without destroying the leaves. Their low maintenance cost is noteworthy, resulting in savings in time and financial cost, by reducing the dispatch of samples to laboratories. Furthermore, there is a possibility that the N deficiency will be detected and corrected in the same crop season (Dwyer et al. 1991, Piekielek & Fox 1992, Sant'ana et al. 2010, Ravier et al. 2017). However, different factors may affect the relative chlorophyll index measurements performed by these devices (Silveira & Gonzaga 2017). Therefore, the nitrogen sufficiency index (NSI) has been used with the purpose of isolating the effect of the N concentration in the leaves from other factors that may influence the readings (Hussain et al. 2000).

The NSI is determined from chlorophyll meter readings, in relation to a reference plot that received a high N dose. Afterwards, measurements of the areas that would still be fertilized are provided, and the data obtained is inserted in the NSI formula proposed by Hussain et al. (2000): Sufficiency index (%) = (chlorophyll meter-based plot readings/well-fertilized plot chlorophyll meter readings) × 100.

According to Barbosa Filho et al. (2009), the adequate NSI for common bean is 90 %, which is below the percentage that N fertilization must be carried out. For Maia et al. (2012), when the NSI is 90 %, the common bean still needs fertilization. Silveira & Gonzaga (2017) proposed, in addition to defining the most appropriate NSI for the bean plant, to establish how much N to provide as topdressing and observed that the NSI of the bean plant is equal to 95 %, and the amount of N to be provided as topdressing must be between 11 and 15 kg ha^{-1} for each 1 % below the NSI of 95 %. However, these studies refer to experiments conducted only with the Pérola cultivar, from the Carioca commercial group. In addition, the aforementioned studies were carried out with a single device model (Minolta SPAD 502), and it is important to understand whether the same NSI established with a device could be adopted for other chlorophyll meters, especially those using Brazilian technology, such as the ClorofiLOG model CFL 1030.

It is noteworthy that the Pérola cultivar had its registration more than 20 years ago (Brasil 2021), and it is known that the efficiency in the use of nutrients is directly linked to the plant genetics. Thus, this study aimed to evaluate, after establishing the NSI, the use of the portable chlorophyll meters Minolta SPAD 502 and ClorofiLOG model CFL 1030, in order to estimate the nitrogen fertilization factor in modern bean genotypes.

MATERIAL AND METHODS

The study was carried out under rainfed conditions at the Universidade Federal de Lavras, in Lavras, southern Minas Gerais state, Brazil (21º14'43"S, 44º59'59"W and altitude of 919 m). The soil in the area is classified as Red Yellow Latosol (Embrapa 2013), which is equivalent to Ferralsols (FAO 2015) and Oxisols (USDA 2014). For the soil chemical characterization, a composite soil sample was taken (0-20 cm layer) prior to sowing, showing the following attributes: pH (H_2O) = 6.5; P (Mehlich-1) = 4.6 mg dm^3; K = 117.8 mg dm^{-3}; organic matter = 3.6 dag kg^{-1}; Ca = 4.0 cmol$_c$ dm^{-3}; Mg = 1.4 cmol$_c$ dm^{-3}; Al = 0.00 cmol$_c$ dm^{-3}; H + Al = 1.5 cmol$_c$ dm^{-3}; CEC = 7.22 cmol$_c$ dm^{-3}; base saturation = 79.2 %; Zn = 3.4 mg dm^{-3}; Fe = 47.6 mg dm^{-3}; Mn = 8.6 mg dm^{-3}; Cu = 0.5 mg dm^{-3}; B = 0.24 mg dm^{-3}; S = 4.90 mg dm^{-3}.

The weather conditions remained in the ideal range for conducting the crop, with an average temperature of 23.5 ºC, minimum temperature of 11.8 ºC and maximum temperature of 34.2 ºC. The accumulated rainfall from sowing to harvest of the later cultivars (October 28, 2018 to Feb. 04, 2019) was 737.8 mm (Figure 1).

A total of eight experiments were carried out, referring to the combination of three cultivars with Carioca grain (Pérola - Type III; BRSMG Uai - Type II; and TAA Gol - Type I) and one red grain bean strain (VR 20 - Type II), and portable chlorophyll meters (Minolta SPAD-502 chlorophyll and ClorofiLOG model CFL 1030). Each cultivar and chlorophyll meter has unique recommendations, due to the reading dynamics of each device and nitrogen absorption of each genotype; thus, comparisons between them are not relevant. Therefore, each experiment was performed under a randomized complete block design, with five replications and four treatments of fertilization

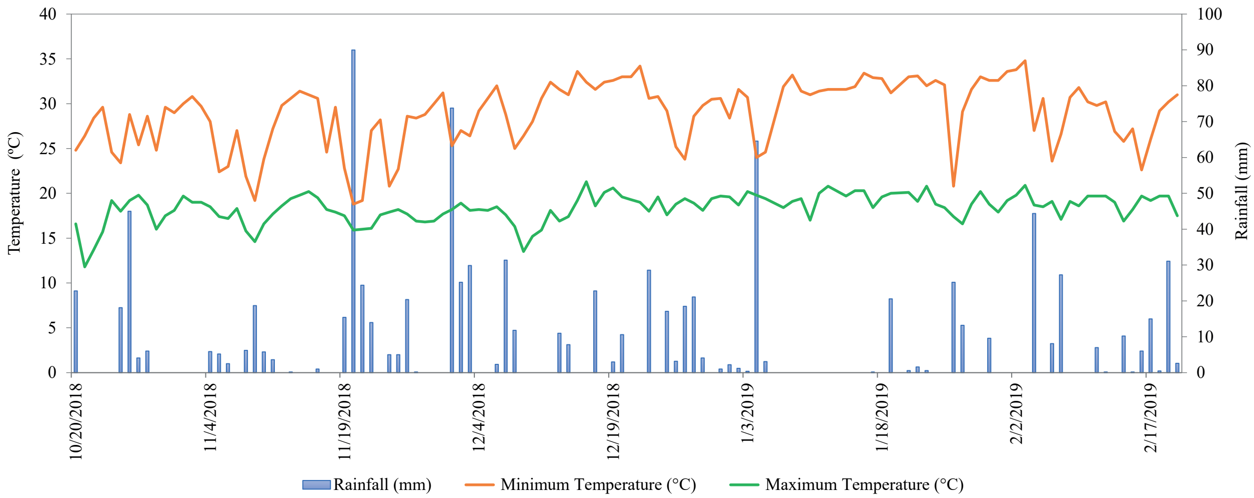


Figure 1. Rainfall, maximum and minimum air temperatures per day in the 2018/2019 crop season (Lavras, Minas Gerais state, Brazil).

factors (0, 5, 10 and 20 kg ha^{-1} of N for each 1 % below the targeted NSI).

For all cultivars, a spacing of 0.6 m between the sowing rows was used, and the sowing density was in accordance with the recommendations, depending on the size characteristics presented by each genotype (Araújo & Camelo 2015). Thus, 11 seeds m^{-1} were used for the Pérola cultivar; 17 seeds m^{-1} for the TAA Gol cultivar; and 14 seeds m^{-1} for the BRSMG Uai cultivar and the VR 20 strain. Each experimental plot was composed of 4 rows of 5 m in length, and the two central rows were considered as useful area.

The sowing fertilization (October 24, 2018) was carried out according to the soil analysis, following recommendations by Souza & Lobato (2004). Thus, 416 kg ha^{-1} of formulated NPK 01-28-00 + 10 % of calcium (Ca) and 5 % of sulfur (S) were used. After sowing, one day later, spreading fertilization was carried out in a total area of 20 kg ha^{-1}, using urea (45 % of N) as a N source, and 80 kg ha^{-1} of K_2O, using potassium chloride as a source (60 % of K_2O). Seed treatment was performed prior to sowing, with a product (fungicide/insecticide) based on pyraclostrobin, thiophanate methyl and fipronil, along with the protective product (nutritional treatment based on cobalt, molybdenum and nickel). The other crop treatments were carried out in accordance with the monitoring of pests, diseases and weeds in the cultivation areas, and registered products were used for the crop, so that the interference in the experimental results was minimized.

On November 05, 2018, seven days after the emergence of the plants (October 29, 2018), the implementations of the reference areas were carried out, with the supply of 150 kg ha^{-1} of N as topdressing, using urea (45 % of N) as a N source. The applications were spread manually between the sowing rows.

The readings with the chlorophyll meters were taken in the mature trefoil of the plant apex, from the opening of the third trefoil of the bean plant (stage V4; November 11, 2018), ten days after the implementation of the reference areas. After obtaining the relative chlorophyll indices, referring to all plots to be fertilized, together with the relative chlorophyll indices of the reference areas of each genotype, the ISN was calculated using the formula: ISN (%) = (average of readings of plots to be fertilized/average readings of reference plots) x 100. Later (November 16, 2018), the topdressing fertilization was performed, aiming to reach the targeted NSI and following the predetermined NSI for each genotype and chlorophyll meter suggested by Nascimento (2019).

Table 1 describes the genotypes and chlorophyll meters used, the obtained NSI, the desired NSI and the N doses, defined according to the fertilization factors.

In all the experiments, the number of pods per plant, number of grains per pod and mass of 100 grains (g) were evaluated after standardizing the grain moisture to 13 %. These assessments were taken from five plants randomly collected per plot.

Table 1. Genotypes and chlorophyll meters used, nitrogen sufficiency index (NSI) obtained at the time of readings, targeted NSI and N dose, defined according to the fertilization factors (FF).

Genotype	Chlorophyll meter	Obtained NSI	Targeted NSI	N doses (kg ha-1)			
			FF	0	5	10	20
TAA Gol	SPAD-502	84.1	90	0	30	59	118
	CFL 1030	90.0	92	0	10	20	40
BRSMG Uai	SPAD-502	87.1	92	0	25	49	98
	CFL 1030	88.1	93	0	25	49	98
VR 20	SPAD-502	87.2	91	0	18	36	72
	CFL 1030	86.8	90	0	16	32	64
Pérola	SPAD-502	86.6	90	0	17	34	68
	CFL 1030	88.8	90	0	6	12	24

The grain yield (kg ha^{-1}) was determined from the harvest of the two central rows of each plot. After standardizing the grain moisture to 13 %, the grain yield was defined based on the estimated yield per hectare, as a function of the harvested area in the plot.

The data were subjected to analysis of variance, followed by the application of the F test, using the Sisvar statistical analysis software (Ferreira 2011). The variables that showed significance at 5 % in the F test were submitted to regression analysis.

RESULTS AND DISCUSSION

The average values for the production components and grain yield of the TAA Gol cultivar, evaluated with the chlorophyll meters used, are shown in Table 2. For this cultivar, there was a significant effect in the analysis of variance for number of pods per plant and grain yield, as a function of the fertilization factors, in the experiment conducted with the use of the SPAD-502 chlorophyll meter. The response of the number of pods per plant was linear and positive, with the Pearson's ratio equivalent to 0.66; so, the correlation is moderate (Dancey & Reidy 2018). Alves Junior et al. (2009) believe that the number of pods per plant is the component that has the greatest positive correlation with yield, since it has priority in the use of available inputs (nutrients, water, etc.), when compared to the other yield components. And despite these components having a positive influence on yield, these characteristics are inherent to the cultivar (Darkwa et al. 2016).

The fertilization factors established with the CFL1030 chlorophyll meter influenced the mass of 100 grains and yield. The mass of 100 grains was linearly modified, corroborating the responses obtained by Binotti et al. (2009), when reporting the increase in the mass of 100 grains with the increase in the N doses supplied to the bean plant.

Both in the experiment with the SPAD-502 chlorophyll meter and in the one evaluated by the CFL 1030, for the TAA Gol cultivar, the response in relation to grain yield was linear and positive, with maximum values estimated for yield equal to 2,097 kg ha^{-1} (SPAD-502) and 1,950 kg ha^{-1} (CFL 1030), referring to doses of 118 kg ha^{-1} and

Table 2. Average numbers of pods per plant (PPP), grains per pod (GPP) and mass of 100 grains (MHG) for the TAA Gol cultivar, as a function of the nitrogen sufficiency indexes and fertilization factors (FF), using the chlorophyll meters SPAD-502 and CFL 1030.

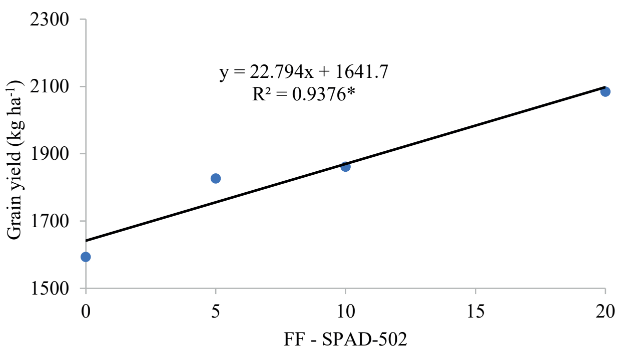
SPAD-502				CFL 1030			
FF (kg ha-1)	PPP	GPP	MHG (g)	FF (kg ha-1)	PPP	GPP	MHG (g)
0	11.9(1)	4.4	19.6	0	11.9	4.4	19.2(2)
5	12.4	4.3	19.5	5	11.9	4.4	19.5
10	12.9	4.5	19.7	10	11.4	4.6	19.8
20	14.0	4.1	20.1	20	11.0	4.6	20.3
Average	12.8	4.3	19.7	Average	11.6	4.6	19.7
CV (%)	2.6	1.9	5.0	CV (%)	4.0	1.7	2.4

(1) y: 0.102971x + 11.8965 (R^2 = 0.5411); (2) y: 0.053729x + 19.235500 (R^2 = 0.8109); () significant at 5 % by the t test.

40 kg ha^{-1} of N, respectively (Figure 2). This is because the N doses supplied as topdressing did not provide the maximum grain yield points in any of the experiments carried out with the use of the respective chlorophyll meters. Nunes et al. (2021) suggested that the TAA Gol cultivar is inefficient and responsive to N topdressing.

For the Pérola cultivar, the grain yield was significantly affected by different N doses defined according to the fertilization factors, in the experiment conducted with the SPAD-502 chlorophyll meter. The fertilization factor defined at the maximum point for mass of 100 grains was 13.9 kg ha^{-1} of N for each 1 % below the NSI of 90 %. Fornasieri Filho et al. (2007) and Binotti et al. (2009) reported an influence of different N doses supplied as topdressing for the Pérola cultivar, in relation to the mass of 100 grains. On the other hand, the grain yield of the Pérola cultivar was not modified by the application of N doses defined according to the fertilization factors, in the experiment carried out with the CFL 1030 chlorophyll meter. Figure 3 shows the averages for grain yield achieved with the use of the CFL 1030 chlorophyll meter, according to the fertilization factors and their respective N doses as topdressing. According to Zeffa et al (2021), the Pérola cultivar has a high adaptability and stability for seed yield, even under high or low N doses. Thus, no response is expected from this cultivar to fertilization factors.

However, in the experiment conducted with the SPAD-502 chlorophyll meter, the plants showed a quadratic response for yield as a function of the N doses defined according to the fertilization factors. According to the data analysis, the dose of 42 kg ha^{-1} of N, corresponding to the fertilization factor of 12.5 kg ha^{-1} of N for each 1 % below the NSI of 90 %, was responsible for reaching the point of maximum grain yield (3,089 kg ha^{-1}) (Figure 4).



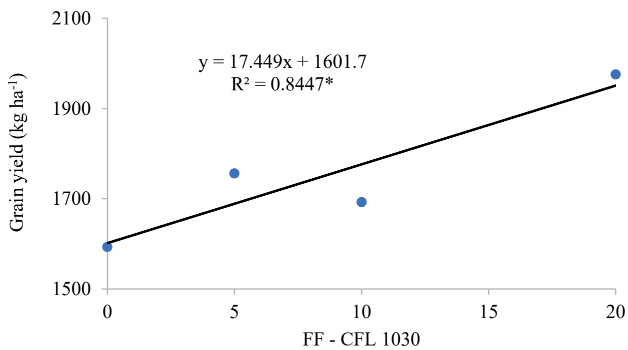


Figure 2. Grain yield of the TAA Gol cultivar, in relation to the fertilization factors (FF) used for the chlorophyll meters SPAD-502 and CFL 1030. * Significant at 5 % by the t test.

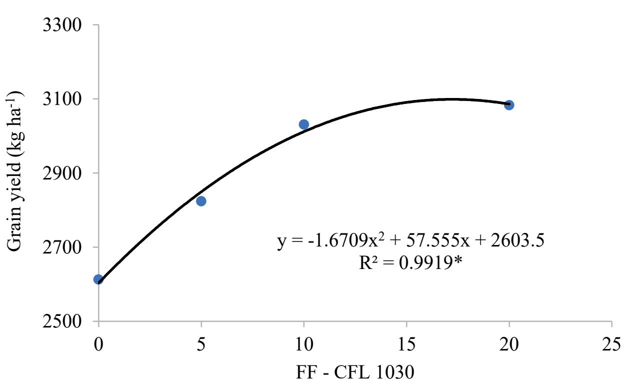


Figure 3. Grain yield of the Pérola cultivar, as a function of the N doses corresponding to the fertilization factors (FF) used in the experiment conducted with the CFL 1030 chlorophyll meter. * Significant at 5 % by the t test.

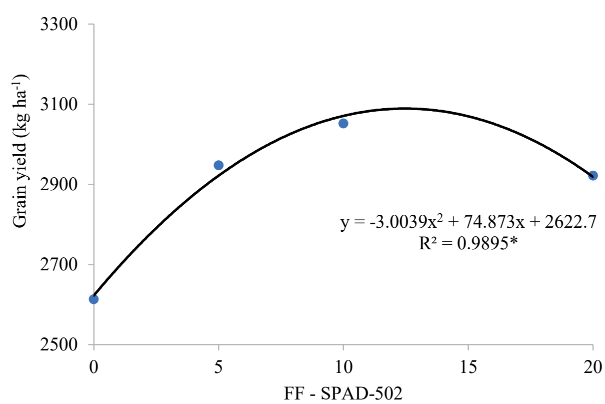


Figure 4. Grain yield of the Pérola cultivar, as a function of fertilization factors (FF), using the SPAD-502 chlorophyll meter. * Significant at 5 % by the t test.

The plants showed an increase in grain yield with the increase in the topdressing N doses, similarly to what was observed by Silveira & Gonzaga (2017). However, according to the authors, the Pérola cultivar presented a point of maximum grain yield with the application of 75 kg ha^{-1} of N. This dose resulted from the adjustment of 15 kg ha^{-1} of N for each 1 % below the NSI of 95 %.

For the BRSMG Uai cultivar, the N doses established based on the SPAD-502 chlorophyll meter significantly modified the number of pods per plant and grain yield. The number of pods per plant responded in a quadratic way to the fertilization factor of 11.4 kg ha^{-1} of N for each 1 % below the NSI of 92 %, corresponding to the dose of 56 kg ha^{-1} of N, providing 16.7 pods plant^{-1} (Table 3). Only yield was influenced in the experiment conducted using the CFL 1030 device (Figure 5).

In the experiment using the SPAD-502 chlorophyll meter, the maximum grain yield was estimated at 2,745 kg ha^{-1}, reached with a dose of 71 kg ha^{-1} of N, corresponding to a fertilization factor of 14.5 kg ha^{-1} of N for each 1 % below the NSI of 92 %. In relation to the CFL 1030 chlorophyll meter, the fertilization factor responsible for estimating the point of maximum grain yield was 15.8 kg ha^{-1} of N for each 1 % below the NSI of 93 %. The N dose defined by this combination between the fertilization factor and the NSI was 77 kg ha^{-1}, with the maximum yield estimated at 2,740 kg ha^{-1}.

The observed grain yield responses are similar to those found by Silveira & Gonzaga (2017), as they noticed that 75 kg ha^{-1} of N were needed for the Pérola cultivar to reach a maximum yield. However, this dose was determined based on the use of a fertilization factor of 15 kg ha^{-1} of N for each 1 % below the NSI of 95 %. By means of comparison, if these parameters were followed in the present study, the provided N doses would be 118.5 and 103.5 kg ha^{-1}, respectively for the experiments conducted using the SPAD-502 and CFL 1030 chlorophyll meters. In other words, in both situations, the N doses would be overestimated. The aforementioned data indicate that differences in NSI may occur according to the chlorophyll

Table 3. Average numbers of pods per plant (PPP), grains per pod (GPP) and mass of 100 grains (MHG) for the BRSMG Uai cultivar, as a function of the nitrogen sufficiency index and fertilization factors (FF), referring to the experiments carried out with the SPAD-502 and CFL 1030 chlorophyll meters.

SPAD-502				CFL 1030			
FF (kg ha^{-1})	PPP	GPP	MHG (g)	FF (kg ha^{-1})	PPP	GPP	MHG (g)
0	13.4[(1)]	4.1	23.2	0	13.9	4.1	23.2
5	15.6	4.3	23.5	5	14.9	4.5	23.6
10	16.6	4.3	23.9	10	15.5	4.7	23.6
20	14.8	4.6	23.6	20	17.8	4.5	23.9
Average	15.1	4.3	23.6	Average	15.5	45.0	23.6
CV (%)	2.8	3.4	2.7	CV (%)	5.6	2.6	2.7

(1) y: -0.02522x2 + 0.574252x + 13.385477 (R^2 = 0.6043); () significant at 5 % by the t test.

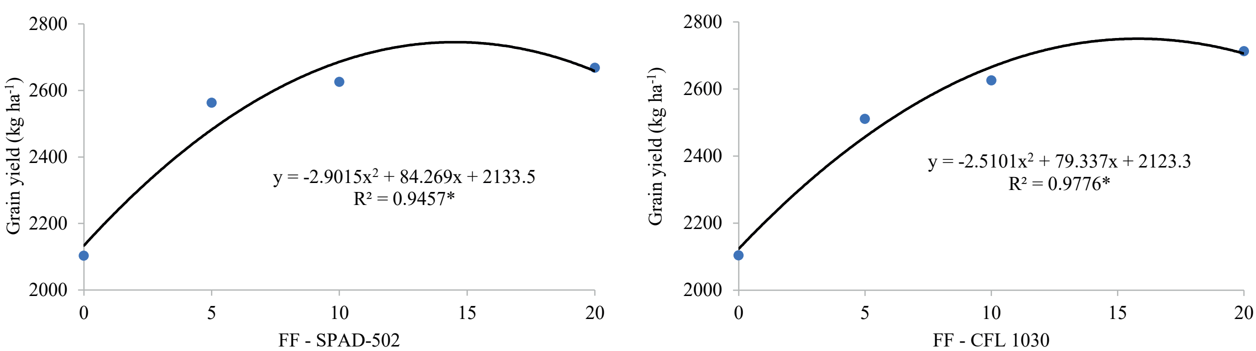


Figure 5. Grain yield for the BRSMG Uai cultivar, as a function of fertilization factors (FF), referring to the experiments carried out using the SPAD-502 and CFL 1030 chlorophyll meters. * Significant at 5 % by the t test.

meter used in the same cultivation environment, in addition to highlighting the need of more studies for other cultivars, with the objective of improving the efficiency of N fertilization for the crop.

For the VR-20 strain, the treatments established according to the fertilization factor and the respective chlorophyll meter used had a significant effect on the number of grains per pod and yield. The average values for the evaluated production components are described in Table 4.

The number of grains per pod varied linearly with the increment of N doses in the experiment using the SPAD-502 chlorophyll meter; while, in the experiment with the CFL 1030 chlorophyll meter, the variation, in relation to the N doses, was quadratic, defined according to different fertilization factors. The fertilization factors equal 10.7 kg ha^{-1} of N for each 1 % below the NSI of 90 %, corresponding to a dose of 34 kg ha^{-1} of N, resulting in 4.5 grains pod^{-1}. The obtained results differ from those reported by Medeiros et al. (2000) and Soratto et al. (2004), who consider that N topdressing fertilization does not influence the number of grains per pod, as this characteristic is more related to genetic factors of the common bean (Darkwa et al. 2016).

Regarding grain yield, the experiments carried out with the chlorophyll meters responded in a quadratic way to the N doses defined according to the different fertilization factors tested (Figure 6).

With the experiment using the SPAD-502 chlorophyll meter, it was possible to estimate a maximum yield of 1,970 kg ha^{-1} with the dose of 56.5 kg ha^{-1} of N, corresponding to the fertilization factor of 15.7 kg ha^{-1} of N for each 1 % below the NSI of 91 %. For the experiment using the CFL 1030 chlorophyll meter, the estimated maximum yield was 1,917 kg ha^{-1}, with a dose of 44.5 kg ha^{-1} of N, correlated to the fertilization factor of 14.2 kg ha^{-1} of N for each 1 % below the NSI of 90 %. Thus, the obtained data show the possibility of reducing the NSI of 95 % when the fertilizer factor used is between 14 and 16 kg ha^{-1} of N, regardless of the chlorophyll meter used. Thus, it is possible to infer that, for red bean genotypes, it is possible to work with an NSI close to 90 %, lower than the NSI of 95 % defined according to Silveira & Gonzaga (2017).

Table 4. Average numbers of pods per plant (PPP), grains per pod (GPP) and mass of 100 grains (MHG) for the VR-20 common bean strain, as a function of nitrogen sufficiency index and fertilization factors (FF), referring to the experiments carried out with the SPAD-502 and CFL 1030 chlorophyll meters.

SPAD-502				CFL 1030			
FF (kg ha^{-1})	PPP	GPP	MHG (g)	FF (kg ha^{-1})	PPP	GPP	MHG (g)
0	14.0	4.1[1]	20.9	0	14.0	4.1[2]	20.9
5	13.4	4.2	21.2	5	13.1	4.4	20.1
10	12.9	4.4	20.7	10	13.8	4.5	20.7
20	15.5	4.7	20.6	20	15.7	4.2	20.6
Average	14.0	4.4	20.9	Average	14.2	4.3	20.6
CV (%)	7.8	3.4	5.4	CV (%)	4.9	1.4	7.0

[1] y = 0.029914x + 4.067000 (R^2 = 0.7216); [2] y: -0.003830x^2 + 0.081898x + 4.058523 (R^2 = 0.8655); () significant at 5 % by the t test.

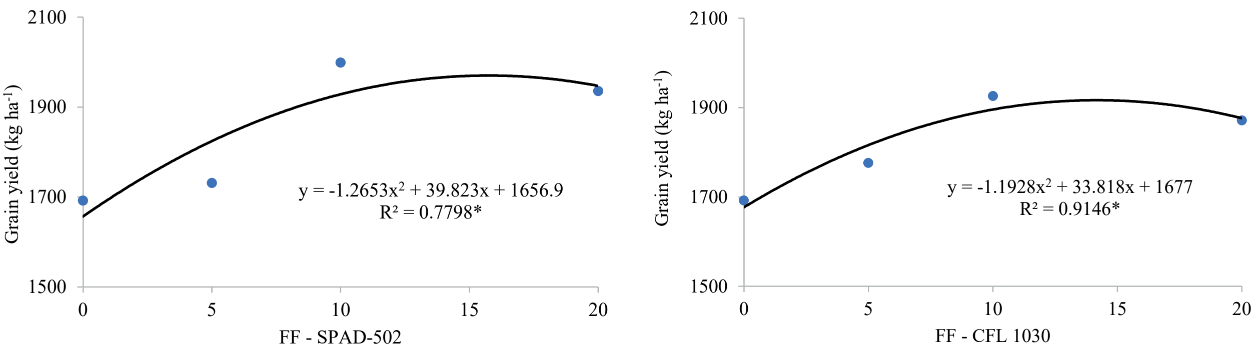


Figure 6. Grain yield of the VR 20 strain, as a function of fertilization factors (FF), referring to the experiments using the SPAD-502 and CFL 1030 chlorophyll meters. * Significant at 5 % by the t test.

CONCLUSIONS

1. It was not possible to obtain precise adjustments for the methodology using chlorophyll meters for the TAA Gol cultivar, probably due to the early cycle and response of the cultivar;
2. The combination of a fertilizer factor of 12.5 kg ha^{-1} of N for each 1 % below the nitrogen sufficiency index of 90 % proved to be efficient for the Pérola cultivar, when the SPAD-502 chlorophyll meter was used;
3. In genotypes with characteristics of size and cycle similar to the BRSMG Uai cultivar and the VR 20 strain, using a fertilization factor between 14 and 16 kg ha^{-1} of N, the nitrogen sufficiency index of 95 % should be reduced, aiming to increase the nitrogen fertilization efficiency.

REFERENCES

ALVES JUNIOR, J.; ANDRADE, M. J. B.; CARVALHO, J. G.; VIEIRA, N. M. B.; MORA, A. R. Adubação nitrogenada do feijoeiro, em plantio e cobertura em plantio direto e convencional. *Ciência e Agrotecnologia*, v. 33, n. 4, p. 943-949, 2009.

ARAÚJO, G. A. de A.; CAMELO, G. N. Preparo do solo e plantio. *In*: CARNEIRO, J. E.; PAULA JUNIOR, T. J.; BÓREM, A. *Feijão*: do plantio à colheita. Viçosa: Ed. UFV, 2015. p. 115-144.

BARBOSA FILHO, M. P.; COBUCCI, T.; FAGERIA, N. K.; MENDES, P. N. Época de aplicação de nitrogênio no feijoeiro irrigado monitorada com auxílio de sensor portátil. *Ciência e Agrotecnologia*, v. 33, n. 2, p. 425-431, 2009.

BINOTTI, F. F. S.; ARF, O.; SÁ, M. E.; BUZETTI, S.; ALVAREZ, A. C. C.; KAMIMURA, K. M. Fontes, doses e modo de aplicação de nitrogênio em feijoeiro no sistema plantio direto. *Bragantia*, v. 68, n. 2, p. 473-481, 2009.

BRASIL. Ministério da Agricultura. *SNPC*: sistema de cultivar web. 2021. Available at: http://sistemas.agricultura.gov.br/snpc/cultivarweb/detalhe_cultivar.php?codsr=60. Access on: Apr. 24, 2021.

CANTARELLA, H. Nitrogênio. *In*: NOVAIS, R. F.; ALVAREZ V., V. H.; BARROS, N. F.; CANTARUTTI, R. B.; NEVES, J. C. L. (ed.). *Fertilidade do solo*. Viçosa: Sociedade Brasileira de Ciência do Solo, 2007. p. 375-470.

CAVALLI, E.; LANGE, A.; BUCHELT, A. C.; CAVALLI, C.; WRUCK, F. J. Subdivision of nitrogen fertilization in irrigated bean culture in the middle-north of Mato Grosso, Brazil. *Nativa*, v. 4, n. 5, p. 296-302, 2016.

DANCEY, C.; REIDY, J. *Estatística sem matemática para psicologia*. Porto Alegre: Penso, 2018.

DARKWA, K.; AMBACHEW, D.; MOHAMMED, H.; ASFAW, A.; BLAIR, M. W. Evaluation of common bean (*Phaseolus vulgaris* L.) genotypes for drought stress adaptation in Ethiopia. *The Crop Journal*, v. 4, n. 5, p. 367-376, 2016.

DWYER, L. M.; TOLLENAAR, M.; HOUWING, L. A nondestructive method to monitor leaf greenness in corn. *Canadian Journal of Plant Science*, v. 71, n. 3, p. 505-509, 1991.

EMPRESA BRASILEIRA DE PESQUISA AGROPECUÁRIA (Embrapa). *Sistema brasileiro de classificação de solos*. Rio de Janeiro: Centro Nacional de Pesquisa de Solos, 2013.

FERNANDES, F. M. SORATTO, R. P.; FERNANDES, A. M.; SOUZA, E. F. Chlorophyll meter-based leaf nitrogen status to manage nitrogen in tropical potato production. *Agronomy Journal*, v. 113, n. 2, p. 1733-1746, 2021.

FERREIRA, D. F. Sisvar: a computer statistical analysis system. *Ciência e Agrotecnologia*, v. 35, n. 6, p. 1039-1042, 2011.

FIORENTINI, M.; ZENOBI, S.; GIORGINI, E.; BASILI, D.; CONTI, C.; CHIARA, P.; MONACI, E.; ORSINI, R. Nitrogen and chlorophyll status determination in durum wheat as influenced by fertilization and soil management: preliminary results. *PloS One*, v. 14, n. 11, e0225126, 2019.

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS (FAO). *International soil classification system for naming soils and creating legends for soil maps*. Rome: FAO, 2015.

FORNASIERI FILHO, D.; XAVIER, M. A.; LEMOS, L. B.; FARINELLI, R. Resposta de cultivares de feijoeiro comum à adubação nitrogenada em sistema de plantio direto. *Científica*, v. 35, n. 2, p. 115-121, 2007.

HUSSAIN, F.; BRONSON, K. F.; PENG, S. Use of chlorophyll meter sufficiency indices for nitrogen management of irrigated rice in Asia. *Agronomy Journal*, v. 92, n. 5, p. 875-879, 2000.

MAGALHÃES, I. D. P. B.; SEDIYAMA, M. A. N.; SILVA, F. D. B. D.; VIDIGAL, S. M.; PINTO, C. L. O.; LOPES, I. P. C. Produtividade e exportação de nutrientes em feijão-vagem adubado com esterco de galinha. *Revista Ceres*, v. 64, n. 1, p. 98-107, 2017.

MAIA, S. C. M.; SORATO, R. P.; BIAZOTTO, F. O.; ALMEIDA, A. Q. D. Estimativa da necessidade de nitrogênio em cobertura no feijoeiro IAC Alvorada com clorofilômetro portátil. *Semina: Ciências Agrárias*, v. 34, n. 5, p. 2229-2238, 2013.

MAIA, S. C. M.; SORATO, R. P.; NASTARO, B.; FREITAS, L. B. D. The nitrogen sufficiency index underlying estimates of nitrogen fertilization requirements of common bean. *Revista Brasileira de Ciência do Solo*, v. 36, n. 1, p. 183-192, 2012.

MAIA, S. C. M.; SORATTO, R. P.; LIEBE, S. M.; ALMEIDA, A. Q. D. Criteria for topdressing nitrogen application to common bean using chlorophyll meter. *Pesquisa Agropecuária Brasileira*, v. 52, n. 7, p. 512-520, 2017.

MEDEIROS, G. D.; ARRUDA, F. B.; SAKAI, E.; FUJIWARA, M.; BONI, N. R. Crescimento vegetativo e coeficiente de cultura do feijoeiro relacionados a graus-dia acumulados. *Pesquisa Agropecuária Brasileira*, v. 35, n. 9, p. 1733-1742, 2000.

NASCIMENTO, G. H. do. *Medidores portáteis de clorofila na estimativa da adubação nitrogenada em cobertura no feijoeiro*. 2019. Dissertação (Mestrado em Agronomia/Fitotecnia) - Universidade Federal de Lavras, Lavras, 2019.

NUNES, H. D.; LEAL, F. T.; MINGOTTE, F. L. C.; DAMIÃO, V. D. A.; COUTO JUNIOR, P. A.; LEMOS, L. B. Agronomic performance, quality and nitrogen use efficiency by common bean cultivars. *Journal of Plant Nutrition*, v. 44, n. 7, p. 995-1009, 2021.

PEREZ, A. A. G.; SORATTO, R. P.; MANZATTO, N. P.; SOUZA, E. D. F. C. D. Extração e exportação de nutrientes pelo feijoeiro adubado com nitrogênio, em diferentes tempos de implantação do sistema plantio direto. *Revista Brasileira de Ciência do Solo*, v. 37, n. 5, p. 1276-1287, 2013.

PIEKIELEK, W. P.; FOX, R. H. Use of a chlorophyll meter to predict sidedress nitrogen requirements for maize. *Agronomy Journal*, v. 84, n. 1, p. 59-65, 1992.

RAVIER, C.; QUEMADA, M.; JEUFFROY, M. H. Use of a chlorophyll meter to assess nitrogen nutrition index during the growth cycle in winter wheat. *Field Crops Research*, v. 214, n. 1, p. 73-82, 2017.

SANT'ANA, E. V. P.; SANTOS, A. B.; SILVEIRA, P. M. de. Adubação nitrogenada na produtividade, leitura SPAD e teor de nitrogênio em folhas de feijoeiro. *Pesquisa Agropecuária Tropical*, v. 40, n. 4, p. 491-496, 2010.

SILVEIRA, P. M. de.; GONZAGA, A. C. de O. Portable chlorophyll meter can estimate the nitrogen sufficiency index and levels of topdressing nitrogen in common bean. *Pesquisa Agropecuária Tropical*, v. 47, n. 1, p. 1-6, 2017.

SILVEIRA, P. M.; BRAZ, A. J. B. P.; DIDONET, A. D. Uso do clorofilômetro como indicador da necessidade de adubação nitrogenada em cobertura no feijoeiro. *Pesquisa Agropecuária Brasileira*, v. 38, n. 9, p. 1083-1087, 2003.

SORATTO, R. P.; CARVALHO, M. A. C.; ARF, O. Teor de clorofila e produtividade do feijoeiro em razão da adubação nitrogenada. *Pesquisa Agropecuária Brasileira*, v. 39, n. 4, p. 895-901, 2004.

SOUSA, D. M. G. de; LOBATO, E. Calagem e adubação para culturas anuais e semiperenes. *In*: SOUSA, D. M. G. de; LOBATO, E. (ed.). *Cerrado*: correção do solo e adubação. Planaltina, DF: Embrapa Cerrados, 2002. p. 283-316.

UNITED STATES DEPARTMENT OF AGRICULTURE (USDA). Soil Survey Staff. *Keys to soil taxonomy*. 12. ed. Washington, DC: USDA, 2014.

ZEFFA, D. M.; MODA-CIRINO, V.; NOGUEIRA, A. F.; DELFINI, J.; ARRUDA, I. M. de; SANTOS NETO, J. dos; GEPTS, P.; SCAPIM, C. A.; GONÇALVES, L. S. Genetic variability and nitrogen response indices in common bean (*Phaseolus vulgaris*) cultivars under contrasting nitrogen environments. *Plant Breeding*, v. 140, n. 5, p. 907-918, 2021.