Influence of Natural Light Colour Spectrum on the Growth of Fungal Plant Pathogen *Alternaria solani*, under Different Light Intensities and Initiation of Leaf spot Disease Symptoms in Tomato Plants: An Advanced Study

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Abstract

Natural sunlight constitutes different light colour spectrums viz. violet, indigo, blue, green, orange and red that are of different wavelengths which are known to affect the growth of fungal plant pathogens. However, the effect of these colour spectrums under different light intensities on fungal growth and plant disease initiation has not yet been studied and reported. In the present investigation, we studied the influence of various light colour spectrums on the growth of tomato leaf spot fungal pathogen *Alternaria solani,* under different light intensities and on the initiation of leaf spot disease symptoms in tomato plants under *in vivo* conditions at a location of 19.392677 latitude and 74.648827 longitude in India.

The natural sunlight having all colour spectrum with the light intensities of 72,000 – 1, 08, 100 and 45, 000 – 1, 05, 200 Lux (received from 12.00-2.00 pm and 2.00- 4 .00 pm respectively) has a detrimental effect on the growth of fungal pathogen *Alternaria solani*. The light intensities lower than 72, 000 Lux were favourable for the growth of this fungal pathogen. Among the light colour spectrum, the navy blue (420-445 nm wavelength) and yellow colour spectrum (570-590 nm wavelength) favour fungal growth whereas a red colour spectrum (620-750 nm wavelength) restricts the fungal growth under field studies. Under *in vitro* experimentation, the maximum fungus growth was obtained under a navy-blue colour spectrum whereas minimal fungal growth was obtained with a red colour spectrum. 6 hrs of light + 18 hrs of darkness under a suitable light colour spectrum produce more growth as compared to 24 hrs of light without any darkness. Less fungal growth was obtained with the red (620-750 nm wavelength), blue (450-495 nm wavelength) and green colour (495-570 nm wavelength) spectra in various light intensities as compared to other colour light spectra.

The initiation and development of Alternaria leaf spot symptoms in tomato leaves were influenced by light-colour-spectrum-dependent light intensities. At 200 Lux maximum PDI (53.4 -54.6 %) was obtained in orange (590-620 nm wavelength), yellow (570-590 nm wavelength) and green colour (495-570 nm wavelength) spectrum as compared to natural white light (53 %). At 100 Lux light intensity, the maximum PDI was produced in a natural white colour as compared to other light-coloured spectra. At 2000 lux intensity the maximum PDI was produced in the orange colour spectrum as compared to the visible light spectrum.

The results on the influence of specific light spectrum on the plant pathogens and their disease initiation are useful to determine the use of colour transparent films in the erection of shade-net or poly-houses structures to get disease-free *in situ* crop cultivation.

Keywords

Sunlight, light-coloured spectrum, fungal growth, *Alternaria solani*, disease development, tomato crop

Introduction

The lights emitted by the sun and moon are a driving force for life on our planet. Though life begins in the dark, both darkness and sunlight illumination are necessarily required for the life processes and several metabolic cycles in living beings. Natural light or sunlight is a compilation of short and long wavelengths identified as violet (400 nm), indigo (445 nm), blue (475 nm), green (510 nm), yellow (570 nm), orange (590 nm), and red (650 nm). Most fungi exhibit a specific response to certain light wavelengths (Ceron-Bustamante et.al, 2023) The human eye sees colour over wavelengths (Table 1) ranging roughly from 400 nanometers to 700 nanometers and is called visible light or the visible light spectrum (Pal and Pal, 2001). Violet light has the shortest wavelength, which means it has the highest frequency and energy while red has the longest wavelength, the shortest frequency, and the lowest energy.

Table 1. The wavelengths of the visible light spectrum

Sr.no.	Light spectrum	Wavelength (in nm)
1	Violet	380 - 450
2	Indigo	420 - 445
3	Blue	450 - 495
4	Green	495 - 570
5	Yellow	570 - 590
6	Orange	590 - 620
7	Red	620 - 750

Light plays a crucial role in the growth and development of living microorganisms including filamentous fungi. Fungi see light of different colours by using photoreceptors such as White Collar protein and cryptochromes for blue light, opsins for green light, and phytochromes for red light. Light regulates fungal development, promotes the accumulation of protective pigment and proteins, and regulates tropic growth (Corrochano, 2019). Plants collect, concentrate, and conduct light throughout their tissues, thus enhancing light availability to their resident microbes (Beattie et.al., 2018). In the process of fungal infection of plants to cause plant disease, how this light spectrum plays a role is not yet studied and understood. Determination of the role of light spectrum under different light intensities on fungal growth and plant infection will enhance our basic understanding and knowledge of plant pathology.

Material and Methods

1. Measuring Light Intensities in Experimental designs and light-colour-spectrum effect in the Laboratory and Open Fields

1.1. Use of Photometric Lux meter to measure visible light intensities

The photometric lux meter was used to measure light intensities in lux (Lx) units. The lux meter having a range of 100 lx to 4, 00, 000 lx was used to measure visible light intensities.

1.1.1. **In vitro, arrangement of experimental set-up to obtain different light intensities**.

The experimental set-up was prepared based on the observation that as the distance increased from the source of light, the intensity of light decreased and that it remained the same at a particular point/location when there was no environmental change (fig 1).

Fig 1. In vitro experimental set-up for obtaining different light intensities.

Based on light intensities observations under *in vitro* conditions up to 11 days, only five light intensities (viz. 2000 lx, 1000 lx, 600 lx, 200 lx and 100 lx) were selected to see their effect on fungus growth while the remaining light intensities were discarded as these were not feasible for the *in vitro* experimentation. The experimental setup and measurement of light intensities were carried out as reported by Borkar et. al. (2024).

2. Isolation of *Alternaria solani,* from tomato plant, its pathogenicity test, and use in the light colour spectrum and light intensity studies.

The isolation of *Alternaria solani* from *Alternaria* leaf blight-infected tomato plants and its pathogenicity was tested as described by Borkar et. al, (2024). The fungus was confirmed as *Alternaria solani* (Fig. 2) based on its morphological characteristics (Barnett and Hunter, 1972). The fungal culture was sub-culture once a month to maintain its viability. The pathogenicity of the culture was proved on the tomato plant leaves by spray inoculation of *Alternaria* spore suspension on leaves, followed by incubation in a humid chamber and observing the development of leaf spot symptoms.

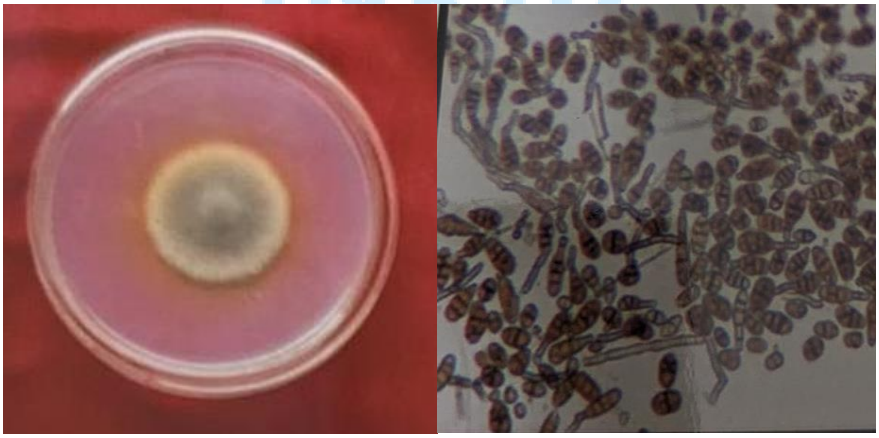


Fig.2. Pure fungal culture of *Alternaria solani* and microscopic *Alternaria* spores

3. *In vitro,* studies on the effect of different light-colour-spectrum under different light intensities on the growth of *Alternaria solani*

The sterile petri plates were poured with 15-20 mL of sterilized PDA media under a laminar flow cabinet and kept overnight at room temperature to detect any contamination. The next day, the un-contaminated petri plates were inoculated with an 8-day-old 1 cm diameter mycelial disc of *A.solani* at the centre of the plate (fig 3).

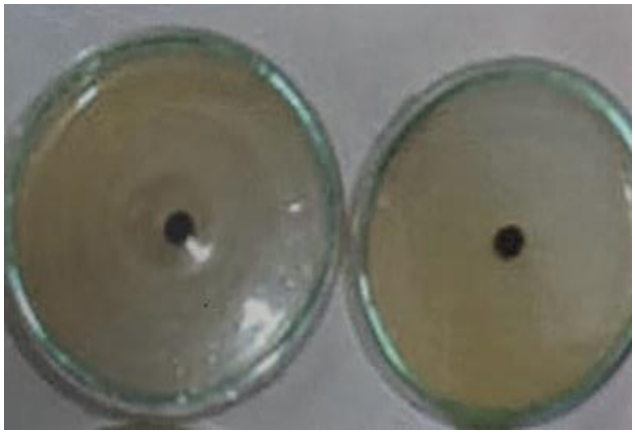
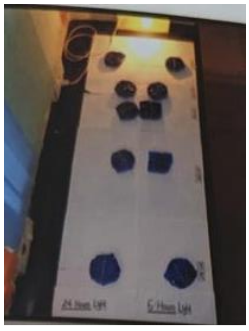
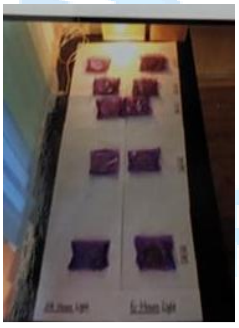


Fig.3. Preparation of *Alternaria* fungal disc plates to be exposed to various light intensities.

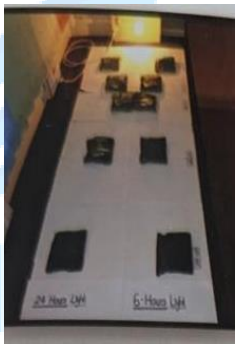
The PDA plates inoculated with fungal discs were sealed by using sticky transparent tape to avoid contamination. The transparent gelatine papers of different colours viz. red, green, yellow, blue, violet, orange and navy blue were used to obtain various light colour spectrums of the visible light. The sealed plates were wrapped in the respective coloured transparent gelatine papers and kept on white paper with marked positions of various light intensities under observation (fig 4). For each colour spectrum, 5 plates were used which were exposed to 24 hours of the respective coloured light spectrum, incubated in a BOD incubator at 28 ± 1 ^{0}C, and observed daily for 8 days for the growth of *A.solani* mycelium.



1. Navy Blue colour (420-445 nm)



2. Violet colour (380-450 nm)



3. Green colour (495-570 nm)

4. Blue colour (450-495nm)

5. Red colour (620-750 nm)

6. Orange colour (590-620 nm)

7. Yellow colour (570-590 nm)

Fig.4. Influence of different light colour spectrums with their wavelengths (in nm) on the growth of *Alternaria solani* under *in vitro* experimentation at different light intensities.

4. *In vivo,* studies on the effect of different light-colour-spectrum of different light intensities during daylight on growth of *Alternaria solani.*

The time slots for this experimentation were natural light hours of 6.00 – 8.00 am, 8.00 – 10.00 am, 10.00 am -12.00 pm, 12.00 - 2.00 pm, 2.00 – 4.00 pm, and 4.00 – 6.00 pm. The PDA plates with fungal discs (1 cm diameter) at the centre were sealed by using sticky transparent tape to avoid contamination. The sealed plates were wrapped in respective coloured transparent gelatine papers individually i. e. in red, green, yellow, blue, violet, orange and navy blue. Then the respective colour paper-wrapped plates were placed in natural visible light for 2 hours in the above time slots. For each time slot, the maximum light intensity was recorded by using a photometric lux meter. After 2 hours of exposure to concern light intensities, the plates were removed and kept in a BOD incubator at 28 ± 1 ^{0}C for 5 days and the mycelial growth of *A. solani* was measured.

5. Effect of Diurnal condition on the growth of *Alternaria solani* under different light colour spectrum

The Petri plates inoculated with *A.solani* mycelial discs as stated above were wrapped in different colours of gelatine papers. These plates were exposed to different light intensities particularly 2000 Lx, 1000 Lx, 600 lux, 200 Lx, and 100 Lx under *in vitro* conditions, under two different sets of diurnal conditions i.e. 6 hours of light + 18 hours of darkness, and 24 hours of light + 0 hours of darkness. After the light exposure treatment, the plates were incubated in a BOD chamber at 28 ±1^{0}C and the fungal mycelial growth was measured after 5 days of incubation.

6. studies on the effect of different light-coloured spectrums on *Alternaria* infection in tomato plants.

6.1. Raising of Tomato Seedlings

The medium-sized plastic pots were filled with a mixture of soil+ FYM (2:1 ratio) to about 3/4th of the pot height, and water a day before sowing the seeds. The pure seeds of tomato variety JK-511 were used for sowing in the above pots at a shallow depth of about 1-2 cm. Three tomato seeds were sown in each pot. The pots were watered after sowing and frequent watering was given as per the requirement. These pots were kept in a place where sunlight and ventilation were available. These were maintained up to 45 days after sowing to attain the 5-6 leaf stage.

6.2. Inoculation of *A. solani* pathogenic culture on tomato seedlings

To obtain *A. solani* fungal spore suspension for seedling inoculation, an aqueous suspension of fungal spores (conidia) was prepared by pouring sterile distilled water onto agar plates containing sporulated *A. solani* cultures, and by gently scraping the fungal growth on the agar surface. The spore suspension was passed through four layers of sterile muslin cloth to remove mycelial fragments. The collected *Alternaria* spore suspension was poured into a small plastic sprayer and the leaves of the seedlings (having eight leaf stage) were sprayed carefully and used to carry out further experiments.

6.3. Studies on the *A. solani* Pathogenesis of inoculated Tomato seedlings under various light colour- spectrums and light intensities.

The arrangement of the experimental unit was the same as described earlier. The pots having *Alternaria solani* inoculated tomato seedlings were wrapped individually with coloured transparent gelatine paper (red, green, yellow, blue, violet, orange and navy blue) in such a way that the seedlings were not disturbed (fig 5).

1. Red colour 2. Orange colour 3. Yellow colour 4. Green colour

5. Blue colour 6. Navy blue colour 7. Violet colour

Fig 5. Effect of different light-coloured spectrums on the initiation of *Alternaria* leaf blight symptoms at different light intensities under in vitro experimentation.

Then, these pots were kept at a particular location under an *in vitro* experimentation setup to obtain the desired lux intensity of visible light as described earlier. There were about 70 pots (with 2 seedings in each pot). For each colour, 10 pots were used (5 pots under 6 hrs of light and 5 pots under 24 hrs of light). After the respective light colour spectrum treatment, these plants were incubated in the humid chamber under glasshouse conditions for 24 hours and then kept in a glasshouse at controlled conditions (28^0C temp, and 89 % RH) (Fig 6) for development of *Alternaria* leaf spot/blight symptoms.

Fig. 6. Incubation of *A. solani* inoculated tomato plants (which were exposed to different light spectra) in a humid chamber for the development of leaf spot symptoms

These plants were observed daily for the development of leaf spot symptoms. For the calculation of the PDI (Percent disease Index) of each plant 1 to 9 scale was used (Rex et.al, 2023). On the 7^{th} day, the leaf area infected per leaf on each plant was recorded and readings were converted for the estimation of PDI.

Statistical analysis

Data obtained during different treatments were analysed statistically by using standard statistical methods.

Results and Discussion

1. *In vivo*, the effect of different light-colour-spectrum on the growth of *Alternaria solani*

As visible light is composed of seven different colours of different wavelengths, the effect of individual light-colour-spectrum was studied on the growth of A. solani during the different light intensity periods. The results (table 1) indicate that more fungal growth was obtained under the natural light of 4.00 pm to 6.00 pm (with maximum light intensities of 40500 lux and minimum light intensity of 7800 lux) in comparison to the different light colour spectrum at this time slot. For orange and yellow colour spectra more fungal growth was obtained at 8.00 to 10.00 am slot (with maximum light intensity of 80000 lux with minimum light intensity of 60200 lux) as compared to natural light. The maximum fungal growth was obtained due to a navy-blue colour spectrum which has a 450 nm wavelength at most of the light intensities. Interestingly there was no growth obtained in any plates in all the light-colour- spectrums which were exposed at 12 to 2 pm, and 2 to 4 pm time slots (where the maximum light intensities were 1,38,000 lux and the minimum light intensities were 1,12,000 lux). Minimal fungal growth was obtained with red colour which has a 700 nm wavelength. It was interesting to note that the fungal growth obtained with violet, navy blue and yellow colour spectra was more than the growth obtained in natural light during certain light intensities. Thus, light colour spectra as well as light intensities influence the growth of *A. solani*.

Table 1. Effect of different light-colour- spectrum x visible light intensities on the growth of *A. solani*

Alternaria Mycelial Disc (1.0cm) Exposed During Time slot of	Max. light intensity (in Lux)	Min. light intensity (in Lux)	Fungal growth (in cm on 5th day) under different light colour spectrum							
			Red	Orange	yellow	Green	Blue	Navy blue	violet	Natural light
6.00 to 8.00 am	65000	10000	6.35	6.5	6.6	6.4	6.55	**6.65**	6.65	6.57
8. 00 to 10.00 am	80000	60200	5.85	**6.15**	**6.2**	6.05	5.95	**6.35**	6.1	6.1
10.00 am to 12.00 pm	110100	81000	5.15	5.9	5.85	5.65	5.55	**6.05**	5.75	5.9
12.00 to 2.00 pm	138000	112000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
2.00 to 4.00 pm	122200	55000	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
4.00 to 6.00 pm	40500	7800	6.55	7.0	6.95	6.75	6.65	7.05	6.85	**7.05**

	SEm (±)	CD at 5 %
Duration	0.0252	0.0719
Colour	0.0272	0.0777
Duration x colour	0.0667	0.1904

2. *In vitro*, the effect of different light-colour-spectrum and diurnal periods on growth of *A. solani*

The results (table 2) indicate that different light-colour-spectrum under different light intensities have differentiated effects on the growth of *Alternaria* mycelium. In the light intensity of 1000 Lux and below, the mycelial growth was more in the plates exposed to 6 hours of light + 18 hours of darkness as compared to 24 hours of light + 0 hours of darkness for the light colour spectrum of red, orange, yellow, blue, navy blue and violet, while in the green colour light spectrum, the mycelial growth was more in the plates exposed to 24 hours of light + 0 hours of darkness. At 2000 Lux light intensity there was no fungal

growth in the red, green and blue colour light spectrum while in other light colour spectra particularly orange, navy blue, yellow and violet mycelial growth was produced, and the growth was more at 6 hours of light + 18 hours of darkness exposer as compared to 24 hours light + 0 hours darkness exposer. Maximum fungal growth was obtained at 100 Lux light intensity with a yellow colour light spectrum while minimum growth was obtained at 1000 Lux light intensity with a red colour light spectrum.

Table 2. Effect of different light- coloured-spectrum and darkness periods on the growth of *A. solani.*

Light Colour Spectrum	Light intensities (in Lux unit)									
	2000		1000		600		200		100	
	Diurnal time duration (in hrs)									
	6 h of light +18 h of dark	24 h of light +0 h of dark	6 h of light+ 18 h of dark	24 h of light+ 0 h of dark	6 h of light+ 18 h of dark	24 h of light+ 0 h of dark	6 h of light+ 18 h of dark	24 h of light+ 0 h of dark	6 h of light+ 18 h of dark	24 h of light+ 0 h of dark
	Alternaria solani growth (in cm)									
Red	0.0	0.0	**4.0**	0.1	**4.5**	2.5	**6.0**	4.6	**6.4**	5.0
Orange	**2.0**	0.5	**5.2**	0.7	**6.8**	2.4	**7.0**	6.5	**7.5**	7.0
yellow	**1.5**	0.7	**5.8**	2.0	**6.6**	4.0	**7.0**	6.5	**8.0**	7.0
Green	0.0	0.0	0.4	**4.5**	2.0	**6.5**	3.6	**7.0**	5.5	**7.8**
Blue	0.0	0.0	**4.0**	0.5	**5.8**	2.1	**6.5**	5.0	**7.5**	6.5
Navy blue	**5.2**	0.7	**6.0**	2.5	**6.5**	4.5	7.0	7.0	**7.8**	7.5
Violet	**4.0**	0.5	**5.0**	2.0	**6.0**	4.0	**6.3**	5.0	**6.8**	5.4
Without colour	1.9	**2.3**	**6.1**	3.5	**6.3**	4.0	**6.7**	4.3	**7.0**	4.7

Factors	*C.D*	*SEm*
Light intensity (A)	*0.094*	*0.033*
Colour spectrum (B)	*0.111*	*0.04*
Interaction A x B	*0.247*	*0.089*
Diurnal duration (C)	*0.059*	*0.021*
Interaction A x C	*0.132*	*0.047*
Interaction B x C	*0.157*	*0.056*
Interaction A x B x C	*0.35*	*0.125*

3. Effect of different light-colour-spectrum on the initiation of *Alternaria* leaf spot symptoms in tomato plant

The results (table 3) indicate that in 2000 Lux, 1000 Lux, 600 Lux, and 200 Lux light intensities more PDI was obtained with different colour light spectrums as compared to no colour light exposure. At 200 Lux maximum PDI (53.4 -54.6 %) was obtained in orange, yellow and green colour-light-spectrum as compared to natural white light (53 %). At 600 Lux the maximum PDI was obtained with an orange, yellow, green and navy blue -colour- spectrum. At 100 Lux light intensity, the maximum PDI was produced in a natural white colour as compared to other light-coloured spectra. At 2000 Lux intensity the maximum PDI was produced in orange colour- spectrum as compared to other colour spectrums. These results indicate that different light-colour- spectrums under different light intensities play an important role in the initiation of *Alternaria* leaf blight symptoms in tomato plants.

Table 3. Effect of different light colour spectrum on initiation of *Alternaria* leaf spot/blight symptoms in tomato

Sr.no.	Colour spectrum	PDI (%) under different light intensities				
		2000 Lx	1000 Lx	600 Lx	200 Lx	100 Lx
1	Red	31 (33.8)	41 (39.8)	49 (44.4)	52.5 (46.4)	55.5 (48.1)
2	orange	**55 (47.8)**	**60 (50.7)**	**58.5 (49.8)**	**66 (54.3)**	67.5 (55.2)
3	yellow	50.5 (45.2)	55.5 (**48.1**)	**65.5 (54)**	**66.5 (54.6)**	72.5 (58.3)
4	Green	47.5 (43.5)	55 (47.8)	**63.5 (52.8)**	**64.5 (53.4)**	66.5 (54.6)
5	Blue	41.5 (40.1)	45 (42.1)	49.5 (44.7)	53 (46.7)	59 (50.1)
6	Navy blue	49.5 (44.7)	53.5 (47)	**59.5 (50.4)**	63 (52.5)	70.5 (57.1)
7	Violet	53 (46.7)	55 (47.8)	55.5 (48.1)	63 (52.5)	69 (56.1)
8	Without colour	53.5 (47)	54.9 (47)	57.3 (49)	64.2 (53)	**79.3 (62)**

Factor	SEm (±)	CD at 5 %
Colour spectrum	0.3465	0.9977
Light intensity	0.2907	0.8432
Colour spectrum x light intensity	0.777	2.2309

The effect of the light colour spectrum on fungal growth, sporulation, formation of fungal fruiting bodies and initiation and development of fungal disease symptoms are reported by different workers. Leach (1972) reported sporulation in *loculoascomycetes* in response to light spectrum wherein the fungal isolate rarely sporulated in darkness but produced abundant perithecia when exposed to UV light (wavelength <350 nm approx.). The spectral region most effective in stimulating the production of perithecia was below 320 nm. The production of perithecia in *Gibberella zeae* requires low-intensity ultraviolet light below 390 nm for initiation, however, the spectrum region required for maturation has not been determined for this pathogen (Tschanz et. al,1976). The fungal growth of *Botrytis cinerea* was stimulated by near-ultraviolet light. Infrared, red and yellow light were also slightly effective, but blue and green light were ineffective. Sclerotium formation occurred in darkness, in yellow, red and infrared light and cultures irradiated for less than 30 min with black light. Continuous black light retarded the linear growth of the fungus (Tan and Epton,1973). Cohen et.al (1975) reported that *phytophthora infestans* failed to produce sporangia on infected potato leaves under continuous light conditions. Blue light (λmax = 450nm) was most inhibitory, while red light (λmax = 650 nm) was ineffective in inhibiting sporangial formation. The low intensity of blue light-induced about 85 % inhibition of sporangial formation. The sporangial production in *Pseudoperonospora cubensis* was inhibited by the blue region of the spectrum on cucumber cotyledons but did not prevent the emergence of sporangiophores through stomata. Sporangiophores emerging from leaves exposed to high light levels were abnormal, but could further produce sporangia upon transfer to darkness (Cohen and Eyal,1977). Vakalounakis and christias (1986) reported inhibition of sporulation in *Alternaria cichorii* by the blue light spectrum (wavelength 360-530 nm) and it increased with an increase in temperature. The inhibition was temporary under continuous black-light-blue irradiation but was permanent under continuous blue light alone. Extended exposure (> 3 days) to black-light blue promoted the sporulation in a temperature-dependent response. Nagy and Fischl (2002) studied the habit of fungal culture *Macrophomina phaseolina* treated by blue light and UV radiation. These treatments changed the fungus habit and formed microsclerotia which was a result of UV irradiation. Velmurugan (2009) observed that incubation of fungi in total darkness increased biomass and extracellular and intracellular pigment production. In contrast, the growth of fungi in green and yellow light wavelengths resulted in low biomass and pigment yield. Suthaparan et. al (2010) studied the illumination effect of LED on rose plant samples bearing the fungal pathogen *Podosphaera pannosa*. Blue light (wavelength 420 to 520 nm) emitting diodes (LEDs) increased the number of conidia trapped by a

factor of approximately 2.7 over white light, however, germination of conidia under blue light was reduced by approximately 16.5% as compared to conidial germination under white light. The number of conidia trapped under far-red (>685 nm) LEDs was approximately 4.7 times higher than in white light, and 13.3 times higher than under red (575 to 675 nm) LEDs, and germination was not induced as compared to white light. Fanelli et.al (2012) reported a reduced fungal growth of *Fusarium verticilliodes* on incubation under a short wavelength blue light (390 nm), whereas white pulsing light did not affect fungal growth. Prub et.al (2014) observed the regulation of mycotoxin production and spore formation in *Alternaria alternata* by light. The spore formation was largely decreased under light conditions. All light effects observed could be triggered by blue light, whereas red light had only a minor effect. Inhibition of spore formation by light was reversible after 1 day of incubation in the dark.

Nilsen et.al. (1979) reported that *Drechslera sorokiniana* inoculated *Poa pratensis* plants when exposed to 10 hours of photoperiod in combination with orange-red-biased light (spectrum A) or with a balanced spectrum (spectrum B) increased leaf spot disease. Inoculated plants subjected to a 14-hour photoperiod in combination with these spectral regimes reduced disease expression. The effect of photoperiod on disease expression was negated by blue-biased light (spectrum C). Schuerger (1997) reported that the disease symptoms of tomato mosaic virus on pepper pathosystem developed slowly and were less severe in plants grown under light sources that contained blue and UV-A wavelength compared to plants grown under light sources that lacked blue and UV-A wavelength. Naito et.al. (1996) studied the effects of UV-B radiation (290-320 nm) on the development of damping-off of spinach and observed that the incidence of disease greatly increased when experimental plants were grown in visible radiation with supplementary UV-B radiation. This increase was suppressed by increasing the irradiation of visible radiation. Rahman et.al (2003) reported the development of lesions induced by *Alternaria tenuissini* in broad bean leaves which was completely suppressed in red light irradiated broad bean leaflets, irrespective of isolate or spore concentration. Pre-treatment of leaflets with red light for 24 h before inoculation also suppressed lesion development. Meyer et.al (2021) reported that supplemental UV-B light has a positive effect on disease resistance in many plant-pathogen combinations, mainly through the induction of the production of specialized metabolites. However, many variables (UV-B light source, plant species, dose and intensity, timing during the day, duration, background light etc) make it difficult to compare and draw general conclusions. Galle et.al. (2021) reported that red light can positively influence plant defence mechanism against different pathogens, and observed that exposing plants to red light increases levels of salicylic acid (SA) and induces SA signalling mediating the production of reactive oxygen species, with substantial differences between species and plant organs. Such changes in SA levels could be vital for plants to survive infection. Therefore, the application of red light provides a multidimensional aspect to developing innovative and environmentally friendly approaches to plant and crop disease management.

The results on inhibition of fungal pathogen, its growth and symptoms development by use of light colour spectrum are useful in the fabrication of shed net or poly houses. Raviv (1989) reported that by using the proper UV absorbent in the required concentration in the plastic film, petal blackening in red rose cultivars can be prevented. Sporulation of *Botrytis cinerea* was enhanced by UV-B radiation but inhibited by blue light spectrum (310 and 480 nm respectively). Nicot et.al (1996) compared several samples of polythene films containing additives that absorb near UV light in the range 280-380 nm for their ability to affect the spore germination, mycelial growth and sporulation of *Botrytis cinerea* on agar medium. Raviv and Antignus (2004) studied various spectral modifications made in greenhouse covers to suppress the proliferation of several foliar diseases and reported that complete or partial absorption of visible UV radiation interrupts the life cycle of several fungal pathogens. Manole and Ciofu (2008) observed that the use of photoselective film type influences the plant resistance to *Alternaria solani* pathogen. Some photo-selective films can limit early blight and leaf mould incidence and could be an important element in the control of these diseases. Kotzabasis et.al (2014) studied the development of a photo-biological greenhouse plastic cover which simulated photonic information that leads to a physiological enhancement of plant productivity and fungal disease control. The main characteristic of

these photo-biological greenhouse plastic covers is the high transmission of photo-synthetically active radiation (PAR 400-700 nm) to control the sporulation of fungi. The plant pathogens perceive and react to light in complex ways to regulate their own growth, development, and virulence. Recent work has shown that varying light wavelengths may provide a novel way of controlling or preventing disease outbreaks in plants (Breen et.al., 2023).

Assefa and Gobena (2019) review the effect of light on disease development and management of horticultural crops under protected cultivation. They reported that different plant species have different light responses, and 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 a significant effect on plant physiology that could alter plant resistance to microbial challenges. Furthermore, many fungal, bacterial and viral diseases of plants are affected by the spectral quality of the primary light source. Foliar fungal diseases of various crops were suppressed in the greenhouse when UV-A (320-400 nm) absorbing viny films were used to cover the structure. The apparent mechanism in disease control was the suppression of spore germination and sporulation of the fungal pathogen caused by extremely low levels of blue or UV-A light. Interestingly, red, blue, and green can induce systemic acquired resistance in various plant species against fungal pathogens. Finally, the light can be useful as a component of an integrated disease management program source in greenhouse conditions. Dieleman et. al, (2020) reported that treatments with additional far-red light reduced the infection rate of powdery mildew, but increased botrytis infection. The difference might be due to the plant defences acting against these pathogens evolving from two different regulatory pathways. These results show that the positive effects of altered spectral compositions on physiological responses were only moderately compensated by increased susceptibility to fungal pathogens, which offers a perspective for sustainable greenhouse horticulture.

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