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Response of Chinese cabbage to source and rate of N topdressing application in tropical soil in Brazil

Carla Verônica Corrêa*, Bruno Novaes Menezes Martins, Aline Mendes de Sousa Gouveia, Ana Emília Barbosa Tavares, Natália de Brito Lima Lanna and Antonio Ismael Inácio Cardoso

Faculdade de Ciências Agronômicas, Rua Doutor José Barbosa de Barros, 1780, 18610-307, Botucatu-SP, Brazil.

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The aim of this study was to evaluate the response of Chinese cabbage (hybrid Deneko) to source and rate of N topdressing application. The experimental design was a randomized complete block, consisting of nine treatments (4x2+1 factorial design), with five replications, that is, four rates of N (54, 108, 162 and 216 kgha^{-1}); two sources of N (urea and ammonium sulphate); and a control (without N topdressing). The experiment was conducted from July to October, 2013. Forty days after transplanting, SPAD index (relative chlorophyll density) was evaluated. After harvesting, fresh matter; leaf number; head diameter and head height were evaluated. It was observed that sources of N did not influence any evaluated traits. For the SPAD index, head height and head diameter linearly increased by improving the rate of N, with values which range from 27.0 to 41.1 SPAD units; 25.9 to 29.3 cm; and 8.9 to 13.4 cm, respectively. The effect of N was quadratic for head fresh matter, with maximum value estimated at1217 g for162 kg N ha^{-1}.

Key words: *Brassica pekinensis*, urea, ammonium sulphate.

INTRODUCTION

Chinese cabbage (*Brassica pekinensis*) is a *brassicaceae* and it is characterized by its bright green leaves; a prominent white midrib; a short thick stalk; and a large compact globular head. These cultivars are good for growing areas with mild temperatures (Filgueira, 2008).
Chinese cabbage is rich in vitamins A, B, C, calcium, potassium, and fibre, which stimulates intestinal activity. It also provides vitamin B3 (niacin), which helps in gastrointestinal problems and nervous system disorders (Gordin et al., 2010). The state of São Paulo is the largest vegetable producer in Brazil and also excels in the production of Chinese cabbage with a 12,588 t of productivity per year (Filho and Camargo, 2015).

Brassicaceae extracts large amounts of nutrients from

*Corresponding author. E-mail: cvcorrea1509@gmail.com

agricultural soil; accumulating high N levels, but they also have a high demand for S (Rathke et al., 2006; Berry et al., 2010). Additionally, the development of a sustainable and productive agriculture has to supplement fertilization management that involves appropriate nutrient management practice; right fertilizer source to each species and the best application time (Fageria and Baligar, 2005). In the literature, it is common to find studies showing that sources and rates of N can have a significant effect on the plants' nutrition; therefore, influencing growth, development and production of plants (Neeteson and Carton, 2001; Rahn, 2002; Sady et al., 2008). Nitrogen is a constituent of cellular components, proteins, nitrogenous bases, triptophane amino acid and chlorophyll (Fagan et al., 2016). Adequate rates of N in vegetative phase augment vegetative growth augmenting a capitation of light, ameliorating the photosynthesis resulting in higher yield.

When seedlings were transplanted to the groove in low and mid fertility soils, Filgueira (2008) recommended for tropical soils, an application of 40; 150-300; and 100-150 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. However, Raij et al. (1997) recommended an application of 60; 400-600; and 180-240 kg ha^{-1} of N, P_2O_5 and K_2O, respectively. In addition, Raij et al. (1997) also suggested topdressing fertilization, such as 15-200 kg N ha^{-1} and 60-120 kg K_2O ha^{-1}. Tropical regions are characterized by weathered soils, greater intensity of rain and acidic soil which facilitates leaching and lack both N and S. In addition, tropical soils are characterized as presenting small amounts of organic matter because of the high temperatures and high microorganisms activity, reducing the availability of N and S over most cultures cycle, requiring replacement of nutrients by organic or chemical fertilizer.

Furthermore, sulphur is also present in many agricultural regions in the world and this nutrient has become a limiting factor for crop production, as an adequate S availability for plants stimulates higher growth, yield responses and quality (Abbey et al., 2002; Eriksen et al., 2004). In Brazil, the S is not considered a very important nutrient. In addition, it uses many formulations of nitrogen, phosphorus and sulfur and not potassium, which causes a reduction in the availability of sulfur in the soil for crops.

Plants have different abilities to absorb, translocate and use sulfur and therefore require different amounts of available ground SO_4^{-2}. Some plants, such as those of the family of legumes, brassicas and Liliaceae only express their genetic potential in terms of productivity and quality when the availability of this nutrient is high, and then established a critical level of 10 mg dm^{-3}, while for the remaining species, this low value is 5 mg dm^{-3}. Considering these reference values for the surface layer of soil, about 50% of the total area of tropical soils and sub-tropical South America can be considered deficient in sulfur. The availability of organic sulfur to plants depends on the processing of the inorganic forms almost exclusively in the form of sulfate ($SO4^{-2}$). In tropical soil conditions due to increased precipitation and temperature, there is a rapid depletion of organic matter and consequently low S content available to plants. In addition, both the total amount of sulfur as the adsorption capacity of SO_4^{-2} are lower in soils with low clay content and retention is further reduced by the application of lime and phosphate, these are highly practiced in Brazil because of the present acidic soils. Thus, there is a shift of this ion to the deeper layers, where it can be adsorbed because of higher clay content and lower levels of organic matter and pH (Rheinheimer et al., 2005). This same behavior is observed for N, and leaching losses due to high precipitation.

Schonhof et al. (2007) observed an increase in the broccoli head matter by applying sulphur. The sulfur is a constituent of diverse enzymes when cysteine and methionine amino acids are used in protein synthesis. The cysteine is the first stable organic compound synthesized in the sulfate assimilation pathway. They are used for the synthesis of a variety of metabolites and other important compounds, such as methionine, SAM, S-methylmethionine, [Fe/S] clusters, hormones, proteins, vitamins and enzyme cofactors. Methionine is sulfur containing essential amino acid, which is an important methyl group donor and a precursor of several metabolites such as ethylene, polyamines, and dimethyl sulfoniopropionate. It is also an important constituent of several peptides and proteins (Buchanan et al., 2015). Besides, the interaction between nitrogen and sulphur enables important growth parameters, such as biomass and yield, as S is an essential constituent of enzymes when associated with nitrogen metabolism, that is, nitrate and nitrite reductase (Salvagiotti and Miralles, 2008; Mendel, 1997; Campbell, 1999; Swamy et al., 2005; Takahashi and Saito, 1996; Koprivova et al., 2000; Hesse et al., 2004; Carfagna et al, 2011).

Taken all these considerations into account, this study aimed to evaluate the response of Chinese cabbage to source (ammonium sulphate and urea) and rate of N topdressing application.

MATERIALS AND METHODS

The experiment was conducted in the Sao Manuel Experimental Farm, Botucatu School of Agronomy, UNESP, Brazil (22°46'28"S, 48°34'37"W; 740 mm altitude). According to the Köppen classification, the climate in the region is mesothermic, *Cwa*, in other words, humid and subtropical; dry winter; rainy season from November to April. The mean annual rainfall of São Manuel is 1445 mm; the mean annual temperature of the warmest month is 22°C; and the mean temperature of the coldest month is 18°C (Cunha

Table 1. SPAD index (SPAD units), fresh matter, head diameter and head height of Chinese cabbage according to different sources of nitrogen. Agronomic Science School, São Manuel-SP, 2013.

Source of N	SPAD index (units)	Fresh matter (g plant^{-1})	Head diameter (cm)	Head heigth (cm)
Urea	35.8[a]	1082[a]	12.0[a]	28.1[a]
Ammonium sulphate	36.4[a]	1125[a]	12.1[a]	28.6[a]
C.V.	9.8%	10.1 %	8.2%	4.7%

Means followed by different letters differ by Tukey test at 5% probability.

and Martins, 2009).

The soil is classified as Dystrophic Red Latosol (Oxisoil). Soil samples were collected in agricultural area characterized per sandy soil. This soil were collected in 20 point in experimental area at a depth of 0-20 cm to determine their chemical properties: pH in $CaCl_2$, 6.4; Organic matter, 11 g dm^{-3}; phosphorus$_{resin}$, 13 mg dm^{-3}; H+Al, 12 mmol$_c$ dm^{-3}; Potassium, 1.9 mmol$_c$ dm^{-3}; calcium, 20 mmol$_c$ dm^{-3}; magnesium, 10 mmol$_c$dm^{-3}; base sum, 32 mmol$_c$ dm^{-3}; cation exchange capacity, 44 mmol$_c$ dm^{-3}; base saturation 82%.

The experimental design was a randomized complete block, with nine treatments (4x2+1 factorial design), five replications; 15 plants per plots, but only the central five were evaluated. Therefore, treatments consisted of five rates of N topdressing (0, 54, 108, 162 and 216 kg ha^{-1}); two sources of N (urea and ammonium sulphate) and a control (without N topdressing). According to the methodology described by Raij et al. (1997), 60 kg N ha^{-1}; 400 kg P_2O_5 ha^{-1}; 180 kg K_2O ha^{-1}; 40 t ha^{-1} of organic compost trade mark Provaso® (moisture content of 37.9%) was applied, which was evenly distributed over the whole bed surface (1.2 m width and 0.3 m height). S was not utilized in fertilizer application.

Hybrid Deneko® of enterprise Bejo was used. On July 10, 2013, sowing was performed in polypropylene trays of 200 cells, filled with coconut fibre substrate. On August 13, 2013, seedlings were transplanted separately into microplots of size 0.5 x 0.4 m. Weed control was done in hand form and sprinkler was used for irrigation.

Regarding the crop, the included doses exceeded the recommendation of Raij et al. (1997), that is, from 15 to 200 kg N ha^{-1}. At 15, 30 and 45 days after transplanting, topdressing was performed by adding 1/3 of the dose in each date. In addition, 90 kg ha^{-1} of potassium chloride was applied to the commercial source which is cheap according to the methodology described by Raij et al. (1997).

When the head started to close (40 days after transplanting), it was determined the SPAD index (relative chlorophyll density). Therefore, chlorophyll content was indirectly measured by using the Clorofilog® device. The measurement was performed in fully developed young leaves (40 days after transplanting) of three plants per plot.

On October 10, 2013 (three month after sowing), plants were harvested. the fresh matter, head height and head diameter were evaluated. Thus, all outer leaves were removed to evaluate the head. For fresh matter, a semi-analytical balance with a precision of 0.1 g was used; for head diameter, a digital calliper was used; and for height, a graduated ruler expressed in centimetres (cm) was used.

Data were subjected to analysis of variance and regression for rates of N. For the source of N, data were compared by Tukey test (p <0.05) by the Sisvar software (Ferreira, 2010).

RESULTS AND DISCUSSION

With regards to the source of N, there were no differences for all the characteristics evaluated (Table 1), since the fertilizer was applied at the recommended rates (30-60 kg S ha^{-1}) as proposed by Raij et al. (1997) and Filgueira (2008) for brassica in tropical soils. This recommendation is similar to that of other brassicas like cabbage and cauliflower. A few studies have been conducted in order to evaluate the response of Chinese cabbage to this nutrient. However, Sanderson and Ivany (1996) presented an increase in the head cabbage matter, when S is applied. The sulfur is constituent of diverse enzymes when cysteine and methionine is the sulfur-containing amino acids used in protein synthesis. The cysteine is the first stable organic compound synthesized in the sulfate assimilation pathway. It is used for the synthesis of a variety of metabolites and other important compounds, such as methionine, SAM, S-methylmethionine, [Fe/S] clusters, hormones, proteins, vitamins and enzyme cofactors. Methionine is sulfur containing essential amino acid, which is an important methyl group donor and a precursor for several metabolites such as ethylene, polyamines and dimethyl sulfoniopropionate. It is also an important constituent of several peptides and proteins (Buchanan et al., 2015). Corrêa et al. (2013) evaluated rates of potassium in cabbage, with and without sulphur topdressing fertilization; but also presented no differences between sources for all the evaluated traits. Losák et al. (2008), when evaluating kohlrabi (another *brassicaceae*), also did not obtain any difference in the production when sulphur was added, which reduced the content of inorganic nitrate (NO_3^-, an anion) in the leaves; this anion could be harmful to human health if consumed in higher levels. High dietary intake due to the high nitrate content of certain vegetables has generated concern about the possible health effects. The toxicity of nitrate per se is low, but in humans, 5 to 10% of the ingested nitrate is converted to the more toxic nitrite by salivary or gastrointestinal reduction. Although, earlier reports linking nitrate with the occurrence of cancer are largely unsubstantiated, other nitrate-induced syndromes, such as methaemoglobinaemia in infants (blue baby syndrome) have been confirmed (Elwam and El-Hamed, 2011).

However, Sanderson (2003), Schonhof et al. (2007) and Salvagiotti et al. (2009) observed an increase in broccoli productivity by applying sulphur. It is as a result of diverse enzymes used for the synthesis of hormones, proteins, vitamins and enzyme cofactors and a precursor for several metabolites such as ethylene and polyamines (Buchanan et al., 2015).

The lack of effect of the sources, that is, no difference by applying doses of S topdressing, perhaps indicates that the application thereof is not necessary. Considering that all the plots received 40 t ha^{-1} of organic compost (37.9% of moisture content), therefore, it may have met the nutrient demands for the plants throughout the cycle, that is, 0.19% of S in the compost dry matter, released up to 288 kg S ha^{-1}, which is higher than the maximum applied dose of ammonium sulphate (110 kg S ha^{-1}). For most vegetables, an application of large amounts of organic compost, which may be sufficient to meet the plants demand for S is recommended. Therefore, sulphur fertilizer is probably unnecessary when using organic fertilizer.

Regarding the rates of nitrogen, all evaluated characteristics presented some differences, independent of different N source. Therefore, a linear increase was obtained for the SPAD index (Figure 1). Pôrto et al. (2014) reported that the SPAD index has a positive correlation with chlorophyll and N in the leaf of cucumber; also, stating that SPAD index can be an easy and fast alternative to diagnose N nutritional status of plant. These significant correlations between have been found by many authors (Chapman and Barreto, 1997), as most of the N from the leaves take part in the structure of chlorophyll molecules because N is part of tetrapirrolic ring of chlorophyll molecule. So, greater concentration of N results in greater availability of this nutrient from formation of chlorophyll. SPAD index has a positive correlation with chlorophyll and so, one form indirect to determine of N. The higher the N rate, the greater the averages of head diameter and head height (Figures 1B and C). For the head fresh matter, a quadratic effect with maximum value of 1216.6 g was obtained by applying 162 kg N ha^{-1} (Figure 1D). The nitrogen is a constituent of cellular components, proteins, nitrogenous bases, triptofane amino acid and chlorophyll (Fagan et al., 2016). Adequate rates of N in vegetative phase augment vegetative growth capitation of light, ameliorating the photosynthesis resulting in higher head diameter, head height and head fresh matter.

Seabra Junior et al. (2013) observed in broccoli, a quadratic effect on productivity when N and K fertilizers were applied, obtaining a maximum estimated production of 306 g $plant^{-1}$ (588 kg K_2O ha^{-1} and 150 kg N ha^{-1}); 370 g $plant^{-1}$ (541 kg K_2O ha^{-1} and 300 kg N ha^{-1}); and 303 g $plant^{-1}$ (751 kg K_2O ha^{-1} and 450kg N ha^{-1}), broccoli production was expressed in inflorescence per plant. At higher rates of N, there was an abortion of flowers due excessive growth of vegetation, bringing out the unbalance of carbohydrates between leaves and flowers. Furthermore, they found that higher doses of K topdressing reduced the severity of black rot in broccoli (*Xanthomonas campestris pv. campestris*) as compared to equilibrate the absorption of nitrogenous. Nitrogen, which is held largely in leaves and plays an important role in mineral nutrition and physiology of plants and is responsible for important physiological processes such as photosynthesis, respiration, development and activity of roots, ionic absorption of other nutrients, growth and cell differentiation. The effect of nitrogen in disease resistance is totally dependent on dose, because in appropriate doses contributes to the synthesis of phenols and alkaloids, but in high concentrations, it reduces the production of phenolics, lignans, due to the carbon demand in photosynthetic pathway cycle Krebs, affecting the synthesis of secondary metabolites via the shikimic acid, and contribute to the production of young tissues extending the vegetative stage and creating favorable conditions for the pathogen attack. The K assists in disease resistance by balancing the nitrogen fertilization and makes them more fibrous tissue, increasing fungal and bacterial resistance. This favorable effect is a direct action, making the establishment and development of the pathogen in the host, in addition to acting indirectly, promoting wound healing and hindering the penetration of pathogens. Potassium plays a role in the conversion of simple sugars and nitrogen compounds of high molecular weight compounds such as cellulose, starch and protein, amino acids and reducing sugars that are food for pests and diseases.

According to Huett and Dettmann (1991), N stimulates growth and development of plants, that is, having direct effect on the drain source relationship; raising the production of assimilates (carbohydrates). Adequate rates of N in vegetative phase augment vegetative growth capitation of light, ameliorating the photosynthesis resulting in higher head diameter and head height and head fresh matter. The higher the rates of N (till dose-limiting extent), the larger the leaf area; for that reason, affecting photosynthesis and so, production of carbohydrates, plant growth and crop production.

Despite the N and organic compost fertilization, all plants need regular supply of nitrogen, which confirms the necessity of multiple split application, as recommended by Raij et al. (1997). Considering the fresh matter, the necessary rate of N to obtain the maximum value was 162 kg ha^{-1}, which is slightly below the maximum recommended by Raij et al. (1997), that is, 200

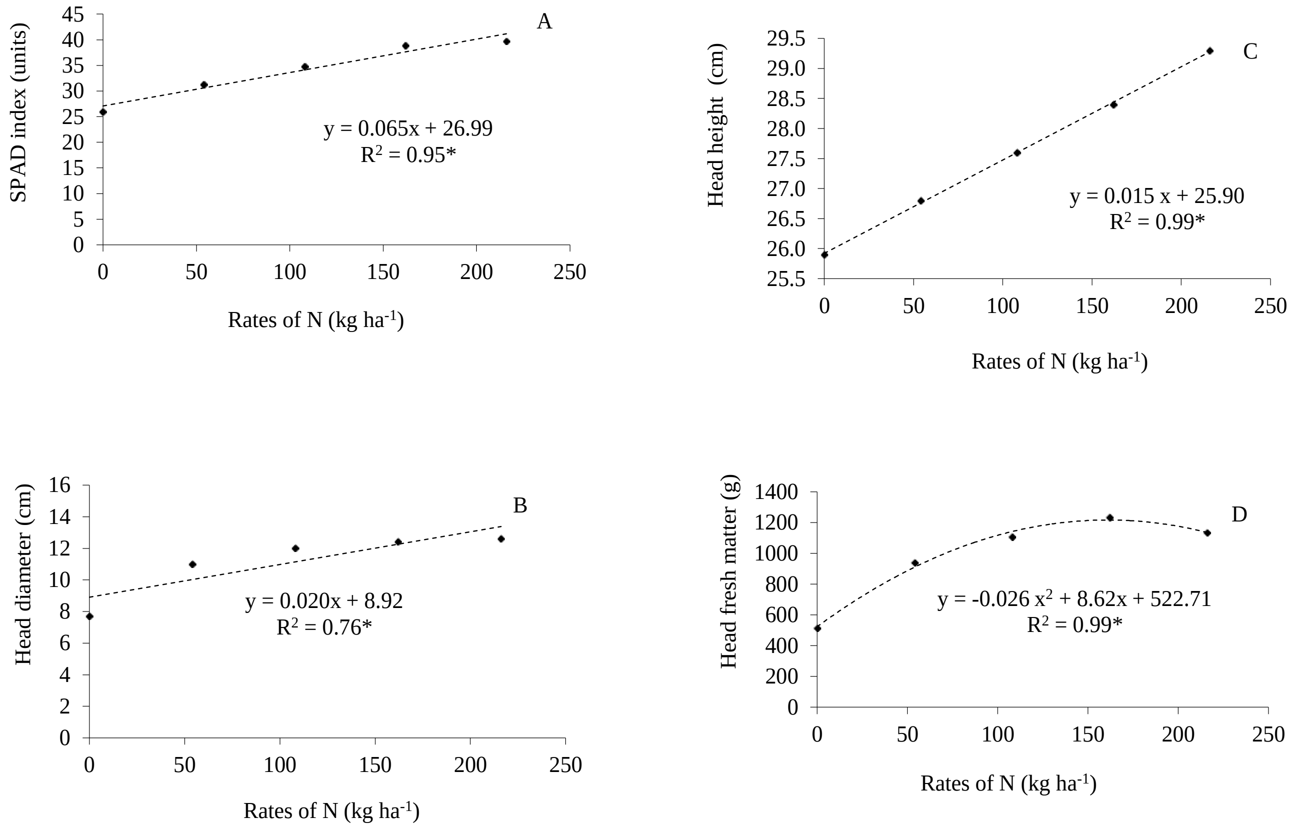

Figure 1. SPAD index, fresh matter, head diameter and head height of Chinese cabbage according to different rates of nitrogen. Agronomic Science School, São Manuel-SP, 2013. *Differ by Tukey test at 5% probability.

kg N ha^{-1}. In this study, the soil was sandy (about 87%sand), thereby, a greater potential to lose N from leaching and, consequently, split applications were effective.

There are some studies that confirm the real increase in production per increase head height and fresh matter by applying N topdressing on *brassicaceae*, such as cabbage (Aquino et al., 2009; Moreira e Vidigal, 2011) and broccoli (Elwan et al., 2011).

Although, studies also confirm the need for split application of total N rate, there are little information on source and rate of sulphur application; despite the importance of this nutrient for brassica, the results are not yet sufficient to recommend the use of S to improve productivity.

Conclusion

The evaluated characteristics were not affected by the sources of N in this study. The largest head fresh matter was estimated to be about 162 kg N ha^{-1}. By improving the nitrogen dose, the SPAD index, head height and head diameter linearly increased.

Conflict of Interests

The authors have not declared any conflict of interests.

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