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Phototherapy: A Ray of Hope in Plant Disease Management

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SUMMARY

This article insights on effect of light on disease development and management of horticultural crops under protected cultivation. As a result of enhanced plant resistance and direct disruption of pest/pathogen biology, light can be used for plant health and quality. In protected horticulture, advances in technology are rapidly exploited to manage diseases. Many aspects of plant biology are influenced by light, including disease resistance. The spores of many plant pathogens are killed by exposure to solar radiation. The different plant species have different light responses, the light responses of different pathogens vary, as do the interactions in different plant/pathogen systems in response to light. Specific wavelengths of light, especially red, blue and green, can induce disease resistance in standing crops against a wide range of phyto pathogens. Spectral quality can have significant effect on plant physiology that could alter plant resistance to microbial challenge. Hence, it is felt essential to intensify the advanced, noval and eco-friendly programme on plant protection through the use of LED’s to mitigate the various biotic stress under protected cultivation.

INTRODUCTION

The rapid growth of the human population puts more pressure on the agricultural sector to produce more crops. Crop yields can be increased by using irrigation, synthetic fertilizers, supplemental lighting and pesticides in greenhouses. Due to this increase in agricultural production to meet out the uncontrolled growing population, there is drastic change in climate and shift of rainfall patterns in recent years. These effects of the agricultural sector and the high costs of crop production have resulted in significant scientific and social debates around the development of new and sustainable plant and crop protection strategies to elevate food production. In this regard, development of environmentally friendly and high-yielding approaches with fewer adverse environmental effects is key to overcoming these problems.

As we know that, light is being the fundamental source for photosynthesis and regulates plant growth, its development and other cellular metabolic processes, such as by controlling the endogenous circadian clock. In particular, plant responses to various biotic stress are influenced by light intensity, quality, duration, and timing. In recent years, lots of research has been conducted extensively on the effect of light for various biotic and abiotic stress management showing light being “Ray of hope” in resolving plant stress and enchaning crop yield.

Phototheraphy:

Initially, Light therapy, also known as phototherapy or bright light therapy was used for humans by exposing skin to direct sunlight or artificial light at controlled wavelengths in order to treat a variety of medical disorders, including seasonal affective disorder (SAD), circadian rhythm sleep-wake disorders, cancers, and skin wound infections. Treating skin conditions such as neurodermatitis, psoriasis, acne vulgaris, and eczema with ultraviolet light is called ultraviolet light therapy. Nowadays, in several countries, phototheraphy is being practiced in their kitchen gardens, greenhouses at particular wavelenths as friendly approaches to plant and crop disease management.

History of Phototheraphy:

It is well documented that, many ancient tribes, such as Greece, Egypt, and ancient Rome, practiced various forms of heliotherapy in human disease management. Indian medical literature dating to 1500 BCE describes a treatment combining herbs with natural sunlight to treat non-pigmented skin areas. Buddhist literature from about 200 CE and 10th-century Chinese documents make similar references. The function of light in regulating plant abiotic stress responses, such as temperature responses and drought resistance, to maintain the normal growth and development of plants has been widely reported (D’Amico-Damião and Carvalho, 2018; Szalai et al., 2018; Roeber et al., 2021; Wang et al., 2021a).

Plant Responses To Light

Light is a form of electromagnetic radiation which is emitted from the sun. White light is composed of the various colors that are visible in the spectrum, which ranges from 400 to 700 nanometers (nm), collectivly called as VIBGYOR *i.e.* violet (400 nm), indigo (445 nm), blue (475 nm), green (510 nm), yellow (570 nm), orange (590 nm) and red (650 nm). Infrared radiation has a longer wavelength than visible red light, while ultraviolet radiation has a shorter wavelength than visible light. There are many reports indicating light in regulating various metabolic reactions in plant cell including germination, de-etiolation, stomatal development, circadian rhythm and flowering. Furthermore, it can influence growth and developmental processes, including different metabolic pathways in plant–pathogen interactions. In contrast to optimal light conditions, high and low light intensity, including darkness, induce different signalling and regulation pathways modulated by phytohormones, especially jasmonic acid (JA) and salicylic acid (SA).

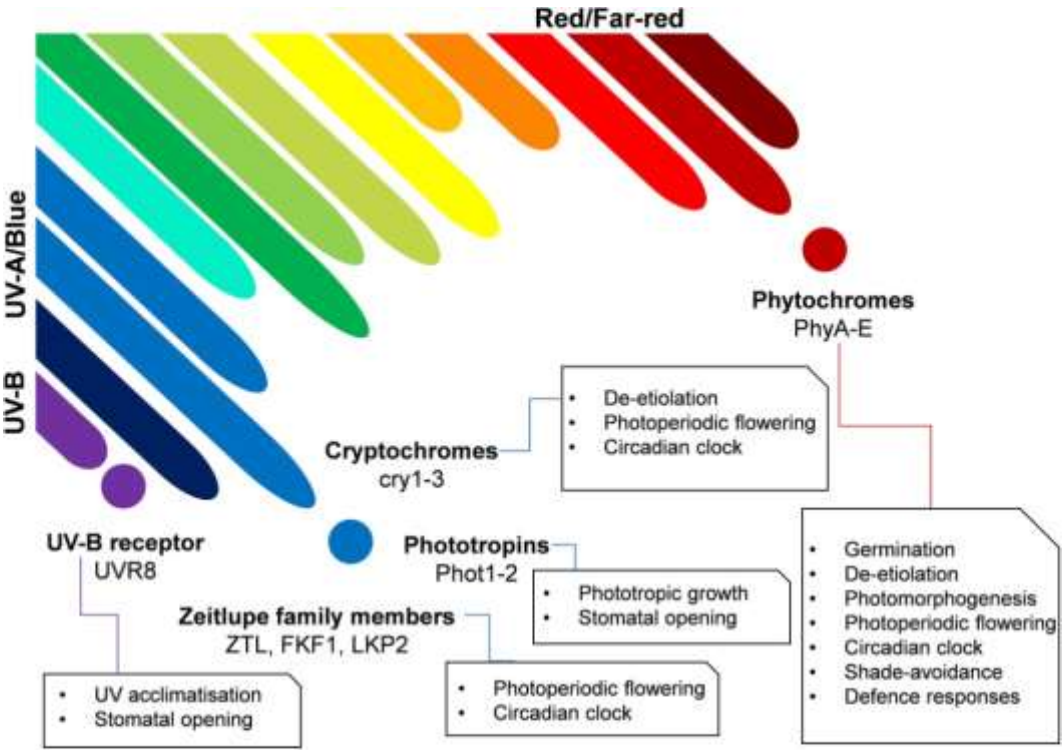

Fig. 1 Plant photoreceptors and their role in plant life regulation. Red/far-red-light is sensed by phytochromes (phyA–phyE), blue-light is absorbed by cryptochromes (cry1-3), phototropins (phot1 and phot2) and Zeitlupe family members (ZTL, FKF1 and LKP2). UV-B is perceived by UVR8. Photoreceptors mediated plant responses are shown in boxes (Paik & Huq, 2019).

Impact of Light in Key Defence Related Proteins in Plants

The variation of light influences the role of phytohormones in regulating plant defense responses. An classical example for influcing phytoharmone under varied light condition is Salicyclic acid (SA). It is required to establish both local and systemic acquired resistance after pathogen infection.An elevated SA concentration in stressed tissues causes a rapid accumulation of reactive oxygen (ROS) and nitrogen species (i.e., nitric oxide and peroxynitrite), which leads to oxidized proteins and hypersensitive responses that cause cell death in infected tissues, which is more pronounced under high light.

Plant Pathogens and Their Interactions With Light

It is also believed that the environment of light affects the interactions between plants and their pathogens. As cited above, light affects many aspects of plant biology and many of these responses influence plant resistance to disease. Several studies showed that, the red: infra-red ratio in particular has been shown to influence the expression of many genes, via the phytochromes, that are involved in disease resistance. Likewise, low red:far- red ratios decrease the production of many secondary metabolites involved in disease resistance and thus reduce resistance.

Schuerger and Brown (1997) observed that in tomatoes infected with bacterial wilt (*Pseudomonas solanacearum*) and cucumber plants infected with powdery mildew (*Sphaerotheca fuliginea*), disease symptoms were at their lowest in plants grown under 100 per cent red light. In contrast, for tomato mosaic virus on pepper plants, disease symptoms were slower to develop and less severe in plants grown in the presence of blue/UVA light. These data shows that spectral modification could be used as part of an integrated disease management system, with the caveat that care must be paid to the development and achievement of appropriate light treatments.

Advanced Leds For Crop Loss Management

Nowadays, LEDs have been gaining attention as a handy tool for sustainable agricultural practices. There are few examples where LEDs are being used to manage the crop loss due to pathogens. Example, single-spectral blue LEDs reduce the postharvest decay of citrus fruits caused by Penicillium species, when compared with dark conditions. In one of the study conducted by Ganesh (2013) showed that germination of powdery mildew conidia can be intrupted by apply light as the germination is reqires dark condition. Hence this study can be harvested in development of disease management statergy against powdery mildew fungi. Amsalem *et al*. (2006) also found in the case of strawberry powdery mildew, significant lower levels of disease severity are recorded at the highest light intensity of 7000 lux, compared to those at 1200 and 3800 lux, which are very similar and not significant in value. Likewise, one of the studies found that the germination of conidia in tomatopowdery mildew species is higher in dark filterwith comparison to combination of pink and green filter.

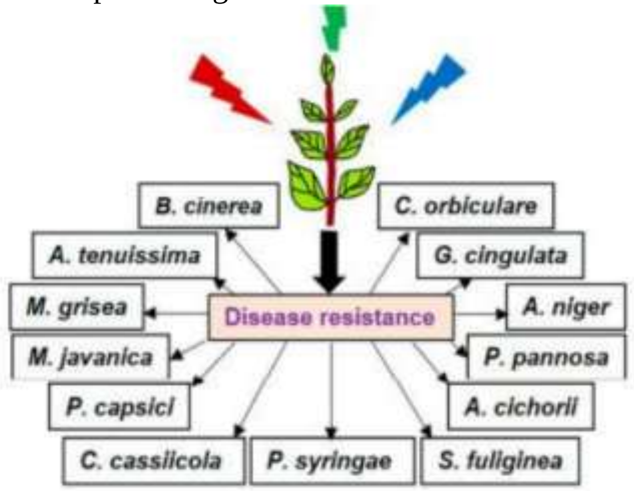

Figure2. Effect of LEDs on disease resistance against different pathogens
Source: Md. Mohidul Hasa et al., 2017, Korea Forest Research Institute, Molecules MDPI.

CONCLUSION

A higher yield and better nutritional quality are the ultimate goals of crop production which can be achived by proper and timely management of biotic and abiotic stress. Due to over explosion of population, change in climate and erratic rainfall advarsly affected the crop production which created scarcity to feed the hunger one. Hence, it is felt essential to intensify the advanced, noval and eco friendly programme on plant protection through the use of LED's to mitigate the various biotic stress under protected cultivation. For this purpose light -induced plant disease resistance could suggest new approaches towards minimizing the use of chemicals for crop protection. Advances in technology are rapidly exploited by the protected horticulture industry light act us disease development and management.

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