Peanut Science (1978) 5, 27-30

Effect of Quantity of Light on the Early Growth and Development of the Peanut[1]

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ABSTRACT

The effects of the quantity and quality of radiation must be determined over a period of time in order to model the growth and development of peanuts (*Arachis hypogaea* L.). Two phytotron experiments were conducted in which light intensity and the duration of light were varied and Florigiant peanuts grown. Dry weights of leaflets, petioles and stems, leaf area, and number of flowers of young noncompetitive plants were measured at four-to five-day intervals over a 39- or 46-day growth period. Top dry weight increased curvilinearly with increasing photosynthetically active radiation becoming asymptotic above about 23 E m^{-2} day $^{-1}$. Leaf area differed due to light treatment much as did top dry weight but differences in light did affect the leaf area per gram of leaflet and the leaflet to top ratio. That the latter also was related to top weight should be useful in modeling. The main stems were quite elongated under the low light treatments but light quality may be a factor in this response. The number of flowers was markedly reduced as less light was received by the plants. Regression techniques were used to fit an equation to describe a daily radiation factor that can be used in a simulation model. This daily radiation factor compared well with those from field estimates. These relations emphasize the importance of radiation only at quite low light levels. There was no apparent interaction between intensity and duration so use of total light should be valid.

Keywords: Modeling, Radiation, Shading

Efforts are underway to mathematically model peanut (*Arachis hypogaea* L.) growth and development. Since light is a basic input into the models, knowledge is needed on effects of the quantity and quality of radiation. For growth and development models data needs to be collected over a long period so that the plants are as nearly in equilibrium with their environment as possible.

Pallas and Samish (1974) determined the net photosynthetic rate (Pn) for several peanut genotypes as a function of the flux density of photosynthetically active radiation (PAR, 400-700 nm) with various light sources in a growth chamber. The genotypes were grown at 255 μE m^{-2} sec^{-1}, while photosynthetic measurements were made at given flux densities for 15 min. They found no genotype quite photosaturated at the highest intensity (1546 μE m^{-2} sec^{-1}), but the slope relating Pn to PAR was distinctly attenuated above 500 to 700 μE m^{-2} sec^{-1}. Similar results were found by Trachtenberg and McCloud (1976). The results of these studies, however, are based on rather short term observations and the plants have little time to adjust to the change in their environment. Therefore, the results are not likely applicable for estimating net assimilation for a longer period.

Shading experiments have been conducted in the field for longer term evaluations. Ono and Ozaki (1971) found that increasing the degree or length of shading of peanuts resulted in less growth. The net assimilation rate (NAR) decreased linearly with relative light intensity between 100 and 26%. It was not directly proportional, however, as 55% of the NAR that existed with no shade was found when only 26% of the light remained. This indicates there would have to be marked non-linear effect at low light intensities. A non-linear effect could be related to stomatal diffusion resistance. This resistance has been found to increase logarithmically with decreasing irradiance (PAR), especially at less than 500 μE m^{-2} sec^{-1} (Allen, *et al.*, 1976).

The current studies were undertaken to determine the effect of quantity of light on the early growth and development of the peanut. The data will be utilized in a mathematical model simulating peanut growth and development.

Materials and Methods

Two studies were conducted in the phytotron unit of the Southeastern Plant Environment Laboratory at North Carolina State University. In the first, Florigiant peanut seed were germinated in a chamber at 27.5°. The day the seed were moistened was considered the first day of growth. On the fourth day the germinating seed were transplanted into 15-cm diameter pots filled with a 1/3 Redi-Earth (W.R. Grace & Co., Atlanta, GA), 2/3 gravel growth media and moved to one of two controlled-environment rooms programmed for daylengths of 4 1/2 and 15 hours. By moving the plants between these two rooms five light treatments were established. They were 4 1/2, 6, 9, 12, and 15 hours of photosynthetically active radiation (PAR) at 680 μE m^{-2} sec^{-1} from a combination of cool white fluorescent and incandescent lamps at a 10:3 input wattage ratio. The photomorphogenic radiation (PR) was 18 w m^{-2} at 700-800 nm during the treatments. In order that all plants have a constant day length of 15 hours, incandescent lamps which emitted PR at 12 w m^{-2} and PAR at 55 μE m^{-2} sec^{-1} were continued for the remainder of the day period. The hours of PAR were then summed and the treatments expressed as 13.1, 16.4, 23.2, 29.9, and 36.7 E m^{-2} day^{-1}.

The temperature was maintained at 27.5° and the CO_2 content between 350 and 400 ppm day and night in these chambers. The relative humidity was maintained near 70%. Each pot was irrigated once daily with a dilute modified Hoagland solution.

The experiment was conducted for a total of 39 days. During this time two plants per treatment were sampled destructively about each five days beginning after emergence on day 8. Measurements included leaf area, dry weights of leaflets, petioles and stems, and number of flowers.

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[1] Paper No. 5359 of the North Carolina Agricultural Experiment Station, Raleigh, North Carolina 27607. Operation of the phytotron unit of the Southeastern Plant Environmental Laboratory at North Carolina State University was supported in part by NSF Grant GI-28951. The use of trade names in this report does not imply endorsement by the North Carolina Agricultural Experiment Station of the product nor criticism of similar ones not mentioned.

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The second study was essentially a repeat of the first except that on the 13th day of growth, five days after germination, a Saran net was placed over the plants to act as a shade. This reduced the PAR and PR from the combination of fluorescent and incandescent lamps to 370 μE m^{-2} sec^{-1} and 9 w m^{-2} and that from the incandescent alone to 38 μE m^{-2} sec^{-1} and 8 w m^{-2}, respectively. The treatments were then 7.4, 9.2, 12.8, 16.4, and 20.0 E m^{-2} day^{-1}. This study lasted 46 days, and since the plants grew larger in this study the pots were irrigated with the modified dilute Hoagland solution twice daily instead of once. Samples were taken about each four days. Pegs were clipped to maintain a vegetative state, but there were essentially none to be clipped in the first study and only a few in the second.

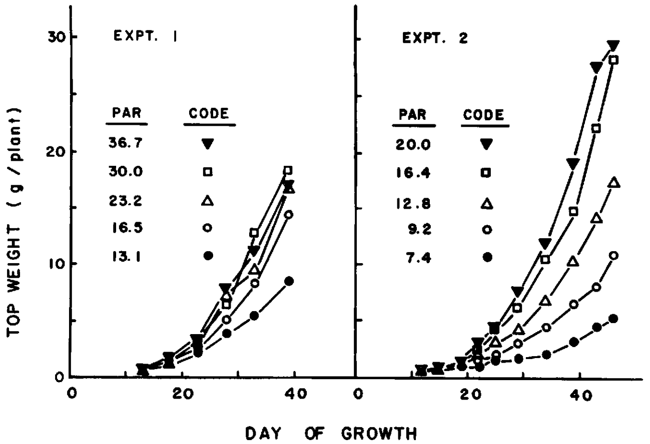

Fig. 1. Effect of amount of light (PAR, E m^{-2} day^{-1}) on the top dry weight of Florigiant peanuts during their early vegetative growth in two experiments.

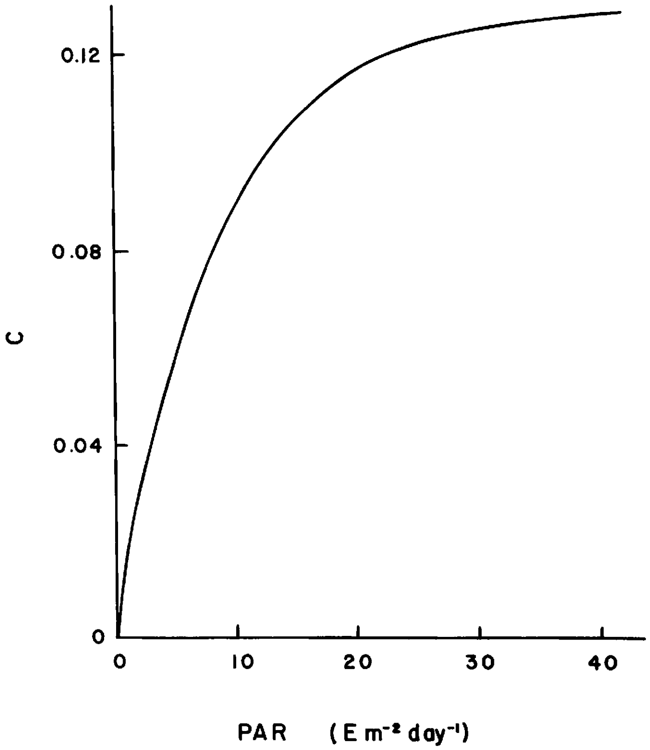

Fig. 2. The relation between the variable "C" and PAR. This variable appears in the equation describing top dry weight as a function of this variable and day of growth.

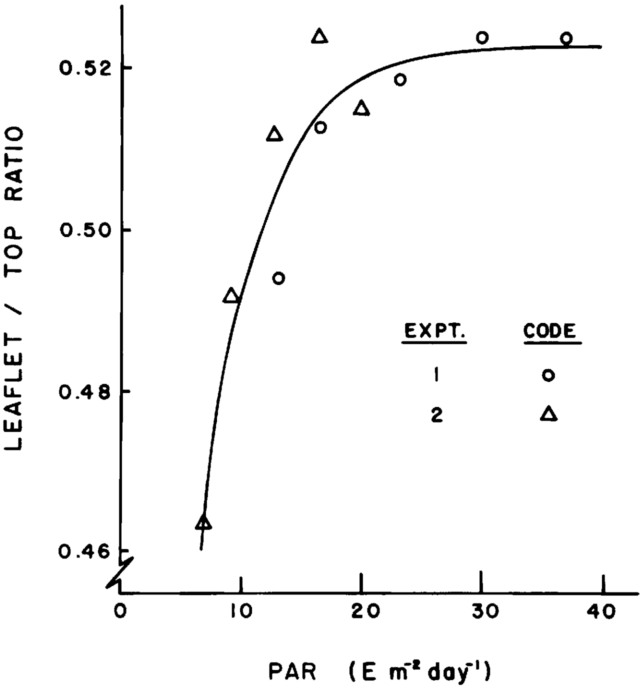

Fig. 3. Relation between the leaflet to top weight ratio (R) and light in the two phytotron experiments. An equation for the line shown is: $R = 0.523 - 0.25\ e^{-0.211\ (PAR)}$

Results and Discussion

The top dry weight increased exponentially during this early vegetative period in four of the ten different light levels in the two experiments (Fig. 1). In the other six there was a slight convexness to a plot of the logarithm of the top dry weight versus time. Since these also were close to linear, the following equation was chosen to describe the relation $W = 0.445\ e^{c\ (DAY\ -8)}$ where W is the top dry weight, DAY is the day of growth, and c is a function of light. The relation between c and light was then described as $c = 0.129\ (1\ - e^{-0.121\ PAR})$ and is presented in Figure 2. It is obvious that there is a marked effect of light at very low levels, but that it becomes almost negligible if the PAR is greater than 25 E m^{-2} day^{-1}. In a 15 hour day this is equivalent to a PAR level of 463 μE m^{-2} sec^{-1}. This contrasts with the results of net photosynthesis measurements by Pallas and Samish (1974) and by Trachtenberg and McCloud (1976). They found a significant increase in net photosynthesis at even higher light levels.

In these experiments two sets of points were similar, one at 12.8 and 13.1 and the other at 16.4 and 16.5 E m^{-2} day^{-1}, but they were achieved with different light levels and exposure times. At 39 days the first gave 8.5 and 10.5 g/plant, while the second gave 14.5 and 14.7 g/plant in the two experiments. Since these weights are similar it indicates that the effects of light level and exposure time must be additive on dry weight accumulation, so the use of a daily light function should be valid.

The leaf area of these noncompetitive young plants increased exponentially in time and was affected by PAR in a manner similar to that of top dry weight. However, the proportionality between leaf area and top dry weight over the PAR levels resulted from an increase in the leaflet to top dry weight ratio with increasing PAR (Fig. 3) and a decrease in the leaf area per gram of leaflet with increasing PAR (Fig. 4). These relationships were derived from samples taken throughout the study.

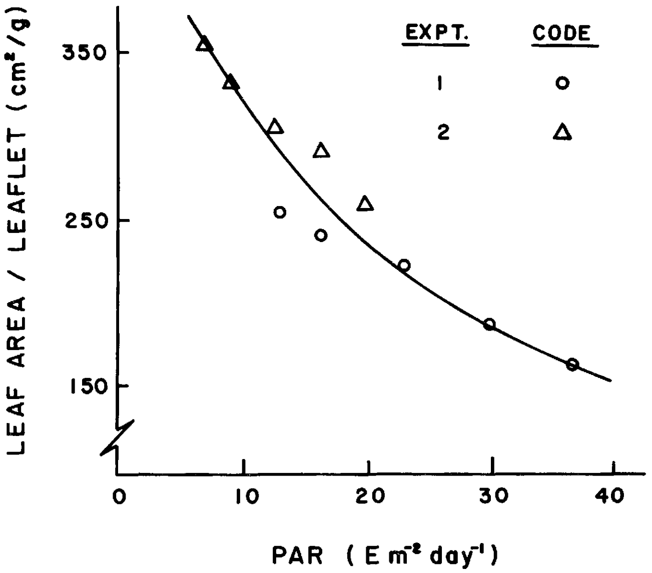

Fig. 4. The relation between leaf area per gram of leaflet (LA/LT) and light in the two experiments during the 20 to 50 day of growth period. An equation for the line shown is: $LA/LT = 97 + 358\ e^{-0.0471\ (PAR)}$

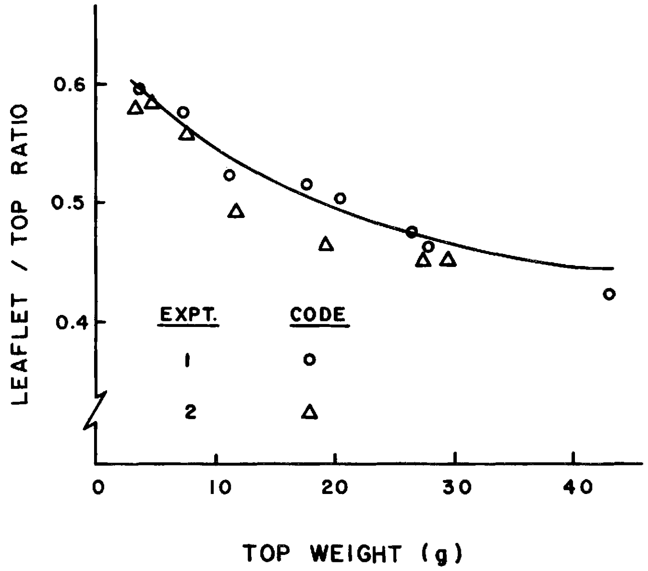

Fig. 5. Relation between the leaflet to top weight ratio (R) and top weight (TPWT) of peanuts. Data are from treatments receiving more than 20 E m^{-2} day^{-1} in the two experiments. An equation for the line shown is: $R = [7.136/ (TPWT + 23.91)] + 0.335$.

The relationship between the leaflet to top dry weight ratio and top dry weight for those treatments receiving greater than 20 E m^{-2} day^{-1} is shown in Figure 5. The ratio decreases from around 0.6 at 3 g top weight, as a lower limit, to about 0.4 at 40 g, the upper limit of our observations. This relationship should be useful in modeling the partitioning of dry matter into leaflet and other plant top parts as the plant grows in size and becomes physiologically older.

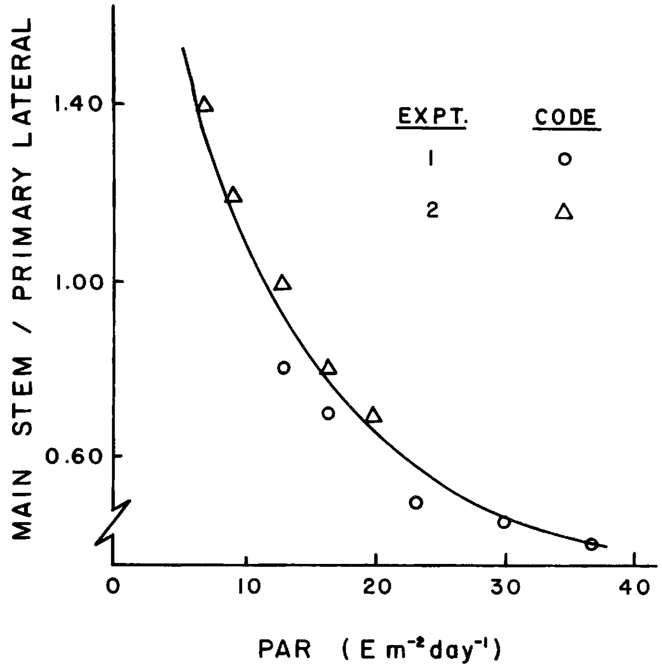

Fig. 6. Relation between the ratio of main stem length to primary lateral length (LR) and light in the two experiments: An equation for the line shown is: $LR = 0.35 + 2.16\ e^{-0.102\ (PAR)}$

Light treatments strikingly affected the morphology of the plant, especially the lengths of the main stem and primary lateral branches. In both experiments less total light resulted in more elongated main stems. Decreasing the light level had less effect on the length of the lateral branches. Overall, there was a non-linear decrease in the ratio of the main stem to primary lateral length with an increase in PAR (Fig. 6). The range was from a ratio of 1.4 down to one of 0.4. These data agree well with those of Cheliadinova (1941). He found shaded plants were taller and had more leaf area than unshaded ones. However, when he reduced light reception by shortening the day length the plants were shorter; hence the observed morphological effect of shading may be due to differences in light quality. If shading caused the light to be more monochromatic, especially more infrared, then this could also lead to greater stem elongation (Fortanier, 1954, 1957). Light quality effects may be involved in day length studies when long days are achieved by interrupting the dark period with several hours of low intensity incandescent light. Wynne *et al.* (1973) found that plants given such long-day treatments had more elongated stems and less early pegs and fruit than plants given short-day treatments. We have observed a change in the main stem to primary lateral ratio when plants in the field were shaded with a white triacetate cloth that reduced sunlight by about 50%. The ratio under the shade was 0.58 while that in full sunlight was 0.43.

Flowering began in these two experiments on the 28th and 30th days of growth. The number of flowers per plant increased in an approximately linear manner until the 40th day. The number of flowers, like dry weight, increased with PAR up to 25 E m^{-2} day^{-1}, but the effect of light was more extreme on flowering. At 7.4 and 9.2 E m^{-2} day^{-1}, there was less than 1 flower per plant whereas at greater than 20 E m^{-2} day^{-1} there were about 6 flowers per plant on the 39th day of growth.

The data from the second experiment were used to calculate the effect of light in a model of peanut growth and development being formulated by F.R. Cox and J.H. Young (unpublished). This model, however, is programmed to accept total radiance measurements in langleys day^{-1}. To convert PAR expressed as E m^{-2} hr^{-1} to ly hr^{-1}, a conversion factor of 1 E m^{-2} hr^{-1} = 7.55 ly hr^{-1} was assumed. This factor is based on comparison of instruments in greenhouses (Raper, *et al.*, 1977). The model utilizes multiplicative input factors, leaf weight adjusted for aging, and a constant for the cultivar to estimate total photosynthesis. The input factors are for temperature, radiation (or light), soil moisture tension and leaf shading. These all are functions that vary between zero and one. The radiation factor (RF) equation that seemed to best fit the range in treatment effects from these phytotron studies was $RF = 1.0 - e^{-0.013\,L}$ where L is the light in ly day^{-1}. With this equation the RF tends to plateau near 1.0 at about 300 ly day^{-1}. We have also evaluated data from planting date studies in the field and found the "Constant" in the equation to vary from 0.009 to 0.012. That causes the plateau to be near 1.0 with slightly higher light readings, about 400 ly day^{-1}. In both cases, however, it indicates that differences in light in the range normally encountered in the field should not have a marked effect on peanut growth. It is a non-linear relation in which the effect is pronounced only at less than 200 ly day^{-1}.

Literature Cited

1. Allen, L.H., Jr., K.J. Boote and L.C. Hammond. 1976. Peanut stomatal diffusion resistance affected by soil water and solar radiation. Proc. Soil Crop Sci. Soc. Fla. 35: 42-46.
2. Cheliadinova, A.I. 1941. Influence of illumination intensity upon the response of peanuts to daylength. Compt. Rend. (Dok.) Acad. Sci. URSS 31 (3): 276-278.
3. Fortanier, E.J. 1954. Some observations on the influence of spectral regions of light on stem elongation, flower bud elongation, flower bud opening and leaf movement in *Arachis hypogaea* L. Med. Landbouwhogeschool, Wageningen, Netherlands 54: 102-114.
4. Fortanier, E.J. 1957. Control of Flowering in *Arachis hypogaea* L. Mededel. Landbouwhogesch. Wageningen 57: 1-116.
5. Ono, Y., and K. Ozaki. 1971. Effects of shading treatment at early growth stage on growth and yield of peanut plants. Crop Sci. Soc. Japan Proc. 40: 480-485.
6. Pallas, J.E., Jr., and Y.B. Samish. 1974. Photosynthetic response of peanut. Crop Sci. 14: 478-482.
7. Raper, C.D., Jr., D.T. Patterson, L.R. Parsons, and P.J. Kramer. 1977. Relative growth and nutrient accumulation rates for tobacco. Plant and Soil 46: 473-486.
8. Trachtenberg, C.H., and D.E. McCloud. 1976. Net photosynthesis of peanut leaves at varying light intensities and leaf ages. Proc. Soil Crop Sci. Soc. Fla. 35: 54-55.
9. Wynne, J.C., D.A. Emery and R.J. Downs. 1973. Photoperiodic responses of peanuts. Crop Sci. 13: 511-514.