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NEWARK PLANT
PIGMENT COLOR RESEARCH REPORT

INFRARED BLOCKING MATERIALS - I

Period Covered July, 1963 - January, 1964

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NEWARK PLANT
PIGMENT COLOR RESEARCH REPORT

SUBJECT: INFRARED BLOCKING MATERIALS - I

PERIOD COVERED: July, 1963 - January, 1964

ABSTRACT

This report summarizes the information gained to date from the literature and from experts in the field of plant physiology and greenhouse management, concerning the need for a product to control infrared radiation through glass. No laboratory work has been done to date.

SUBMITTED BY: E. F. KLENKE, JR. DATE SUBMITTED: 1/20/64

APPROVED BY: J. H. COOPER DATE RELEASED: 1/24/64

TABLE OF CONTENTS

I. INTRODUCTION

A major problem faced by all greenhouse users is overheating in the summer, for which the only current remedies are screening with slats, coating the glass with whitewash, or using vents and large air circulating fans. In addition to other objections, screening and whitewash function by virtue of opacity, thus removing as much as 80% of the desirable visible light. The fans are expensive to purchase and install.

The problem of overheating due to solar energy is not restricted to greenhouse users. Most households and industrial office buildings are faced with keeping the heat out in the summer and in in the winter. Storm windows and/or awnings or shades are currently used for this purpose, but there are cost and other objections to each.

There appears to be a need for a product that is transparent to visible radiation, but opaque to infrared (IR) radiation, since blocking the IR excludes approximately 50% of the solar energy. This report summarizes the information gained to date from a survey of the literature and from contact with qualified experts in plant physiology and/or greenhouse management. Also included is a brief discussion of the use of such a product for home and/or industrial applications. The next phase of this study is a search of the literature for information which can be used to formulate a laboratory program for developing a product to fit the above indicated requirements. No laboratory work has been done to date.

II. SUMMARY AND CONCLUSIONS

1. U.S. Department of Agriculture figures show that 300,000,000 sq. ft. of greenhouse glass is in commercial use, with an estimated 100,000,000 sq. ft. in use by hobbyists and others. The "New Scientist" reports 240,000,000 sq. ft. of greenhouse glass in use in Great Britain, for an estimated $500,000,000 business in crops.

2. Plant physiologists agree that lowering the greenhouse temperature, with minimum reduction of the visible light (primarily red and blue) would significantly increase greenhouse productivity and reduce losses due to high temperature stimulated fungi or excessive transpiration.

3. It was the consensus of those contacted that a transparent, IR-blocking coating that could be easily applied to the glass in the spring and easily removed in the winter would be worth as much as $20/gallon, assuming the same coverage (sq.ft./gal.) as with whitewash. This would mean a gross business of $10,000,000, if only 50% of the U.S. market were involved (British market not included).

4. An F and F Market Research Division report indicated that home owners, builders and architects are not satisfied with storm windows, awnings, etc. and that the large percentage of those questioned would pay up to $10/window for some easily applied treatment of the window glass, to control heat input or loss. Assuming 20,000,000 homes in the U. S. and an average of 15 windows per home and $10/window, reaching only 1% of the market would mean $30,000,000 gross income.

5. No quantitative data were found for the value of a product to reduce heat[redacted] entering or leaving industrial office building windows, but merely lowering the room temperature a few degrees would mean significant savings in air conditioning installation and/or operating costs.

6. It appears that there is a very sizable and lucrative potential market for an IR controlling product, and that considerable research effort can be justified to develop such a product.

III. DISCUSSION

1. Greenhouse Application

A study of curves I and II indicates approximately 50% of the solar energy reaching the surface of the earth (at sea level) is due to IR radiation in the wavelength range of 0.8 to 2.3μ. The remaining 50% is almost all due to visible radiation, in the wavelength range of 0.4 to 0.8μ, with relatively little attributed to the UV (0.3 to 0.4μ). Plant physiologists (I) have stated that radiation in the range 0.8 - 3.0μ (IR) may be eliminated without harmful effects on plant growth. To achieve further reduction of solar energy, without loss of beneficial radiation, the green and half of the yellow/orange light can be filtered out. As indicated in curves I and II, this would remove a sizable portion of energy in the visible portion of the solar spectrum.

At noon on a clear day at sea level, sunlight averages 10,000 foot candles. Clear glass transmits approximately 9,000 foot candles maximum. Tabulated below (2) are the amounts of light that can be tolerated by the range of plants indicated, beyond which leaf temperatures rise dangerously and transpiration accelerates. If the plant cannot convey sufficient water to the leaves to keep pace with that transpired, damage occurs.

Plants	Tolerable Light (foot candles)	% Light Transmitted*
Orchids	1000- 3500	11 - 40
Foliage	1000- 2000	11 - 22
Corn	5500- 6500	61 - 73
Roses	6500- 7500	73 - 83

*9000 foot candles for clear glass is 100%.

It is known (3) (4) that more light would cause faster growth, provided that the leaf temperatures do not exceed 115°-140°F. Therefore, if the heat producing radiation (IR plus green) were removed and the full amount of blue, orange and red radiation were transmitted to the plants, significant increases in growth rate could be achieved. Furthermore, transpiration would be reduced and, therefore, watering rates could be reduced, a factor of significant economic importance. Add to this a reduction in plant losses due to dehydration, and heat stimulated plant diseases and fungi, and the economic importance of heat control is further increased (3) (4) (5).

At the present time, greenhouse temperatures are controlled by (1) shading, with slats or blinds, (2) coating the glass with whitewash, (3) opening and closing vents and/or using large volume air circulating fans, and (4) using large fans to pull air into the greenhouse through or over a moist surface (felt or wood turnings, etc.), and thus achieve evaporative cooling. The first two are objectionable, primarily because they reduce the amount of light admitted to the greenouse, by virtue of their opacity. The second objection is cost. Slats are expensive and do not last long. Applying whitewash requires skill and a considerable amount of labor, since the coating needs frequent attention. The second two are expensive installations, and still do not permit the greenhouse to be operated without slats or glass coating.

It was the consensus of those contacted (2) (4) (5) (6) (7) that a coating that could be easily applied (by brushing, spraying, etc.) to greenhouse glass, and that would reduce the amount of IR transmitted, would be of significant economic importance. The extent of its use would depend on its efficiency and cost. A 5°F. drop in greenhouse temperature was considered significant and, of course, more would be highly desirable. Assuming most of the IR could be blocked, it was estimated that most commercial greenhouse users would be willing to pay as much as $20/gallon for a coating of the same coverage (sq.ft./gal.) as achieved with whitewash.

U.S. Dept. of Agriculture figures show that 300,000,000 sq. ft. of greenhouse glass is in commercial use, and an additional 100,000,000 sq. ft. is in use by hobbyists, universities, etc. If only 50% of this market were reached, the gross sales would exceed $10,000,000 annually.

2. Home and Office Window Glass Applications

The F and F Market Research Division recently completed a survey to determine the market for "devices to control heat and light transmission through windows". This survey is based on interviews with home owners, architects, and builders, and the results are covered in a special report (8). The majority of those questioned indicated that the ideal solution to this problem would be a product which could be easily applied to the glass itself, and the consensus was that they would be willing to pay $10.00 per window for such a product.

Omitting the very large potential market in office window treatment, and considering only the house or apartment windows, the potential business is very large for a product that will satisfy the above requirements. Assuming 20,000,000 houses in the U.S. and an average of 15 windows per home, at $10.00 per window, there is a potential $3,000,000,000 business if 100% of the market were reached. If only 1% of this market were reached, the gross potential would be $30,000,000 - a very attractive goal.

3. Some Approaches to the Problem

The control of IR radiation should be possible by absorption, reflection, or scattering. Absorption implies re-radiation; therefore, the heat generated should be removed for maximum benefit. Reflection or scattering would be preferable provided that the beneficial radiation is not measurably reduced also.

Regardless of which of the above approaches is selected, there are at least two systems to be considered for initiation of the effect - permanent, or radiation initiated (photo chromic or thermochromic). Some work is already being done (9) (10) (11) (12) in the general field, for the Armed Services; however, no mention is made in any of the reports of applications such as are being considered in the work covered by this report (Research Project 4622-006-14).

So far, the only time spent on this project has been devoted to a search of the literature and discussions with some experts in the field of plant physiology and/or greenhouse management. The purpose for this preliminary survey was to determine whether this is an attractive field for further study. It must be concluded that this is a field with tremendous potential and intensive research effort therein would appear justified. The first step in this direction, to formulate a program for laboratory study, is in progress.

IV. REFERENCES

(1) U.S. Dept. of Agriculture; Drs. G. Barry and H. Barthwick
(2) Dr. O. W. Davidson, Rutgers - supplied data.
(3) Greenhouse Operation and Economics, O. W. Davidson
(4) Boyce Thompson Institute - Mr. Kirkpatrick
(5) Dr. W. R. Robbins - Plant Physiologist - Rutgers
(6) Dr. G. Barry - Plant Physiologist - DuPont
(7) J. B. Lager - American Orchid Society
(8) Report #2-28, J.E.Mayerberg, Jan. 1963 - "Qualitative Survey of Markets for Devices to Control Heat and Light Transmission through Windows".
(9) "Systems for Automatic Reversible Control of the Intensity of Visible Radiation Through Transparent Materials" - Midwest Research Institute AD-241, 593, AD-253,515, AD-251, 247.

(10) "Development of a Reversible Color Coating for Aircraft Camouflage", National Cash Register Co. AD-246, 915L, AD-248, 645L.
(11) "Infrared Coating Studies - Bausch and Lamb AD-246, 618, AD-252, 956, AD-246, 617
(12) Study of Thermochromism - Brooklyn Polytech. (Dr. Post)
(13) Automatic Light Filters - Space Technology Labs. Redondo Beach, Cal.

Additional References

Measurement of Radiant Energy - Forsythe
Space and Materials Handbook, NASA-1963
J. Franklin Institute - P. Moon 230, 583-618 (1940)
Official Digest, Vol. 34, #453, Oct. 1962 (1061-1064)
Plant Physiology - Meyer and Anderson - Van Nostrand - 1952
and Büring - 1960
Plant Physiology - Steward - Academic Press
Science and the Glass House - Lawrence (Brit.)
Economics of Plastics vs. Glass Greenhouses - paper by N. Harold Gray - Lord and Burnham
Heat Absorbing Glass - Fed. Spec. DD-G-451a
Optics and Spectroscopy (Engl.Transl.) 14, 78-9 (1963) Jan. Coating which strongly absorb IR radiation.

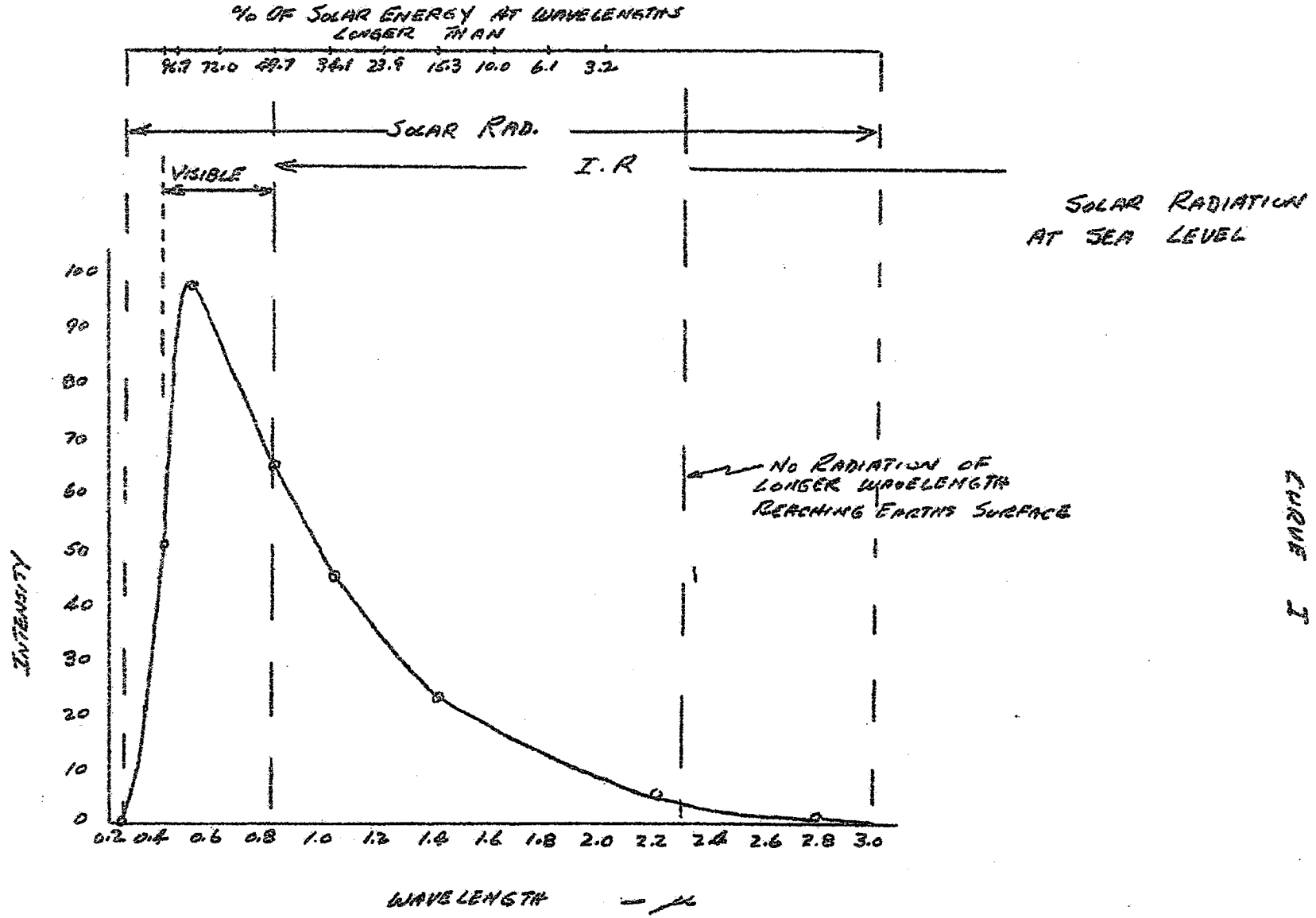

FIGURE 1