NDVI AS SALINE STRESS INDICATOR IN BELL PEPPER PLANTS CV. ALL BIG TREATED WITH HUMIC ACID

Ana Carolina Santos Lima[1], Genilson Lima Santos[2], Bismarc Lopes da Silva[2], Rosilene Gomes de Souza Pinheiro[2], Filipe Moreira Sousa[1], Cristiano Tagliaferre[3]

ABSTRACT: Irrigation is indispensable where water deficit occurs, but agricultural production can be limited by the quality of irrigation water. Salinity management strategies using humic substances have been assessed to attenuate the effects of salinity on plants. Also, identifying plant stress early is crucial to prevent production losses. Thus, this study aimed to evaluate if NDVI can detect differences in bell pepper plants under irrigation with saline water and if the use of humic acid attenuates saline stress. The experimental design was randomized complete blocks, in a 5 × 4 factorial arrangement, five humic acid doses and four saline water levels. Humic acid did not attenuate salt stress, but NDVI was effective in detecting salt stress in bell pepper plants.
KEYWORDS: abiotic stress, humic substances, Capsicum annuum L.

NDVI COMO INDICADOR DE ESTRESSE SALINO EM PIMENTÃO ALL BIG TRATADAS COM ÁCIDO HÚMICO

RESUMO: A irrigação é indispensável em regiões onde ocorre déficit hídrico, mas a produção agrícola pode ser limitada pela qualidade da água. Estratégias de manejo da salinidade usando substâncias têm sido avaliadas para atenuar os efeitos da salinidade nas plantas. Além disso, a identificação precoce do estresse é fundamental para evitar perdas de produção. Desse modo, este trabalho teve como objetivo avaliar se o NDVI pode detectar diferenças em plantas de pimentão sob irrigação com água salina e se o uso de ácido húmico atenua o estresse salino. O delineamento experimental utilizado foi blocos ao acaso, em esquema fatorial 5 x 4, cinco doses

[1] Discente de Mestrado, Programa de Pós-Graduação em Agronomia, Universidade Estadual do Sudoeste da Bahia (UESB), Vitória da Conquista, BA. (77) 3424-8771, carolslima@outlook.com
[2] Discente de Doutorado, Programa de Pós-Graduação em Agronomia, UESB, Vitória da Conquista, BA
[3] Prof. Doutor, Depto. de Engenharia Agrícola e Solos, UESB, Vitória da Conquista, BA

de ácido húmico e quatro níveis de água salina. O ácido húmico não atenuou o estresse salino, porém o NDVI foi eficaz para detectar o estresse salino em plantas de pimentão.
PALAVRAS-CHAVE: estresse abiótico, substâncias húmicas, Capsicum annuum L.

INTRODUCTION

Water shortage can be a limiting factor for agricultural production, especially for crops that are sensitive to water deficit, such as vegetables. Thus, the practice of irrigation is indispensable in arid and semi-arid regions (ABIOYE et al., 2022). Agricultural production can also be limited by the quality of irrigation water. Due to the capture of subsurface waters, there is often water with higher amounts of salts such as calcium, magnesium, and sodium (LIMA et al., 2020).

Irrigation with saline water can result in adverse effects on soil-water-plant relationships and cause severe restrictions on the physiological activities and productive potential of cultivated plants (SAFDAR et al., 2019). Intensive management carried out in crops in protected environments can also cause soil salinization. Since plastic cover isolates the soil from rain, it results in strong transpiration and the rise of water in soil through capillarity, accumulating salts in soil that might be harmful to crops (FAN, 2021).

Recently, studies have reported good results concerning salinity management strategies. In addition to the use of leaching fractions, several substances have been assessed to attenuate the effects of salinity on plants, such as proline, ascorbic acid, hydrogen peroxide and humic acid (ALI et al., 2020; EL-KADY & BORHAM, 2020).

Identifying plant stress early is crucial to prevent production losses. Non-destructive methods have been noteworthy lately, including remote sensing methods. Reflectance indices have been used successfully to detect water stress in bell pepper plants under greenhouse conditions (IHUOMA & MADRAMOOTOO, 2019). It also detected saline stress in Arabidopsis thaliana seedlings and Eruca sativa before it was visible (BEISEL et al., 2018).

During photosynthesis, plants utilize red light (R) as an energy source, while reflecting near-infrared light (NIR) (BAYAT et al., 2018). NDVI values range from -1 to 1, where a higher value indicates a healthier plant with a greater amount of chlorophyll (ZUZULOVA & VIDO, 2018). Unlike specialized sensors that can detect infrared light reflections, the human eye is unable to perceive this specific wavelength. Consequently, NDVI technology enables the early detection of plant stressors that may not be visible to the naked eye.

The development of studies and management techniques that can identify and attenuate the effects of saline stress is essential. Therefore, this study aimed to evaluate if the Normalized Difference Vegetation Index (NDVI) can detect differences in bell pepper plants under irrigation with saline water and if the use of humic acid attenuates saline stress.

MATERIAL AND METHODS

This study was carried out in a greenhouse located at the State University of Southwest Bahia, in the municipality of Vitória da Conquista, Bahia (14º 53' 08" S, 40º 48' 02" W, and altitude of 881 m). The climate, according to the Köppen classification, is Cwb type (Subtropical highland climate) (SEI, 2014).

During the study, an automatic meteorological station, model Davis Vantage Pro, was used to monitor meteorological data inside the greenhouse (Figure 1). The average temperature and relative humidity (RH) were 23ºC and 75.6%, respectively. The soil, classified as sandy clay loam, was collected from 0 to 20 cm deep surface soil layer in an adjacent field. Liming was carried out according to physicochemical soil analysis (pH (H_2O) = 5.2; P = 3.0 mg dm^{-3} (Mehlich-1 Extractor); K^+ = 0.26 cmolc dm^{-3} (Mehlich-1 Extractor); Ca^{2+} = 0.9 cmolc dm^{-3} (KCl 1N Extractor); Mg^{2+} = 0.6 cmolc dm^{-3} (KCl 1N Extractor); Al^{3+} = 0.3 cmolc dm^{-3} (KCl 1N Extractor); H^+ = 2.8 cmolc dm^{-3} ($CaCl_2$ 0,01M); Sum of bases (SB) = 1.8 cmolc dm^{-3}; effective CEC (t) = 2.1 cmolc dm^{-3}; CEC in pH 7 (T) = 4.9 cmolc dm^{-3}; Base saturation (V) = 36 %; Aluminum saturation (m) = 15 % and Organic matter (OM) = 14 mg dm^{-3}) to raise the percentage of the sum of exchangeable bases according to local recommendations.

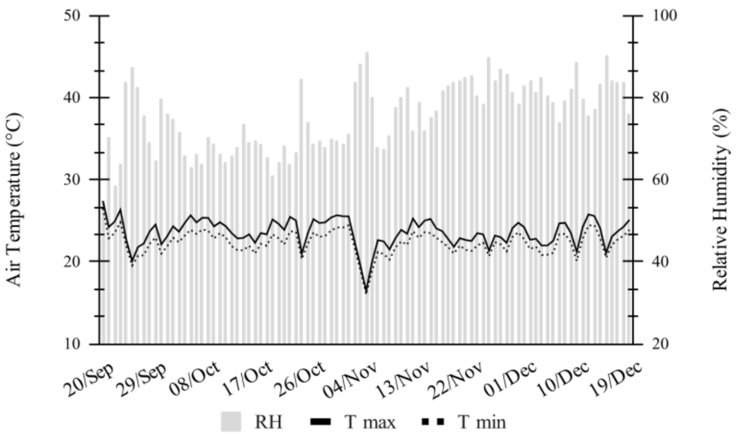

Figure 1. Maximum, minimum temperature and relative humidity during the experimental period.

The experimental design was randomized complete blocks (RCBD), in a 5 x 4 factorial arrangement, with three replicates. The plants were bell pepper cultivar All Big, seeds were sown in polystyrene trays, with 128 cells, and the seedlings were kept for approximately 20 days in the trays after emergence and then transplanted to 20 L pots. The treatments were five humic acid doses and four proportions of non-saline water:saline water levels.

Saline water treatments contained four salinity levels (100, 75, 50, and 0%) with an equivalent electrical conductivity (EC) of 3.77, 2.99, 2.40, and 0.35 dS m^{-1}, respectively. The saline water was supplied by groundwater from a water well. Humic acid treatments were composed of five levels: 0.0, 1.5, 3.0, 4.5, and 6.0 L ha^{-1}. These levels were obtained using the commercial product Ecohumic® with a 30% concentration of total humic extract, which was applied on the soil in two separate instances to prevent leaching.

Spectral reflectance, expressed as normalized difference vegetation index (NDVI), was measured using a handheld optical sensor (GreenSeeker®, Trimble, USA). The device uses red (660 nm) and infrared (780 nm) bands and converts reflected data into NDVI directly. The readings were collected by holding the equipment at a height of about 0.5 m above the plant canopy. NDVI is calculated using the formula: NDVI = (NIR-R)/(NIR+R) (HUANG et al., 2020).

The data obtained from the study were initially tested for normality using the Shapiro and Wilk test ($p \leq 0.05$). Then they were subjected to analysis of variance (ANOVA) using the F-test ($p \leq 0.05$) according to the experimental design, which was a factorial design. Regression analysis was used to discern whether there was a linear or non-linear response to humic acid doses. The means were compared when significant factors or interactions were observed using the Tukey test ($p \leq 0.05$) on R Studio software (POSIT TEAM, 2022).

RESULTS AND DISCUSSION

According to the results of the analysis of variance, the mean of squares due to salinity levels was significant. The interaction of salt stress and humic acid, and the treatment of humic acid were not significant at the 5% probability level. Shapiro-Wilk test at 5% significance showed that the residuals can be considered normal by showing a p-value = 0.79.

A negative correlation was found between NDVI and salinity levels, the index decreased as the salinity levels increased (Figure 2). Plant stress caused by saline water can harm plant development. The presence of excessive salts in soil leads to a reduction in plant water uptake due to the decreased osmotic potential of soil. Consequently, this decline in water uptake results in a decrease in plant development and the accumulation of dry mass (SAFDAR et al., 2019).

NDVI is one of many vegetation indices that can be obtained through spectral reflectance. It is a combination of red and infrared reflectance and has a great correlation with plant morphological and physiological characteristics (KASIMATI, 2023). A study on the definition of the best index to identify stress in bell pepper plants showed that vegetation indices could detect water stress (IHUOMA & MADRAMOOTOO, 2019).

Beisel et al. (2018) studying Arabidopsis thaliana showed that saline stress can be detected by NDVI in up to 15 minutes after the plant has been exposed to saline treatments. When the plant is under saline stress, it responds by closing its stomata, which leads to a decrease in various biochemical processes including the photoassimilates production, as well as cell growth and division (SHAHID et al., 2020). Thus, reducing photosynthetic pigments indicates the plant is absorbing less red light, resulting in lower NDVI.

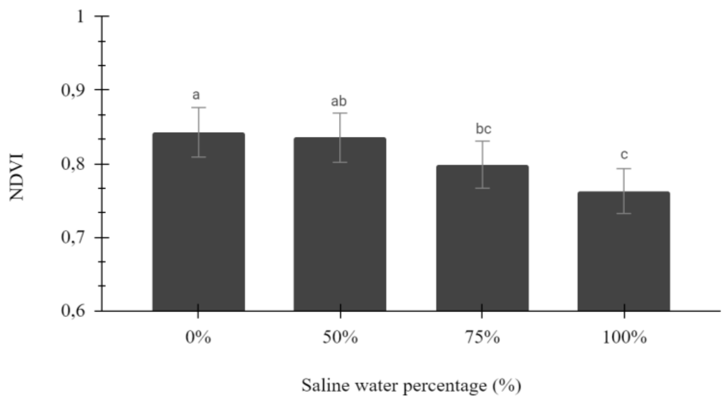

Figure 2. Effect of saline water on normalized difference vegetation index (NDVI) of bell pepper plants.

CONCLUSION

Normalized Difference Vegetation Index collected by a handheld device was effective to distinguish differences between plants under saline stress and non-stressed plants. Water dilution attenuated saline stress and the 50:50 proportion did not differ significantly from the control treatment.

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