Capturing micro-vibration images in plants caused by homeopathic application

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Abstract – The use of images, sensors and mathematical algorithms can help in the generation of technical attributes and facilitate the plant health diagnosis. Combined with this, computer vision provides a non-destructive and non-invasive strategy for collecting samples and analyzing plant propagules, provided the experiment traceability. Thus, the objective of this research was to identify signs of homeopathies of Magnetitum and Arsenicum tartaricum applied in purslane [Pilea microphylla (L.) Liebm.], using computational algorithms. The work of images capturing was carried out in the Laboratory of Plant Production and Didactic Garden of the Agronomy Course, UNISUL University. To evaluate signs in plants, based on the images, algorithms found in VibaHT® and ImageJ were used. The images were generated by webcam (online) and two homeopathies at 250 milesimal were applied for 14 days. The experimental procedure consisted of generating "640 × 480" pixel images from a transformed webcam to simulate a "red-green-NIR" (RGN) sensor, replacing the channel with a blue light filter and thus produce a near-infrared image (NIR). The images were also generated in their normal "red-green-blue" (RGB) channels to test the algorithms' competence. After capturing the images, mathematical analyzes of the pixel's variation were performed, represented by three variables, developed by specific algorithms: lacunarity, entropy and stress. The number of experimental repetitions was sufficient to identify significant differences at the 1% probability level between the images, and the algorithms were robust to identify the signs of homeopathy.

Index terms: Agrohomeopathy; Vibraimage; Electric tension; Computational vision.

Captação de microvibrações da imagem para identificação de sinais de homeopatia em plantas

Resumo – O uso de imagens, sensores e algoritmos matemáticos podem auxiliar na geração de atributos técnicos e facilitar o diagnóstico do estado de saúde das plantas. Combinado a isto, a visão computacional proporciona uma estratégia não-destrutiva e não-invasiva na coleta de amostras e na análise propágulos vegetais, facilitando a rastreabilidade do experimento. Assim, o objetivo desta pesquisa foi identificar sinais das homeopatias Magnetitum e Arsenicum tartaricum aplicadas em plantas de beldroega [*Pilea microphylla* (L.) Liebm.], com o uso de algoritmos computacionais. O trabalho de captação das imagens foi realizado em laboratório de Produção Vegetal e Horto Didático do Curso de Agronomia da UNISUL Universidade. Para avaliar as plantas, com base nas imagens, foram utilizados algoritmos encontrados no VibaHT® e no ImageJ. As imagens foram geradas por webcam (online) e duas homeopatias na 250 milesimal foram aplicadas durante 14 dias. O procedimento experimental consistiu em gerar imagens 640 × 480 pixels a partir de uma webcam transformada para simular um sensor "red-green-NIR" (RGN) substituindo o canal por um filtro de luz azul e assim, produzir uma imagem do infravermelho próximo. Também foram geradas imagens com a webcam nos canais normais "red-green-blue" (RGB), para testar a competência dos algoritmos. Após a captação das imagens foram feitas as análises matemáticas da variação de pixels, representadas por três variáveis, desenvolvidas por algoritmos específicos: lacunaridade, entropia e estresse. O número de repetições do experimento foi suficiente para identificar diferenças significativas ao nível de 1% de probabilidade entre as imagens e, os algoritmos foram robustos para identificar os sinais da homeopatia.

Termos para indexação: Agrohomeopatia; Vibraimage; Tensão elétrica; Visão computacional.

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Introduction

Image analyses, with the use of computer processing, can facilitate the assessment of plant health status and diagnosis as a non-destructive and non-invasive method to study plant propagules (MISHRA et al., 2020; PATRICIO & RIEDER, 2018; ZANCO et al., 2021).

Image analysis can be seen as a fundamental part of computer vision methodology, improving our level of understanding and automating the human visual learning process (CHOUHAN et al., 2021; ZANCO et al., 2021).

In turn, homeopathy applied to agriculture lacks methodologies that assist in decisions, such as the choice of potencies and periods of plant management in the field. The application of image-related technologies has the potential to contribute with and provide powerful support for those decisions (ZANCO et al., 2013).

This study aimed is to develop a non-destructive method of image analysis that could capture and identify the impact of homeopathy applied to plants in a short period of time.

Material and methods

The research was carried out in the didactic garden and in the Agronomy's Laboratory of Plant Production of the Unisul University, Tubarão, SC. Preview trials were carried out over a two-week period to identify the condition that could best capture measurable images of the purslane species, *Pilea microphylla* (L.) Liebm., Urticaceae (Figures 1a, Figure 1b).

In the laboratory, a bench was set up with two cameras. One of them was a camera of low resolution (640 × 480 pixels) that could reach a minimum pixel of 145µm (640 × 480px), which was modified to generate images, replacing the original lens filter for a blue one, purchased from http://publiclab.org. The other camera, Logitech C270 HD 720p®, was installed at the same resolution to measure signals in the plant without the use of filters. The distance between the cameras and the plants was 30cm (Figure 2). To prevent light variation during the experiment, the images were generated under artificial lighting, with a LED lamp measured between 3600 and 4180lux (Figures 2a, 2b, 2c) using a Digital Lux Meter LD-200 Instrutherm. Electric tension measurements in microvolts (mV) were also made with a 22812 RadioShack® digital multimeter to identify changes in plants due to homeopathy and water management (Figures 2d, 2e). DongBang® acupuncture needles (0.20 × 0.30mm) were used at the end of the

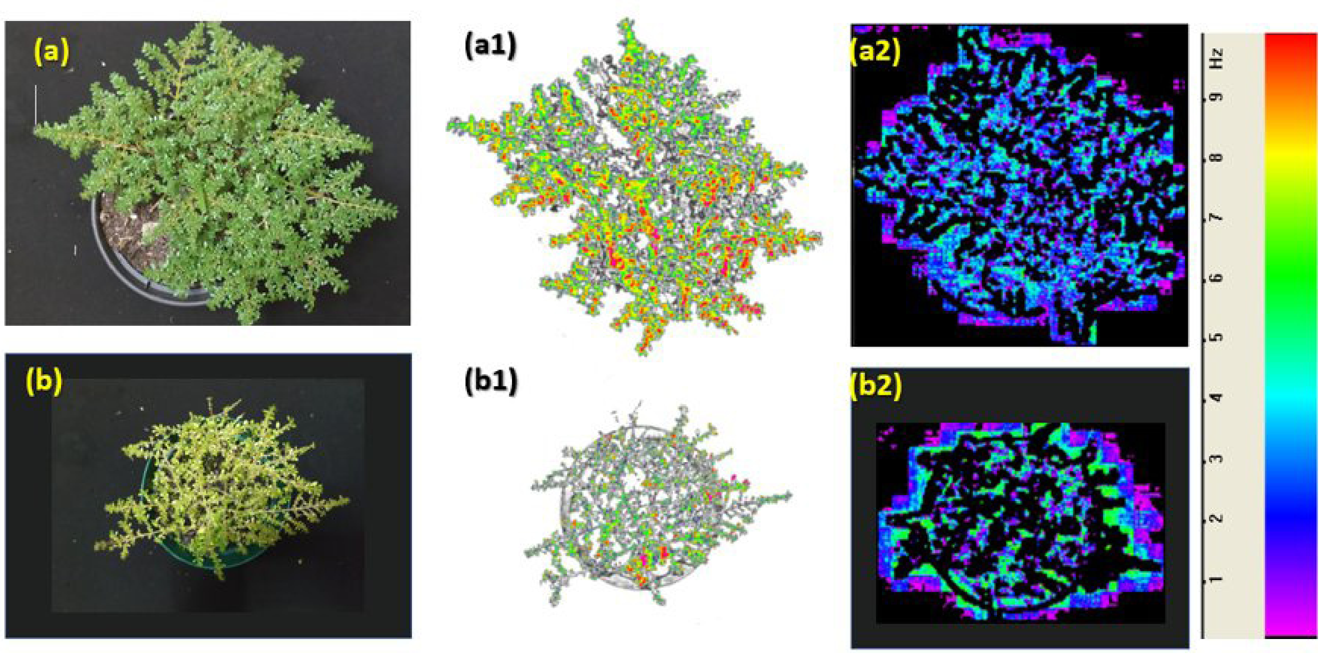

Figure 1. Purslane plants with regular (a) and low (b) photosynthetic activity and their respective NIR (a1, b1) and VibraHT (a2, b2) images. In contrast to VibraHT amplitude, each point of VibraHT frequency is a frequency dimension (Hz). Violet color of VibraHT frequency represents vibration range 0 to 1 Hz. Blue color of frequency VibraHT represents vibration range 0 to 4 Hz. Green color of frequency VibraHT represent the vibration range 4 to 8 Hz. Red color of frequency VibraHT represents vibration range 8 to 10 Hz. These frequency values are generated by the VibraHT software and converted into parameters, "stress" and "entropy", used in this research

Figura 1. Plantas de beldroegas com atividade fotossintética regular (a) e baixa (b) e respectivas imagens NIR (a1, b1) e VibraHT (a2, b2). Em contraste com a amplitude VibraHT, dimensão de cada ponto de frequência VibraHT é dimensão de frequência (Hz). A cor violeta de frequência VibraHT representa a faixa de vibração de 0 a 1 Hz. A cor azul da frequência VibraHT representa a faixa de vibração de 0 a 4 Hz. A cor verde da frequência VibraHT representa a faixa de vibração de 4 a 8 Hz. A cor vermelha da frequência VibraHT representa a faixa de vibração de 8 a 10 Hz. Esses valores de frequência são gerados pelo software VibraHT e convertidos em parâmetros, "estresse" e "entropia", utilizados nesta pesquisa multimeter's electrodes, fixed to the stems of the plants, aiming at the least possible impact.

The capture and partial analysis of the images was initially carried out with the VibraHT program provided through a partnership between the Research Group on Plant Production and Biotechnology (Anima-UNISUL), Santa Catarina, Brazil, and the ELSYS Corp., Saint Petersburg, Russia. The generated images were transferred to the ImageJ free software and compared before and after plant treatments. Homeopathies of Magnetitum and Arsenicum tartaricum, prepared in the proportion of two hundred and fifty millesimal scale (1/250,000), provided by the Homeopatia Rural company (https://www.homeopatiarural.com), and the dose used was 10 drops diluted in a sprayer with a capacity of 300 mL of water.

The images were generated from treated and non-treated purslane plants placed on a bench and its canopies were photographed every 5 seconds for 12 hours. These images were converted into AVI format (Audio and Video Intercal file) and then analyzed in VibraHT®, according to Akimov and Minkin (2021), to identify micro-vibrations related to the frequency of image taking in different time lapses (MINKIN & NIKOLAENKO, 2008). The second step was to analyze the same continuous VibraHT® images using the ImageJ program and the proprietary numerical algorithms according to Zanco et al. (2021).

Purslane collections were carried out in a ruderal environment, around and within the Pedra Branca university campus. The plants were grown in plastic bags (m^3 volume), totaling 16 plants (Figure 3). The plants were grown for 3 months, from their collection to their development. Figure 3 shows the differences between the collected and developed plants. In the first stage, the effect of homeopathies (UHD) on plant development was observed: experimental design consisted of four treatments with four repetitions, entirely at random. After observing adequate plant development, four repetitions were chosen to analyze the signal emitted from homeopathies. Each plant was considered an experimental unit.

Plant treatments were performed for one week after transfer to pots (Figure 3b), at a dose of 3mL of UHD per plant per day. In the laboratory, after the complete growth of the plants, some were chosen and separated from the others to carry out the experiment of analysis of the UHD signaling.

Still, the laboratory's experiments were repeated 10 times for each analyzed plant. During this procedure, the same plant was treated with homeopathy more than once. The repetition occurred in an alternating manner: one day with treatment and one without, totaling 20 days of experiment.

The statistics were generated with

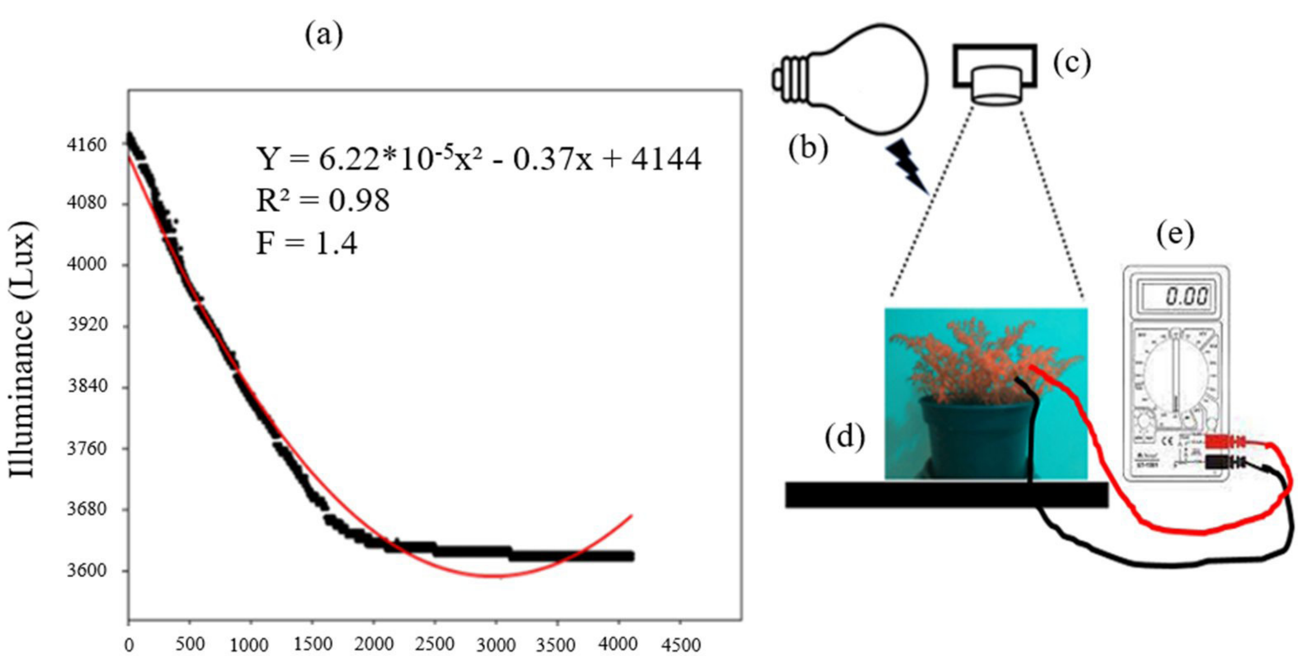

Figure 2. Behavior of the luminous intensity density (a) measured at the experiment site, emitted by an LED lamp (b) on the analyzed plants. The camera lens (c) formed a 90-degree angle over the bench surface and over the apex of the plants in the pots (d) and a digital multimeter (e) measured the electrical voltage (mV)

Figura 2. Comportamento da densidade da intensidade luminosa (a) medida no local do experimento, emitida por uma lâmpada LED (b) nas plantas analisadas. A lente da câmera (c) formou um ângulo de 90 graus sobre a superfície da bancada e sobre o ápice das plantas nos vasos (d) e medição da tensão elétrica (mV) com um multímetro digital (e) two softwares: Past (https://www.nhm.uio.no/english/research/infrastructure/past) and VibraHT® (http://psymaker.com/support/downloads). To read the information on VibraHT®, videos were generated and treated with ImageJ software (https://imagej.nih.gov/ij/download.html), in AVI format.

Pixel analyzes of the images were performed using algorithms developed for the VibraHT and ImageJ software. The amount of data followed the collection of images discreetly at 25 frames per second (fps), according to the technical characteristics of the webcam used. The pixel variation was represented by the entropy and stress variables, originated in VibraHT. The other variable was the lacunarity (LnΛ) generated in ImageJ, and it is related to image fractability.

The experimental procedure consisted of generating "640 × 480" pixel images from a web cam transformed to simulate a "red-green-NIR" (RGN) CMOS sensor, replacing the channel with a blue light filter (with wavelength between 500 and 540 nm) and thus generate the near-infrared image, acquired from a public design laboratory, PublicLab (https://publiclab.org). The images were also generated with the normal webcam, showing all "red-green-blue" (RGB) channels.

Results and discussion

There was detectable signaling by the model generated in VibraHT®; with less intensity in the image pixels when compared with the images generated with a blue filter (Figure 4). During the procedure, the same plant was treated with homeopathy more than once and this repetition was done in an alternating manner, one day with treatment and one without.

In general, both the measured images and the voltage (mV) showed significant differences. The most significant differences occurred in the combination between images in the near-infrared (NIR) spectrum and the use of VibraHT®, resulting in shorter imaging time (Figure 4).

The electrical voltage in the plants was also measured (Figure 5). The analysis of the electrical voltage in the plants showed that the treatment with *Magnetitum* remained active for less time than the treatment with Ars*enicum tartaricum* after the application of homeopathy (Figures 5a and 5b). According to Akimov and Minkin (2021), VibraHT was able to differentiate micro-vibrational signals for the diagnosis of COVID-19 due to its sensitivity. This extraordinary result raised our expectations regarding biophotonics research, which led to a partnership with Russian researchers to use the VibraHT software in plant analysis.

The average of 10 applications of UHDs observed with the use of NIR, VHT, and the set of technologies showed significant differences before and after the application of UHD (Figure 6). Figure 6 shows the biggest difference that occurred when VibraHT and NIR methods were used combined. Even so, the isolated methods obtained significant signals in reaction to the analysis without the application of UHD.

The wavelength generated using a blue filter was close to 450nm. Therefore, it is possible to measure some change in plants since chlorophyll absorbs this wavelength of light. In general, the pixel intensity was significantly increased with the help of the blue filter associated with VibraHT® (Figures 6 and 7).

The images generated by VibraHT®

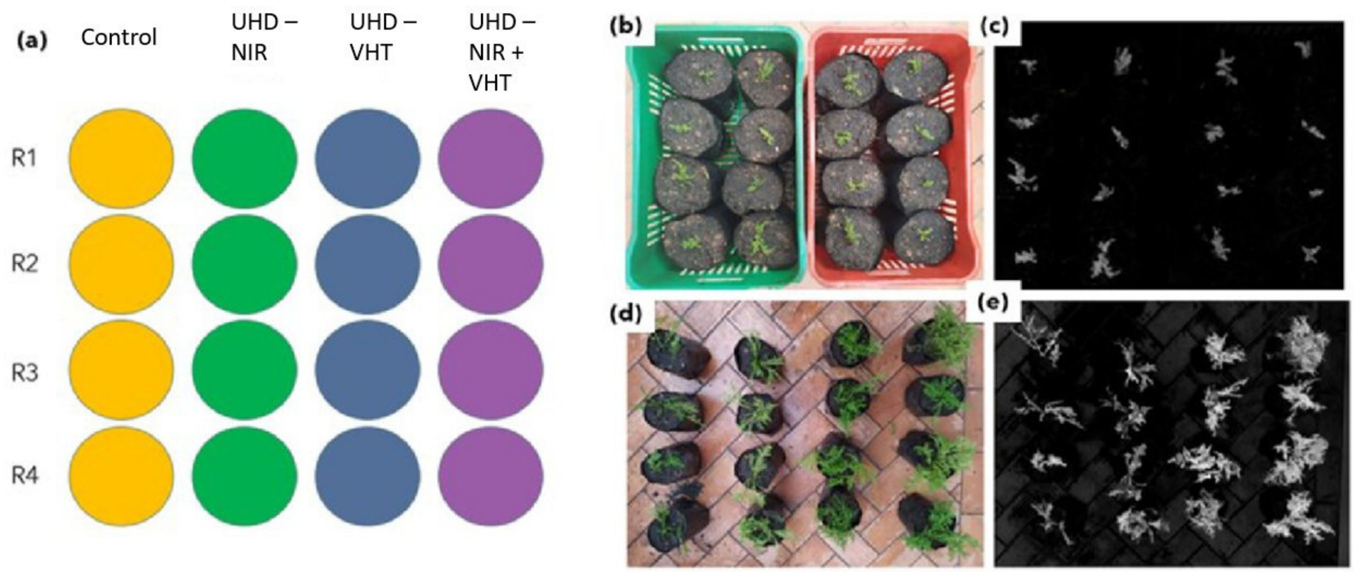

Figure 3. The experimental design comprised 4 treatments and 4 repetitions (a), from seedling collection (b) and monitoring of the signals with near-infrared images (c) until the complete development (d), with the respective images of the near infrared (e)
Figura 3. O desenho experimental compreendeu 4 tratamentos e 4 repetições (a), desde a coleta das plântulas (b) e o acompanhamento dos sinais com imagens de infravermelho próximo (c) até o completo desenvolvimento (d), com as respectivas imagens do infravermelho próximo (e)

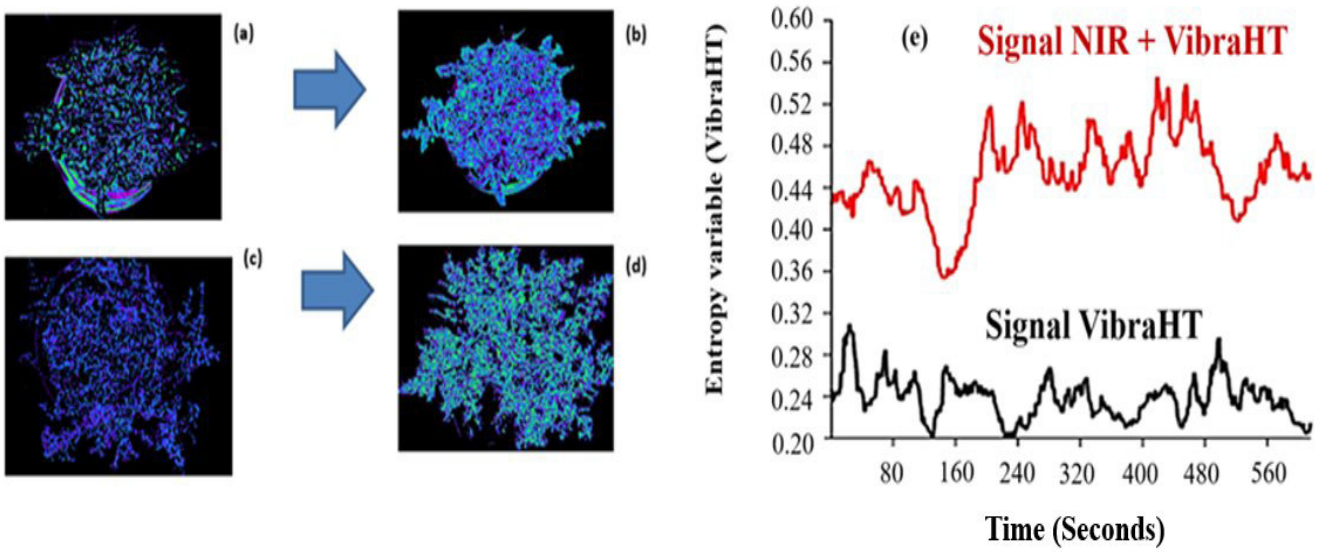

Figure 4. Analysis of the application of homeopathy using a blue filter and the analysis with VibraHT, in which two plants were treated: (a) with lower photosynthetic activity with UV filter; (b) with blue filter and higher photosynthetic activity; (c) with UV filter; (d) with blue filter; (e) comparison between signal intensities with and without filter, for the numerical variable VibraHT-T9 named "inhibition", in which the differences by Tukey's test were highly significant ($p<0.001$)

Figura 4. Análise da aplicação da homeopatia com filtro azul e análise com VibraHT, onde duas plantas foram tratadas: (a) com menor atividade fotossintética com filtro UV; (b) com filtro azul e maior atividade fotossintética; (c) com filtro UV; (d) com filtro azul; (e) comparação entre intensidades de sinal com e sem filtro, para a variável numérica VibraHT-T9 denominada "inibição", onde as diferenças pelo teste de Tukey foram altamente significativas (p <0,001)

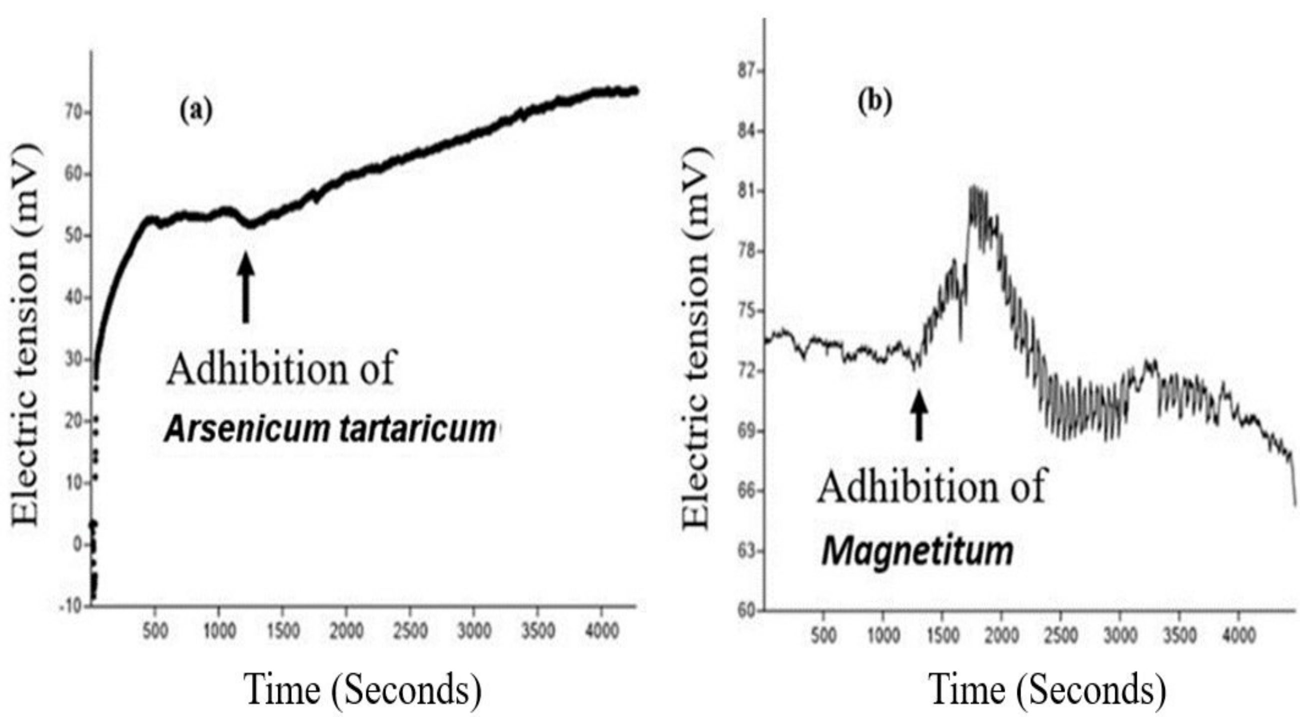

Figure 5. Application of *Arsenicum tartaricum* 250 CCLM (a) and *Magnetitum* 250 CCLM (b) measured electrical voltage in real time, in purslane plants, using a RadioShack® digital multimeter

Figura 5. Aplicação de Arsenicum tartaricum *250 CCLM (a) e* Magnetitum *250 CCLM (b) mediram a tensão elétrica em tempo real, em plantas de beldroega, utilizando um multímetro digital RadioShack®*

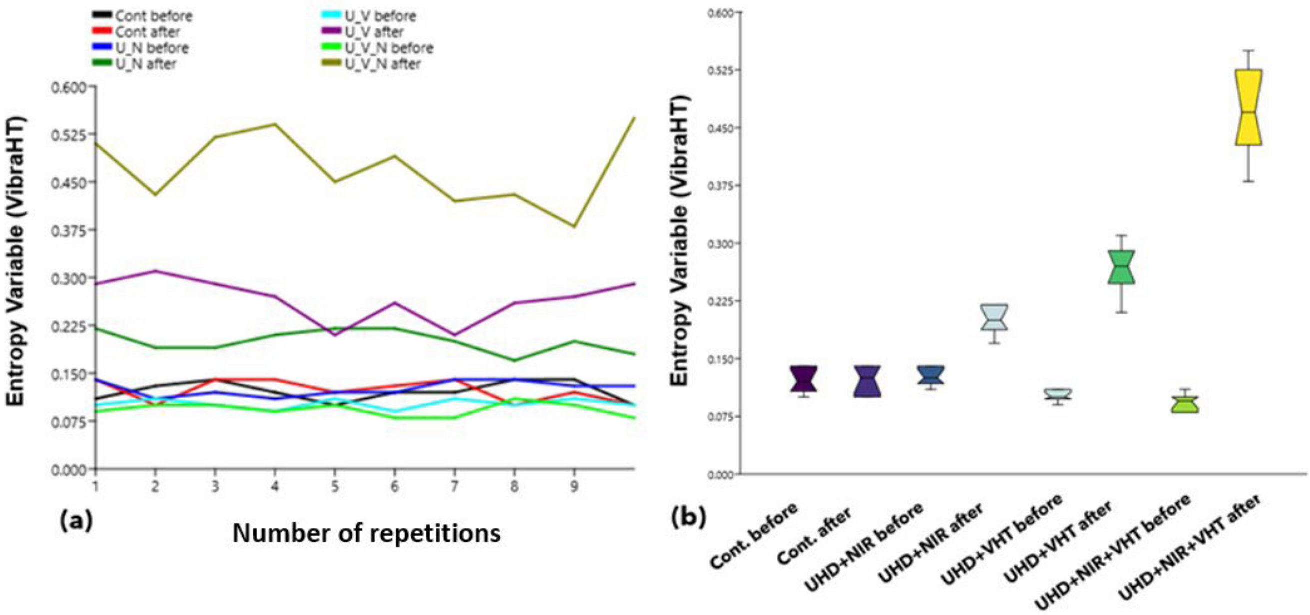

FIgure 6. Signaling of *Magnetitum* 250 CCLM in plants, analyzing the entropy variable (VibraHT), before and after application, observing the number of repetitions (a) and the notched box plots and narrowed around the median (b). The width of the notches is proportional to the interquartile range of the sample and inversely proportional to the square root of the sample size; if the notches of two boxes do not overlap, this provides evidence of a statistically significant difference between the medians. The ANOVA for comparing the means was significant for all UHD applications and for the computer vision method used, VHT, NIR or VHT+NIR, with higher probability for the association: Fisher-Snedecor's F = p(same)<0.0001; Levene test p(same) = 0.068 and omega² = 0.97

Figura 6. Sinalização de Magnetitum *250 CCLM em plantas, analisando a variável entropia (VibraHT), antes e após a aplicação, observando o número de repetições (a) e os "box plots entalhados" e seu estreitamento da caixa em torno da mediana (b). A largura dos entalhes é proporcional ao intervalo interquartil da amostra e inversamente proporcional à raiz quadrada do tamanho da amostra; se o entalhe de duas caixas não se sobrepõe, isso fornece evidência de uma diferença estatisticamente significativa entre as medianas. A Anova para comparação das médias foi significativa para todas as aplicações UHD e o método de visão computacional utilizado, VHT, NIR ou VHT+NIR, com maior probabilidade de associação: F de Fisher-Snedecor = p(mesmo)<0,0001; Teste Levene p(mesmo) = 0,068 e ômega² = 0,97*

are very similar to each other in terms of fractal dimension (D_F) and a strategy to detail this aspect of the fractal model was to analyze the lacunarity (L_C). Agreeing with Conceição et al. (2021), the fractal characterization of the samples showed dependence on the calculation of fractal dimension and fractal lacunarity. In our study, the D_F quantitatively also showed the complexity of the object (the image of the plant canopy), that is the level of detail available in different parts of the canopy. The L_C evaluated the size distribution of gaps in the fractal surface of the canopy and provided a quantitative measure of the surface gap heterogeneity. The D_F pattern was complex, but without significant differences between the generated images, except when observing the fractal lacunarity of the images. The L_C showed evidence of impact from the application of homeopathies by indicating a change in the position of pixels and smaller homogenization in their distribution, after application (Figures 7b and 7c).

Also, Figures 7a and 7e show a strong correlation between the pixel intensity and the "stress" variable, generated in the VibraHT® software. This result indicates that pixel analysis has the potential to confirm the proposed numerical and statistical variables, which technically identified an increase in micro-vibrations due to the application of homeopathy and, therefore, higher entropy in the system.

The images generated by VibraHT® were sufficient to detect signs caused by the applied homeopathies. The use of the blue filter increased the imaging system's ability to recognize these signals. The water treatment (control) in the plants was also perceived in the VibraHT® images, with a significant difference only when the NIR was used to integrate the analysis. The proposed method has potential for diagnosis and management of plants in the field, both for anticipation of decisions and for real-time monitoring. The flexibility to use the computer vision technology developed in VibraHT® can even help with fieldwork, using drones or any video capture equipment. The electrical voltage measured in the plants also showed promise and needs to be better studied in future experiments.

Conclusion

- The images generated by the webcam were sufficient to provide acceptable diagnoses.
- The CMOS webcam sensor

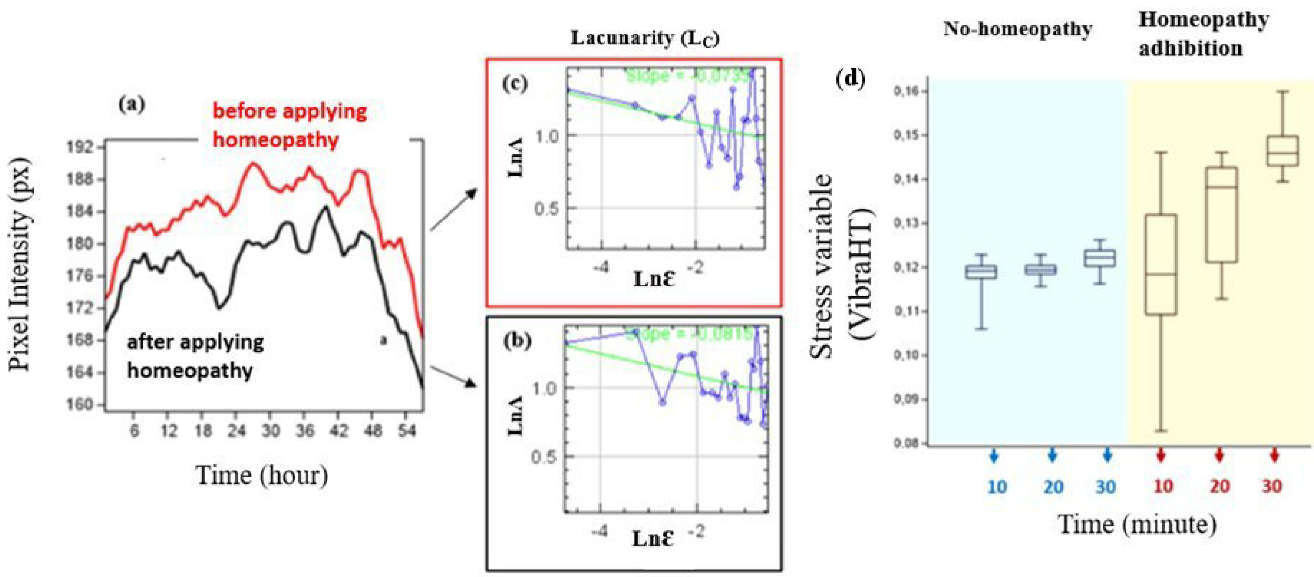

Figure 7. Average pixel intensity of the images (a) and fractal analysis regarding the lacunar variable, the differences by Tukey's test were highly significant, p<0.001, (b) before and (c) after the application of *Arsenicum tartaricum* 250 CCLM, referring to 10 repetitions: (d) analysis of the overall mean of the tests and the variation over time. The abbreviations LnΛ = neperian logarithm of lacunarity and Lnε = neperian logarithm of image scale

Figura 7. Intensidade média dos pixels das imagens (a) e análise fractal em relação à variável lacunar, as diferenças pelo teste de Tukey foram altamente significativas, p <0,001, (b) antes e (c) após a aplicação do *Arsenicum tartaricum* 250 CCLM, referindo-se a 10 repetições; (d) análise da média geral dos testes e da variação ao longo do tempo. As abreviaturas LnΛ = logaritmo neperiano da lacunaridade e Lnε = logaritmo neperiano da escala da imagem

and the blue spectral filter, allied to the mathematical modeling (VibraHT®) were aproved to capture signals with negligible random noise, ensuring the validation of the results obtained.

- The generated signals were demonstrably related to the application of homeopathy in plants.
- Despite the favorable results, studies should further investigate the signal-to-noise ratio of the generated measurements and ratify the stability and useful life of the proposed model.

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