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Monitoring Biotic and Abiotic Stress in Crop Plants through Remote Sensing

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Abstract

Determination of plant stress factors is challenging as it can be a compound result of water deficit, nutrient deficiency and disease infection. Symptoms arising from these stress factors may also be similar. Hence, visual observation alone could result in flawed diagnosis which would eventually disrupt remedial action for the affected plants. Spectral reflectance measurements help to identify and select wavelengths sensitive to different types of plant stress. Use of Remote sensing (RS) to monitor the crop affected by biotic and abiotic stress is based on the assumption that stress interferes with photosynthesis and physical structure of the plant at tissue and canopy level, and thus affects the absorption of light energy and alters the reflectance spectrum. Research into vegetative spectral reflectance can help us gain a better understanding of the physical, physiological and chemical processes altered in affected plants due to stress and to detect cause by different stress factors.

1. Introduction

Plant stress is defined as a significant deviation from the optimal conditions for plant growth that could cause harmful effects on plant which limits the normal growth and development. Plant stress can affect almost every part of a plant, although typically one or few plant structures are influenced depending on the age and the source of stress (Chong Yen Mee et al., 2017). Two types of environmental stresses are encountered by the crop plants which can be categorized as (1) Abiotic stress and (2) Biotic stress. The abiotic stress causes the loss of major crop plants worldwide and includes radiation, salinity, floods, drought, extremes in temperature, heavy metals, etc. On the other hand, attacks by various pathogens such as fungi, bacteria, oomycetes, nematodes and weeds are included in biotic stresses. A successful agricultural activities and operations are dependent on crop monitoring for nutrients, disease, water-stress, insect attack and the overall plant health. Previously, crop monitoring was done by visual examination of crops on the ground or from the air at times. However, these methods are so limited by the human eye which

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is not very accurate to distinguish between healthy crop and crops suffering from various kinds of stress. Most of the times, there are conditions that might not be visible but does not imply that the cop is very healthy. Now a days availability of optical techniques, like hyperspectral sensors, RGB imaging, remote sensing and chlorophyll fluorescence which can be utilized for early detection of plant stress factors which helps in taking better control measures and minimizing the damage caused by stress factors.

2. Remote Sensing

2.1. An overview

Remote sensing (RS) is the science and art of obtaining information about an object, area, or phenomenon through the analysis of data acquired by a device that is not in contact with the object under investigation. When electromagnetic energy is incident on any feature present on the earth surface, three energy reactions with the feature are possible: reflection, absorption and/or transmission. The portion of energy reflected, absorbed or transmitted will vary for different earth features depending on their material type and condition. Even within a given feature type, the portion of reflected, absorbed and transmitted energy will vary at different wavelengths. Thus, two features may be distinguishable in one spectral range and be very different in another wavelength band. Because many remote sensing systems operate in the wavelength regions in which reflected energy predominates, the reflectance properties of earth surface are very important. The reflectance characteristics of earth surface features may be quantified by measuring the portion of incident energy that is reflected. Reflectance is measured as a function of wavelength and is called spectral reflectance. A graph of the spectral reflectance of an object as a function of wavelength is termed as 'spectral reflectance curve' (Figure 1). However, spectral features are useful in detecting plant stress only if one single factor is involved. This approach may be challenging when discriminating different stress factors affecting a plant at the same time, which is more likely to happen in reality. This is due to the fact that some stressors may affect plant physiology in a similar manner, as in the case of nutrient deficiency and disease and changes in pigment content, moisture and canopy architecture. As a result, similar spectral responses may be recorded, thus making differentiation of crop disease and nutrient stress very challenging.

2.2. Plant responses to water stress

Plant responses to water stress are numerous and complex. They appear synergistically or antagonistically and are modified by co-occurring plant stresses under field

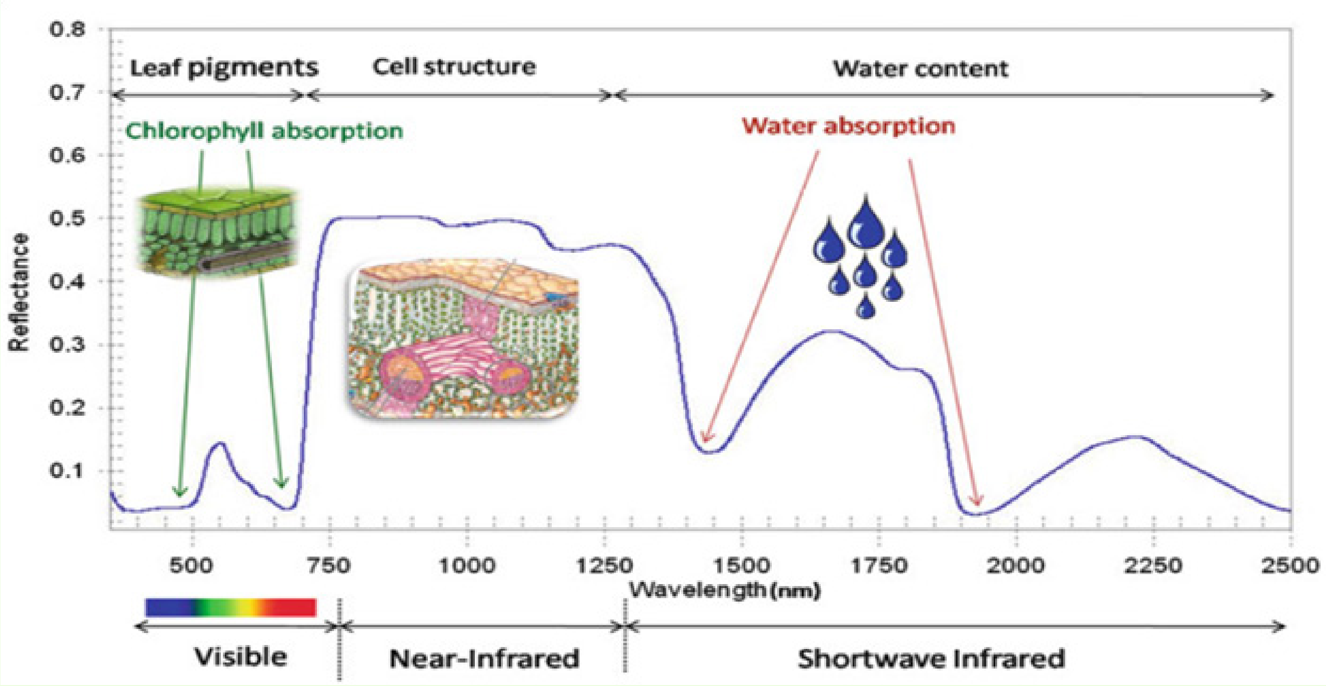

Figure 1: Typical spectral reflectance curve of healthy vegetation depicting different absorption peaks

conditions (Figure 2). Therefore, it remains difficult to detect and monitor plant water deficit based on a single plant response. In general, water deficit causes physiological and biochemical changes which induce a reduction in photosynthesis and thus plant growth.. However timing, intensity and duration of water stress are crucial to determine physiological responses and their impact on plant metabolism. For example, under water-stress conditions, plant regulation of water loss and uptake allows the plant to maintain relative leaf water content with no or only little change in photosynthetic capacity. In contrast, water deficit induces serious physiological and biochemical changes,which lead to effects ranging from inhibition of photosynthesis and growth to leaf wilting

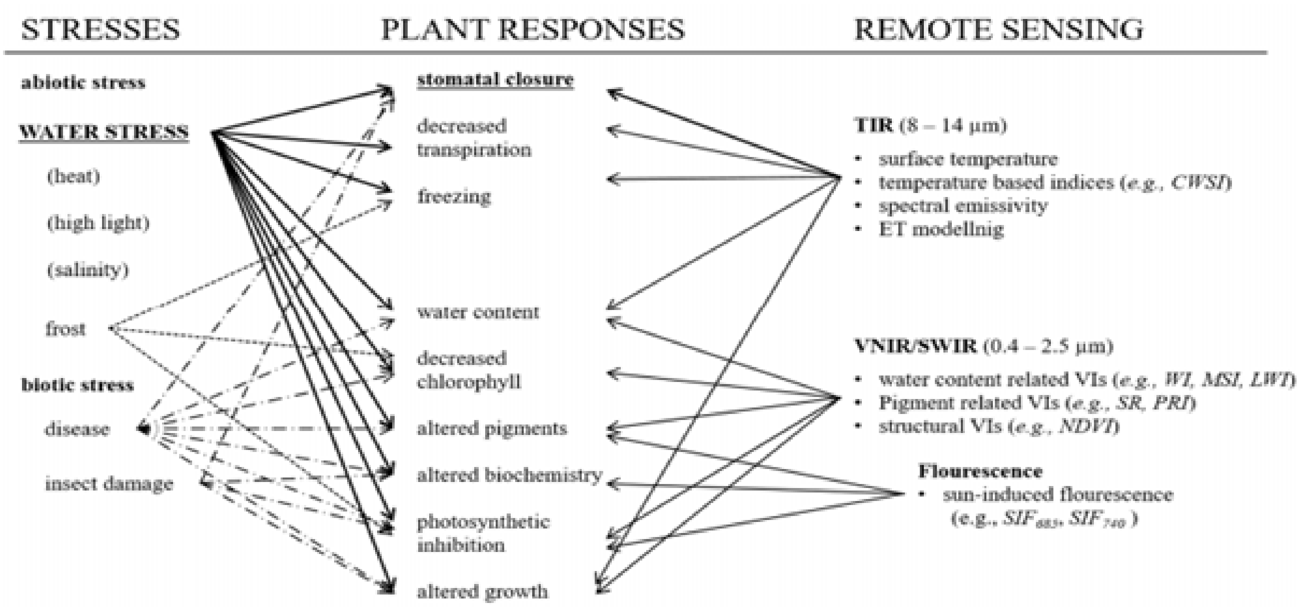

Figure 2: Multi/hyperspectral RS techniques for the detection of stresses (Max Gerhards et al., 2019)

and the loss of key pigments such as chlorophyll and thus to irreversible damages to the photosynthetic machinery. Hence, plants have developed multiple mechanisms to prevent severe damage through water stress and details are as mentioned below (Vijaya Kumar et al., 2005).

2.3. Plant responses to biotic (pest and disease) stress

Hyper spectral Imaging can help in distinguishing the signatures of healthy and infested plants to allow intervention before there is significant damage. The reflection of healthy plants in comparison to diseased ones is clearly higher at most portions of the spectrum, especially at the near infrared sector. Normalized Difference Vegetation Index (NDVI) {NIR − Red / NIR + Red} uses the NIR and red channels in its formula. Healthy vegetation (chlorophyll) reflects more near-infrared (NIR) and green light compared to other wavelengths. But it absorbs more red and blue light. The details of hyperspectral indices for assessing pest severity is mentioned below. (Jones and Schofield, 2008; Prabhakar et al., 2012).

Indices	Formula
Normalized difference vegetation ines (NDVI)	$(R_{800}-R_{670})/(R_{800}+R_{670})$
Green normalixed dirrerence vegetation index (GNDVI)	$(R_{750}-R_{550})/(R_{750}+R_{550})$
Pigments specific simple ration (PSSR)	$(R_{800})/(R_{635})$
Aphid index (AI)	$(R_{610}-R_{908})/(R_{712}+R_{719})$

3. Conclusion

The RS techniques applied to solve agricultural problems specifically related to nutrient stress that could have been influenced by other stressors. The geospatial techniques detect and interpret shapes and patterns of remotely-sensed imagery based on respective spectral signatures to quantify and visualize the changes in plants. Generally, these tools assessed are proved effective and efficient in detecting and monitoring nutrient stress but each of them has advantages and disadvantages which makes them unreliable when used solely.

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