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Nitrogen content, SPAD index and production of single head broccoli

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ABSTRACT

In the management of single head broccoli nitrogen fertilization, there is no study indicating the critical level and adequate range of N content and SPAD index in the leaves to evaluate the nitrogen nutritional status. This work was carried out in two consecutive years with control without N and three rates of N (150; 300 and 450 kg ha⁻¹). The treatments were arranged in the experimental design of random blocks, with four replications. All productive characteristics were significantly influenced by N rates. The fresh inflorescence mass reached a maximum value of 822 g with 308 kg ha⁻¹ N. The critical levels were 61.1 g kg⁻¹ for total N foliar content and 71.31 ud SPAD at 40 DAT. The SPAD index presented high correlations with the total N content in the leaves ($r = 0.93$; $p < 0.034$) and with the maximum fresh mass of the inflorescence ($r = 0.99$; $p < 0.001$). The ranges of N content (low ≤ 52.5 ; medium 52.6 to 57.4; sufficient 57.5 to 61.1 and high > 61.1 g kg⁻¹) and SPAD index (low ≤ 68.48 ; medium 68.49 to 70.47; sufficient 70.48 to 71.31 and high > 71.31 ud SPAD) are proposed for assessing the N nutritional status of single head broccoli.

Keywords: *Brassica oleracea* var. *italica*, nutritional diagnosis, nitrogen fertilization.

RESUMO

Teor de nitrogênio, índice SPAD e produção de brócolis cabeça única

No manejo da adubação nitrogenada do brócolis cabeça única, não há estudo que indique nível crítico, faixa adequada do teor de N e índice SPAD nas folhas para avaliar o estado nutricional de N. Com esse objetivo realizou-se este trabalho, em dois anos consecutivos e com a testemunha sem N e três doses de N (150; 300 e 450 kg ha⁻¹). Os tratamentos foram arranjados no delineamento experimental de blocos ao acaso, com quatro repetições, nos dois anos. Todas as características produtivas foram influenciadas significativamente pelas doses de N. A massa de matéria fresca da inflorescência alcançou o valor máximo estimado de 822 g com a dose de 308 kg ha⁻¹ de N. Os níveis críticos (aos 40 DAT) foram 61,1 g kg⁻¹ para teor de N e 71,31 ud SPAD. O índice SPAD apresentou elevadas correlações com o teor de N total nas folhas ($r = 0,93$; $p < 0,034$) e com a máxima massa fresca da inflorescência ($r = 0,99$; $p < 0,001$). Propõem-se as faixas de teor de N (baixo $\leq 52,5$; médio 52,6 a 57,4; adequado 57,5 a 61,1 e alto $> 61,1$ g kg⁻¹) e de Índice SPAD (baixo $\leq 68,48$; médio 68,49 a 70,47; adequado 70,48 a 71,31 e alto $> 71,31$ ud SPAD) para avaliação do estado de N de brócolis cabeça única.

Palavras-chave: *Brassica oleracea* var. *italica*, diagnóstico nutricional, adubação nitrogenada.

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Nitrogen (N) deserves to be highlighted, since it is the nutrient absorbed in greater quantity by single head broccoli (Cecílio Filho *et al.*, 2017). Moreover, the application of nitrogen fertilizers requires an adequate rate to obtain plants with inflorescence of better commercial acceptance.

N fertilization increases broccoli yield with rates above 200 kg ha⁻¹ of N (Cecílio Filho *et al.*, 2012; Seabra Júnior *et al.*, 2013; Ambrosini *et al.*, 2015; Oliveira *et al.*, 2016; Silva *et al.*, 2019). On the other hand, Campagnol *et al.* (2009) did not observe the influence of N fertilization on broccoli yield. Therefore,

the management of nitrogen fertilization of single head broccoli should be done with criteria; the recommendation for Minas Gerais is 200 kg ha⁻¹ N (Vidigal & Pedrosa, 2019). Studies have shown that broccoli responds to a dose of 315 kg ha⁻¹ of N (Cecílio Filho *et al.*, 2012) and, to express its full productive potential, it is necessary to apply higher rates, above 240 kg ha⁻¹ N, higher than the recommended 130 kg ha⁻¹ N by Bakker *et al.* (2009).

The diagnosis of N status is usually associated with the plant response to soil fertilization. However, this can be done directly and indirectly, using

appropriately calibrated indices (Godoy *et al.*, 2010; Fontes, 2011). The most commonly used criterion for monitoring plant total N, NH₄⁺ and N-NO₃⁻ contents is the chemical analysis of leaf dry matter in the laboratory, which is a high cost and time-consuming analysis performed by qualified personnel.

Researches have been published, using the analysis of the green color intensity of the plant, represented by the amount of chlorophyll, which can be measured instantaneously and non-destructively by the portable meter SPAD-502. These researches emerged as an alternative to evaluate the N

status of the plant (Godoy *et al.*, 2010; Fontes, 2011). High correlations of the N content in single head broccoli leaves with the amount of chlorophyll *a*, *b* and *total* were observed by Ambrosini *et al.* (2015); so, the amount of chlorophyll estimated by SPAD can be correlated with the N leaf contents in broccoli leaves and the SPAD index can be used in the evaluation of the N status. Several studies have shown that the chlorophyll content measured with SPAD-502 correlates with N concentration in the plant, and also with the yield of several species (Godoy *et al.*, 2010; Moreira & Vidigal, 2011; Vidigal *et al.*, 2018).

There are no studies indicating the critical level and the appropriate range of N, the SPAD index on the leaves and the SPAD recommendation for the evaluation of the nutritional status N of single head broccoli. Prezotti & Fullin (2007) and Trani *et al.* (2018) present the range considered adequate of 30 to 55 g kg⁻¹ N in leaf dry mass. However, there is no indication that these values refer to single head or branched broccoli.

Thus, the objective of this work was to verify the critical level and the adequate range of N and SPAD index in the single head broccoli leaves to evaluate the nitrogen nutritional status and yield as a function of nitrogen fertilization.

MATERIAL AND METHODS

The experiments were conducted at the experimental farm of EPAMIG (20°24'S; 42°49'W; 480 m altitude), Oratórios, Minas Gerais state, from June to October 2012 (Year 1) and 2013 (Year 2). The region's climate is classified as "Aw", according to Köppen and Geiger. The maximum average annual temperature is 21.6°C and minimum annual average 19.5°C; average precipitation 1162 mm. In the experiment period, accumulated rainfall was 84.19 mm (Year 1) and 152.21 mm (Year 2).

In both years, four N rates (0, 150, 300 and 450 kg ha⁻¹) were evaluated, and urea (45% N) was used as N source. These rates were applied in topdressing, in three equal plots, at 14, 26, and 41

days after transplantation (DAT), defined according to the recommendation of Vidigal & Pedrosa (2007).

The treatments were arranged in a randomized complete block design, with four replications. The cultivar Legacy was evaluated. Seeds were sown respectively, on June 21, 2012 and June 18, 2013, in 200-cell expanded polystyrene trays, filled with commercial substrate. Seedlings were transplanted with 3 to 4 leaves, on February 8, 2012 and July 30, 2013, respectively, in 0.80 x 0.50 m spacing. Each experimental unit consisted of five rows, with 12 plants each, and the useful area consisted of 30 central plants of the three central rows.

The soil of the area (Red-Yellow Argisol) presented, in the 0-20 cm depth layer, on the two years, respectively: pH (water) = 6.1 and 5.4; Ca = 1.9 and 1.5 cmol_c dm⁻³; Mg = 1.2 and 0.6 cmol_c dm⁻³; Al = 0.0 and 0.1 cmol_c dm⁻³; H + Al = 1.98 and 2.31 cmol_c dm⁻³; P = 16.7 and 35.2 mg dm⁻³ (Mehlich 1); K = 144 and 118 mg dm⁻³; organic matter = 22 and 19 g kg⁻¹; B = 0.4 and 0.3 mg dm⁻³; Cu = 1.1 and 1.3 mg dm⁻³; Fe = 89.5 and 91.3 mg dm⁻³; Mn = 98.3 and 99.6 mg dm⁻³; and Zn = 4.9 and 5.2 mg dm⁻³.

Soil preparation consisted of plowing, harrowing, and opening 15 cm deep furrows. Except for N, planting fertilization, based on soil analysis and recommendations of Vidigal & Pedrosa (2019), consisted of 1,500 kg ha⁻¹ single superphosphate, 80 kg ha⁻¹ potassium chloride, 20 kg ha⁻¹ borax, and 20 kg ha⁻¹ zinc sulfate. In addition, 320 kg ha⁻¹ potassium chloride were used, applied in three plots, together with the nitrogen fertilizer applications, in topdressing on both years. Cultural treatments (pest control and conventional sprinkler irrigation) were applied according to the needs, following the recommendations for the crop (Vidigal & Pedrosa, 2019).

In the first stage of flowering, 40 days after transplanting, nitrogen nutritional status was evaluated by determining the green intensity and the total N content on the expanded fourth leaf. Leaf green color intensity was determined using the portable chlorophyll meter SPAD-502 (Soil Plant Analysis Development 502), considering the average of three readings in the leaf blade (right and left

border, plus leaf apex), held between 8:00 and 11:00 hours. The leaves used for this determination were collected and conditioned in paper bags and later placed in a forced air circulation oven at 70°C until constant mass. After drying, the dried material was ground in a Willey mill, equipped with a 20-mesh sieve, and subjected to sulfur digestion for the determination of total N contents by titration after distillation in Kjeldahl microdistiller (Silva, 2009).

Plants were harvested in the periods from 64 to 69 (Year 1) and from 66 to 73 DAT (Year 2). Harvest was performed by cutting the stem close to the soil. Subsequently, the following data were evaluated: number of leaves per plant, diameter of the inflorescence, fresh mass of leaves, stem and inflorescence (without leaves and with the stem cut close to the inflorescence), and florets (inflorescence without the stalk). The fresh mass of the whole plant corresponded to the sum of the fresh masses of leaves, stem and inflorescence.

Obtained data were submitted to analysis of variance, polynomial regression and correlation. Then, simple linear regression equations were adjusted to better describe the relationship between dependent and independent variables. The data were also analyzed together to evaluate the effect of Year of conducting the experiments. The software Genes was used to perform the analysis (Cruz, 2013).

The value of the critical level for total N foliar content and SPAD Index were estimated with the rate of N associated with the maximum fresh mass of inflorescence at the final harvest, introduced in the previously established model of each variable (Fontes, 2011).

RESULTS AND DISCUSSION

The productive characteristics were significantly influenced by the N rates applied in topdressing. There was a significant difference between the results of Years 1 and 2, except for inflorescence and plant fresh mass and the N-total content in the leaves.

Nitrogen increased the inflorescence fresh mass ($p < 0.001$) and plant fresh mass ($p < 0.001$) up to 308 kg ha⁻¹ N, regardless of the year, and reaching respectively 822 g/inflorescence and 3,005 g/plant (Figure 1), for a population of 25,000 plants ha⁻¹.

The intensity of the response to applied nitrogen can be variable depending on several factors, among them the hybrid and the plant population. The application of N in rates greater than 200 kg ha⁻¹ has provided results of inflorescence fresh mass equal to 365 g with 315 kg ha⁻¹ N, Monaco hybrid with 62,500 plants ha⁻¹ (Cecilio Filho *et al.*, 2012); 344 g with 250 kg ha⁻¹ N, hybrid BRO 068 with 20,000 plants ha⁻¹ (Ambrosini *et al.*, 2015); 600 g with 211 kg ha⁻¹ N, Lord Summer hybrid with 20,000 plants ha⁻¹ (Oliveira *et al.*, 2016) and 485 g with 224 kg ha⁻¹ N, Avenger hybrid with 20,000 plants ha⁻¹ (Silva *et al.*, 2019).

The florets fresh mass varied between Years 1 and 2 ($p < 0.019$) and was influenced by N ($p < 0.001$). The maximum fresh mass of 729 g for Year 1 ($\hat{Y} = 243.75 + 3.1N - 0.00495N^2$ $R^2 = 0.99$) and 644 g for Year 2 ($\hat{Y} = 143.113 + 3.0416N - 0.00462N^2$ $R^2 = 0.99$) were estimated with 313 and 331 kg ha⁻¹ N, respectively.

There were more leaves in Year 2 (23.8 ud plant⁻¹) in relation to Year 1 (19.4 ud plant⁻¹), but it was not possible to adjust the regression model for this characteristic. Nitrogen increased the total fresh mass of leaves up to 305 kg ha⁻¹ N ($\hat{Y} = 885.444 + 4.8134N - 0.00789N^2$ $R^2 = 0.98$), reaching an estimated maximum of 1,620 g/plant, regardless of the year. However, in Year 1, the average leaf fresh mass increased until 297 kg ha⁻¹ N, with the maximum estimated value of 78.05 g ($\hat{Y} = 49.566 + 0.1919N - 0.00032N^2$ $R^2 = 0.96$) and, in Year 2, until 331 kg ha⁻¹ N reaching the maximum estimated value of 72.14 g ($\hat{Y} = 33.050 + 0.236N - 0.00035N^2$ $R^2 = 0.98$). In Year 1, the stem fresh mass increased until 263 kg ha⁻¹ N, with maximum estimated value of 516 g ($\hat{Y} = 394.75 + 0.9258N - 0.00176N^2$ $R^2 = 0.96$) and in Year 2, it increased until 308 kg ha⁻¹ N, with maximum estimated value of 640 g ($\hat{Y} = 355.8 + 1.8437N -$

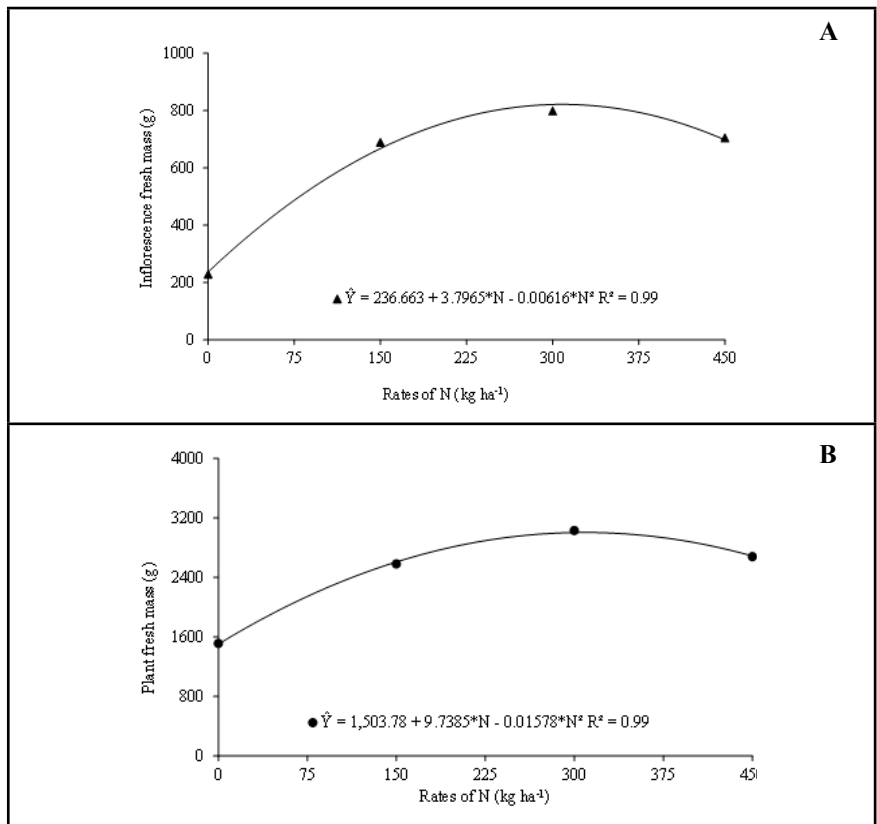


Figure 1. Inflorescence fresh mass (A) and plant fresh mass (B) of single head broccoli, cv. Legacy, according to nitrogen (N) rates. Oratórios, EPAMIG, 2012/2013.

$0.00299N^2$ $R^2 = 0.99$).

The inflorescence diameter increased up to 287 and 283 kg ha⁻¹ N, reaching estimated maximum values of 21.00 cm in Year 1 ($\hat{Y} = 14.611 + 0.0447N - 0.00008N^2$ $R^2 = 0.99$) and 21.08 cm in Year 2 ($\hat{Y} = 10.781 + 0.0728N - 0.00013N^2$ $R^2 = 0.94$).

The diameter may vary with the hybrid, however larger inflorescences generally have greater mass due to the high correlation ($r = 0.99$; $p < 0.01$) between the diameter and inflorescence fresh mass. The diameter of 19.65 cm was estimated with 187 kg ha⁻¹ N for the Lord Summer hybrid with 20,000 plants ha⁻¹ (Oliveira *et al.*, 2016). However, Lalla *et al.* (2010) observed that the inflorescence diameter (15.20 to 16.60 cm) did not follow the difference in fresh mass of the single head broccoli with 220 kg ha⁻¹ N. Silva *et al.* (2019) observed, in fertirrigated cultivation with the Avenger hybrid, the maximum diameter of 25.00 cm with 193.33 kg ha⁻¹ N.

The inflorescence diameter is a characteristic that can be influenced by

several factors such as the population/arrangement of plants, management of the crop and stage of development in which this measure is carried out. Therefore, although it is an important characteristic in terms of visual aspects during marketing, it is not a very precise characteristic in comparative terms.

The total N content increased ($p < 0.001$), on the fourth leaf, regardless of the year. The maximum estimated value of 61.7 g kg⁻¹ was obtained with 375 kg ha⁻¹ N, and in the control, only 43.1 g kg⁻¹ was observed (Figure 2A). The plants, which did not receive N (control), presented the characteristic symptoms of N deficiencies, such as yellowing of older leaves and lower plant growth (Vidigal *et al.*, 2019), which resulted in lower production of plant fresh mass (Figure 1).

A high correlation ($r = 0.96$; $p < 0.018$) was observed between the total N content on the fourth leaf and the inflorescence fresh mass, which demonstrates the direct effect of nitrogen on the yield of single head broccoli. Higher inflorescence fresh

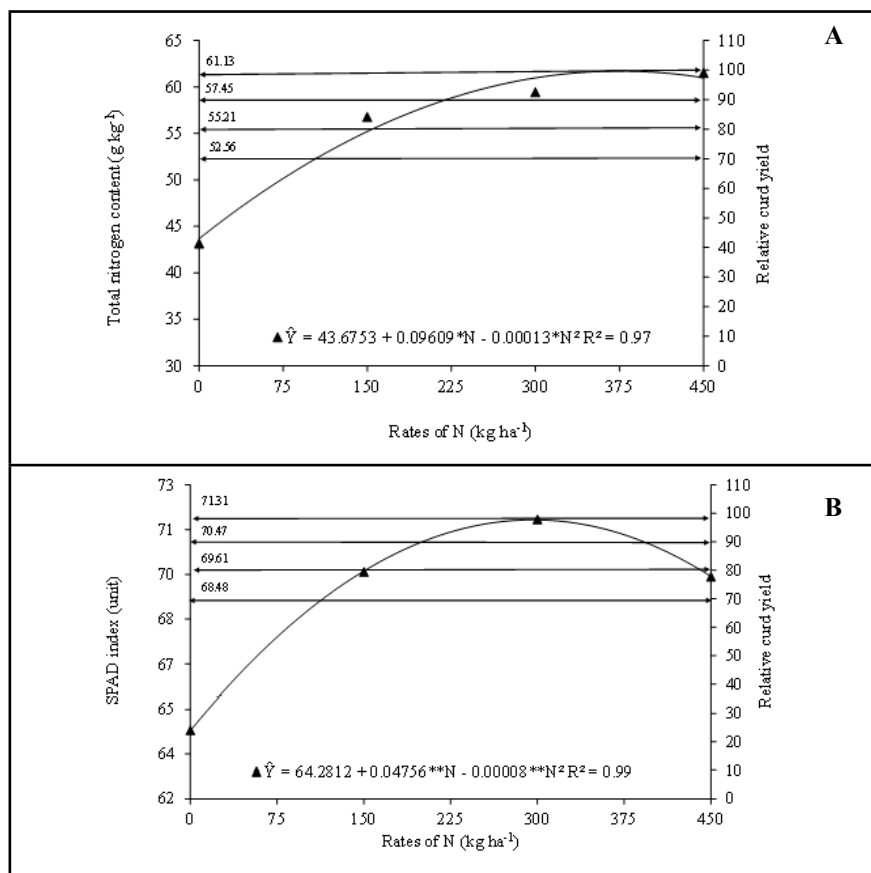


Figure 2. Total N content (A) and SPAD index (B) on the fourth leaf of single head broccoli plants, cv. Legacy, at 40 DAT, according to nitrogen (N) rates. Oratórios, EPAMIG, 2012/2013.

mass in plants with higher N leaf contents (Figure 1A and 2A), were also observed by Yildirim *et al.* (2007) and Schellenberg *et al.* (2009).

Campagnol *et al.* (2009) observed an increase in leaf N content with nitrogen fertilization, for the BRO68 hybrid. Leaf N content varied from 37.8 to 56.3 g kg⁻¹, obtained with 100 to 250 kg ha⁻¹ N in topdressing. Cecílio Filho *et al.* (2012) observed, for the leaf total N content, the maximum estimated of 43.7 g kg⁻¹ with 262.50 kg ha⁻¹ N, and the maximum estimated of 365 g of inflorescence fresh mass. Yildirim *et al.* (2007) observed leaf N content varying from 23.5 to 29.0 g kg⁻¹, in the control without N application and from 31.7 to 36.5 g kg⁻¹ with 275 kg ha⁻¹ N associated with foliar applications of 0.4 to 1.0% urea. Ambrosini *et al.* (2015) observed an increase in leaf N contents (ammoniacal and nitric) with nitrogen fertilization, for the BRO68 hybrid.

Cecílio Filho *et al.* (2012) observed

leaf N contents between 33.2 and 43.7 g kg⁻¹, which were considered adequate for broccoli because they were within the range of 30 to 55 g kg⁻¹ (Prezotti & Fullin, 2007; Trani *et al.*, 2018), however these authors do not indicate if this range refers to single head or branched type broccoli. All total N contents on the fourth leaf of single head broccoli, estimated with N rates, are within or above this range (Figure 2A).

Considering that the critical level for leaf total N content was 61.1 g kg⁻¹, estimated with 308 kg ha⁻¹ N for the maximum estimated inflorescence fresh mass of 822 g is equivalent to 100% of relative production (Figures 1A and 2A). The following range is proposed for diagnosis and evaluation of the nitrogen nutritional status of single head broccoli plants: low ≤52.5; medium 52.6 to 57.4; adequate 57.5 to 61.1 and high >61.1 g kg⁻¹ total N in the leaf dry mass, on the fourth leaf, under conditions similar to this work (Figure 2A). Considering

this range, N contents of 37.8 to 56.3 g kg⁻¹ (Campagnol *et al.*, 2009) and 43.7 g kg⁻¹ (Cecílio Filho *et al.*, 2012) would be inadequate for single head broccoli, which may justify the lower observed values of inflorescence fresh mass of 468 g and 365 g, respectively.

The SPAD index increased ($p < 0.001$), on the fourth leaf, and varied between Years 1 and 2 ($p < 0.001$). Read values were only 5.4% lower in Year 2 than in Year 1, being observed small variations from one year to another (Godoy *et al.*, 2010). However, it was not possible to adjust a significant regression model for each year, as a function of the N rates. The SPAD index increased up to 296 kg ha⁻¹ N, reaching the maximum estimated value of 71.33 SPAD units (Figure 2B).

Broccoli plants presented SPAD index values between 64.28 and 71.33 (Figure 2B). No studies were found using SPAD on the single head broccoli culture in Brazil. However, in Turkey, Yildirim *et al.* (2007) observed SPAD index of 56.32 and 63.05 on the control without N and varying from 68.88 to 78.12 with 275 kg ha⁻¹ N associated with foliar urea applications of 0.4 to 1.0%, respectively.

The SPAD index values in single head broccoli were much higher than other species of brassica such as values between 53.50 and 60.80 for cabbage (Moreira & Vidigal, 2011) and 55.90 to 66.63 for cauliflower (Vidigal *et al.*, 2018). The difference in the intensity of the green color between these species, which can be observed visually, shows that the higher values in broccoli may be associated with higher amount of chlorophyll (possibly chlorophyll *b*) and/or other pigments that may interfere with the SPAD readings. The critical level values with the SPAD-502 are variable and need to be adjusted for each situation, such as nutrient deficiency and environmental conditions, variety and crop growth stage (Godoy *et al.*, 2010; Fontes, 2011). It is worth noting that deficiencies of Mg and Mo can cause chlorosis in the leaves (Vidigal *et al.*, 2019), which can interfere with SPAD readings. However, in the conditions of this work, the yellowing of leaves was only observed in the control plants,

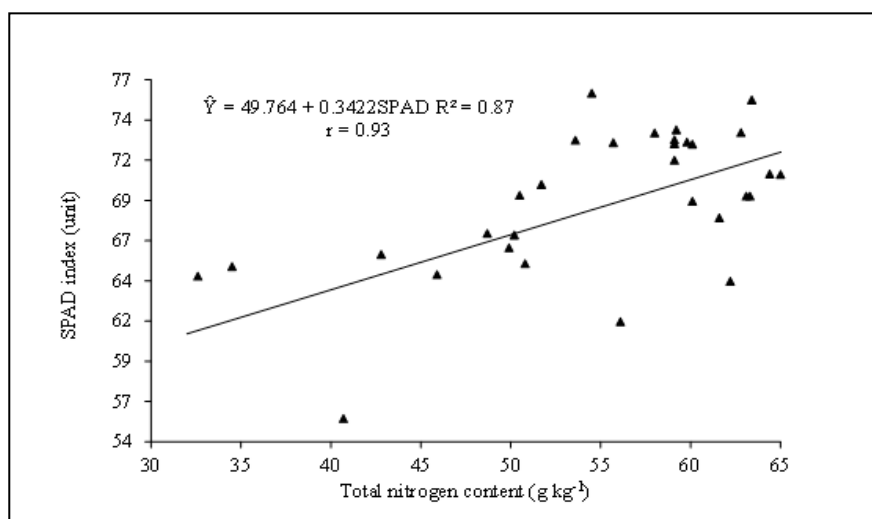


Figure 3. Relationship between SPAD index and total N content on the fourth leaf of single head broccoli plants, cv. Legacy, at 40 DAT, according to nitrogen (N) rates. Oratórios, EPAMIG, 2012/2013.

which did not receive N.

High correlations, of N content in single head broccoli leaves with the amount of chlorophyll *a*, *b* and *total* were observed by Ambrosini *et al.* (2015). The amount of chlorophyll estimated by the SPAD index showed a high correlation $r = 0.93$ ($p < 0.034$) with the total N content (Figure 3), as observed by Yildirim *et al.* (2007) for broccoli and other crops (Moreira & Vidigal, 2011; Pôrto *et al.*, 2014; Milagres *et al.*, 2018; Vidigal *et al.*, 2018).

The SPAD index showed a higher correlation ($r = 0.99$; $p < 0.001$) with fresh mass of the inflorescence than the total N content ($r = 0.96$; $p < 0.018$). In this case, the SPAD index, which is determined by immediate reading and in a non-destructive manner, has proved to be a better indicator of the nitrogen nutritional status in plants, the total N content being a slightly less sensitive indicator. These results are similar to those obtained by Coelho *et al.* (2010), who observed that the leaf N content in potato presents a lower correlation with yield than the SPAD index.

Based on the obtained results, considering that the critical level was 71.31 SPAD units estimated with 308 kg ha⁻¹ N for the maximum estimated inflorescence fresh mass of the 822 g is equivalent to 100% of relative production (Figures 1A and 2B),

the following range is proposed for diagnosis and evaluation of the nitrogen nutritional status of single head broccoli plants: low ≤ 68.48 ; medium 68.49 to 70.47; adequate 70.48 to 71.31 and high 71.31 SPAD units, on the fourth leaf, under conditions similar to this work.

The inflorescence is a commercial product of the single head broccoli; therefore the following model has been adjusted for the prognosis of the production of inflorescence fresh mass based on SPAD readings ($\hat{Y} = -5,196.9 + 84.41\text{SPAD}$ $R^2 = 0.99$).

Therefore, the ratio of the N content in the leaves and the amount of chlorophyll (estimated by the SPAD Index) allow the prognosis of single head broccoli production, especially when N is the most limiting factor in production. Models for estimating crop yields based on SPAD reading have been proposed (Yildirim *et al.*, 2010; Islam *et al.*, 2014; Milagres *et al.*, 2018). However, variations in SPAD readings can occur due to several factors, besides nutrient deficiency, such as environmental conditions, variety and crop growth stage. Thus, the models need to be adjusted for each situation. Therefore, the results obtained, in the conditions of this work, present the possibility of the SPAD index being used in the evaluation of the nitrogen nutritional status in the single head broccoli.

The nitrogen applied increased the N content and the amount of chlorophyll (estimated by the SPAD Index) in the leaves, which directly reflects the photosynthetic rate and production of photoassimilates and other structural compounds such as amino acids, carbohydrates and fats (Lima *et al.*, 2011; Tuncay *et al.*, 2011), resulting in greater mass of reproductive organs, such as inflorescence, which is the marketed part of single head broccoli.

The maximum values of all variables were estimated with N ranging from 260 to 373 kg ha⁻¹ N, regardless of the year. In the evaluation of the effect of N on single head broccoli production, the N that estimated the maximum values are within this range, 315 kg ha⁻¹ N (Cecílio Filho *et al.*, 2012) and from 286 to 328 kg ha⁻¹ N (Seabra Júnior *et al.*, 2013), except the 224 kg ha⁻¹ N, in fertirrigated culture (Silva *et al.*, 2019) and the 211 kg ha⁻¹ N (Oliveira *et al.*, 2016). These results demonstrate the productive potential of single head broccoli in responding to high doses of N, higher than those currently recommended, 100 to 160 kg ha⁻¹ N for Espirito Santo (Prezotti & Fullin, 2007), 210 to 290 kg ha⁻¹ N for São Paulo (Cecílio Filho *et al.*, 2018) and 200 kg ha⁻¹ N for Minas Gerais (Vidigal & Pedrosa, 2019), which corroborates with Bakker *et al.* (2009).

These differences demonstrate the variation of productive potential between varieties/hybrids, confirming that in the management of fertilization with nitrogen, a nutrient absorbed in greater quantity by single head broccoli (Cecílio Filho *et al.*, 2017), the genetic material, the plant population, the time of cultivation and the type of soil must be considered, being necessary regional studies.

The results of the work allow us to conclude that the SPAD index, evaluated in the fourth leaf at 40 days after transplanting, in the initial stage of flowering, can vary from one year to another; and because it presents high correlations with the total N content in the leaves ($r = 0.93$; $p < 0.034$) and with the maximum inflorescence fresh mass ($r = 0.99$; $p < 0.001$) can be used in the evaluation of the nitrogen nutritional

status in single head broccoli, together with the leaf total N content. They also allow proposing the N content ranges (low ≤ 52.5 ; medium 52.6 to 57.4; adequate 57.5 to 61.1 and high >61.1 g kg⁻¹) and SPAD index (low ≤ 68.48 ; medium 68.49 to 70.47; adequate 70.48 to 71.31 and high >71.31 ud SPAD) for evaluating the N nutritional status of single head broccoli. And, higher production of inflorescence fresh mass of single head broccoli can be obtained with the application of higher N doses than currently recommended.

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REFERENCES

- AMBROSINI, VG; VOGES, JG; BENEVENUTO, RF; VILPERTE, V; SILVEIRA, MA; BRUNETTO, G; OGLIARI, JB. 2015. Single-head broccoli response to nitrogen application. *Científica* 43: 84-92.
- BAKKER, CJ; SWANTON, CJ; MCKEOWN, AW. 2009. Broccoli growth in response to increasing rates of pre-plant nitrogen. I. Yield and quality. *Canadian Journal of Plant Science* 89: 527-537.
- CAMPAGNOL, R; NICOLAI, M; MELLO, SC; ABRAHÃO, C; BARBOSA, JC. 2009. Boro e nitrogênio na incidência de hastes ocas e no rendimento de brócolis. *Ciência e Agrotecnologia* 33: 1477-1485.
- CECÍLIO FILHO, AB; CARMONA, VMV; SCHIAVON JUNIOR, AA. 2017. Broccoli growth and nutrient accumulation. *Científica* 45: 95-104.
- CECILIO FILHO, AB; SCHIAVON JÚNIOR, AA; CORTEZ, JWM. 2012. Produtividade e classificação de brócolos para indústria em função da adubação nitrogenada e potássica e dos espaçamentos entre plantas. *Horticultura Brasileira* 30: 12-17.
- CECÍLIO FILHO, AB; TRANI, PE; CAMARGO, MS; MELO, SC; FIGUEIREDO, GJB. 2018. Brócolis, couve-flor e repolho. In: TRANI, PE; RAIJ, B; CANTARELLA, H; FIGUEIREDO, GJB (eds). *Hortaliças: Recomendações de calagem e adubação para o estado de São Paulo*. São Paulo: CATI. p. 38-40.
- COELHO, FS; FONTES, PCR; PUIATTI, M; NEVES, JCL; SILVA, MCC. 2010. Dose de nitrogênio associada à produtividade de batata e índices do estado de nitrogênio na folha. *Revista Brasileira de Ciência do Solo* 34: 1175-1183.
- CRUZ, CD. 2013. Genes: A software package for analysis in experimental statistics and quantitative genetics Acta Scientiarum. Agronomy. 35: 271-276.
- FONTES, PCR. 2011. *Nutrição mineral de plantas: avaliação e diagnose*. Viçosa: Arka Editora. 296p.
- GODOY, LJG; SOUZA, TR; VILLAS BOAS, RL. 2010. Perspectivas de uso de métodos diagnósticos alternativos: análise da seiva e medida indireta da clorofila. In: PRADO, RM; CECÍLIO FILHO, AB; CORREIA, MAR; PUGA, AP (eds). *Nutrição de plantas: diagnose foliar em hortaliças*. Jaboticabal: FCAV/CAPES/FAPESP/FUNDUNESP. p.135-184.
- ISLAM, MR; HAQUE, KS; AKTER, N; KARIM, MA. 2014. Leaf chlorophyll dynamics in wheat based on SPAD meter reading and its relationship with grain yield. *Journal of Scientia Agriculture* 8: 13-18.
- LALLA, JG; LAURA, VA; RODRIGUES, APDC; SEABRA JÚNIOR, S; SILVEIRA, DS; ZAGO, VH; DORNAS, MF. 2010. Competição de cultivares de brócolos tipo cabeça única em Campo Grande. *Horticultura Brasileira* 28: 360-363.
- LIMA, MC; AMARANTE, L; MARIOT, M; SERPA, R. 2011. Crescimento e produção de pigmentos fotossintéticos em *Achillea millefolium* L. cultivada sob diferentes níveis de sombreamento e doses de nitrogênio. *Ciência Rural* 41: 45-50.
- MILAGRES, CC; FONTES, PCR; SILVEIRA, MV; MOREIRA, MA; LOPES, IPC. 2018. Índices de nitrogênio e modelo para prognosticar a produção de tubérculos de batata. *Revista Ceres* 65: 261-270.
- MOREIRA, MA; VIDIGAL, SM. 2011. Evolução das características da planta associadas à nutrição nitrogenada de repolho. *Revista Ceres* 58: 243-248.
- OLIVEIRA, FC; GEISENHOF, LO; ALMEIDA, AC; LIMA JÚNIOR, JA; NIZ, AIS; BARBIERO, DF. 2016. Produtividade do brócolis de cabeça sob diferentes doses de adubação nitrogenada. *Revista Agrarian* 9: 326-333.
- PÔRTO, MLA; PUIATTI, M; FONTES, PCR; CECON, PR; ALVES, JC. 2014. Índice SPAD para o diagnóstico do estado de nitrogênio na cultura do pepino japonês em ambiente protegido. *Horticultura Brasileira* 32: 292-296.
- PREZOTTI, LC; FULLIN, EA. 2007. Avaliação da fertilidade do solo e do estado nutricional de plantas. In: PREZOTTI, LC; GOMES, JA; DADALTO, GG; OLIVEIRA, JA (eds). *Manual de recomendação de calagem e adubação para o Estado do Espírito Santo – 5ª Aproximação*. Vitória: SEEA/INCAPER/CEDAGRO. p.11-42.
- SHELLENBERG, DL; BRATSCH, AD; SHEN, Z. 2009. Large single-head broccoli yield as affected by plant density, nitrogen, and cultivar in a plasticulture system. *HortTechnology* 19: 792-795.
- SEABRA JÚNIOR, S; LALLA, JG; GOTO, R; MARINGONI, AC; VILLAS BOAS RL; ROUWS, JRC; ORIANI, EE. 2013. Suscetibilidade à podridão negra e produtividade de brócolis em função de doses de nitrogênio e potássio. *Horticultura Brasileira* 31: 426-431.
- SILVA, FCD. 2009. *Manual de análises químicas de solos, plantas e fertilizantes*. Brasília: Embrapa Informação Tecnológica; Rio de Janeiro: Embrapa Solos. 627p.
- SILVA, PA; BISCARO, GA; OLIVEIRA, GQ; SCHWERZ, F; DREHMER, KKB. 2019. Fertirrigação com nitrogênio na cultura do brócolis. *Revista Engenharia na Agricultura* 27: 472-480.
- TRANI, PE; RAIJ, B; CANTARELLA, H; FIGUEIREDO, GJB. 2018. Composição química e diagnose foliar. In: TRANI, PE; RAIJ, B; CANTARELLA, H; FIGUEIREDO, GJB (eds). *Hortaliças: Recomendações de calagem e adubação para o estado de São Paulo*. São Paulo: CATI. p. 8-13.
- TUNCAY, Ö; ESIYOK, D; YAGMUR, B; OKUR, B. 2011. Yield and quality of garden cress affected by different nitrogen sources and growing period. *African Journal of Agricultural Research* 3: 608-617.
- VIDIGAL, SM; CECÍLIO FILHO, AB; CORTEZ, JWM; PEREIRA, PRG. 2019. Diagnóstico visual na avaliação do estado nutricional das hortaliças. *Informe Agropecuário* 308: 41-54.
- VIDIGAL, SM; LOPES, IPC; PUIATTI, M; RIBEIRO, MRF; SEDIYAMA, MAN. 2018. SPAD index in the diagnosis of nitrogen status in cauliflower as a function of nitrogen fertilization. *Científica* 46: 307-314.
- VIDIGAL, SM; PEDROSA, MW. 2007. Brócolis. In: PAULA JÚNIOR, TJ; VENZON, M (eds). *101 Culturas: manual de tecnologias agrícolas*. 1.ed. Belo Horizonte: EPAMIG. p.175-178.
- VIDIGAL, SM; PEDROSA, MW. 2019. Brócolis. In: PAULA JÚNIOR, TJ; VENZON, M (eds). *101 Culturas: manual de tecnologias agrícolas*. 2.ed. Belo Horizonte BR: EPAMIG. p.210-213.
- YILDIRIM, E; GUVENC, I; TURAN, M; KARATAS, A. 2007. Effect of foliar urea application on quality, growth, mineral uptake and yield of broccoli (*Brassica oleracea* L., var. *italica*). *Plant Soil and Environment* 53: 120-128.
- YILDIRIM, M; KILIÇ, H; KENDAL, E; KARAHAN, T. 2010. Applicability of chlorophyll meter readings as yield predictor in durum wheat. *Journal of Plant Nutrition* 34: 151-164.