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RESEARCH PAPER

Non-Invasive Electro Photon Image (EPI) Analysis to Detect Seasonal Variation in Leaf Growth of *Commiphora wightii*

Jagdishchandra K. Monpara[1]*, Kiran S. Chudasama[2], Manish L. Vekaria[1], Virendra J. Patel[1] and Vrinda S. Thaker[2]

[1]Vimal Research Society for Agro-Biotech and Cosmic Power, 80 feet road, Aji area, Rajkot, Gujarat, India
[2]Department of Bioscience, Saurashtra University, Rajkot, Gujarat, India

*Corresponding author: jagdish.monpara@gmail.com (**ORCID ID:** 0000-0002-7555-6747)

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ABSTRACT

The objective of the present study was to evaluate seasonal variation changes in leaf growth using the electrophoton image (EPI) analysis technique. This technique is based on electromagnetic energy in unique patterns generated by the object in the given conditions. In the present work, different ages of fix size leaves of *Commiphora wightii* were collected, and measured the fresh and dry weight, water content, and leaf area for throughout the year. Further, all leaves were evaluated with the EPI technique. All gravimetric parameters fluctuate with seasonal changes with all physiological ages of the leaf. The EPI parameters like GDV area, average intensity, length of isoline, energy and entropy by isoline, etc., were measured using its software. The EPI parameter was given a highly significant correlation with fresh and dry weight, and water content. The GDV area, length of isoline, and energy characterize the metabolic status of the leaf. The entropy by isoline can serve as an informative characteristic of the state of a plant leaf, which can be used to assess its physiological state in its environment. This technique is user-friendly, non-invasive rapid, and accurate. It can be used in agriculture and others field for the various applications.

HIGHLIGHTS

- EPI analysis is very fast and non-invasive technique.
- Study the seasonal change effect on leaves using the electrophoton image technique.
- Significant relationship was observed between the growth and EPI parameter.

Keywords: Leaf growth, Seasonal variation, Electro photon image, metabolic status, Non-invasive

A leaf is the principal organ of photosynthesis and transpiration (Wright *et al.* 2004). leaf size (leaf surface area, leaf dry mass, and leaf length) will affect the various biological processes of plant growth, survival, reproduction, nutrient supply, yield, quality, and ecosystem function (Wang *et al.* 2019; Ke *et al.* 2022). Therefore, leaf growth measurements are required in most physiological, horticultural, and agronomic studies (Guo and Sun, 2001; Blanco and Folegatti, 2003). Leaf area is an important parameter for phenology study, in which plant development can be measured in responding to the environment (Badeck *et al.* 2004). Leaf growth is affected by various environmental factors such as light, temperature, and precipitation (water). The leaf area is sensitive to environmental changes due to its large plant surface area being exposed to the atmosphere; this makes it highly sensitive to climate change. The leaves play a vital role in biogeochemical cycles in ecosystems and consequently, changes in leaf behaviors strongly affect plant growth and yield (Chapin, 2003). Leaf area is measured by grid count method, regression

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model, planimeter, gravimetric method, and image processing digital method (Datta and Chakroboarty, 2018; Dey *et al.* 2019). The grids measurement, computation, and regression model are low-cost techniques, but very time-consuming (Singh *et al.* 2021). Therefore, it is necessary to require an alternative non-invasive technique.

In this regard, Electro photonic imaging (EPI) technique has several applications in agricultural research as a non-invasive approach. A novel technique of EPI is being developed for the purpose of assessing health status through the use of bioenergy (Korotkov, 2002). The EPI technique is measuring the level of functional energy stored by the particular systems of an organism. These inbuilt characteristics of the object permits to conclusion about the differential metabolic status and physical functionality in a holistic view (Korotkov and Korotkin, 2001). EPI is based on recording the optoelectronic emission of a biological object upon stimulation with short (3–5 μs) electromagnetic pulses. A high-voltage electromagnetic field (EMF) is used to record and quantify luminescence near an object's surface. It is used to study how an EMF or gas discharge stimulated the emission of photons, electrons, and other particles from an object. Biological emission strengthens in a gas discharge and is transformed into a digital code by a video transformation system, digitalized by a computer, and imaged as EPI gram. Analysis of changes in EPI images includes calculation of the characteristics of their amplitude and geometric, brightness fractal, and stochastic parameters. The EPI technique is a non-invasive method, it may help to understand subtle changes in a biological object without compromising its integrity.

Considering these in the present study, a new method of EPI is established for the determination of seasonal variation of leaf size growth of *Commiphora wightii*. It is one of the important customaries and endangered medicinal plants of the semi-arid region of India.

MATERIALS AND METHODS

Collection of Plant materials

Throughout the whole year fix the size and weight of *C. wightii* leaves were collected from the VIRSACO campus, Rajkot, Gujarat, India. It was washed under tap water and blotted dry. Further used for experiments. All the data is divided into the seasons-wise summer (February, March, April, May-2023) monsoon (June, July, August, September -2023), and winter (October, November, December-2023, January-2024).

Growth analysis

Growth was measured i.e. fresh weight, dry weight, and water content. For the measurement of fresh and dry weights, freshly harvested smaller to large-sized leaves were taken. Freshly separated leaves were weighed before and after oven drying to a constant weight at 60 °C for 72 hours to obtain the data on fresh and dry weights. The water content of each stage was determined by the difference in fresh and dry weight.

Leaf area measurement

Freshly collected leaves were washed thoroughly under running tap water and blotted over filter papers. Each leaf area was measured using Petiole Android mobile application.

EPI experiment

C. wightii fresh leaves of fixed size and weight were collected and divided into four groups according to size (G1: 1.5 to 2.8 cm^2), (G2: 3.2 to 5 cm^2), (G3: 5.5 to 6.7 cm^2) and (7.2 to 10.1 cm^2). Fresh weight (G1: 19.6 to 48 mg), (G2: 35 to 95.4 mg), (G3: 67.2 to 160 mg) and (66 to 239 mg). For the measuring EPI leaf was clean or sometimes wet, they should be dried using a cloth. The image of the leaves (adaxial surface) was captured using a specialized camera instrument (Kirlionics technologies international, st.petersburg, Russia). Leave was place of camera glass surface and for the grounding electrode were put on leaf and cover with cloth for darkness and electrode voltage of 12.5 kV with the impulse duration of 10 mcs, repetition frequency 1024 Hz and exposure for 1 second. EPI was capture in GDV software suite in attached computer (Plate 1). EPI was analyzed in GDV scientific library and data correlated with the growth parameter of plant leaves. The step of EPI measurement is mentioned in Plate 2.

Terms of EPI parameters

Electro-Photonic Imaging (EPI) technology based on Kirlian effect that allows to capture and process

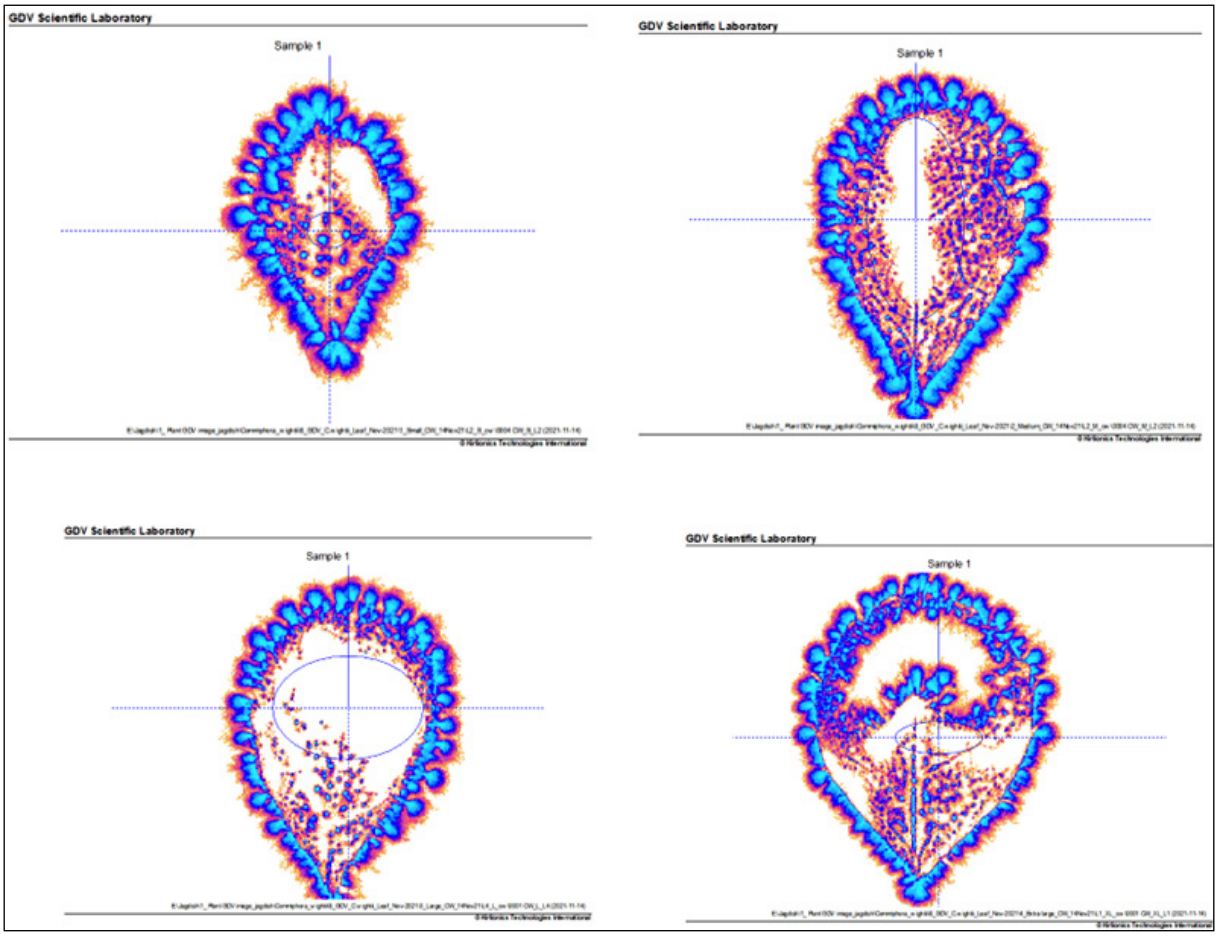

Plate 1: Electro Photon Image of different size leaf

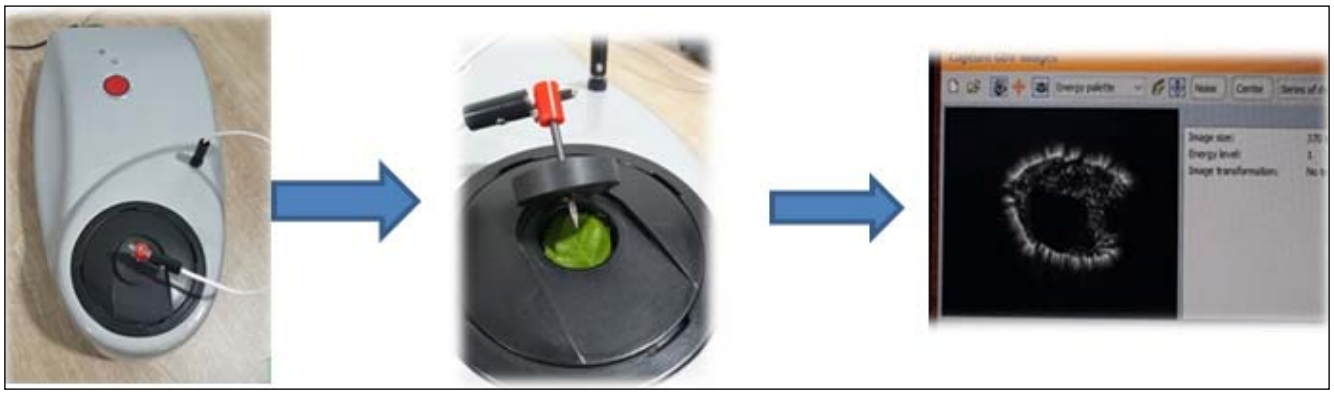

Plate 2: Steps of Electro Photonic Imaging (EPI) measurement

digital images of the gas discharge (Glow). **Area**: EPI software parameter calculated as number of pixels on the GI related to the object being analyzed. **GDV area**: light emitted by the gas (air) due to the excitation of its molecules by the electrons and photons from an object under study with the use of EPI technology. **Intensity**: EPI software parameter calculated as the average value of intensity (brightness from 0 (black) till 255 (white) of pixels on the GI related to the objects being analyzed. **Energy**: EPI software parameter derived as numeric evaluations of the energy of the Glow captured by the EPI device and calculated by multiplication of Area on Average Intensity on correction coefficient (E = S * I * 0.00002 (0.00002 = Constant coefficient of EPI camera). **Isoline length**: The length of the external contour of an image.

Isoline Entropy: The ratio of an image's external contour to its internal contour.

Statistical analysis

The correlation coefficient was worked out between growth and EPI parameters (Fwt, WC, Dwt, leaf area, GDV area, average intensity, energy, length of isoline, entropy by isoline). P values significant at 0.1 or less were considered for the data interpretation. The correlation matrix and graphs were prepared using the R package.

RESULTS AND DISCUSSION

The present study was intended to investigate the seasonal variation of specific leaf area, fresh and dry weight, and water content of *Commiphora wightii* by physiological and EPI methods.

In this work, four groups of small to large size leaves of *C. wightii* were collected throughout the year seasons wise further used for the experiment. The leaf area was measured by the petiole mobile application and presented in Fig. 1A. The leaf area of the G1 group of summer, monsoon, and winter was observed 1.5 to 2.4 cm^2 leaf $^{-1}$, 1.6 to 2.8 cm^2 leaf $^{-1}$, and 1.7 to 2.8 cm^2 leaf $^{-1}$, respectively. The leaf area of the G2 group of summer, monsoon, and winter was observed 3.2 to 4.5 cm^2 leaf $^{-1}$, 3.6 to 4.8 cm^2 leaf^{-1}, and 3.7 to 4.5 cm^2 leaf $^{-1}$, respectively. The leaf area of G3 group was observed in summer (5.6 to 6. 5 cm^2 leaf $^{-1}$), monsoon (5.6 to 6.7 cm^2 leaf $^{-1}$), and winter (5.5 to 6.5 cm^2 leaf $^{-1}$) seasons. The G4 group of leaf area was observed in the range 7.9 to 10.1 cm^2 leaf $^{-1}$ (summer), 8.0 to 9.8 cm^2 leaf $^{-1}$ (monsoon), and 7.2 to 9.5 cm^2 leaf $^{-1}$ (winter) seasons. Leaf area was increased with age of leaf. From our results very less variation was observed in the leaf area thought out all the seasonal leaf groups.

The fresh weight of all seasons was presented in Fig. 1B. The fresh weight of summer seasons was observed in the range G1 (19 to 48 mg), G2 (36.6 to 95.4 mg), G3 (67.2 to 149.8 mg), and G4 (98.4 to 183.4 mg). The fresh weight of monsoon seasons G1, G2, G3, and G4 groups 20.3 to 46.5 mg, 35 to 60.4 mg, 70.6 to 89.1 mg, and 89.9 to144.5 mg /leaf, respectively. The fresh weight of winter seasons was 24.2 to 47.4 mg, 54.1 to 90.1mg, 68.2 to 118.2 mg, and 66.4 to 239.6 mg per leaf, respectively G1, G2, G3, and G4 groups. A large variation of fresh

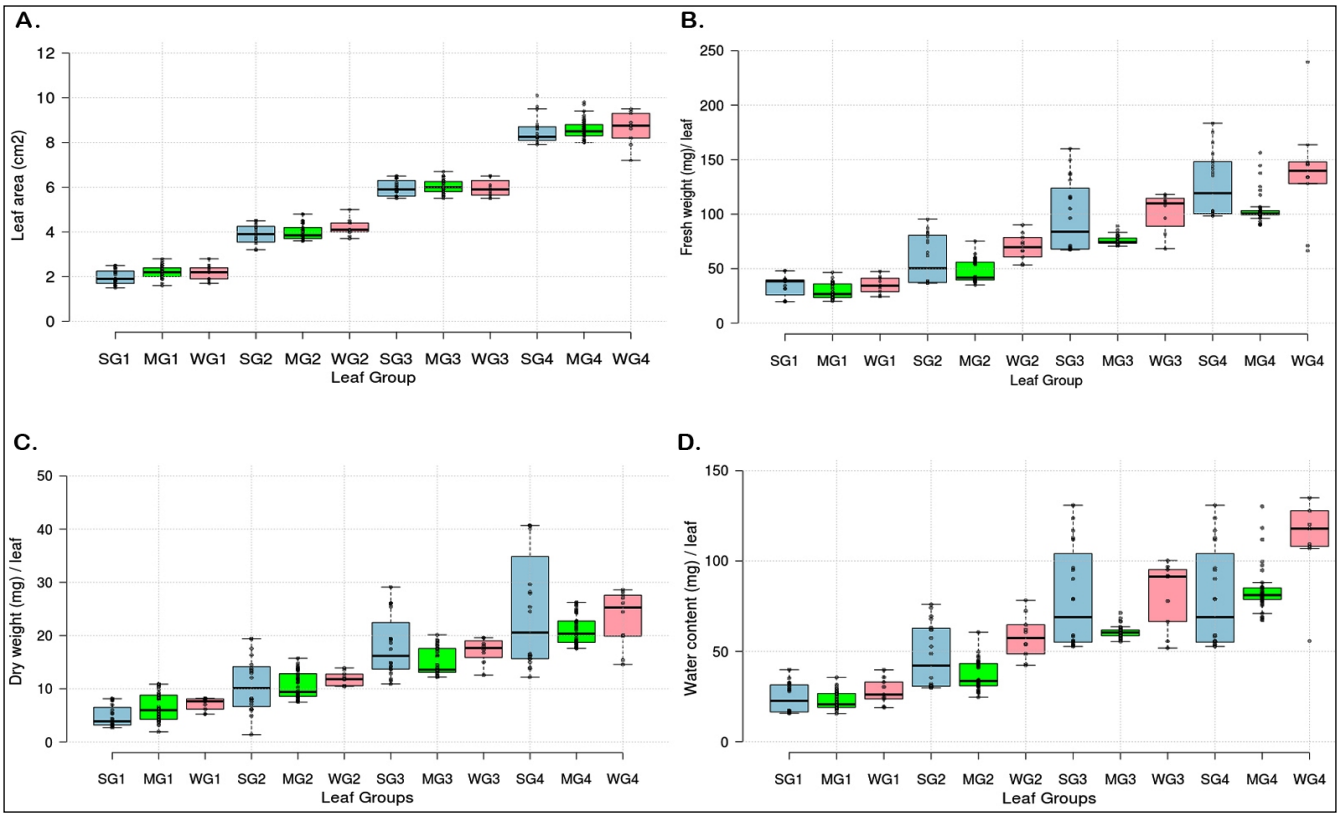

Fig. 1: Seasonal summer, monsoon and winter effect on different leaf size growth **(A)** Leaf area **(B)** Fresh weight **(C)** Dry weight and **(D)** Water content. **Note: SG**: summer group, **MG**: monsoon group, **WG**: winter group

weight was observed in all seasons, in the same size of the group, due to the environmental factors effect (Ojeda *et al.* 2012). Previously Catoni *et al.* (2012) summer and winter seasons leaves strongly differed in anatomical, morphological, and physiological character. The same pattern of dry weight and water content was observed in all physiological ages of leaves in all seasons (Fig. 1C and Fig. 1D).

Correlation matrix of summer, monsoon and winter season of gravimetric parameters was presented in Figs. 3,4, 5. The data of all season's leaf area gave a better correlation with fresh and dry weight and water contents. The data of leaf area and fresh weight (R^2: 0.939) Dry weight (R^2: 0.879), and water content (R^2: 0.938) have a high correlation in monsoon seasons compared to summer and winter. Many authors used dry weight as the representative of leaf biomass when studying the relationship between leaf biomass and area (Lee and Heuvelink, 2003; Young *et al.* 2007; Lin *et al.* 2020). Leaf dry mass or its equal leaf area is an important trait that is closely associated with plant growth rates, photosynthetic rate, reproductive strategies, and life span (Poorter *et al.* 2009; Falster *et al.* 2018). Correlation analysis demonstrated that there was a significant relationship between water content and leaf area. Water content is also an important parameter to study the role of water in the expansion growth of plants (Monpara *et al.* 2019, 2022). Many studies observed that dry weight accumulation and water content are closely related to the expansion growth of the plant (Chudasama and Thaker, 2007; Bhatt and Thaker, 2008,). It is assumed that an increase in the size of the leaf may also increase the water content up to a certain size of the leaf. Saura-Mas and Lloret, (2007), observed the variation in water content from season to season. Water content may be the one of marker for the study of seasonal variation effect on plants.

Electro photonic imaging analysis

These all-seasonal leaves also proceeded for EPI analysis and parameters are derived. With the help of the EPI instrument, GDV area, average intensity, length of isoline, entropy by isoline, and Energy (joules) parameters are recorded. The EPI quantifies the glow that occurs near the surface of the leaf when it is placed in a high-intensity electromagnetic field. The changes in the GDV area of all seasonal groups of leave were presented in Fig. 2A. The GDV area defined the inner glow of the leaf and is measured in pixels. A large variation of GDV area was observed in the G1, G2, G3, and G4 group of the all-seasons leaves. When increasing the size of the leaf GDV area also increases with age. The summer season leaves have a large variation in the GDV area compared to other monsoons and winter. This variation may be due to physiological and seasonal changes that affect the internal structure of a leaf. This method is used for finding the structural defects in healthy and infected seeds (Arkhipov *et al.* 2013), as well as functional changes in the metabolism of different varietal seeds (Kolesnikov *et al.* 2021). Tsukaya (2013) reported that the leaves of Arabidopsis differ in shape, thickness, and size with the age of the plant.

The length of the isoline is given the outer glow of the object and measured in pixels. The length of the isoline of *C. wightii* leaves was presented in Fig. 2B. The length of the isoline was increased with leaf size. The length of the isoline of the G1 group was observed in the range 1113.25 to 2034.62 pixels (summer), 1212.22 to 2663.14 pixels (monsoon), and 1470.49 to 3694.89 pixels (winter). Very less fluctuation was observed in the G1 group of leaves in the summer, monsoon, and winter seasons. The group G3 and G4 have more variation in the length of isoline of all seasons (Fig. 2A). This large variation is due to the seasonal change and irregular shape of *C. wightii* leaves at a later stage. GDV area and length of the isoline are given the inner and outer structural information of the leaf. The metabolic processes in the plant are controlled by the physiological age of the plant, genetic factors, and the surrounding environmental conditions (Gómez-Maqueo *et al.* 2021; Zhan *et al.* 2022).

Correlation analysis of gravimetric with EPI parameters was presented in Figs. 3,4, 5. The data of all season's GDV areas and length of isoline was showed a high correlation with fresh and dry weight and water contents. The data for summer seasons was showed a highly significant correlation for GDV area with fresh weight (R^2: 0.794) Dry weight (R^2: 0.802), and water content (R^2: 0.770). In monsoon seasons GDV area has a highly significant correlation with fresh weight (R^2: 0.615), Dry weight (R^2: 0.633), and Water content (R^2: 0.600). The GDV area showed a weak correlation with fresh weight

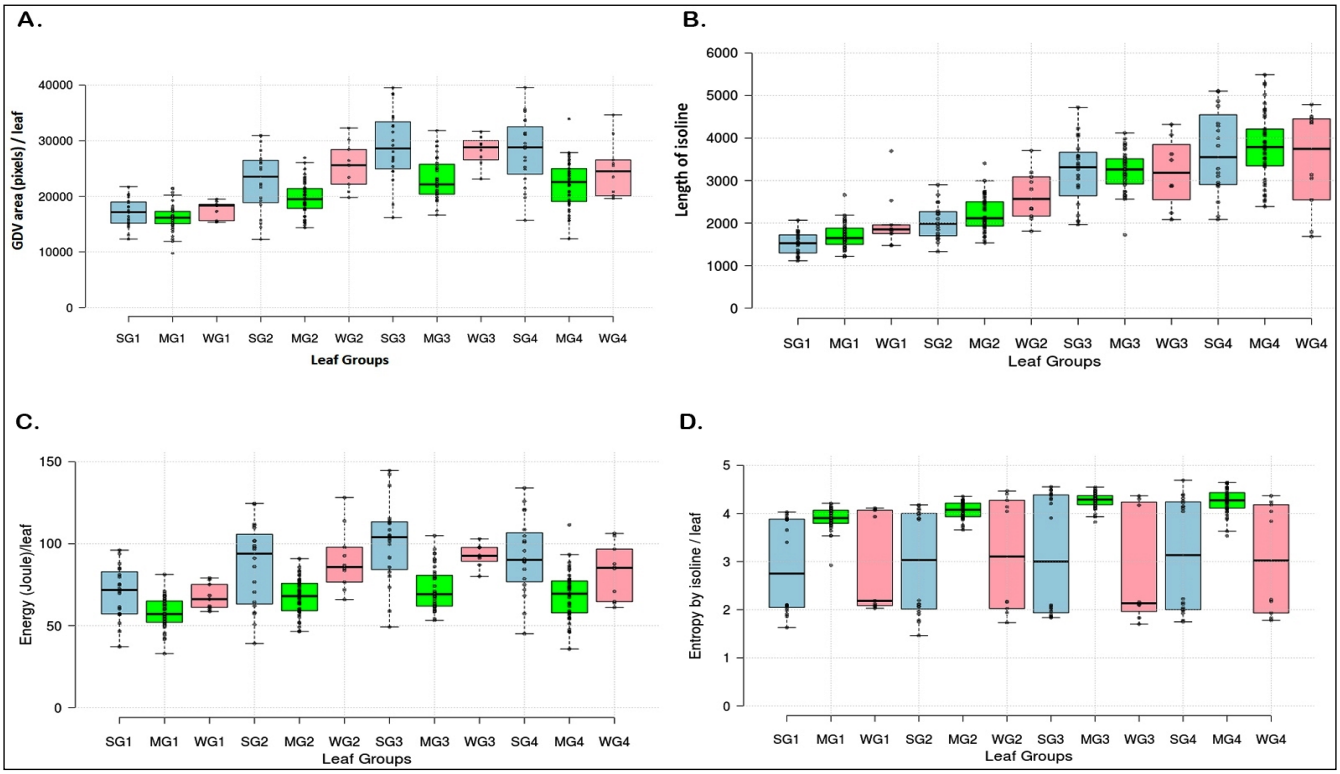

Fig. 2: Seasonal summer, monsoon and winter effect on different leaf size growth **(A)** GDV area **(B)** Length of isoline **(C)** Energy **(D)** Entropy by isoline. **Note: SG**: summer group, **MG**: monsoon group, **WG**: winter group

(R^2: 0.384), Dry weight (R^2: 0.320) and water content (R^2: 0.389) in winter seasons. The length of isoline of monsoon season showed a very high significant correlation with fresh weight (R^2: 0. 796), Dry weight (R^2: 0.775), and water content (R^2: 0.788) compared to summer and monsoon seasons. Plants can change their behavior to adapt to different environmental conditions through metabolic change (Khan *et al.* 2019). The isoline length is an important indicator of seed quality and a positive correlation with seed weight reported (Arkhipov *et al.* 2016).

The energy level of all groups of leaves was presented in Fig. 2C. The level of energy is presented in the form of a joule. The energy level of leaves in the summer season was showed a wide variation in all groups of leaves. The energy level was not increased with leaf age. The energy of leaves in monsoon seasons G1, G2, G3, and G4 groups 32.9 to 81.2, 46.4 to 90.8, 53.1to 104.9, and 35.7 to111.9 joule /leaf, respectively. In winter seasons energy levels in G1 and G3 group as less variation compared to G2 and G4. Leaf energy (total or gross energy balance) controls leaf temperature. The leaf energy balance is the difference between all the environmental energy inputs (into a leaf) and all energy output (from the leaf). This difference is energy accumulated or utilized in metabolic activities and changes the leaf temperature. Leaf temperature affects various physiological processes like photosynthesis, respiration, and climatic processes (Hikosaka *et al.* 2016). The energy of summer leaves showed a highly significant correlation with fresh weight (R^2: 0.629), Dry weight (R^2: 664), and water content (R^2:0.602) compared to monsoon and winter seasons (Fig. 2C). From the results, it is concluded that the variation in energy of all seasonal group leaves may be due to temperature and other environmental factors. Any imbalance in the energy fluxes in the leaf is due to the change in environmental conditions that impact the stored energy of the leaf (Silvere and Lawson, 2019).

The entropy by isoline of seasonal leaves was presented in Fig. 2D. Entropy is the indicator of a disturbed bio-energy system of the organism. In this work, the entropy of summer and winter have huge variation in G1, G2, G3, and G4 groups leaves. The entropy of summer and winter seasons was observed in a range of approximately 1.4 to 4.4 range in all groups of leaves. Entropy level in monsoon seasons was found in the range 3 to 4.6

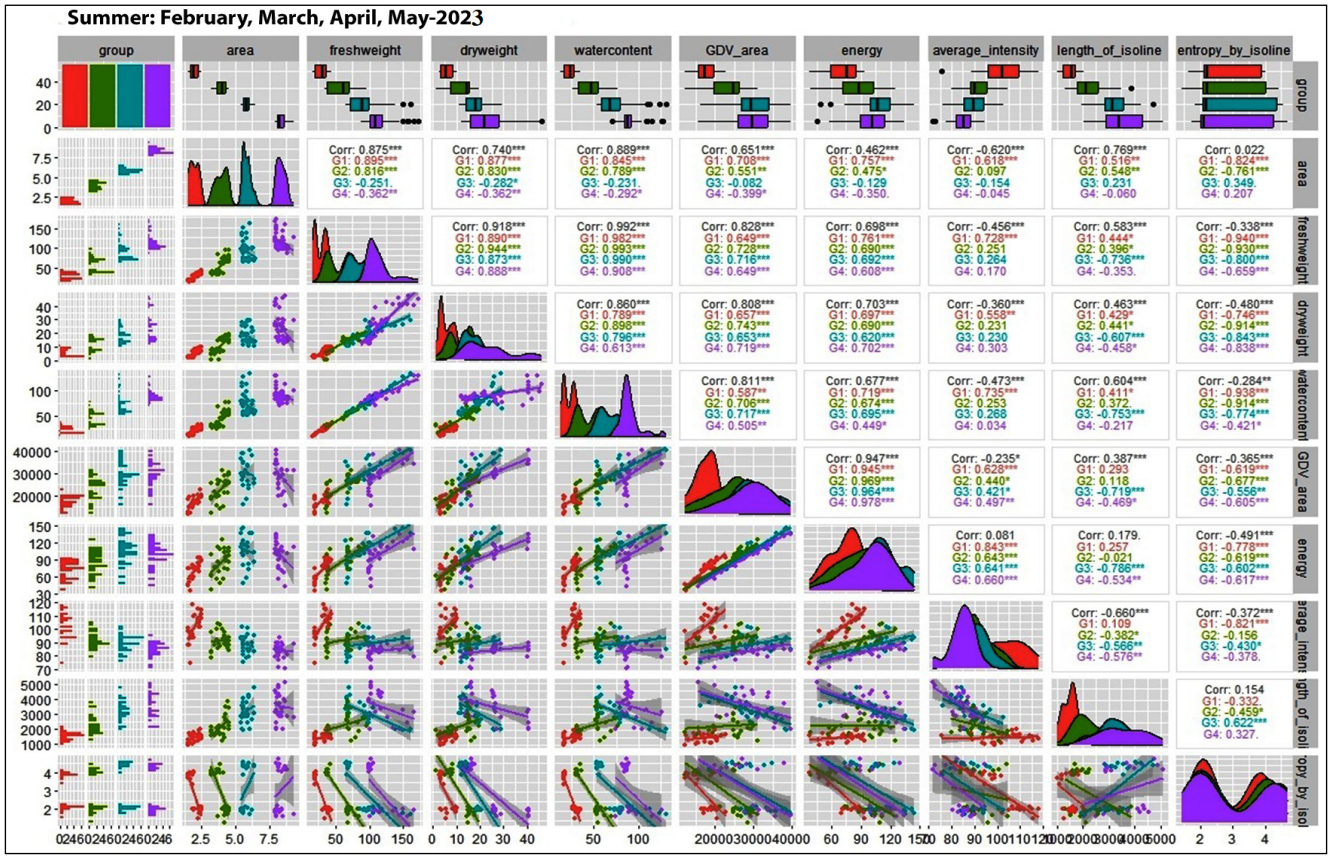

Fig. 3: Correlation matrix of summer seasons gravimetric and EPI parameter

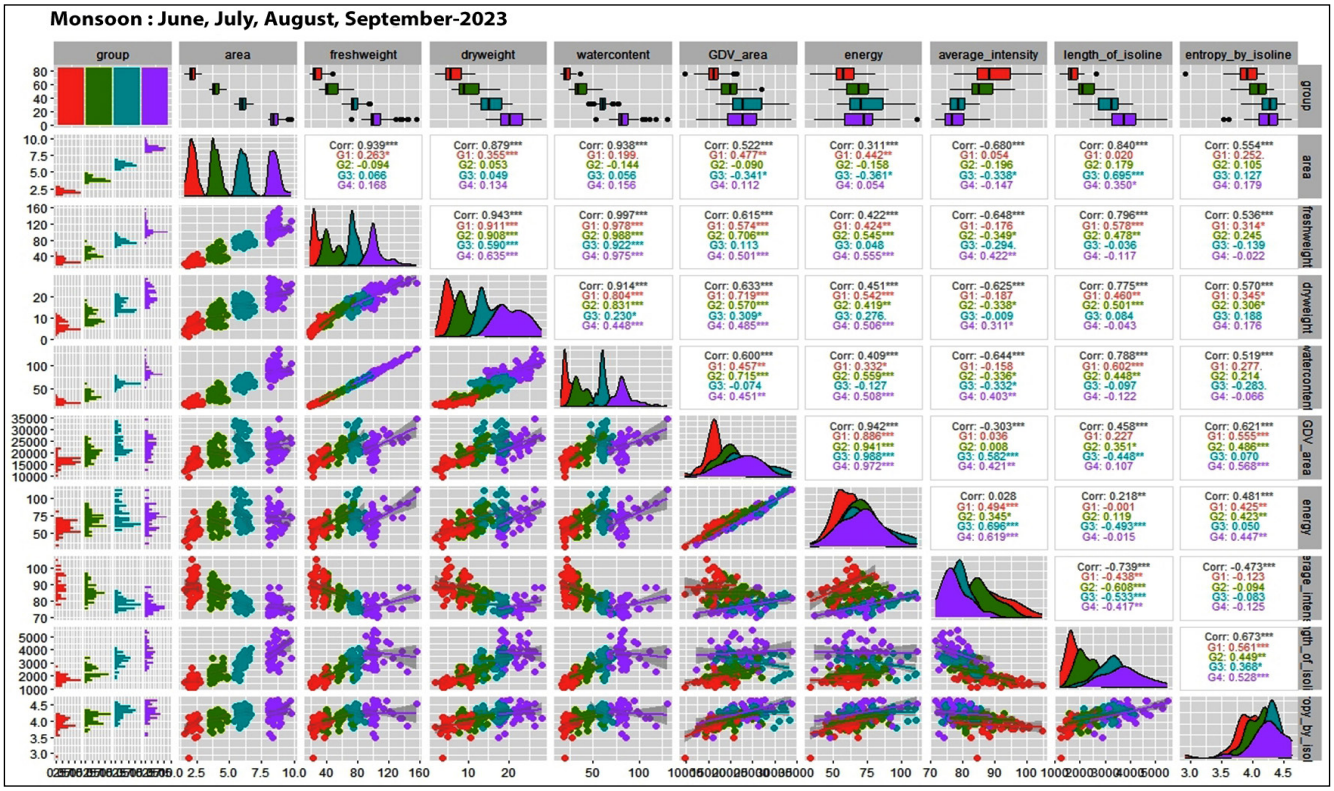

Fig. 4: Correlation matrix of monsoon seasons gravimetric and EPI parameter

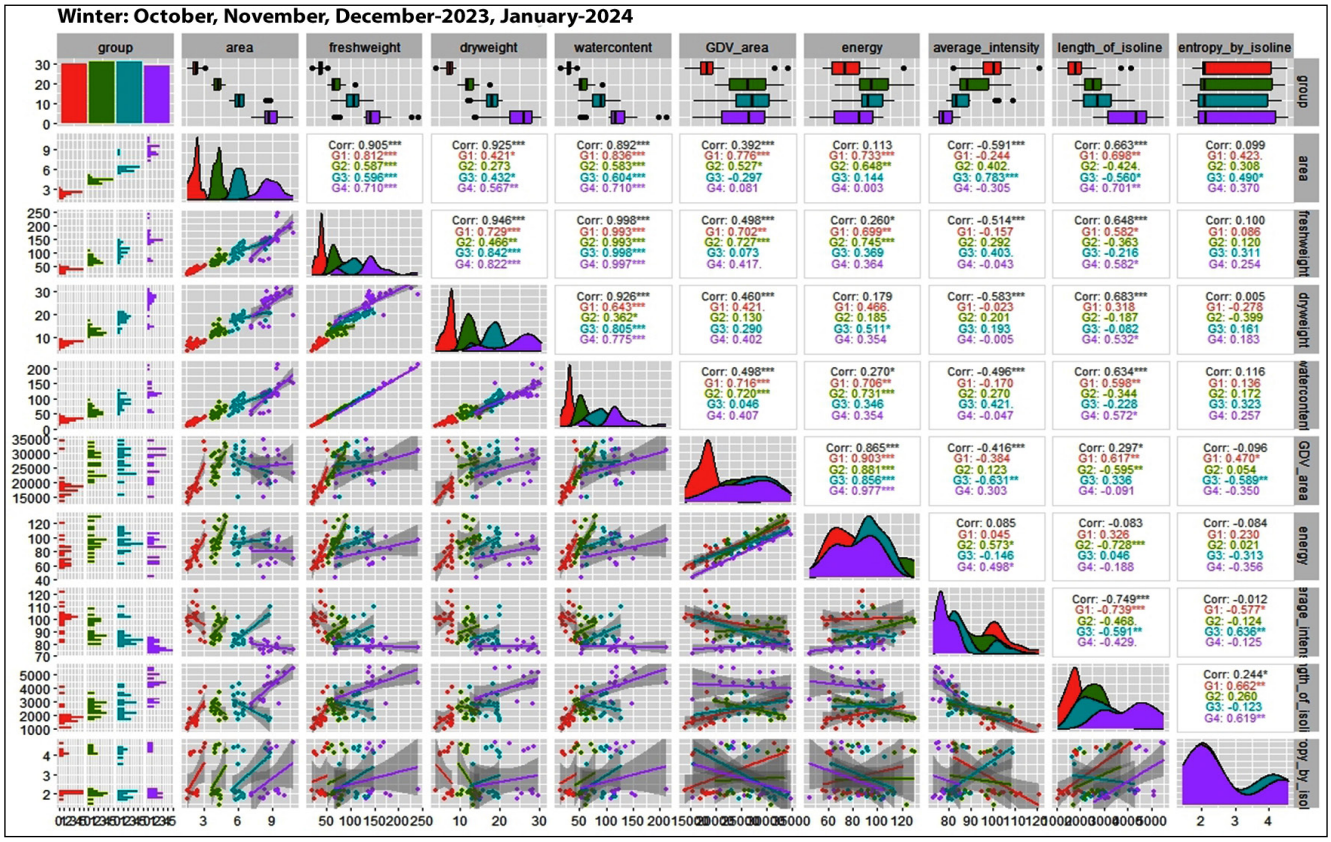

Fig. 5: Correlation matrix of winter seasons gravimetric and EPI parameter

in all groups of leaves. The entropy of monsoon season leaves showed a significant correlation with fresh weight (R^2: 0.536), Dry weight (R^2: 0.570), and water content (R^2: 0.519). Winter seasons leaves showed a very weak correlation with gravimetric parameters, while summer seasons leaves showed a negative correlation with gravimetric parameters. Thermodynamically, the leaf is open system that maintains its entropy by exporting the metabolic process. Due to the metabolism, the compartmentation of metabolites between the cells, within the different cell organelles and extracellular medium implies a decrease in entropy (Marín *et al.* 2009; Sabater, 2022). The higher entropy values present in the leaf could indicate the higher capacity of the system to change for the metabolic process. Variation in the entropy of the system is due to seasonal changes in the environment (Puzachenko *et al.* 2013).

EPI images of leaves and fruits give useful information about the stress status of plants and their variety (Korotkov, 1998). EPI images are very useful to find the differences in energy fields of organically grown foods versus foods treated with pesticides, herbicides, fertilizers, etc. (Prijatkin and Korotkov, 2014) and also to detect the germination rate of the seeds (Arkhipov *et al.* 2014). Many studies report the correlation between the glow area of control plant samples and treated ones (Priyatkin *et al.* 2018; Zanco *et al.* 2021; Nimavat *et al.* 2023).

From the overall results, it is concluded, The EPI analysis is very fast and non-invasive technique, the tested material can be used for other analyses if needed. Advantage of this technique, it does not require any special sample preparations (washed and blotted plant samples can be used directly). It represents the metabolic energy status changes of materials at the tested time; Thus, it saves the long time required for chemical analysis. Therefore, these EPI parameters can be used as a marker for study of seasonal variation of plant growth. Thus, EPI technique showing a very bright future for further applications in the fields of agriculture, and environmental sciences.

REFERENCES

Arkhipov, M.V., Priyatkin, N.S, Krueger, E.D., Kurtener, D.A. and Bondarenko, A.S. 2014. Seed assessment using fuzzy logic and gas discharge visualization data. *Eur. Agrophys. J.*, **1**(4): 124-33.

Arkhipov, M.V., Priyatkin, N.S., Velikanov, L.P., Bondarenko, A.S. and Zhigunov, A.V. 2013a. Identification of empty and plump seeds of spruce fir by X-ray and gas discharge visualization methods. *Agrophysica.*, **1**(9): 8-12.

Arkhipov, M.V., Pryatkin, N.S., Gusakova, L.P., Borisova, M.V. & Kolesnikov, L.E. 2016. Methodology for studying the characteristics of gas-discharge glow of seeds// Methodological guide (recommended for publication by the Scientific Council of the AFI, protocol No. 1 of February 18, 2016). St.-Petersburg: AFI, 52 pp. (in Russian).

Badeck, F.W., Bondeau, A., Böttcher, K., Doktor, D., Lucht, W., Schaber, J. and Sitch, S. 2004. Responses of spring phenology to climate change. *New Phytol*., **162**(2): 295-309.

Bhatt, K.R. and Thaker, V.S. 2008. Relationship between gibberellic acid and water amount in the cotton seed. *Russ. J. Plant. Physiol.*, **55**(6): 808-813.

Blanco, F.F. and Folegatti, M.V. 2003. A new method for estimating the leaf area index of cucumber and tomato plants. *Hortic Bras*., **21**: 666-669.

Catoni, R., Gratani, L. and Varone, L. 2012. Physiological, morphological and anatomical trait variations between winter and summer leaves of *Cistus species*. *Flora.*, **207**: 442–449.

Chapin, F.S. 2003. Effects of plant traits on ecosystem and regional processes: a conceptual framework for predicting the consequences of global change. *Ann. Bot.*, **91**(4): 455-463.

Chudasama, R.S. and Thaker, V.S. 2007. Free and conjugated IAA and PAA in developing seeds of two varieties of pigeon pea (*Cajanus cajan*). *Gen. Appl. Plant Physiol.*, **33**(1-2): 41-57.

Datta, U. and Chakroboarty, K. 2018. Fast and accurate method for estimation of leaf area index by image processing system: an innovative concept. *Pharma Innov J*., **7**(8): 401-4.

Dey, A.K., Guha, P., Sharma, M. and Meshram MR. 2019. Comparison of different methods of in-situ leaf area measurement of betel leaf (*Piper betle* L.). *Int. J. Recent Technol. Eng*., **7**: 1512-6.

Falster, D.S, Duursma, R.A. and FitzJohn, R.G. 2018. How functional traits influence plant growth and shade tolerance across the life cycle. Proc. Natl Acad. Sci. USA., **115**(29): E6789-98.

Guo, D.P. and Sun, Y.Z. 2001. Estimation of leaf area of stem lettuce (*Lactuca sativa var angustana*) from linear measurements. *Indian J. Agric Sci.*, **71**(7): 483-486

Hikosaka, K., Noguchi, K. and Terashima, I. 2016. Modeling leaf gas exchange. *In:* Hikosaka K, Niinemets U, Anten NPR, eds. Canopy photosynthesis: from basics to applications. Advances in Photosynthesis and Respiration, Vol. 42. Dordrecht: Springer, pp. 60–99.

Ke, M., Wang, W., Zhou, Q., Wang, Y., Liu, Y., Yu, Y., Chen, Y., Peng, Z and Mo Q. 2022. Response of leaf functional traits to precipitation change: A case study from tropical woody tree. *Glob. Ecol. Conserv.*, **37**:e02152.

Korotkov, K. 1998. Aura and consciousness: New stage of scientific understanding. St. Petersburg, Russian Ministry of Culture.

Korotkov, K. 2002. Human Energy Field: study with GDV bioelectrography. *Backbone*, **23**: 1-10.

Korotkov, K.G. and Korotkin, D.A. 2001**.** Concentration dependence of gas discharge around drops of inorganic electrolytes. *J. Appl. Phys.*, **89**(9): 4732-4736.

Kolesnikov, L.E., N.S. Priyatkin, M.V. Arkhipov, I.E. Razumova, D. Yu Radishevskiy, and Yu R. Kolesnikova. 2021. Influence of the structural and functional characteristics of the seeding material on the yield structure elements and resistance to leaf diseases of spring soft wheat. *Agronomy Research*, **19**(4): 1791–1812.

Lee, J.H. and Heuvelink, E. 2003. Simulation of leaf area development based on dry matter partitioning and specific leaf area for cut chrysanthemum. *Ann. Bot.*, **91**: 319-327.

Lin, S., Niklas, K.J., Wan, Y., Hölscher, D., Hui, C., Ding, Y. and Shi, P. 2020. Leaf shape influences the scaling of leaf dry mass vs. area: a test case using bamboos. *Ann. For. Sci*., 77(1): 1-5.

Marín D., Martín M. and Sabater B. 2009. Entropy decreases associated to solute compartmentalization in the cell. *Biosyt.*, **98**: 31–36.

Monpara, J.K., Chudasama, K.S., Vekaria, M.L, Patel, V.J. and Thaker, V.S. 2022. Standardization of linear model for leaf area measurement for medicinally important plants: *Balanites aegyptiaca* L. and *Gymnosporia montana* (Roth.). *Int. J. Agri. Environ. Biotechnol*., **15**(2): 157-65.

Monpara, J.K., Chudasama, K.S. and Thaker, V.S. 2019. Role of phytohormones in soybean (*Glycine max*) seed development. *Russ. J. Plant Physiol.*, **66**: 992–998.

Nimavat, N.M., Monpara J.K, Chudasama, K.S., Vekariya, M.L., VJ. Patel and Vrinda S. Thaker. 2023. Non-invasive electro photon image (Epi) analysis to detect chromium toxicity in cotton (*Gossypium hirsutum* l.) Cotyledons. *J. Cotton Res. Dev.*, **37**(1): 75-82.

Ojeda, A.D., Ligarreto, G.A. and Martínez, O. 2012. Effects of environmental factors on the morphometric characteristics of cultivated lettuce (*Lactuca sativa* L.). *Agron Colomb.*, **30**(3): 351-358.

Poorter, H., Niinemets, Ü., Poorter, L., Wright, I.J. and Villar, R. 2009. Causes and consequences of variation in leaf mass per area (LMA): a meta-analysis. *New Phytol.* 182(3): 565–588.

Priyatkin, N.S. and Korotkov, K.G. 2014. Testing of organic and conventionally grown seeds with Gas Discharge Visualization technique. Congress Science Information Spirit, St. Petersburg, 2014.

Priyatkin, N., Butenko, O., Shabunin, D.A, Arkhipov, M.V., Gusakova, L.P, Boitsov, A.A, Potrakhov, N., Staroverov, N. and Savvina, K.A. 2018. Examination of digital X-ray and gas discharge characteristics of English oak acorns (*Quercus robur* L.) for assessment of their sowing qualities. *Proceedings of the Saint Petersburg Forestry Research Institute*, pp. 18-29.

Puzachenko, Y., Sandlersky, R. and Sankovski, A. 2013. Methods of evaluating thermodynamic properties of landscape cover using multispectral reflected radiation measurements by the Landsat satellite. *Entropy*., **15**(9): 3970-82.

Sabater, B. 2022. Entropy perspectives of molecular and evolutionary biology. *Int. J. Mol. Sci.,* **23**(8): 4098.

Saura-Mas, S. and Lloret, F. 2007. Leaf and shoot water content and leaf dry matter content of Mediterranean woody species with different post-fire regenerative strategies. *Ann. Bot.,* **99**(3): 545-54.

Vialet-Chabrand, S. and Lawson, T. 2019. Dynamic leaf energy balance: deriving stomatal conductance from thermal imaging in a dynamic environment. *J Exp. Bot*., **70**(10): 2839–2855.

Singh, J., Singh, L., and Kumar, A. 2021. Estimation of leaf area by mobile application: Fast and accurate method. *Pharma Innov. J.,* **10**: 272-5.

Tsukaya, H. 2013 Leaf development. *The Arabidopsis Book,* **11**: e0163

Wang, C., He, J., Zhao, T.H., Cao, Y., Wang, G., Sun, B., Yan, X., Guo, W., and Li, M.H. 2019. The smaller the leaf is, the faster the leaf water loses in a temperate forest. *Front Plant Sci*., **10**: 58.

Wright, I.J., Reich, P.B., Westoby, M., Ackerly, D.D., Baruch, Z., Bongers, F. *et al.* 2004. The worldwide leaf economics spectrum. *Nature*., 428: 821–827.

Young, Y.C., Sungbong, O., Myoung, M.O. and Jung, E.S. 2007. Estimation of individual leaf area, fresh weight, and dry weight of hydroponically grown cucumbers (*Cucumis sativus* L.) using leaf length, width, and SPAD value. *Sci. Hortic*., **111**: 330-334.

Zanco, J.J., Boff, P., Werner, S.S and Boff, M.I. 2021. Biophototic in azuki bean seeds treated with ultrahigh dilutions. *Res. Soc. Dev.,* **10**(2): e26110212462.

Zhan, X., Chen, Z., Chen, R. and Shen, C. 2022. Environmental and genetic factors involved in plant protection-associated secondary metabolite biosynthesis pathways. *Front Plant Sci*., **13**: 877304.