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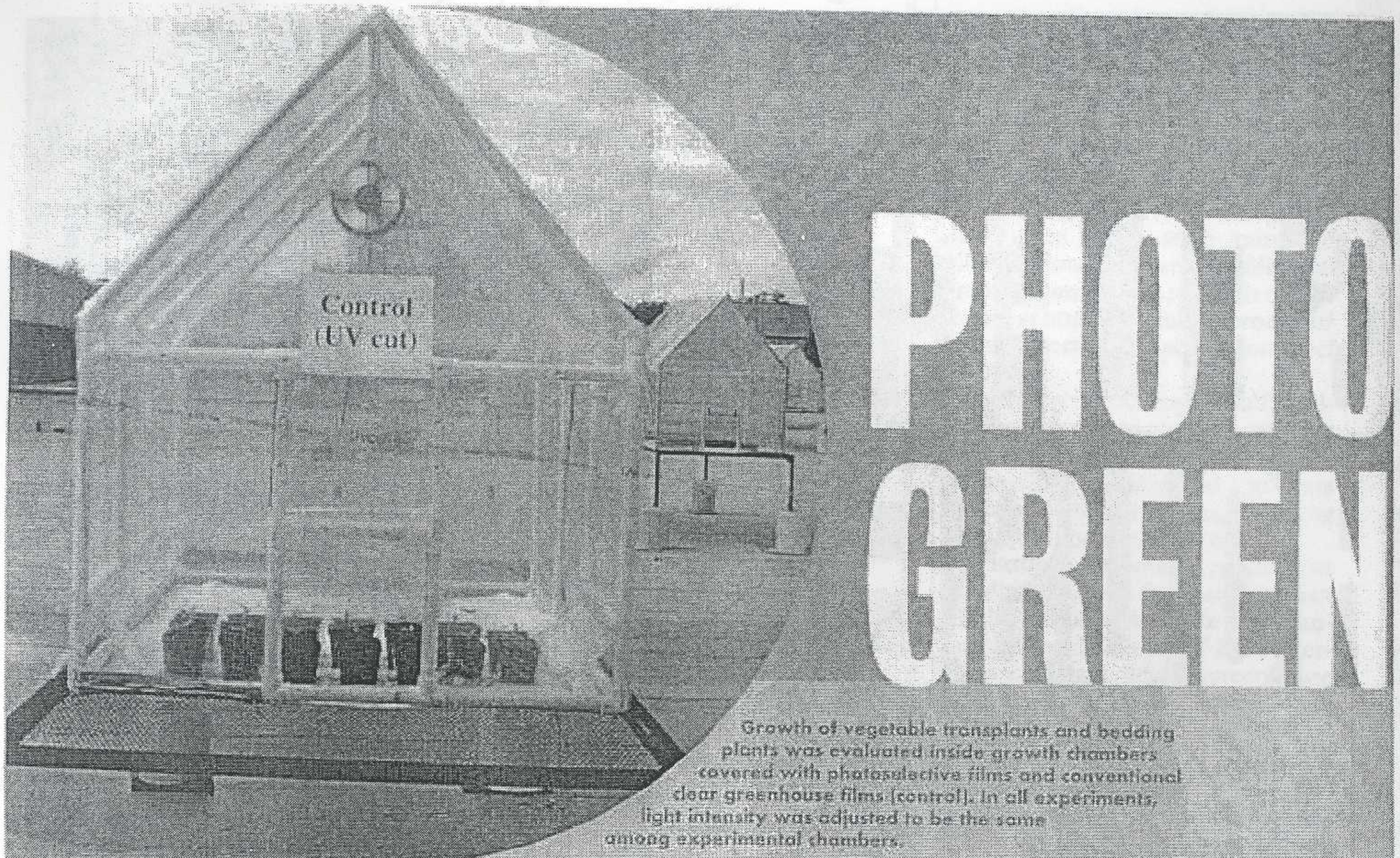
PHOTO GREEN



Growth of vegetable transplants and bedding plants was evaluated inside growth chambers covered with photoselective films and conventional clear greenhouse films (control). In all experiments, light intensity was adjusted to be the same among experimental chambers.

Increased environmental concerns, a need for more non-chemical controls and rising production costs lead to alternative methods to control plant growth.

By Nihal C. Rajapakse
and Sandra B. Wilson

Traditionally, plant growth regulators have been used to control plant growth. Because of increasing environmental concerns, researchers are investigating alternative methods to produce compact plants.

Plant genetic manipulation, greenhouse temperature control, water and nutrient management, mechanical conditioning and greenhouse light manipulation are some techniques that have been studied to produce uniform, compact plants.

These production methods are particularly advantageous to the vegetable transplant industry because daminozide (Alar), which was the primary chemical used for controlling vegetable transplant height, was banned in the late 1980s. No chemical growth regulators have since been labeled for vegetable production in the United States.

Role of light

Photoreceptors in plants function as light sensors to provide information on subtle

SELECTIVE HOUSE FILMS can control growth

changes in light composition in the growing environment. These allow plants to make physiological and morphological changes to be competitive. This process is technically known as photomorphogenesis.

Photomorphogenesis involves the activation of several photoreceptors by specific wavelengths of light (e.g., blue is 400-500 nanometers; red is 600-700 nm and far-red is 700-800 nm). Phytochrome is the photoreceptor that controls photomorphogenesis in response to changes in red (R) and far-red (FR) light. Phytochrome (P) exists in two interconvertible forms: an active FR light absorbing form and an inactive R light absorbing form, which have peak absorption in the far-red region at 730 nm and the red region at 660 nm. Phytochrome$_R$ absorbs red light which is converted to phytochrome$_{FR}$ (far-red absorbing form). When P_{FR} absorbs far-red light it converts it back to P_R.

Effects of light quality

The effects of FR light are mostly the opposite of R light. Red light enhances seed germination, reduces seedling stem elongation and promotes lateral shoot growth of many plant species.

In general, environments high in R light relative to FR light (high R:FR ratio) are favorable for producing short, compact plants. In a greenhouse, this can be achieved either with supplemental lighting systems with relatively high R and low FR light or by spectral filters that can alter the R and FR balance of sunlight entering a greenhouse. Incandescent lamps, which have high FR light relative to R light frequently lead to stem elongation while fluorescent light sources, which are high in R light relative to FR light, produce short, compact plants.

Light filtering research

During the 1970s and '80s, liquid color filters were investigated for filtering out infrared radiation (heat) from sunlight as a method to cool greenhouses. The ability of various aqueous dye filters to selectively remove elongation-stimulating FR light from the natural light spectrum and to reduce plant height was investigated during the late '80s in Norway and the United States.

Of the different filters tested, liquid copper sulfate ($CuSO_4$) filters were effective in removing FR light from sunlight and in reducing stem elongation of a wide range of dicotyledonous plants. Additional information on this research can be found at http://virtual.clemson.edu/groups/hort/sctop/photomor/specfltr.htm.

Although liquid copper sulfate filters were found to produce compact plants, liquid filters have limited value to commerical growers because of the difficulties handling the liquid and the high costs.

Plastic greenhouse coverings or shading material that can filter out FR light would facilitate the commercial applications of light-filtering technology. Several greenhouse film manufacturers and chemical companies in Europe and Japan are working to develop these materials. In England, British Visqueen and Reading University are working together to develop photoselective greenhouse covers for plant-growth regulation.

In the early 1990s, Clemson University researchers collaborated with Klerk's Plastic Products Manufacturing to evaluate its KoolLite greenhouse film that contains an infrared light (heat) reflecting pigment. The main goal of developing these films was to reduce greenhuse temperature by selectively filtering infrared radiation. Films tested in initial trials reduced the greenhouse temperature by 10°F-14°F. However, photomorphogenic effects were minimal.

In late 1990s, Clemson University and Ohio State University researchers collaborated with Mitsui Chemicals to develop and test photoselective greenhouse plastic films that can remove FR light to use as a growth regulator substitute. Universities and research institutions around the world tested these films in Japan, Europe and Scandinavia.

Photoselective greenhouse films

Early research focused on identifying FR light absorbing dyes that are stable in plastic films and selecting optimum dye concentrations that can be incorporated into films without excessively reducing the transmission of photosynthetic light. Based on initial findings, photoselective greenhouse films with red light absorbing (A_R) and far red light absorbing (A_{FR}) dyes were produced with a dye concentration that results in a 75-80 percent light transmission.

Growth of vegetable transplants and bedding plants was evaluated inside growth chambers covered with these experimental films. Plants grown inside the photoselective film chambers were compared with plants grown inside chambers covered with conventional clear greenhouse films. In all experiments, light intensity was adjusted to be the same among experimental chambers.

Film effects

Height. Two of the three A_{FR} films were equally effective in producing compact plants. Plants produced under the A_{FR} film were, in general, shorter than the control plants. Plants produced under the A_R film had similar or increased height compared to the controls. The magnitude of height reduction varied with the species and cultivar.

Flowering. Flowering of miniature roses was not affected. Flowering of cosmos, zinnia and chrysanthemum (short-day plants) was delayed by one to two days under the A_{FR} film.

Photoselective films had the greatest influence on flowering of snapdragon and petunia (long-day plants). Flowering of these species was delayed by seven to 13 days under the A_{FR} films during short photoperiods. However, flowering of these species was not delayed during long photoperiods. Further research indicated that during short photoperiods, flower initiation of long-day plants was delayed, but flower development was not affected once initiation occurred.

A_R film did not affect the flowering of the species tested in this study, but accelerated flowering has been reported else where. Currently, Clemson University researchers are evaluating ways to improve

Influence of plastic films on plant height and flower development at Clemson University

Crop	Control film		A_R film		A_{FR} film	
	Height (cm)	Days to flower	Height (cm)	Days to flower	Height (cm)	Days to flower
Cucumber 'Sweet Success'	17.3	-	19.8	-	8.6	-
Tomato 'Mountain Pride'	15	-	15.8	-	11.2	-
Bell pepper 'Capistrano'	11.1	-	11.4	-	8.4	-
Snapdragon						
'Ribbon White'	48.3	63	53.8	61	48.9	70
'Tahiti Red'	25.5	51	24.7	50	23	59
Petunia 'Supercascade Burgundy'	-	53	-	54	-	66
Zinnia Pumila Mix	24.5	33	28.4	32	18.8	35
Cosmos 'Sonata White'	37.3	26	38.1	27	33.5	27
Miniature rose 'Cherry Cupido'	28.8	46	29.2	46	27.2	46
Chrysanthemum						
'Bright Golden Anne'	32.6	64	34.6	65	28.4	65
'Iridon'	22.6	59	25.8	60	19.8	62
'Yellow Snowden'	50.8	55	50.4	57	40.7	56

Control is a clear polyethylene film. The R/FR ratio of transmitted light was 0/8, 1/1 and 1/7, respectively in A_R, control and A_{FR} films.

Influence of plastic films on plant height and flower development of ornamentals in Florida

Crop	Control film		A_R film		A_{FR} film	
	Height (cm)	Days to flower	Height (cm)	Days to flower	Height (cm)	Days to flower
Orthosiphon stamineus (cat's whiskers)	58.7	37	58.9	31	46.8	34
Pachystachys lutea (golden shrimp plant)	30.1	38	32.8	38	27	38
Strobilanthes dyerianus (Persian shield)	34.2	-	38.9	-	30.2	-
Salvia						
Salvia x 'Indigo Spires'	72.7	-	68.8	-	46.7	-
Salvia splendens 'Van Houtter' (wine sage)	52	34	56.1	32	43.0	36
Salvia leucantha (Mexican sage)	51.5	35	47.3	38	40.5	36
Zinnia elegans						
'Profusion Cherry'	19.6	36	18.7	34	15.2	35
'Old Mexico'	59.5	42	58.8	39	56.7	39
'Isabellina'	80.8	43	69.4	43	64.8	43
Eustoma grandiflorum						
'Florida Blue'	31.2	30	30.4	28	27.9	31
'Florida Pink'	23.6	26	27.2	27	22.5	25
'Florida Sky Blue'	26.7	30	28.1	30	23.4	32

Control is a clear polyethylene film. The R/FR ratio of transmitted light was 0/8, 1/1 and 1/7, respectively, in A_R, control and A_{FR} film.

flowering under A_{FR} films during non-inductive photoperiods.

Reduced plant height

The reduction in light transmission (25 percent) by photoselective films could be a concern for Northern growers, especially during low-light seasons. However, in the South where sunlight is abundant, the reduction in light transmission may not be a concern.

Recently, researchers at the University of Florida and Clemson University began collaborating to test photoselective films in Florida (USDA Hardiness Zone 9b) to grow subtropical perennials and bedding annuals. The results were similar to those observed in Clemson University trials.

Plants produced under A_{FR} film were shorter (5-36 percent) than the control plants while plants produced under A_R film had similar or increased height (0-13 percent) compared to the control plants. Flowering was not affected for species tested, except for salvia.

Similar experiments have been conducted at Ohio State University and the Agricultural University of Norway. Combined results indicate that A_{FR} films are effective in producing short and compact plants regardless of the geographic location. In extreme temperate regions, light reduction can pose a problem for crops grown in winter.

Greenhouse plants are naturally exposed to a lower R:FR ratio during twilight hours due to the increase in FR light. Exposure of plants to FR light at the end of the day (EOD) increases stem elongation resulting in tall plants. Therefore, in areas where sunlight is limited, using A_{FR} films as an EOD curtain may help exclude FR light while maximizing use of full light during the daytime.

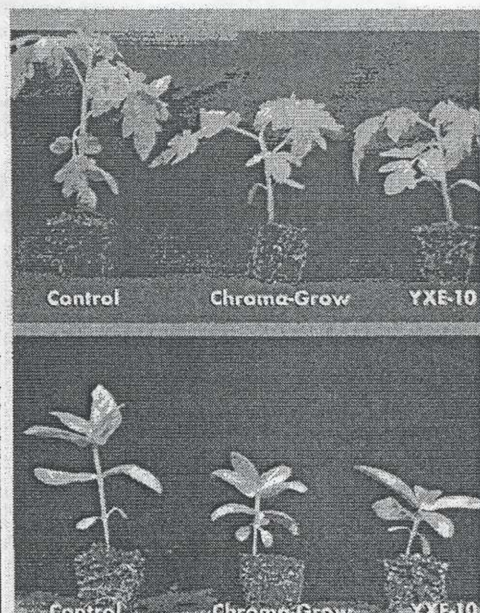
Clemson University researchers tested the use of A_{FR} film as an EOD curtain to block FR light during the evening (5 p.m.-9 a.m.) from October to November. EOD exposure to A_{FR} film was effective in height reduction of cucumber seedlings. However, the height reduction by EOD exposure to A_{FR} film was not as great as continuous exposure (44 vs. 25 percent height reduction in continuous and EOD exposure). Cucumbers are one of the most responsive crops to photoselective films. Further experiments with more crops are warranted to test the effectiveness of A_{FR} film as an EOD curtain.

Future prospects

Short film life was a limitation with the photoselective films we tested. The dye began to degrade within a year after installation on the experimental chambers. A film that lasts for at least two to three years would be needed as frequent film replacement is difficult and costly.

The A_{FR} film that was ineffective as a photomorphogenic film in previous trials contained a dye that absorbed both far-red and infra-red wavelengths. The FR light absorption by this film was not as great as the two effective films. As a result, light transmitted through this film had a R/FR ratio of 1/4 as compared to 1/7 for the other two films tested. However, the dye was more stable in this film than the dyes in other films tested.

Although ineffective as a photoselective film, Mitsui Chemicals produced this A_{FR} film for commercial testing in southern Japan as a heat-blocking greenhouse film. Mitsui reported the film was effective in reducing greenhouse temperature.



Comparison of seedling growth under different photoselective films

Control is clear plastic film (R/FR ratio is 1/1). Chroma-Grow is the a red light absorbing (A_R) film with more stable far-red light absorbing (A_{FR}) dye (R/FR ratio is 2/0). YXE-10 is the former less stable far-red light absorbing film (R:FR ratio is 1/7). Seedlings were grown inside experimental film chambers for three weeks before pictures were taken.

Southern Japan growers successfully produced crops such as spinach in summer.

By changing the composition of this stable dye, Mitsui has developed a new film with a sharper FR light absorption that has a R/FR ratio of 2/0. This film has been produced for commercial testing in Japan under the trade name of Chroma-Grow.

Clemson University researchers have evaluated the response of selected crops under Chroma-Grow. Results indicate that Chroma-Grow is as effective as the previous A_{FR} films in reducing stem elongation of cucumber, tomato, bell pepper and zinnia seedlings. The researchers are evaluating other crops and the effective life of these films under nursery conditions.

Since the discovery that ultra violet (UV) light causes some fungal species to sporulate and induces the spread of certain viral diseases, researchers have been investigating the insect and disease occurrence under UV-blocking greenhouse covers. Greenhouse covers with UV-blocking ability have been shown to reduce diseases and insect populations.

Researchers at Israel's Agricultural Research Organization showed that polyethylene films that blocked FR and UV light reduce infection of fungal diseases in certain greenhouse crops. UV-light-absorbing films have also reduced the spread of viral diseaes due to a reduction in insect (whitefly) populations.

Mitsui Chemicals has developed a more stable dye. The company is interested in exploring the possibilities of collaborating with glazing manufacturers in North America to further develop photoselective films for multiple tasks.

◆ **For more:** *Mitsui Chemicals America Inc., 2500 Westchester Ave., Suite 110, Purchase NY 10577; (914) 253-0777; fax (914) 253-0790; www.mitsuichemicals.com.*

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On the cover: Find out why designing, building and covering a greenhouse involves more than creating a structure capable of withstanding nature's extremes. See Pages 40 and 49. Photo by Todd Davis. **Inset photo:** NGMA president Rob Nearing talks about greenhouse construction issues. See Page 60.

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