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TÍTULO DA TESE: YIELD AND QUALITY OF POTATO TUBERS IN RESPONSE TO NITROGEN MANAGEMENT

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AUTHOR'S CURRICULUM INFORMATION

CAMILA SENO NASCIMENTO was born on September 20, 1990, in Diadema, São Paulo, Brazil to Yaeko Senô and Jorge José de Luna Nascimento. She graduated from São Paulo State University, at the campus of Jaboticabal (FCAV/UNESP) in 2015 with a degree in Agronomic Engineering. Throughout her undergraduate years, she was an intern at Crop Production Science Department, where she acquired knowledge in hydroponics, greenhouse production, agronomic biofortification, intercropping systems, and nutrient management for vegetable crops. During this period, she received three scientific initiation grants from FAPESP (2011/2012) and PIBIC/CNPq (2012/2013 and 2013/2014) to develop projects related to vegetable production. Besides that, since she was a freshman, she was involved with extracurricular activities, such as extension projects, clubs, and volunteer works. From March 2014 to August 2015, Camila participated in the Science Without Borders program in the United States. During her stay in the U.S., she attended academic classes at Michigan State University and did a three-month internship at the University of Wisconsin-Madison. In March 2016, she started her master's degree in Agronomy (Crop Production Science) at São Paulo State University, at the campus of Jaboticabal (Dissertation Title: N: K ratio for phenological growth stages of net melon cultivated in NFT hydroponic system). Her project was sponsored by the Coordination for the Improvement of Higher Education Personnel (CAPES) through the granting of a scholarship. In March 2018, she started her Ph.D. in Agronomy (Crop Production Science) at the same university (Title Ph.D. research project: Yield and quality of potato tubers in response do nitrogen management, CNPq, 141300/2018-3). The funding agency National Council of Scientific and Technological Development (CNPq) supported her Ph.D. project under the supervision of Prof. Dr. Arthur Bernardes Cecílio Filho.

“I may not have gone where I intended to go, but I think I have ended up where I needed to be.”

Douglas Adams

DEDICATION

To my dearest grandparents **Ziro Senô** (*In memoriam*) and **Ana Akemi de Britto Senô** (*In memoriam*) for all the support, teaching, and encouragement, being my great examples in life. To my sister **Carolina Seno Nascimento** for always encouraging me throughout this journey. To my mother **Yaeko Senô** for always believing in me.

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SUMMARY

page

PRODUTIVIDADE DA BATATEIRA E QUALIDADE DE SEUS TUBÉRCULOS EM RESPOSTA AO MANEJO DA ADUBAÇÃO NITROGENADA

RESUMO - O inadequado manejo da adubação nitrogenada pode ocasionar distúrbios fisiológicos na cultura da batata e promover a redução da produção e da qualidade dos tubérculos, afetando a rentabilidade dos cultivos. Desta maneira, o objetivo deste trabalho foi estabelecer doses ótimas de nitrogênio (N) para serem aplicadas em diferentes cultivares de batata, assim como avaliar a influência de fontes e doses de N na performance agronômica e qualidade dos tubérculos. Para isso, os seguintes experimentos foram desenvolvidos em campo: Experimento 1: Foi avaliada a influência de doses de N (0, 70, 140 e 210 kg ha^{-1}) no estado nutricional, fisiologia, crescimento e produtividade das cultivares Ágata (mercado in natura) e Asterix (indústria de fritura). Experimento 2: Foi analisado como a aplicação de N (0, 70, 140 e 210 kg ha^{-1}) nas formas de nitrato de amônio e ureia afetam o desempenho agronômico e o acúmulo de nitrato nos tubérculos de batata. No experimento 1, observou-se que máxima produtividade foi obtida com a aplicação de 131 kg ha^{-1} de N. A aplicação de 210 kg ha^{-1} de N ocasionou uma redução significativa na transpiração, taxas de fotossíntese e massa seca dos tubérculos. No experimento 2, a aplicação de ureia proporcionou maiores produtividades do que o nitrato de amônio. A aplicação de 210 kg ha^{-1} de N, em ambas as fontes, proporcionou máximos teores de nitrato, entretanto não ultrapassou o limite (200 mg kg^{-1}) recomendado para o consumo humano. O método de cozimento promoveu uma diminuição no teor de nitrato nos tubérculos.

Palavras-chave: *Solanum tuberosum*, cultivares, fertilizante nitrogenado, nitrato.

YIELD AND QUALITY OF POTATO TUBERS IN RESPONSE TO NITROGEN MANAGEMENT

ABSTRACT - Inadequate nitrogen (N) fertilizer management can cause physiological disorders in potato crops and promote a reduction in production and quality of tubers, affecting the profitability of the system. In this sense, this study aimed to establish optimal rates of N to different potato cultivars, as well as evaluate the influence of sources and rates of N in the agronomic performance and quality of potato tubers. For this, two experiments were carried out in the field: Experiment 1 evaluated the influence of N rates (0, 70, 140, and 210 kg ha^{-1}) on nutritional status, physiology, growth, and yield of Agata (fresh market) and Asterix (frying industry) cultivars. Experiment 2 assessed how the application of N (0, 70, 140, and 210 kg ha^{-1}) in the forms of ammonium nitrate and urea influence the agronomic performance and nitrate accumulation in potato tubers. In experiment 1, it was noticed the highest yield at 131 kg N ha^{-1}. Application of 210 kg N ha^{-1} led to a remarkable decrease in transpiration, photosynthesis rates, and tuber dry mass. In experiment 2, it was noticed that the application of urea provided a higher yield than ammonium nitrate. The highest nitrate content in potato tubers was achieved at 210 kg N ha^{-1} for both sources, not exceeding the limit (200 mg kg^{-1}) recommended for human consumption. The boiled method promoted a decrease in nitrate content.

Keywords: *Solanum tuberosum*, cultivars, nitrogen fertilizers, nitrate.

LIST OF ABBREVIATIONS

N - nitrogen

P - phosphorus

K - potassium

Ca - calcium

Mg - magnesium

S - sulfur

Cu - copper

Fe - iron

Mn - manganese

Zn - zinc

B - boron

a.s.l - above sea level

K_2O - potassium chloride

P_2O_5 - simple superphosphate

NO_3^- - nitrate

NO_3^-B - nitrate content after boiling

DAP - days after planting

DAE – days after emergence

PAR - photosynthetically active radiation

WUE - water use efficiency

Ci - internal CO_2 concentration

E - transpiration rate

gs - stomatal conductance

A - net photosynthetic rate

SDM - shoot dry biomass accumulation

TDM - tuber dry biomass accumulation

TODA - total dry biomass accumulation

NS - nitrogen content in the shoots

NT - nitrogen content in the tubers

NA - nitrogen accumulation

NAS - nitrogen accumulation in the shoot

NAT - nitrogen accumulation in the tuber

TNA – total nitrogen accumulation

PF - pulp firmness

FM - fresh mass

NUE - nitrogen use efficiency

LIST OF TABLES

LIST OF FIGURES

CHAPTER 1 - General considerations

1 INTRODUCTION

Potato (*Solanum tuberosum*) is a fast-growing, high-yielding crop, with excellent market acceptance. It represents a cheap and nutritionally rich food source, and it is, therefore, an outstanding cultivation option for farmers. Currently, potato growers find a wide variety of potato cultivars on the market, with different characteristics in relation to pests and diseases tolerance, size and shape of the tuber, skin and flesh color, and culinary aptitude (fresh, boiling, frying, roasting), leaving it up to them to adopt the cultivar that best suits the growing and market condition of their region. In Brazil, Agata (fresh market) is the most grown cultivar, occupying about 50 % of the total cultivated area. Together with Asterix (processing industry), the second most-produced cultivar, it leads the domestic market (Assunção et al., 2020; Oliveira et al., 2020).

Because this crop is a short-cycle species with a high growth rate, it demands a large amount of fertilizers per unit area, especially nitrogen (N), the second most required nutrient by potato crop (Pereira et al., 2020; Zhang et al., 2022). The efficiency of N fertilization in potato plants depends on several factors, such as the cultivar adopted, phenological growth stage, soil attributes, climatic conditions, rate and source of N applied, and plant efficiency in converting absorbed nutrients into biomass (Gitari et al., 2018; Tang et al., 2021). In Brazil, technical guides to mineral fertilizers recommend N rates ranging from 60 to 250 kg ha^{-1}, varying according to the region of potato growth (Fernandes and Soratto, 2012). In São Paulo State, for example, Miranda Filho (1997) recommends rates of N up to 160 kg ha^{-1} splits into two portions, one at planting and one before hilling. However, because N is a main limiting nutrient for potato growth and development, in general, in intensive potato production systems, N is often supplied at rates far greater than those recommended, causing a surplus of this element in soils, that thereafter leads to negative environmental issues (Dong and Lin, 2020; Zhang et al., 2020a).

Establishing the effective management of N fertilization is one of the most difficult and important decisions to be made by producers since insufficient rates of N

reduce the development and yield of plants, as well as cause changes in the shape, color, and quality characteristics of tubers (Rens et al., 2018). On the other hand, over-fertilization increases the risk of environmental pollution, causes excessive vegetative growth, reduces starch accumulation, and increases the nitrate content in tubers (Elrys et al., 2021). Nitrates are in nature as part of the N cycle and play an essential role in the process of plant nutrition, growth, and development (Brkić, 2017). However, excess of nitrates in food increases the incidence of Methemoglobinemia (MetHba) and the formation of carcinogenic compounds. MetHba is a clinical syndrome, which can lead to death, caused by increased methemoglobin (MetHb) content (Greer and Shannon, 2005; Chui et al., 2005). This disease is caused by the unbalance in the reactions of reduction and oxidation induced by exposure to nitrite (Nascimento et al., 2008). The nitrite resulting from nitrate reduction promotes the oxidation of iron ions present in hemoglobin, transforming them from Fe^{2+} to Fe^{3+}, which prevents the transportation of oxygen to the cells. About, 4 to 7 % of the total nitrate ingested in food is reduced to nitrite in oral saliva (Walker, 1990). Overall, plant products account for 80 % of the source of nitrates ingested by humans, of which 32 % comes from potato consumption (Santamaria, 2006; Thomson, Nokes and Cressey, 2007; Bryan and van Grinsven, 2013). So, the high accumulation of nitrate in potatoes is a factor that requires a response, since the food industries use this tuber as a basis for preparing ready-to-eat baby foods, which may represent a possible health risk for children (Greer and Shannon, 2005).

The aspects that lead to the difference in nitrate levels in different vegetables are complex, and studies on the mechanisms of nitrate accumulation in vegetables are still scarce. Thus, further research on this topic becomes imperative since, besides the genetic factor, the management adopted (N fertilization, cultivars, light intensity, soil moisture, and temperature) also plays an essential role in the accumulation of nitrates in plants (Hmelak-Gorenjak and Cencič, 2013).

Therefore, establishing the correct management of N fertilization is essential for producers to achieve high yields and obtain tubers with appropriate nitrate content, not offering toxicological risks to human health.

3.5 CONCLUSION

The findings obtained in this study unveiled that the screening of sources and rates of N is important for building an effective potato nutrition program since the management of N fertilization can alter the performance of potato plants, influencing the agronomic outcomes and quality of tubers. In this manner, based on potato yield, the best strategy to maximize profits in the agricultural sector without compromising the quality of tubers is to apply 136 kg N ha^{-1} using urea as a source, which gives a nitrate content equal to 49.24 mg kg^{-1}, below the limit, recommended for human consumption (200 mg NO_3^- kg^{-1}).

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