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UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
FACULDADE DE ENGENHARIA
CÂMPUS DE ILHA SOLTEIRA

TAUAN RIMOLDI TAVANTI

**PHYSIOLOGICAL ROLES OF MAGNESIUM ON UREIDES METABOLISM OF
SOYBEAN PLANTS CULTIVATED IN HIGH ALTITUDE CERRADO**

Ilha Solteira
2021

PROGRAMA DE PÓS-GRADUAÇÃO EM AGRONOMIA

TAUAN RIMOLDI TAVANTI
Agronomist Engineer

**PHYSIOLOGICAL ROLES OF MAGNESIUM ON UREIDES METABOLISM OF
SOYBEAN PLANTS CULTIVATED IN HIGH ALTITUDE CERRADO**

Thesis presented to the Engineering College
of Ilha Solteira – UNESP as part of the
requirements to obtain the title of Doctor in
Agronomy. Specialization: Production
Systems

Prof. PhD. André Rodrigues dos Reis
Supervisor

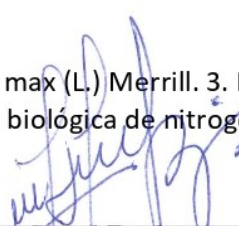
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AUTOR: TAUAN RIMOLDI TAVANTI

ORIENTADOR: ANDRÉ RODRIGUES DOS REIS

Aprovado como parte das exigências para obtenção do Título de Doutor em AGRONOMIA, área: Sistemas de Produção pela Comissão Examinadora:

Prof. Dr. ANDRÉ RODRIGUES DOS REIS (Participação Virtual)
Departamento de Engenharia de Biosistemas / FEI / UNESP - Tupa

Prof. Dr. MARCELO CARVALHO MINHOTO TEIXEIRA FILHO (Participação Virtual)
Departamento de Fitossanidade, Engenharia Rural e Solos / Faculdade de Engenharia de Ilha Solteira - UNESP

Prof. Dr. SALATIER BUZETTI (Participação Virtual)
Departamento de Fitossanidade, Engenharia Rural e Solos / Faculdade de Engenharia de Ilha Solteira - UNESP

Dr. FERNANDO SHINTATE GALINDO (Participação Virtual)
Centro de Energia Nuclear na Agricultura / Universidade de São Paulo - USP

Prof. Dr. CID NAUDI SILVA CAMPOS (Participação Virtual)
Universidade Federal de Mato Grosso do Sul-UFMS / Chapadão do Sul/MS

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“Que possamos transmitir a todos em nosso caminho,
a bondade de Deus que habita em nosso coração”
Alguimar Tavanti

ABSTRACT

Magnesium (Mg) is often overlooked in fertilization practices and agricultural research. However, its vital role is being increasingly recognized, considering its essentiality in several physiological processes in plants, such as photosynthesis, production and transport of photoassimilates, enzymatic antioxidant metabolism, nitrogen (N) metabolism and biological nitrogen fixation (BNF). The aim of this study was to provide an overview of how these processes are regulated by Mg. For this, chapter 1 of this study composes a systematic literature review, gathering information from 50 articles published in the last two decades about Mg. In chapters 2, 3 and 4, the objective was to evaluate the effect of doses (0 to 90 kg ha⁻¹) and sources of magnesium oxide (MgO) and magnesium sulfate (MgSO₄) on the photosynthetic process, production of photoassimilates, N and BNF metabolism in soybean varieties, since the role of Mg in BNF and ureide synthesis is still poorly understood. In chapter 1, the results of the literature demonstrate that the application of Mg increased photosynthetic pigments, liquid photosynthesis and production of photoassimilates. Higher sucrose concentrations in plant roots compared to shoots, together with increased activity of ATP-ases enzymes, indicate greater transport of photoassimilates by the phloem when Mg is applied. Mg increased the resistance of plants to abiotic stresses, reducing the need for expression of the antioxidant enzymes SOD, GPX, APX, CAT and POD, when compared to Mg deficient situations. Mg improved N and FBN metabolism, increasing the activity of nitrate reductase, nitrite reductase, glutamine synthase, GOGAT and nitrogenase enzymes. In chapter 2, the results showed that MgO increased the leaf Mg content of soybeans and did not change the levels of calcium (Ca) and potassium (K) in the leaf tissue, providing an increase in photosynthetic pigments and production of photoassimilates. There was an increase in the concentrations of nitrogen compounds and greater conversion of atmospheric N₂ into ureides in soybean plants. Regarding the results of chapter 3, the use of MgSO₄ increased the Mg content in soybean leaves, did not change the K content and reduced the Ca content. There was an increase in photosynthetic and photoassimilated pigments. Higher rates of photoassimilates provided greater conversion of atmospheric N₂ into ureides for NA 5909 RG RR (allantoin and allantoic acid) and P98Y30 (allantoic acid), indicating higher FBN. In chapter 4, MgO and MgSO₄ sources increased leaf Mg content and did

not change leaf Ca content in most varieties. With the application of Mg, the photosynthetic and photoassimilated pigments were increased. With greater production of photoassimilates, there was greater activity of N metabolism, due to greater production of amino acids and greater conversion of atmospheric N₂ and synthesis of ureides in most varieties, resulting in greater grain yield. The MgO source promoted the greatest increases in the concentrations of photosynthetic pigments, photoassimilates, ureides and grain yield for most varieties. This thesis contains up-to-date and valuable information on the influence of Mg on important physiological processes in plants. Incorporating these findings in future work can contribute to the optimization of fertilization programs and management strategies through magnesium fertilization in plants.

Keywords: Mg. *Glycine max* (L.) Merrill. biological nitrogen fixation. antioxidant metabolism. genotypic variation.

RESUMO

O magnésio (Mg) é frequentemente esquecido nas práticas de fertilização e pesquisas agrícolas. No entanto, seu papel vital está sendo cada vez mais reconhecido, considerando sua essencialidade em diversos processos fisiológicos nas plantas, como fotossíntese, produção e transporte de fotoassimilados, metabolismo antioxidante enzimático, metabolismo de nitrogênio (N) e fixação biológica de nitrogênio (FBN). O objetivo deste estudo foi fornecer uma visão geral de como esses processos são regulados pelo Mg. Para isso, o capítulo 1 deste estudo compõe uma revisão sistemática da literatura, reunindo informações de 50 artigos publicados nas últimas duas décadas sobre o Mg. Nos capítulos 2, 3 e 4, objetivou-se avaliar o efeito de doses (0 a 90 kg ha⁻¹) e fontes de óxido de magnésio (MgO) e sulfato de magnésio (MgSO₄) sobre o processo fotossintético, produção de fotoassimilados, metabolismo de N e FBN em variedades de soja, uma vez que o papel do Mg na FBN e síntese de ureídeos ainda é pouco conhecido. No capítulo 1, os resultados da literatura demonstram que a aplicação de Mg aumentou os pigmentos fotossintéticos, a fotossíntese líquida e a produção de fotoassimilados. As maiores concentrações de sacarose nas raízes das plantas em comparação com a parte aérea, juntamente com o aumento da atividade das enzimas ATP-ases, indicam maior transporte de fotoassimilados pelo floema quando o Mg é aplicado. O Mg aumentou a resistência das plantas a estresses abióticos, reduzindo a necessidade de expressão das enzimas antioxidantes SOD, GPX, APX, CAT e POD, quando comparado a situações de deficiência de Mg. O Mg melhorou o metabolismo do N e do FBN, aumentando a atividade das enzimas nitrato redutase, nitrito redutase, glutamina sintase, GOGAT e nitrogenase. No capítulo 2, os resultados mostraram que o MgO aumentou o teor foliar de Mg da soja e não alterou os teores de cálcio (Ca) e potássio (K) no tecido foliar, proporcionando aumento dos pigmentos fotossintéticos e produção de fotoassimilados. Houve aumento nas concentrações de compostos nitrogenados e maior conversão de N₂ atmosférico em ureídeos nas plantas de soja. Em relação aos resultados do capítulo 3, o uso de MgSO₄ aumentou o teor de Mg nas folhas de soja, não alterou o teor de K e reduziu o teor de Ca. Houve aumento de pigmentos fotossintéticos e fotoassimilados. Maiores taxas de fotoassimilados proporcionaram maior conversão de N₂ atmosférico em ureídeos para NA 5909 RG RR (alantoína e ácido alantóico) e P98Y30 (ácido alantóico), indicando maior FBN. No capítulo 4, as

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Palavras-chave: Mg. *Glycine max* (L.) Merrill; fixação biológica de nitrogênio; metabolismo antioxidante; variação genotípica.

Graphical abstract: The application of Mg increases the concentrations of Mg in plant tissues, promoting higher concentrations of photosynthetic pigments and liquid photosynthesis. This effect contributes to greater production and transport of photoassimilates in plants, positively influencing the activity of important enzymes belonging to the metabolism of N and FBN, with ureides as the final product. At the same time, the highest concentrations of intracellular Mg can alleviate the inhibitory action of different abiotic stressors in plants, reducing the production of ROS and, consequently, the activity of enzymatic antioxidant enzymes, when compared to situations deficient in Mg.

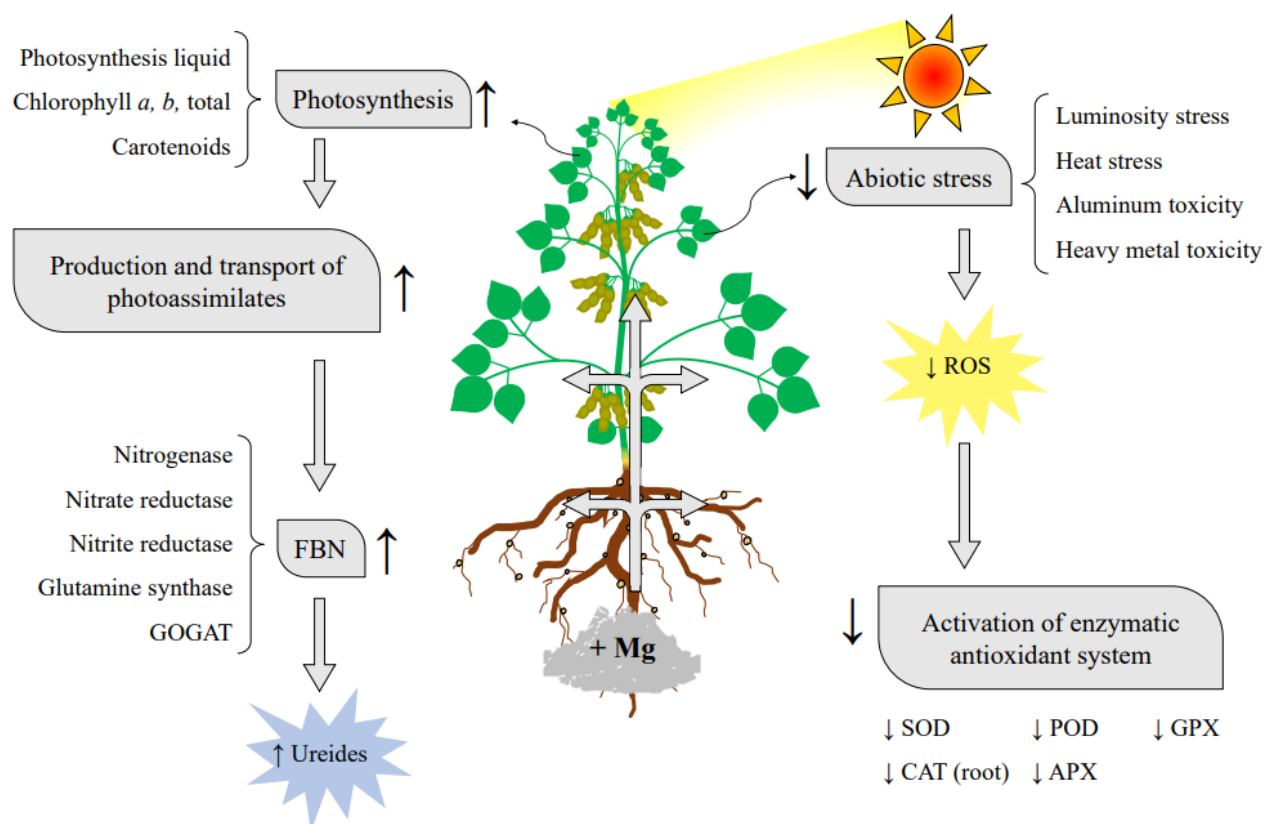


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consistent with innovative techniques aiming to increase soybean yield in field conditions.

4.7. CONCLUSION

The MgO and MgSO₄ application increased Mg concentration in soybean leaves without impairing leaf Ca concentration in most varieties evaluated.

The application of Mg improved photoassimilates (sucrose and total sugar) production in most varieties evaluated, indicating an enhancement in the photosynthetic process due to increased concentration of pigments. Under higher levels of photoassimilates, higher N₂ conversion occurred and higher ureides synthesis, indicating improvement in BNF efficiency.

Amino acids concentration increased under Mg application in most varieties, indicating higher N metabolism activity.

Between both Mg sources, MgO provided the highest increases to pigments (total chlorophyll, pheophytin b, and total pheophytin), total sugars, sucrose, and ureides in most soybean plants. While MgSO₄ application provided higher increases in chlorophyll b, pheophytin a, carotenoids, and amino acids.

This study provides valuable information about the Mg effect on BNF metabolism in soybean varieties. The presented results are important tools to further studies aiming to increase soybean grain yield and BNF by supplying Mg to the plants.

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