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LEAF PIGMENTS IN CAULIFLOWER CULTIVATED WITH DIFFERENT WATER CONDITIONS AND SILICON APPLICATIONS

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ABSTRACT - Environmental factors and crop management can influence the characteristics of plant morphology and physiology, altering photosynthetic efficiency and mass accumulation. The study aimed to analyze the contents of leaf pigments in cauliflower cultivated under different conditions of water availability and silicon (Si) applications. The experiment was carried out in a protected environment in the city of Maringá-PR. A randomized block design, in a 3x4 factorial scheme, with three replacement conditions [40, 70 and 100% of crop evapotranspiration (ETc)] and four Si doses (0, 50, 100 and 150 kg ha^{-1}), with four repetitions. The cauliflower cultivation, cultivar Sharon, was carried out in dystroferric RED NITOSOL. Daily evapotranspiration was determined with a constant level water table lysimeter and water replacement was performed with drip irrigation. Si was applied in split doses in three applications (initial, intermediate and final phases). At flowering, leaf tissue from the upper third of the plant was collected, with pigment extraction performed with pure acetone and determination in a spectrophotometer. At harvest, the leaf area of the plants was determined. Data were subjected to analysis of variance and regression analysis. Cauliflower crop under water-deficient reduces leaf area development and alters chloroplast pigments dynamics. Silicon use in the soil increases leaf development, chlorophyll a and b contents, and reduces carotenoids concentration. Under water stress conditions, silicon addition to the soil improves cauliflower performance.
Keywords: *Brassica oleracea* var. *botrytis*, physiological responses, water management.

PIGMENTOS FOLIARES EM COUVE-FLOR CULTIVADA EM DIFERENTES CONDIÇÕES HÍDRICAS E APLICAÇÕES DE SILÍCIO

RESUMO - Fatores ambientais e o manejo da cultura podem influenciar nas características da morfologia e da fisiologia das plantas, alterando a eficiência fotossintética e o acúmulo de massa. O estudo teve como objetivo analisar os teores de pigmentos foliares em couve-flor cultivada sob diferentes condições de disponibilidade hídrica e aplicações de silício (Si). O experimento foi desenvolvido em ambiente protegido no município de Maringá-PR. O delineamento em blocos ao acaso, em esquema fatorial 3x4, sendo três condições de reposição (40, 70 e 100% da evapotranspiração da cultura (ETc) e quatro doses de Si (0, 50, 100 e 150 kg ha^{-1}), com quatro repetições. O cultivo de couve-flor, cultivar Sharon, foi realizado em Nitossolo Vermelho distroférrico. A evapotranspiração diária foi determinada com lisímetro de lençol freático de nível constante, e a reposição hídrica realizada em irrigação por gotejamento. O Si foi aplicado com dose parcelada em três aplicações (fase inicial, intermediária e final). No florescimento foi coletado tecido foliar do terço superior da planta, com extração de pigmentos realizada com acetona pura e determinação em espectrofotômetro. Na colheita foi determinado a área foliar das plantas. Os dados foram submetidos a análise de variância e análise de regressão. O cultivo de couve-flor com déficit hídrico reduz o desenvolvimento da área foliar e altera a dinâmica de pigmentos cloroplastídicos. A utilização do silício no solo eleva o desenvolvimento foliar, os teores de clorofila a e b, e reduz a concentração de carotenoides. Em condições de estresse hídrico, a adição de silício ao solo melhora o desempenho da couve-flor.
Palavras-chave: *Brassica oleracea* var. *botrytis*, respostas fisiológicas, manejo hídrico.

INTRODUCTION

Cauliflower (*Brassica oleracea* var. *botrytis*) has gained prominence among the herbs in national production. Among the morphological traits, it brings elongated leaves, and it is the most efficient photosynthetic organ and with the greatest participation in mass accumulation until the flowering period (MAY et al., 2007). The plant development has a direct reflection in the crop productivity, and it is influenced by the characteristics of the ground, water, environment, productive management and cultural traits (TORRES et al., 2014; ANDREAN et al., 2021; TERASSI et al., 2021).

Due to a diversity of climate and soil conditions involved during their development, the plants have presented adaptations in order to maximize solar interception and raise photo-assimilated production (ALVES et al., 2020). Among the factors involved in determining the productive potential, we can highlight the

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number of leaves and leaf area, which can influence the photosynthetic efficiency when related to the angle of insertion and interception of light (TORRES et al., 2014).

Chlorophyll is the main pigment present in leaves, whose performance is directly related to photosynthesis (TAIZ et al., 2017). The total levels of chlorophyll *a*, chlorophyll *b* and chlorophyll are changed according to water regime, solar incidence and nutrition (SALES et al., 2018; MAIA JÚNIOR et al., 2017; OLIVEIRA et al., 2018; CRUZ et al., 2018). With regard to nutritional and productive factors, the determination of leaf pigments can be adopted as a tool to help in determining crop management, with qualification performed through destructive and non-destructive techniques (FREIRE et al., 2013; XIAOYAN et al., 2020).

The occurrence of water deficit in cultivation can significantly affect its potential of production, with changes in biochemical processes and nutrient flows with a variable degree of damage in the level of restriction and development stage (HACHMANN et al., 2019; FERREIRA et al., 2019). Silicon, considered a beneficial element in unfavorable conditions, can raise photosynthetic efficiency, and mitigate stress effects (MENEGALE et al., 2015). This way, this study aimed at quantifying the chlorophyll contents in cauliflower submitted to different levels of water availability and silicon doses.

MATERIALS AND METHODS

The study was developed at the Center for Irrigation Technology (CIT) located at 23°25'S, 51°57' O and 542 m high, in the municipality of Maringá (Paraná State), which belongs to State University of Maringá (UEM). The place has an annual rainfall between 1400 and 1600 mm and temperature between 22.1 and 22ºC as climate characteristics, and an average solar radiation of 14.5 to 15 MJ m^{-1} day^{-1} and annual evapotranspiration between 1000 to 1100 mm (NIETSCHE et al., 2019).

The experiment was conducted in a protected environment, in randomized blocks with treatment in factorial scheme 3x4, and three water reposition conditions (40,70 and 100% of daily evapotranspiration) and four doses of silicon (0, 50, 100 e 150 kg ha^{-1}), with four repetitions for treatment.

For cultivation, cauliflower hybrid Sharon was used, sown in polyethylene trays with 128 cells, being transplanted within 45 days to beds with 3m length, 0.5 m width and 0.25 m high. The soil is regarded as dystroferric RED NITOSOL (SANTOS et al., 2018), with clay content over 70%, it showed an average density of Mg m^{-3}, and chemical characteristics described in Table 1. It was fertilized with 30 kg ha^{-1} from N, 250 kg ha^{-1} from P_2O_5, 100 kg ha^{-1} from K_2O and 4 kg ha^{-1} from B incorporated to soil.

TABLE 1 - Chemical characterization of soil.

pH $CaCl_2$	pH SMP	Al^{3+}	H^+	Ca^{2+}	Mg^{2+}	K^+	Capacity of cations exchange (effective)
		$cmol_c$ dm^{-3}					
6.70	7.10	0.00	2.17	12.31	2.70	0.92	15.93
Organic material	P	P remainder	S	B	Cu	Fe	Zn
%	mg dm^{-3}						
1.99	98.88	18.96	129.70	0.06	14.70	71.16	9.66

The determination of daily evapotranspiration was performed using lysimeters of constant level groundwater, and the irrigation was done with drippers with flow rate of 5 L h^{-1} and coefficient of uniformity (CUC) equivalent to 94%. The application of silicon was performed with installment doses in three applications (initial phase, intermediate and final phase), using as a source silicon oxide, diluted in water (2 L) and applied over the soil surface.

Culture was conducted according to technical recommendations for pests and diseases management. Weed control was performed manually during all culture circles. During flourishing, leaf segments were collected from the superior third to determine chlorophyll and carotenoid contents. The extraction was performed using 150 mg of fresh mass of leaf, packaged in Eppendorf with pure acetone (1.5 mL), being kept in low temperature environment with absence of light. The quantification (ug g^{-1}) of chlorophyll pigments *a*, chlorophyll *b*, total chlorophyll (*a*+*b*) and carotenoids was performed using values of absorbance in spectrophotometer at lengths of wave of 661.4; 644.8 and 470 nm and it was calculated according to Lichtenthaler (1987).

In harvest it was determined the leaf area with equipment LI-COR® (model LI 3100), and from the average values it was calculated the relative percentage in conditions of water deficit (40 and 70% of ETc) in relation to condition without water deficit (100% ETc) in different conditions of application of Si and the accumulation of dry mass. Data from pigment content have undergone variance analysis, through test F ($p<0.05$) and regression analysis, and Math models and coefficient of determination.

RESULTS AND DISCUSSION

The adoption of water restriction and application of nutrients can change characteristics related to the morphological and physiological development of plants, with reflections over their income (HACHMANN et al., 2019; FERREIRA et al., 2019). Leaf development is related to nutritional conditions, a main factor in photosynthetic activity (TAIZ et al., 2017). The presence of water deficit in the absence of application of Si has reduced the development of leaf area from 23 to 30% (Table 2). The application of Si has mitigated the water deficit, minimizing the reduction of leaf areas in the condition of 40% of ETc and increasing the development of the condition of reposition of 70% of ETc (Table 2). The acting of Si is related to the dynamic of nutrients, reduction of transpiration and increasing of photosynthetic efficiency (MENEGALE et al., 2015; SOUZA et al., 2015).

Regarding the accumulation of dry mass by area unit, there was an improvement, mainly for high water restriction conditions (40% ETc) for quantities up to 100 kg ha^{-1} of Si (Figure 1).

The total chlorophyll contents and carotenoids, which are straightly related to photosynthetic activity, have had variation of environmental conditions and of management, as an adaptive strategy in order to obtain maximum interception of sunlight (ALVES et al., 2020). However, stress conditions such as water deficits can be harmful to one or more leaf pigments (MAIA JÚNIOR et al., 2017). The total chlorophyll has demonstrated a meaningful variability ($p<0.05$) between doses of Si in different levels of water reposition, and the dynamic presented by squared models (Figure 2).

TABLE 2 - Variation of average leaf area.

Si (kg ha^{-1})	Level of reposition (% ETc)		
	100	70	40
0	-	-23.77	-30.60
50	1.12	2.29	-6.26
100	11.71	10.96	-12.33
150	25.96	2.94	-11.32

*Control treatment = 0 kg ha^{-1} of Si and water reposition of 100% ETc.

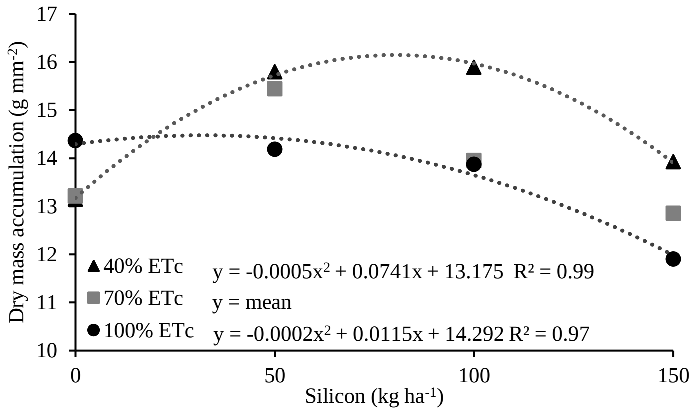


FIGURE 1 - Dry mass accumulation in cauliflower leaves cultivated in a protected environment under different conditions of water reposition and silicon application.

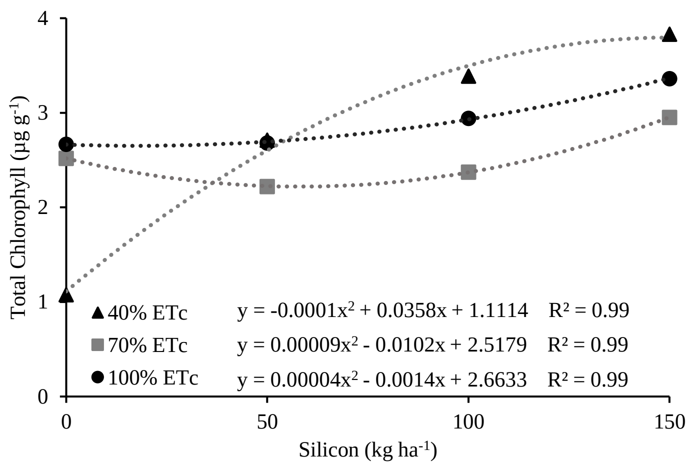
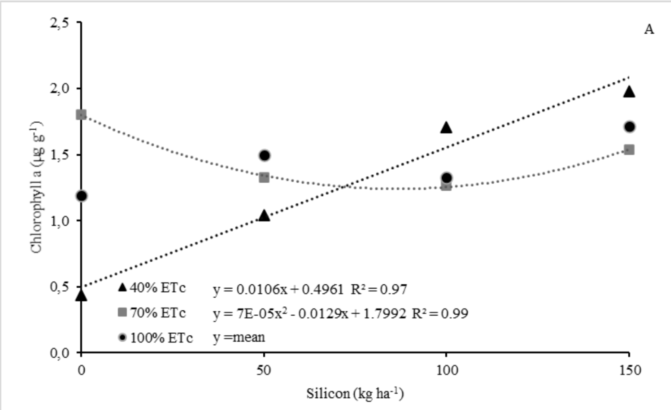


FIGURE 2 - Total chlorophyll content in cauliflower leaves cultivated in different conditions of water reposition and silicon application.

Among plants with intensive deficit, in conditions of 40% ETc, the total chlorophyll variation was higher in Si application than in comparison to treatment without application. Water availability has a straight correlation to chlorophyll and leaf temperature, and damages have occurred by high restriction. However, the element functions in the leaf, keeping the water potential of tissue and conservation in biochemical activity (SOUZA et al., 2015). In cauliflower, the improvement in leaf development by using Si is also observed in stress conditions by ammonium concentration (BARRETO et al., 2017).

The cultivation management can be performed in different forms with each component, chlorophyll of chlorophyll b, and changes have been reported only in chlorophyll b content due to using sources of organic material and bovine biofertilizer (FREIRE et al., 2013; SALES et al., 2018). Moreover, concerning chlorophyll b there is a change in contents due to the water system adopted (MAIA JÚNIOR et al., 2017). Regarding the chlorophyll contents a and b, individually there wasn't a meaningful increase to the condition without water deficit (Figure 3).



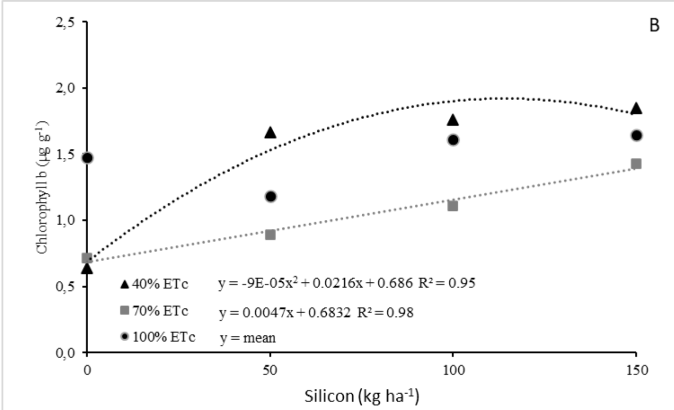


FIGURE 3 - Chlorophyll pigments in cauliflower cultivated in different conditions of water reposition and silicon application. a) Chlorophyll *a* (µg g^{-1} of fresh leaf mass), b) Chlorophyll *b* (µg g^{-1} of fresh leaf mass).

The chlorophyll content *a* for reposition of 40% ETc has performed a linear increase due to an increment in the dose of Si. Nevertheless, in order to get a reposition of 70% ETc, the increment in the supply of silicon to the plants has resulted in a decrease in of chlorophyll *a* content (Figure 3A), whereas to the chlorophyll *b* contents the application of Si has raised the concentration of that pigment (Figure 3B).

The dynamic of chlorophyll content a and *b* in leaves and the relation of pigments is influenced by environmental and managing factors (GALVÍNCIO et al., 2010). In arugula, chlorophyll *b* content and the total chlorophyll content b are influenced by environmental factors, whereas the chlorophyll and mass action have been influenced by management and fertilizing. (MOURA NETO et al., 2021). The application of Si has also raised the levels of chlorophyll *a* and *b*, besides productive components of the culture of rice with different conditions of nitrogenous fertilizing (ÁVILA et al., 2010). On the other hand, in tomatoes, the usage of this element having sources K_2SiO_3, has resulted in meaningful increments in chlorophyll *a* content (RODRIGUES et al., 2016).

The determination of the characteristics of chlorophyll, such as fluorescence, can be adopted to identify stress conditions in plants such as cowpea (OLIVEIRA et al., 2018). Besides chlorophyll, with the development conditions of plants, the carotenoids are variable, whose levels are criteria for the selection of plants (ALVES et al., 2020; DIAS et al., 2020). In this study, the carotenoid content has demonstrated a correlation with chlorophyll *b* (-0.62), and in the condition without deficit there wasn't meaningful variation due to Si (Figure 4).

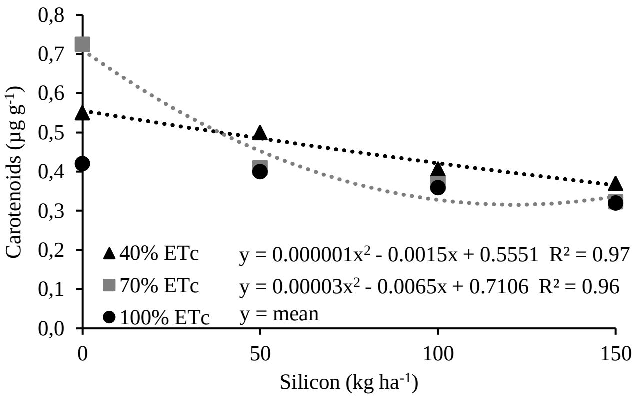


FIGURE 4 - Carotenoids content in cauliflower leaves cultivated in different conditions of water reposition and silicon application.

In cultivation with water deficit, the utilization of Si has reduced carotenoids content in leaves (Figure 4); avoiding damage to chlorophyll molecules, and in stress conditions can show an increase in content as a physiological response of the plant (CAVALCANTE et al., 2011). Being produced by plants under water stress, photoprotector pigments (carotenoid and chlorophyll b) prevent the photooxidation of chlorophyll *a* in the process of photosynthesis (MARQUES et al., 2011; TAIZ et al., 2017). It happens because, under water deficit, plants decrease the leaf water potential and regulate stomata opening, reducing its photosynthesis and transpiration and invest in chlorophyll *b* production (FRANÇA et al., 2017).

Time changes in photochemical efficiency and in pigment content are a response to stress caused by environmental conditions, water salinity within irrigation, fertilizing and application of phytosanitary products (SILVA et al., 2020; FREIRE et al., 2013; SALES et al., 2018, SILVA et al., 2016). This way, the reduction of carotenoid content by application of Si indicates a reduction of water stress. The measurement of leaf pigments can be performed in order to analyze and understand the influence of the conditions of cultivation over the physiological and productive aspects that reflect onto the efficiency in the usage of the resources. Therefore, it is important the development of new researches with cauliflower and other plant species.

CONCLUSIONS

The cultivation of cauliflower with water deficit reduces the development of leaf area and changes the dynamic of chloroplast pigments.

The use of silicon in soil raises the leaf development, the chlorophyll *a* and b contents, and reduces the carotenoid concentration.

When in conditions of water stress, the adding of silicon in soil improves the cauliflower performance.

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REFERENCES

ANDREAN, A.F.B.A.; REZENDE, R.; SOARES WENNECK, G.; HARA, A.T.; MENEZES, C.S.L.; TERASSI, D.S. Aspectos agronômicos da formação da inflorescência da couve-flor sob diferentes condições hídricas. **Irriga**, v.1, n.2, p.308-320, 2021.

ALVES, T.N.; ECHER, M.M.; COUTINHO, P.W.R.; MACEDO JÚNIOR, E.K.; KLOSOWSKI, E.S.; SACKSER, G.A.B.; BLACK, A.V.; INAGAKI, A.M. Efeitos dos consórcios com quiabeiro nas características físico-químicas da couve de folha sob manejo orgânico. **Brazilian Journal of Development**, v.6, n.10, p.79987-80001, 2020.

BARRETO, R.F.; SCHIAVON JÚNIOR, A.A.; MAGGIO, M.A.; PRADO, R.D. Silicon alleviates ammonium toxicity in cauliflower and in broccoli. **Scientia Horticulturae**, v.225, p.743-750, 2017.

CAVALCANTE, L.F.; DIAS, T.J.; NASCIMENTO, R.; FREIRE, J.L.O. Clorofila e carotenoides em maracujazeiro-amarelo irrigado com águas salinas no solo com biofertilizante bovino. **Revista Brasileira de Fruticultura**, v.33, n.1, p.699-705, 2011.

CRUZ, A.F.S.; SILVA, G.F.; SILVA, E.F.F.; SOARES, H.R.; SANTOS, J.S.G.; LIRA, R.M. Stress index, water potentials and leaf succulence in cauliflower cultivated hydroponically with brackish water. **Revista Brasileira de Engenharia Agrícola e Ambiental**, v.22, n.9, p.622-627, 2018.

DIAS, L.A.; SILVEIRA, P.H.A.M.; OMURA, S.S.; GARCIA, B.; OLIVEIRA, R.E.V.; PEREIRA, M.S.C. Determinação de teores de clorofilas e carotenoides em alface, rúcula e cebolinha. **Brazilian Journal of Animal and Environmental Research**, v.3, n.4, p.3100-3107, 2020.

FERREIRA, A.R.; LIMA JÚNIOR, J.A.; OLIVEIRA, P.D.; AVIZ, W.L.C.; SANTOS, H.C.A. Desempenho produtivo de couve-flor submetida a diferentes manejos de irrigação e doses de boro em ambiente protegido. **Revista Engenharia na Agricultura**, v.27, n.5, p.440-451, 2019.

FREIRE, J.L.O.; CAVALCANTE, L.F.; NASCIMENTO, R.; REBEQUI, A.M. Teores de clorofila e composição mineral foliar do maracujazeiro irrigado com águas salinas e biofertilizante. **Revista de Ciências Agrárias**, v. 36, p. 57-70, 2013.

GALVÍNCIO, J.D.; PIMENTEL, R.M.M.; FERNANDES, J.G. Relação da temperatura do ar e do solo com a quantidade de clorofila a e b em jurema preta (*Mimosa tenuiflora* (Willd) Poiret) no semi-árido do Nordeste do Brasil. **Revista Brasileira de Geografia Física**, v.3, n.1, p.41-46, 2010.

HACHMANN, T.L.; REZENDE, R.; PINTRO, P.T.M.; SAATH, R.; ANJO, F.A.; MENEZES, C.S.L. Yield, antioxidant activity and shelf-life of cauliflower inflorescences under drought stress and foliar spraying of selenium. **Ciência e Agrotecnologia**, v.43, e017819, 2019.

MAIA JÚNIOR, S.O.; ANDRADE, J.R.; FERREIRA, R.S.; ARAÚJO, D.L.; GUERRA, H.O.C.; SILVA, F.G. Teores de pigmentos, fluorescência da clorofila a e índice SPAD em cultivares de girassol sob regimes hídricos. **Revista Agrarian**, v.10, n.36, p.105-112, 2017.

MARQUES, R.P.; FREIRE, C.S.; NASCIMENTO, H.H.C.; NOGUEIRA, R.J.M.C. Relações hídricas e produção de pigmentos fotossintéticos em mudas de *Eugenia uniflora* L. sob condições de salinidade. **Revista Brasileira de Geografia Física**, v.4, n.3, p.497-509, 2011.

MAY, M.; TIVELLI, S.W.; VARGAS, P.F.; SAMRA, A.G.; SACCONI, L.V.; PINHEIRO, M.Q. **A cultura da couve-flor.** Campinas: Instituto Agronômico, 2007.

MENEGALE, M.L.C.; CASTRO, G.S.A.; MANCUSO, M.A. Silício: interação com o sistema solo-planta. **Journal of Agronomic Sciences**, v 4, n. especial, p.435-454, 2015.

NITSCHE, P.R.; CARAMORI, P.H.; RICCE, W.S.; PINTO, L.F.D. **Atlas Climático do Estado do Paraná**. Londrina: IAPAR, 2019.

MOURA NETO, A.; MOURA, B.S.; SILVA, L.L.S.; PORTELA, W.N.; LIMA, E.A.; GONÇALVES JUNIOR, A.S.; RODRIGUES, L.S.; ROCHA, J.G.J.H. Teores de clorofila da rúcula em função de diferentes ambientes e doses de esterco caprino. **Brazilian Journal of Development**, v.7, n.1, p.6502-6512, 2021.

OLIVEIRA, W.J.; SOUZA, E.R.; SANTOS, H.R.B.; SILVA, E.F.F.; DUARTE, H.H.F.; MELO, D.V.M. Fluorescência da clorofila como indicador de estresse salino em feijão caupi. **Revista Brasileira de Agricultura Irrigada**, v.12, n.3, p.2592-2603, 2018.

RODRIGUES, C.R.; RODRIGUES, T.M.; LUZ, J.M.Q.; SOUSA, V.B.F.; SOUSA, J.B.; NUNES, A.C.P.; TRINDADE, P.R. Clorofila a e b de tomateiro tratado com silicato de potássio e fungicida. **Global Science and Technology**, v.9, n.2, p.54-64, 2016.

LICHTENTHALER, H.K. Chlorophylls and carotenoids: pigments of photosynthetic biomembranes. **Methods in Enzymology**, v.148, n.1, p.350-382, 1987.

SALES, R.A.; SALES, R.A.; SANTOS, R.A.; QUARTEZANI, W.Z.; BERILLI, S.S.; OLIVEIRA, E.C. Influência de diferentes fontes de matéria orgânica em componentes fisiológicos de folhas da espécie *Schinus terebinthifolius* Raddi (Anacardiaceae). **Revista Scientia Agraria**, v.19, n1, p.132-141, 2018.

SANTOS, H.G.; JACOMINE, P.K.T.; ANJOS, L.H.C.; OLIVEIRA, V.A.; LUMBRERAS, J.F.; COELHO, M.R.; ALMEIDA, J.A.; ARAÚJO FILHO, J.C.; OLIVEIRA, J.B.; CUNHA, T.J.F. **Sistema Brasileiro de Classificação de Solos.** 5. ed. Brasília: EMBRAPA, 2018.

SILVA, C.B.; SILVA, J.C.; BRANDÃO JUNIOR, W.Q.; DAMASCENO, F.A.; BARBOSA JÚNIOR, M.R.; SANTOS, M.A.L. Teor de clorofila, carotenoides e índice SPAD na alface (*Lactuca sativa*) em função de lâminas de irrigação e níveis salinos. **Ciência Agrícola**, v.18, n.13, p.19-22, 2020.

SILVA, L.Q.; ARAÚJO, A.C.F.; ALMEIDA, G.M.; CRISPIM FILHO, A.J.; COSTA, A.C.; JAKELAITIS, A. Modificações fisiológicas em folhas de pequi (*Caryocar brasiliense*) causadas pela aplicação de glyphosate. **Revista Brasileira de Herbicidas**, v.15, n.2, p.184-194, 2016.

SOUZA, L.C.; MELO, N.C.; SIQUEIRA, J.A.M.; SILVA, V.F.A.; OLIVEIRA NETO, C.F. Comportamento bioquímico no milho submetido ao déficit hídrico e a diferentes concentrações de silício. **Revista Agrarian**, v.8, n.29, p.260-267, 2015.

TAIZ, L.; ZEIGER, E.; MÖLLER, I.M.; MURPHY, A. **Fisiologia e Desenvolvimento Vegetal.** 6ª ed., Artmed, 2017. 918p.

TERASSI, D.S.; REZENDE, R.; WENNECK, G.S.; MENEZES, C.S.L.; ANDREAN, A.F.A.; VILA, V.V.; SILVA, L.H.M. Broccoli production with regulated deficit irrigation at different phenological stages. **Journal of Agricultural Science**, v.13, n.12, p.71-80, 2021.

TORRES, J.L.R.; VALLE, D.X.P.; CUNHA, M.A. Aspectos morfológicos e produtividade da cultivar Sharon de couve-flor cultivada em diferentes solos. **Magistra**, v. 26, n.2, p.124-132, 2014.

XIAOYAN, W.; ZHIMWEI, L.; WENJUN, W.; JIAWEI, W. Chlorophyll content for millet leaf using hyperspectral imaging and an attention convolutional neural network. **Ciência Rural**, v.50, n.3, e20190731, 2020.