

Fig. 11 .... Room Latent Heat in a Hog House[34]

ing and market quality of broilers. Air velocity effects have received limited attention. Some benefit from increased velocity, up to 500 fpm is obtained as air temperatures are increased from 75 to 95 F.[35] It has been reported that the use of cyclic temperatures has stimulated growth.

Heat and Moisture

Heat and moisture dissipation rates of caged laying hens are expressed in Fig. 12.[35] Results of limited calorimetric tests with a modern strain of broilers, Athens Randombred, are given in Table 3.

PART II: PLANTS

Forces caused by the expanding world population and our desire to eat more and better food have induced a considerable increase in practical and fundamental research on the factors influencing the growth of plants. Since growing seasons in Canada and many parts of the United States are short, and the natural environment is full of variables, biologists have asked for plant growth chambers in which part or all of the environmental variables are controlled. There are more than 300,000 species and approximately 1,000,000 varieties of plants. These plants grow under natural conditions, from the polar regions to the equator, from below sea level to the top of the highest mountain, and from the driest desert to the humid jungle. The day length to which they are exposed varies from continuous semidarkness at one polar region during the winter, to 12 hr at the equator, to continuous daylight at the opposite polar region. The type, fertility, and temperature of the soil vary from one locality to another. The plant, in relation to the environment, is extremely complex, because every variety of plant and every factor of environment has an infinite number of variables, and because there is a continuous interaction between all factors at every level of variation. As a result, the design of plant growth chambers presents many new kinds of problems for the engineer.

Table 2 .... Cumulative Growth and Feed Consumption for Broiler Chickens

Weeks of Age	1	2	3	4	5	6	7	8	9
Weight—Pounds	0.19	0.43	0.78	1.15	1.62	2.15	2.67	3.20	3.80
Feed—Pounds	0.14	0.56	1.23	1.92	2.97	4.22	5.57	7.05	8.70
Feed/unit body weight	0.76	1.30	1.58	1.67	1.83	1.96	2.08	2.20	2.29

ENVIRONMENT AND PLANT GROWTH

Light

Light is absolutely essential for plant growth and development. Moreover, every characteristic of light, including intensity, spectral energy distribution, and duration affects the growth of plants.

Intensity. The intensity of the sun increases from 0 at the beginning of the day to as much as 10–12,000 foot candles at noon and then decreases to 0 at the end of the day. In the controlled-environment chamber, the light level becomes maximum within a few minutes after the beginning of the day and remains at a maximum until the end of the day. Although the light intensity in the controlled-environment chamber is considerably less than that of sunlight, good plant growth is easily attained. Reasonably good plant growth can be obtained with constant intensities of 1000 to 1500 foot candles, and plants grow quite well at intensities of 2–3000 foot candles (Fig. 13). At light levels in excess of 3000 foot candles, the rate of growth may be increased or decreased, depending in part on the kind of plant, but mainly depending upon the cultural conditions used by the biologist. When cultural conditions are matched to the environment, better plants can be grown in the controlled environment room than in the greenhouse.

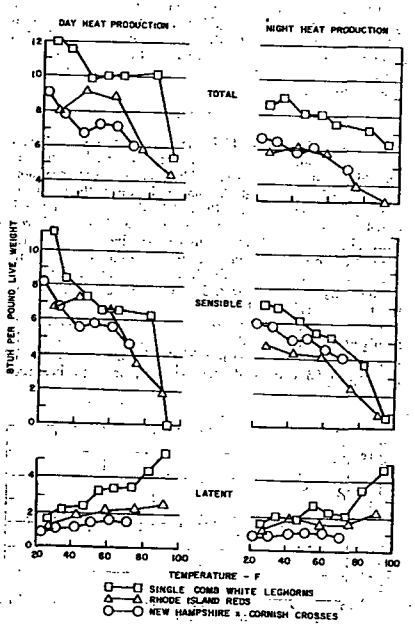


Fig. 12 .... Heat and Moisture Loads for Caged Laying Hens at Various Air Temperatures[35]

Table 3 .... Heat Production[a] of Broiler Chickens

Dry Bulb Temperatures Decreasing From 92.9 to 85.9 During Growth							
Age, Days	2	11	20	33	40	55	62
Sensible Heat[b]	6.0	17.7	15.1	11.0	8.2	6.8	6.1
Latent Heat[b]	6.0	4.1	3.4	3.4	2.6	2.8	2.2
Total Heat[b]	12.0	21.8	18.5	14.4	10.8	9.6	8.3
Dry Bulb Temperatures Decreasing From 95.2 to 53.3 During Growth							
Age, Days	3	14	20	31	40	50	
Sensible Heat[b]	16.7	23.0	17.9	13.1	11.3	13.9	
Latent Heat[b]	1.1	3.3	2.6	2.8	2.7	2.3	
Total Heat[b]	17.8	26.3	20.5	15.9	14.0	16.2	

[a] Btu per (hr) (lb of live weight).

Spectral Quality. The sun has a spectral range of approximately 200 to 3000 nanometers (1 nanometer = 1 millimicron = 10^{-9} meters), with significant depressions beyond 700 nm due to the effect of water vapor in the air (Fig. 14). Plants appear to utilize only the radiant energy in the visible and near-visible portions of the spectrum. The food manufacturing process of photosynthesis operates after chlorophyll absorbs light. Chlorophyll has absorption maxima in the blue range at about 430 nm and in the red at about 660 nm (Fig. 15). Photocontrol of germination, growth, flowering, and coloration of many plant parts operates through the absorption of light by phytochrome (a photoreversible plant pigment that has absorption maxima at 650 nm and at 735 nm) (Fig. 15). The plant also contains many other pigments such as anthocyanins, carotenoids, flavanoids, etc., that absorb light differentially in the visible region of the spectrum,[41] but the exact function of many of these pigments is not known.

The xenon lamp (Fig. 14) emits radiation with approximately the same spectral energy distribution as the sun, but no artificial light sources have been developed that exactly reproduce the spectral quality of the radiation received from the sun. However, the necessity of such a development is not clear because, although plants have adapted themselves to utilize sunlight more or less efficiently, there is not reason to assume that the spectral distribution of sunlight is the best for plant growth. Certainly we know that good plant growth is obtained with artificial light, and the most common source of light for plant growth chambers is a combination of fluorescent and incandescent lamps. Lamps especially designed for the growth of plants are currently available, but they have not been evaluated sufficiently to assess their value for controlled-environment room light sources.

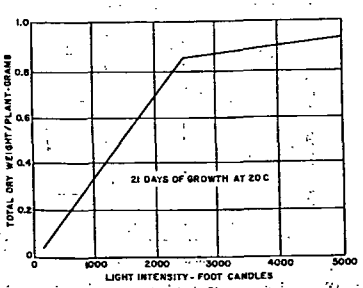


Fig. 13 .... Effects of Light Intensity on Growth of Marquis Wheat[39]

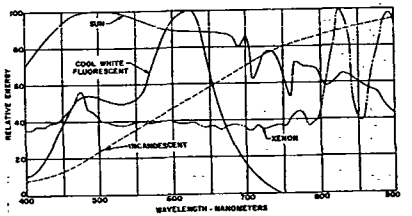


Fig. 14 .... Spectral Energy Distribution of the Sun for Air Mass[39] and for Flourescent, Incandescent, and Xenon Lamps[40]

Many plant responses, such as germination of seeds, rate of flowering,[42] and elongation of stems[43] are controlled by the relative amounts of red (660 nm) and far red (735 nm) radiant energy emitted by the light sources. Thus, one function of the incandescent lamps is to supply the far red radiant energy lacking in the fluorescent lamps (Fig. 14).

Photoperiod. The relative durations of the light and dark periods often control the advent and cessation of dormancy and the initiation and later development of flowers.[45,46,47] Any day length can be readily obtained in the controlled-environment chamber by the addition of a facility for making the plant's dark period occur during the investigator's light period. Inversion of the light and dark periods is frequently a requirement in investigations of the mechanism by which light controls plant growth and development. Because very low levels of light, even 0.1 foot candles, leaking into a room that is supposed to be dark can completely alter experimental results, darkness must be the complete absence of light.

Temperature

Temperature is a dominant factor in the environment for the growth of plants. Each stage of plant development usually has a different optimum temperature (Fig. 16), so a range of day and night temperatures must be established to obtain

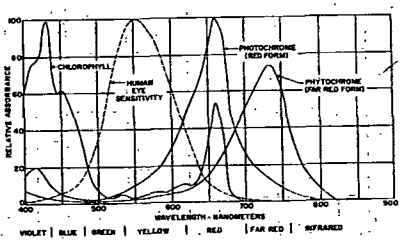


Fig. 15 .... Absorption Spectra of Chlorophyll[41] and Phytochrome[44] Relative to the Spectral Sensitivity of the Human Eye[40]