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Infra-red Thermography: A Potential Tool for Plant Phenotyping

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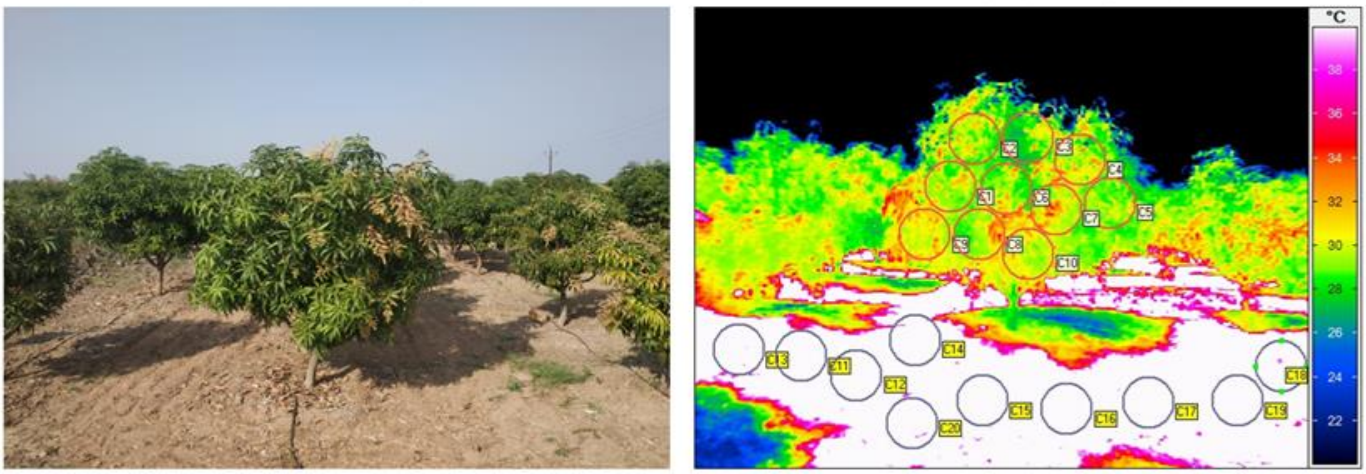
SUMMARY

Increasing occurrences of biotic and abiotic stresses driven by global climate change are increasingly challenging crop production. Among abiotic stresses, the drought, the supra optimal temperatures and the flood like situations are major constraints to the global food security. To meet the food demands of the ever-increasing population, in an environmentally sustainable way, there is an urgent need to develop abiotic stress resilient crop germplasms. This can be accomplished by the introduction of plant traits associated with abiotic stress tolerance in crop cultivars. Hence identification of germplasm serving as genetic sources of stress tolerance traits and the novel stress tolerance traits are crucial for the development of climate-resilient cultivars. It needs characterisation of stress responses of plants in a large scale. Feasibility gaps in conventional methods to accomplish this task can be easily bridged by cutting-edge phenotyping tools in plant-science research. Among the various phenotyping tools, infra-red thermography facilitates a high throughput screening of a large number of genotypes by characterizing canopy temperature responses to various stresses including high temperature and drought.

INTRODUCTION

Continuously rising ambient air temperature across the globe is a strong indicator of climate change that can severely impact agriculture and rural livelihood. The past thirty years were the warmest years of the last 1400 years in the Northern hemisphere (Singh and Singh 2012). Due to recurrently occurring drought events, world food production is declining. It may steadily result in developing the food scarcity for ever increasing world population. Due to climate change-induced abiotic stresses across the globe, the losses in food production can be above 40% (Bailey-Serres, 2019). During the past 2-3 decades, the Indian subcontinent has witnessed recurring drought-like situations that have resulted in a considerable loss in agricultural production hence affected the country`s socio-economic status. The occurrence of drought has enhanced in states like Maharashtra, Gujarat, some parts of Rajasthan, Tamil Nadu, Andhra Pradesh, and Telangana.

Visible image IR image (analyzed)



In this context, there is a need to accelerate crop breeding for abiotic stress resilience which can ensure yield stability and genetic gain in yield. Conventional breeding approaches have met with limited success in developing tolerant genotypes as they rely on yield and yield components as selection traits. The feasibility of employing difficult to measure physiological trait was one of the constraints for crop scientists. Hence the introduction of modern phenotyping tools for facilitating the ongoing attempts for the climate-resilient crop is highly essential to bridge this gap. These phenotyping tools usually help capture plants stress responses in terms of changes in morphological and physiological attributes. Based on these responses, researchers can identify promising traits contributing to stress tolerance and also the potential donor germplasm for crop breeding aiming at a particular abiotic stress condition. When plants exhibit perturbed physiological and metabolic activities under supra-optimal ambient temperatures (Wahid *et al*. 2007), modern phenomics tools such as infrared thermography can help understand the canopy temperature dynamics of plants non-destructively. Capacity to keep the canopy has been identified as a critical trait to find out the drought-tolerant genotypes in various crops. Besides, canopy temperature of plant provides vital information on genotypic screening (Rebetzke *et al*. 2013). When a plant experiences a shortage of soil moisture in the upper layers of soil, efficient plants tend to extract it from deeper soil layers. Genotypes differing in their capacity to remove water from a deeper layer of soil can be differentiated based on their canopy temperature (Kumar M *et al.* 2017).

Role of Infra – red thermography in Plant Phenotyping

Infra - red (IR) thermography is a method of detecting surface temperature of an object from which infrared energy is emitted. IR thermography works on the basis of conversion of emitted infra – red energy into temperature. The principle of infrared thermography is based on the physical phenomenon that any material of a temperature above absolute zero (-273.15°C) emits electromagnetic radiation (https://www.bestech.com.au/blogs/infrared-thermography-operating-principle-and-applications/). There is strong correlation between the surface of a body, and the intensity and spectral composition of its emitted radiation. Thermographic cameras usually sense radiation in the long-infrared range of the electromagnetic spectrum (approx. 9–14 µm) and can generate images of that radiation, called thermograms. Every object with a temperature above absolute zero emits infrared radiation in compliance with the black body radiation law. Infrared thermography enables examination of temperature dynamics of growth environment of a living organism with or without visible clarification (https://en.wikipedia.org/wiki/Thermography).

Assessment of plant canopy temperature by IR thermography is primarily used to study plant water relations, because a major determinant of leaf temperature is evapotranspiration from the leaf (Sofi et al. 2019, Jones et al. 2009). IR imaging can also be employed to study the water status and relative chlorophyll content of leaves (Munns et al. 2010). The plant maintains its canopy temperature below threshold level by regulating water movement in leaves (i.e. through stomata). This phenomenon is said to be transpirational cooling. IR thermography can be considered as micro remote sensing approach in agriculture research because IR based imaging or thermometer senses the canopy temperature remotely and without interfering the plant. Canopy temperature can be measured both by the IR-thermometer and the thermographic camera. There is well-established relation between canopy temperature and some other physiological traits like stomatal conductance, transpiration rate and photosynthetic health and ultimately describes the yield of the plant. It significantly differentiated leaf temperature, air temperature, and canopy temperature under drought and high-temperature stress in melons, tomatoes, and lettuce (Qiu *et al*. 2009). Wheat genotypes like MACS 3125, HI 8627, HI 8638, HI 8498, WH 896 and HI 8691 showed stable performance under both late and very late sown conditions over the years (Gautam *et al*. 2015) owing to their tolerance to terminal heat. Kumar M *et al*. 2017 employed this technology to screen soybean genotypes in association with seed yield under semi-arid region of India. Therefore, it is clearly evident that canopy temperature reveals plant health (Kumar M *et al.* 2017). This technology is beneficial for screening drought-tolerant genotypes in various crops (Kirkham 1983, Sojka 1985).

Factors to be considered while using IR thermography (Reynolds *et al*. 2012)

- Soil moisture level
- Ambient temperature
- Sunshine
- Relative Humidity
- Time at which observation to be taken
- Angle at which images are captured
- Background of the object
- Plant species
- Crop growth stage

Difference between IR thermometer and IR thermography (IR Imaging)

IR thermometer	IR thermography (IR Imaging)
Shows temperature in digital number format	Generates image of whole object which further analyzed to derive indices
Shows temperature of one single spot	Gives temperature of each pixel of analyzed image thus the background and the plant can be assessed simultaneously for temperature dynamics
There should be least possible distance between thermometer and object to get accurate temperature reading,	Can sense temperature from longer distance
Tedious to use over larger area	Easy to monitor the temperature over larger area and for longer time
Accuracy and precision level is less	Accuracy and precision level is high

IR Thermometer (IR Gun)

IR Camera

Platforms used for Infrared Imaging

- Phenotyping platform in controlled environment
- Ground base mobile system in open environment
- Aerial imaging (Drone)

CONCLUSION

IR thermography provides an efficient, rapid and non-invasive monitoring of plant response to different stresses like soil moisture deficiency, salinity and some biotic stresses. IR imaging provides more accurate and précise temperature measurements to screen the large number of germplasm lines rapidly. Hence, this high throughput technology has emerged as potential tool for breeders who are aiming at development of abiotic stress tolerant varieties.

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