CHARACTERISTICS OF LIGHT AND SOME FEATURES OF PLANT GROWTH

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Light is energy released by the sun to support all types of plant and animal life. This energy is transmitted as electro magnetic spectrum which influences every activity on the face of this planet.

Artificial light represents man's efforts to devise a partial substitute for sunlight. Modern artificial electric light has contributed to every phase of our society and serves as a tool for agricultural research.

The Electro Magnetic Spectrum

To fully appreciate the physical characteristics of light it is necessary to study the entire electro magnetic spectrum. Within this spectrum energy travels in waves with definite wave lengths and corresponding frequencies at a single speed of 300,000,00 meters or 186,000 meters per second.

Cosmic rays at one extreme of the spectrum have a frequency of about 10 to the 24 power cycles per second and a wave length of roughly 0.000 000 000 000 39 inches. These high frequency waves pentrate every known substance and they may have untold influence on our existence.

Electric power waves located at the other extreme of the spectrum have a frequency of 25 to 60 cycles per second and a wave length of roughly 3100 miles.

Within this spectrum energy waves include cosmic rays, gamma rays, x-rays, ultra-violet radiation, light rays (380 to 760 MU), infrared rays, radar (1 centimeter range), television (1 meter range), radio (1 kilometer) and electro power waves.

Gamma rays and x-rays are used to produce artificial mutations in plant breeding research while light waves foster photosynthesis for plant growth.

Visible Light

Light or the visible spectrum has wave lengths from 380 to 760 millimicrons which include the colors of the rainbow combined to produce white light. The main color bands are violet (380-450), blue (450-490), green (490-560), yellow (560-590), orange (590-640) and red (640 to 760).

Solar Radiation

Light produced by the sun has a broad spectrum which includes ultraviolet light (290 to 380 millimicrons) normal light used for vision and also infrared energy from 760 to over 1500 millimicrons. Light reaching the surface of the earth has less ultra violet waves due to absorption by ozone while oxygen and water vapour eliminates parts of the infrared sepctrum.

The illumination provided by the sun on a clear day is approximately 10,000 foot candles, while the intensity falls below 100 foot candles on overcast days in the winter. Special high output fluorescent tubes produce an intensity of about 4,000 foot candles while the light on an office desk is usually 25 to 50 foot candles.

Beyond the atmosphere (air mass of zero) the energy received from the sun is about 1.94 calories per min. per square centimeter or 1350 watts per square meter or approximately 350 B.T.U. per square foot per hour. On the basis of average light in bright and dull weather the energy falling on an acre of land is very roughly 100 million B.T.U.'s. This is equivalent to burning 4 to 5 tons of coal per hour.

If 150 B.T.U.'s per square foot penetrate a greenhouse measuring 25 x 40 feet, it would require more than 10 tons of refrigeration (10 h.p.) to remove this heat and maintain a temperature of 72 degrees. Twenty tons or 20 h.p. would be needed on very hot days if there was no cooling from evaporation.

Sources of Artificial Light

Visible light is created by combustion, by incandescent radiation and by electric discharge. The sun provides light and heat by thermal nuclear combustion.

Relative efficiencies of various sources of light are: candle 0.1 lumens per watt; modern tungsten bulb 14 and fluorescent tube 65.0.

Incandescent Tungsten Electric Bulbs

Common tungsten bulbs produce light across the visible spectrum (380 to 760 millimicrons) and extends into the red and far red spectrum to about 3,000 millimicrons, with maximum radiation at roughly 1,000 millimicrons Filaments in a tungsten lamp operate at about 2800 degrees Kelvin.

Incandescent light bulbs produce more than 75% of their energy as red light thus creating a large amount of heat. Accordingly, these bulbs are not commonly used as a primary source of light in growth rooms but reflector incandescent bulbs are commonly used in greenhouses to obtain a photo period effect.

Infrared incandescent lamps are designed to radiate heat in the far red section of the spectrum between 1000 and 3000 millimicrons. Lamps of this type are used for baking paint on automobiles, heating milk houses, etc. Plant and animal tissues containing water transmit little energy beyond 1500.

Electric Discharge Lamps

Discharge lamps include carbon arc lights, and also mercury, neon and sodium lamps.

Mercury arc lamps radiate energy in about 12 bands ranging from 253 to 578 mu. The relative strength of these bands is regulated by the pressure in the arc tube and by filter glass used for the outer shell of the lamp. If the energy is concentrated in the 253 band, rays have a germicidal effect. If it is concentrated on the 296 band, the rays provide a sun tan effect on the skin. Within the visible spectrum the four mercury lines (404, 435, 546, 580) give a blue-yellow type of light.

Standard mercury lamps with blue-yellow bans give a colur effect with no red light in contrast to common incandescent bulbs which are more effective in the red and far red region. Various colour corrected mercury lamps are used in Europe for lighting greenhouses.

Fluorescent tubes are mercury lamps with a phosphorus coating on the inside of the glass container. In these tubes, the mercury radiation is concentrated at 253.7 mu. to activate the phosphorus coatings by electron bombardment. By this means the energy is converted to a full light

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$$Cu = 1.0 - \frac{x}{m\,n}$$

where Cu is the coefficient of uniformity, n is the number of observations and x is the deviation from the mean value m. A series of Spraying System nozzles $\frac{1}{4}$TT–80015E, gave a coefficient of uniformity of 0.96 at 40 pounds per square inch and at a spray height of 25 inches. These are the nozzle tips that were chosen for the field trials.

The machine was moved to the field and the spray was measured for uniformity by collecting the water in a rectangular pattern of 35 open topped cans. The resulting depth of water was then calculated for uniformity of application. Test runs were made for varying wind conditions, operating pressures and spray height. It was not possible to duplicate the laboratory results in the field. The wind was responsible for a drop in the uniformity coefficient to about 0.70 as the fine spray drifted considerably. Reducing the pressure to obtain larger drop sizes did not result in any appreciable improvement. A shield was then constructed to reduce the wind action with the result that a uniformity coefficient of 0.90 was easily obtained in the field with moderate wind speeds. This was an acceptable value.

The computed precipitation rate of 0.84 inches per hour did not result in puddling of an almost bare, loam soil. The application rate of 0.21 in-

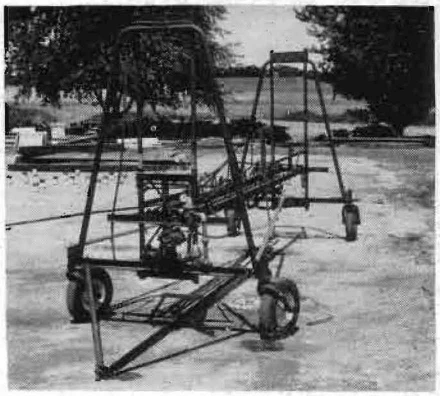

Fig. 3. Small plot irrigator in transport position.

ches every 15 minutes to a small section of soil apparently did not exceed the infiltration capacity of the soil. This application rate may be changed by using other nozzle tips.

Conclusions

This machine was constructed primarily for irrigation research work on small plots. The machine is highly maneuverable in the field and may be moved by hand by not more than two men from plot to plot. In many situations one man is adequate. The irrigation water is applied uniformly over the plot for all stages of plant growth. The rate of application may be varied to suit the crop and soil conditions. The power source requires little skill to operate and uses the same water supply as that for the spray booms. Some care must be taken to see that the discharge water is carried away from the experimental area. This machine under average irrigation conditions should cover three or four replicates per day. This would appear to be adequate for many experiments.

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spectrum with variations depending on the chemical coatings. All tubes of this type require ballasts or converters.

"Daylight" or "Cool White" fluorescent units provide a broad spectrum of light and these are used extensively for plant growth purposes in greenhouses and growth rooms. To obtain more energy in the red sector some incandescent lights are frequently used with the fluorescent tubes.

Light Intensity

As noted, the maximum intensity of sunlight (50° Lat.) is about 10,000 while moonlight is less than one-tenth of one foot candle. With a concentrated assembly of incandescent bulbs an intensity of roughly 10,000 can be obtained but about ninety percent of the energy is released as heat and this presents certain problems in

When fluorescent tubes are installed in solid panels they produce 3,000 to 4,000 foot candles and with im-growth rooms.

provements in equipment this may be exceeded. Mercury bulbs will provide 15,000 f.c. and higher intensities in solid panels.

For special investigations it is desirable to measure energy in gram calories per square centimeter for each section of the spectrum under consideration but foot candles are satisfactory as routine tests. However, a proper technique must be secured in obtaining foot candle data and the characteristics of equipment (cosine corrections) should be noted or the information is of little value.

Light and Plant Growth

The relationship between the characteristics of light and plant is so complex that current knowledge of this subject is in effect primitive or elementary. Accordingly, all data must be presented in general terms with provision for modifications.

In general, light has a photo period effect on many plants involving flowering and some features of vegetable growth. However, varieties of soybeans may range from long to neutral to short day plants. Helicopters with electric lights are being used to promote vegetable growth in sugar cane.

For photosynthesis some plants seem to prefer blue and red light according to the Hoover curve. However, some type of photosynthesis may take place in evergreen trees without light.

Wheat seems to desire an intensity of 2500 foot candles at 25 degrees centigrade, but many plants require much less light. In general, lower temperatures seem to be associated with lower light requirements for many plants.

Red and infra-red light affects seed germination in lettuce and ultra-violet light may cause conditions which are not yet understood.