Effect of Soluble Silica On Plant Stress: An Experimental Study

Abstract

This paper investigates the potential of using soluble silica as an innovative solution to enhance crop yield and address deteriorating soil health. This study aligns with Sustainable Development Goals 1 (No Poverty), 2 (Zero Hunger), and 13 (Climate Action), emphasizing sustainable agricultural practices. Soluble silica, administered as silicon dioxide (SiO2) or in water-soluble forms such as potassium silicate (K2O3Si) and calcium silicate (Ca2O4Si), has shown promising results in improving plant growth, yield, and resilience to abiotic and biotic stresses[1,2].In this work we also reviewed various 'Computations Methods for Plant growth.' There have been many researches done where we see different computational methods being applied to study plant growth slow-normal-fast due to different factors. As per our studies we would like to name under computational techniques: artificial intelligence; Computer vision; pattern recognition; and computer graphics on the main front. Although they may have some inter relationships. These are presented further with their applications in this research work.

1.0 Introduction:

India is currently facing an unprecedented decline in crop production and yield, leading to widespread food shortages. This crisis is exacerbated by the rising population, urbanization, and industrialization, which have significantly reduced the amount of arable land. As the demand for food continues to grow, there is an urgent need to improve crop production on existing land to meet the food requirements without compromising the sustainability of agricultural practices.

Abiotic and biotic stresses: Living and non-living external conditions hindering the plant growth. Adverse conditions can cast bad effect on physiology of plant.

Silica is sand by common name and Sio2 silicon dioxide chemically. Other forms available are potassium silicate and calcium silicate.

Food Security and agriculture sustainability: To keep crops free from insects and getting destroyed by any external condition, by testing; monitoring with technological solutions and implementations. Security is to protect- whereas sustainability of agriculture is give longer life to that activity.

The research aims to experimentally verify the benefits of soluble silica in enhancing crop production, reducing plant stress, and increasing the nutritive content of crops. By adopting this sustainable and cost-effective method, the study aims to elevate farmers' incomes, improve their livelihoods, and contribute to the overall economic growth of the country [14,15]. The findings suggest that soluble silica can significantly improve soil quality, boost photosynthesis, accelerate nutrient absorption, enhance fruit quality, and increase resistance to pests and diseases[3,4,5]. This research provides a viable solution to address the challenges of food security and agricultural sustainability in India.

We have also studied about role of computational methods and techniques on plant growth. Under this following subject and techniques have been studied

1. Artificial Intelligence
2. Computer Vision
3. Pattern Recognition
4. Computer Graphics
5. Color Detection Models
6. Color Detection Algorithms

Computers for Research in Plant Growth

Computers as such with their processing-storage-inputting and out putting along with software capabilities can be utilized in serving various aspects pertaining to plant growth monitoring-data capturing- processing-analytics-data storage and suggesting solutions. Plant growth studies fall under different subject sub sets of biology such as biotechnology; botany; and bioinformatics. These subjects with computer applications in plant growth research are presented below:-

Computers offer several benefits in the field of botany. They provide flexibility in changing set points of controlled variables and enable data acquisition, leading to optimal conditions for plant growth .

Additionally, computers play a crucial role in bioinformatics, aiding in data management, visualization, integration, analysis, modeling, and prediction in plant science .

In agricultural, ecological and scientific contexts measuring plant growth is essential for several reasons. For example, metrics obtained by such studies are useful in: maximizing crop output, ecosystems care, studying environmental factors, and conducting research in botany.

Plant growth measurements in bio technology are used to develop crops with improved traits- such as fighting ability against pests- diseases- environmental stress.

What is Plant Stress?

2.0 PLANT STRESS

Plant stress refers to any external condition that adversely affects plant growth, development, or productivity. These conditions can be abiotic (non-living) or biotic (living) and can disrupt the normal physiological processes of plants, leading to reduced crop yield and quality. understanding plant stress and its disadvantages is crucial for developing strategies to mitigate its impacts and improve agricultural sustainability. Lack of sufficient water can lead to reduced cell turgor, wilting, and impaired metabolic processes. High salt levels in soil can cause ion toxicity, osmotic stress, and nutrient imbalances. Both high and low temperatures can damage cellular structures and inhibit enzymatic activities. Excessive amounts of heavy metals like cadmium and lead can interfere with nutrient uptake and cause oxidative stress. Lack of essential nutrients can impair various physiological functions and reduce growth. Bacteria, fungi, viruses, and nematodes can cause diseases that impair plant health. Insects and other herbivores can cause physical damage and transmit diseases [16,17]. Competition for resources such as light, water, and nutrients can reduce the growth and yield of crops. Stress conditions can significantly lower crop productivity. For example, drought stress can reduce grain filling in cereals, leading to lower harvests. Stress can adversely affect the quality of produce. For instance, salinity stress can lead to smaller fruits and vegetables with poor taste and nutritional value. Stressed plants are more vulnerable to infections by pathogens. Abiotic stress factors can weaken plants' natural defense mechanisms, making them more prone to diseases. Stress conditions can slow down the growth rate of plants, delaying flowering, fruiting, and overall development. This can result in a prolonged growing season and delayed harvests. Reduced yields and poor-quality produce translate into financial losses for farmers [18-20]. This can be particularly devastating for small-scale farmers who rely heavily on crop sales for their livelihoods. Stress factors like salinity and heavy metal toxicity can degrade soil health over time, making it less fertile and more difficult to cultivate in the future. To combat stress, farmers may resort to using more water, fertilizers, and pesticides, which can lead to environmental degradation, including water pollution, soil erosion, and loss of biodiversity.

3.0 Computational Methods-Algorithms for Plant growth Studies:

Artificial intelligence(AI):

is the imparting of human intelligence to computer systems since they do not possess their own decision making abilities i.e. intelligence. AI finds its applications in various areas which include expert systems, natural language processing (NLP), speech recognition and machine vision.

AI systems investigate; analyze; interpret; large amounts of labeled training data. These analyze that data for correlations and patterns for making future predictions.

A relatively newer form of AI I machine learning. Machine learning (ML) is a type of artificial intelligence (AI) focused on building computer systems that learn.Machine learning is a method of data analysis that automates analytical model building. It is a branch of artificial intelligence based on the idea that systems can learn from data, identify patterns and make decisions with minimal human intervention.

Supervised Learning: In Supervised Learning algorithms learn to map points between inputs and correct outputs.

Unsupervised Learning: The main goal of unsupervised learning is to discover hidden patterns, similarities, or clusters within the data. These results can be used for data exploration, visualization, dimensionality reduction, and others

Semi-Supervised Learning: it uses both labeled and unlabelled data. It's particularly useful when obtaining labeled data is costly, time-consuming, or resource-intensive.

Reinforcement Learning: algorithm is a learning method that interacts with the environment by producing actions and discovering errors. Trial, error, and delay are the most relevant characteristics of reinforcement learning.

Machine learning is an important decision support tool for crop yield prediction, including supporting decisions on what crops to grow and what to do during the growing season of the crops. Several machine learning algorithms have been applied to support crop yield prediction research[6].

Computer Vision:

Computer vision also called machine vision is an interdisciplinary field that deals with how computers can be made to gain high-level understanding from digital images or videos.

These systemsfind their applications in different areas of agriculture with specific attention to plant growth.

Drone technologies for monitoring of crop; crop Yield monitoring in agriculture; smart systems for classifying and sorting crops by giving them a computerized eye and vision; automatic pesticide spraying-where to spray and how much to spray can be decided only after looking through computer vision systems. The other systems are:-

- Weather records-metrology through mobile and other data capturing and processing ways.
- Forest informatics
- Smart Farming offering them efficiency and effectiveness and application of electronics and Artificial Intelligence.

- Crop field security by offering them computerized vigilance

Pattern recognition:

is a field that can be very well be used in plant growth studies, it uses various methods/algorithms to extract information from signals and captured data which are from the statistical approaches and artificial neural networks subject areas.Application of machine learning has utilization inplant science and plant breeding. Various phenotype levels can be analyzed, from biochemical to yield, and in connecting genotypes to these. Thus machine learning provides methods that helps researchers to find patterns giving some meaning from plant data[7].

Computer Graphics:

Plant growth, these days, involves measuring changes in organ dimensions in terms of length, height, or width of stem, leaves, and fruits or increases in the number of leaves and fruits for quantitative analysis. Computer graphics is the subject for this.

The growth model and geometric calculations makes it possible to perform random plant simulation in 3-D according to morphology. Computer graphics methods such as perspective projection, coloring, shadowing, texturing are then used to visualize the computed plant for this they need special software and graphic CPU and card computers[8].

Color Detection Models:

There have been several instances of plant growth measurements with different instruments requiring color detection, which can be automated with color detection techniques and technologies. In computer vision, color detection algorithms are used to identify and track objects or regions of specific colors in an image or video. Some popular color detection algorithms include:

1. RGB color model: The RGB color model is based on the theory which tells us that every color is a mix of different proportions of 1) red2)green 3) blue in any image. This method is used to detect colors by comparing the intensity of each color in a given pixel.

2. HSV color model: The HSV color model another one which is based on the mix of

    1) hue
    2) saturation, and
    3) value

    parameters in an image.

    This method is less effected by changes in lighting conditions and has applications in object tracking and image segmentation.

A few of the other methods and models are:-

3. YCbCr color model: commonly used in image and video compression.

4. CIELAB color model:. is designed commonly used in color matching and color difference applications.

5. Color histograms: In this distribution of colors are studied and plotted in the for of histograms and the method is widely used to detect and track objects based on the histograms..

6. Machine Learning algorithm: These depend on training and testing with data sets storing color and image information, the data sets are labeled i.e. classified. Algorithm representative of ML are –

    1) Neural Network,
    2) Random Forest,
    3) KNN

    These perform the job of detecting colors within an image. Their results are highly accurate in terms of color detection.

Color detection Algorithms and Researches:

Colour detection is a process of detecting the name of any colour. There are number of different technologies which have been used for this purpose to implement various techniques. To mention a few they are: OpenCV, Python, pyttsx3 API, numpy and pandas libraries, and Tkinter module for GUI interface[9].

There are various color detection algorithms in computer vision, each with its own approach and use cases. Some commonly used color detection algorithms include:

Color Thresholding: This is simplest of all methods. In this method a color range is selected and we identify pixels falling in a range and assign it a color.

Histogram-based Methods: color histograms of an image are created and those are utilized to identify main colors and specific color patterns.

Color Space Conversion: Bringing images into different color spaces such as HSV, LAB etc. and applying thresholding or other techniques to colors.

Machine Learning Approaches: Using machine learning models to detect colors in images. These models could be :-

1) support vector machines
2) decision trees
3) deep learning methods .

Region-based Detection: Dividing an image into regions and color within each region is detected for tracking any of the objects andperforming image segmentation.

Hough Transform for Lines and Circles: Detecting colors for specific shapes- let us say for lines or circles by applying 'Hough Transform' in them.

Edge Detection and Color Association: In this method color information and edge detection information are used together to find regions where colors meet edges so as to perform object boundary detection.

In some situations color detection has been performed by applying Neural networks in Red-Green-Blue Spaces[10]. Color detectors were modeled and designed with appropriate algorithms using Internet of things boards[11].

Computers are playing big roles in studies in biotechnology, botany and bioinformatics [12,13].

5.0 Experiment

The objective of this research was to investigate the effects of soluble silica on the growth and development of Mung Beans (Vigna radiata). With declining crop yields in India due to various

stress factors, finding sustainable solutions to enhance agricultural productivity is crucial. Soluble silica, known for its benefits in improving plant resilience and growth, was chosen as the treatment to be tested.

Experimental Setup

Two groups of Mung Bean plants were grown: Group A (Experimental Group) and Group B (Control Group). Group A was treated regularly with soluble silica, while Group B received no silica treatment. All other growth conditions, such as light, temperature, and watering schedule, were kept identical for both groups.

Physical Growth Parameters Measured

1. Relative Water Content (RWC) 2. Root and Shoot Length

Biochemical Growth Parameters Measured

1. Carbohydrate Content 2. Protein Content 3. Total Chlorophyll Conten

6.0 Findings:

Physical Growth

1. Relative Water Content (RWC) - Group A exhibited higher RWC compared to Group B, indicating better water retention in silica-treated plants.
2. Root and Shoot Length - Group A showed greater root and shoot lengths, demonstrating enhanced growth due to silica treatment.

Biochemical Growth

1. Carbohydrate Content - Group A had significantly higher carbohydrate content, as evidenced by the stronger brick-red color in the Benedict's test.
2. Protein Content - Group A exhibited a higher protein content, indicated by a stronger purple color in the Biuret test.

3. Total Chlorophyll Content (TCC) - Leaves from Group A had higher chlorophyll content than those from Group B, suggesting better photosynthetic efficiency and plant health.

Conclusion

The research on Mung Beans (Vigna radiata) demonstrated the substantial positive impact of soluble silica on plant growth and development. The study was conducted by growing two groups of Mung Bean plants under identical conditions, with the experimental group receiving soluble silica treatment while the control group did not. The findings revealed that plants treated with soluble silica exhibited significantly improved physical and biochemical growth parameters compared to the control group. These results highlight the potential of soluble silica as an effective, sustainable, and environmentally friendly soil supplement. By enhancing water retention, nutrient absorption, and stress resistance, soluble silica can significantly improve crop yield and quality. This aligns with the need for sustainable agricultural practices to meet the growing food demands while adhering to Sustainable Development Goals (SDGs) such as No Poverty, Zero Hunger, and Climate Action. In conclusion, the application of soluble silica presents a promising approach to boost agricultural productivity, improve farmers' livelihoods, and contribute to food security and sustainable development.

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