THE EFFECT OF SHADE ON THE BIO-CLIMATE AND PRODUCTION OF VEGETABLE CROPS

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There is available in Northwest Florida about 5,000 acres of shade covered crop land under which is grown cigar wrapper tobacco. These shades are used for tobacco during the spring and early summer (February - June) and then with the cloth removed, remain unused for the remainder of the year. The use of this shade covered land for vegetable production could possibly offer solutions to some of the problems now present in vegetable production in Northwest Florida. These problems include poor plant stands and rather low yields in the fall vegetable season. Frequently high summer temperatures, intense insolation, and rapid evapotranspiration result in plants wilting even though soil moisture is adequate. High soil temperatures drastically reduce stands of some seedlings. A study of the effects of shading upon the growth, development and productivity was begun at the North Florida Experiment Station in 1959 with meteorological instrumentation additions in 1962 and 1963.

REVIEW OF LITERATURE

Numerous studies have been undertaken to define the effects of shade on the phytoclimate but most of these studies related to the production of tobacco under shade cloth. The object of growing tobacco under shade is to produce a thinner smoother leaf with smaller veins which is suitable for fine cigar wrappers. Jenkins (1) demonstrated that this could be done by the use of cheese cloth shading although the precise physiological and chemical changes that could be attributed to the shading were not known. In fact, he concluded that the close spacing of the plants under the tent caused more auto-shading than the tent cloth. The first attempt at quantitative measurement of the effect of shade on the micro-climate was by Stewart (2) in 1907. This study showed increased relative humidity, reduced evaporation and higher soil moisture under the shade tent. Street (3, 4) first measured the reductions in incoming radiation caused by the shade cloth. He reported these reductions to range from 30 per cent to 60 per cent. Waggoner et al. (5) made a rather comprehensive study of an empty shade tent in 1959. They concluded that the shade cloth reduced incoming radiation by one third on sunny days but by only one fifth on cloudy days, with evaporation reduced by 20 per cent, but that the changes in the bio-climate were slight relative to other changes noted and relative to changes necessary for plant response. Purdy (6) reported that on very warm days shade reduced temperatures from 1 to 5 degrees but on cool days no significant differences were recorded. Trotter and Griffiths (7) found that the average relative humidity under shade was significantly higher, and that soil moisture at both the 2 inch and 4 inch levels was higher in the shade with the 2 inch showing the greatest variation from the open. Young (9) showed that the light intensity did not appear limiting under shade and that unshaded plants often wilted in the afternoon despite adequate soil moisture. Valli and Young (8) in 1962 first studied the effects of shading on the bioclimate and vegetable crops.

Their results indicated the following: insolation was reduced about 43 percent by the shade on a monthly basis, but on mostly sunny days the reduction was 58 percent while on mostly cloudy days the reduction was only 36 percent. Mean monthly temperatures were reduced 1.4° F. under the shade, mean monthly maximum temperatures were reduced 3.3° F. and mean minimum temperatures averaged 0.5° F. higher under shade. Relative humidity in the shade averaged about 5 percent higher under the shade but dew points averaged 2.1° F. higher. Results from Livingston atmometer bulbs showed that evaporation losses were reduced by 15 percent from the white bulbs and 22 percent from the black bulbs. Mean maximum soil temperatures were reduced 5.7° F. by the shade. Stand counts under the shade were better for both the pole beans and the cucumbers, and these counts were credited for the increased total and marketable yields in the shaded plots.

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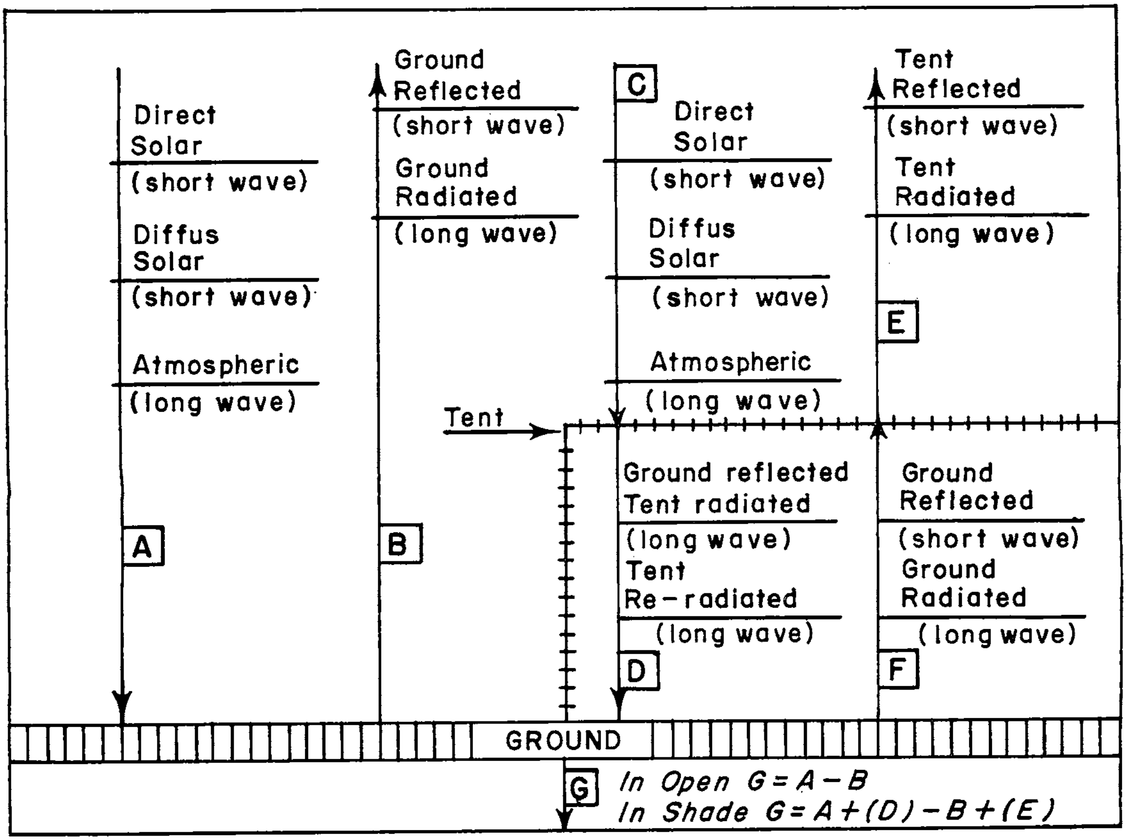

FIGURE 1 ENERGY DISTRIBUTION

Materials and Methods

An area 400 feet long and 50 feet wide was divided into ten 40 x 50 foot sections. Alternate sections were covered at a height of 8 feet with cheesecloth, 12 x 12 weave, treated with lead chromate. Plots extended the length of the field, providing five replications of each treatment, shaded and open. Micrometeorological instrumentation in duplicate was placed in a shaded and an open plot. Equipment at each location consisted of the following: (1) a standard cotton region type instrument shelter with a floor elevation of 12 inches above the soil; (2) a recording pyrheliometer exposed on the top of each shelter; (3) a hygrothermograph; (4) a Palmer maximum-minimum soil thermometer placed at 4 inches in the soil; and (5) maximum and minimum air thermometers. Exposed on the top of each shelter were sets of Livingston black and white atmometer bulbs. Figure 2 shows the instrument shelter and instruments.

Ashley cucumbers and Kentucky Wonder 191 pole beans were seeded in four foot rows on April 5, 1963, and were later thinned to about one plant per foot. Both crops were trained to strings suspended from overhead wires. Shade and open plots were treated with equal amounts of fertilizer in accordance with present recommendations for the area. Weekly applications of fungicides and insecticides were made. Irrigation was applied equally to both treatments when it was needed. Harvesting extended from May 29 until July 1 for cucumbers and from May 27 to June 13 for pole beans.

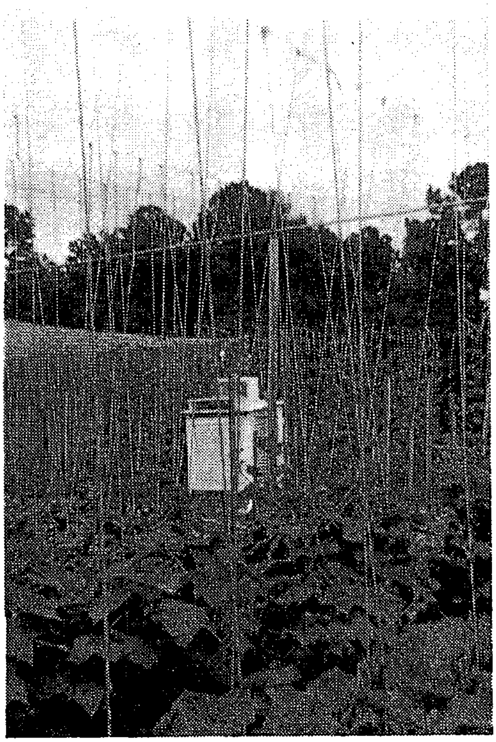

Figure 2.—Instrumentation.

RESULTS

Insolation

Incoming radiation in the open is composed of solar and atmospheric radiation. Under the shade tent there is also the tent reflected and tent radiated energy, less the amount of incident energy which is reflected and radiated by the top of the shade back into the atmosphere. Figure 1 indicates the distribution of energy from various sources without regard to actual percentages. Solar radiation is composed of two parts, direct and diffuse. The direct radiation is the energy that is received at the surface (tent or ground) directly from the sun, and diffuse is the energy which is reflected, or absorbed and reradiated by the clouds and other atmospheric impurities. Both direct and reflected radiation are in the short wave lengths. Part of the diffuse radiation however, is that short wave energy which is absorbed by the water, CO_2 and other aerosols in the atmosphere and reradiated as long wave energy. Incoming radiation at the soil surface under the shade is affected by the shade cloth. The cloth reflects a portion of the total energy incident upon it and absorbs some of the energy which is then reradiated out as long wave energy. Outgoing energy from bare soil is mostly ground radiated long wave, with some

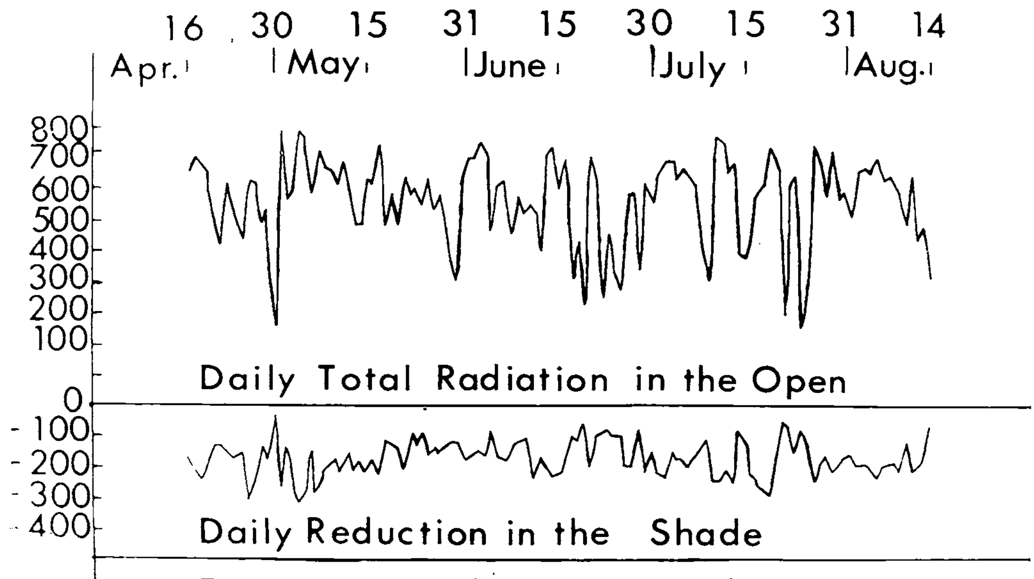

Figure 3. Insolation. April 16-August 14

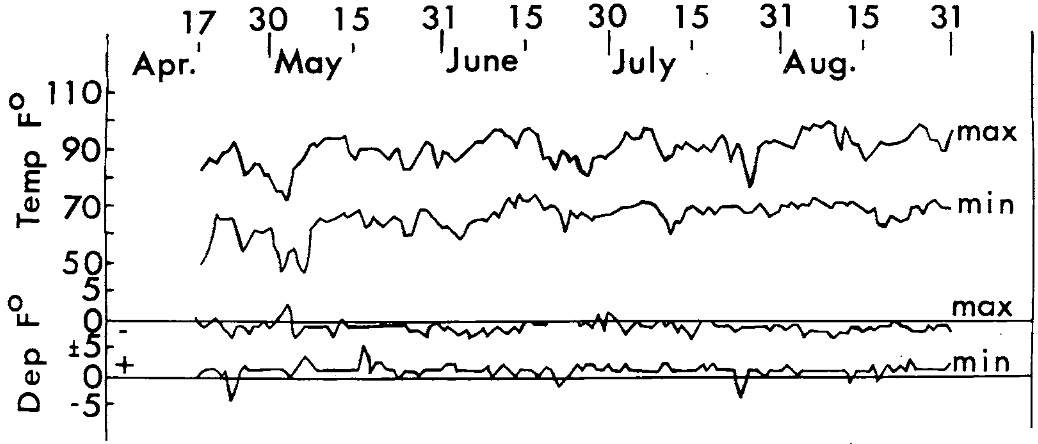

Figure 4. Daily Maximum and Minimum Air Temperatures in the Open and Departures from Open in the Shade. April 17-Aug 31

reflected short wave. Outgoing radiation from the soil under the shade cloth is modified by the reflection back from the underside of the shade cloth.

Figure 3 shows incoming radiation for the period April 16 to August 14, 1963, which totaled 68,566 Langleys in the open as compared to 49,013 Langleys under the shade tent. This represents a reduction in incident energy by the shade tent of 29 percent for the entire period. Breaking the total period into monthly segments, the reductions ranged from a high of 31 percent for the period in April to 26 percent for the month of June.

Air Temperatures

Mean monthly air temperatures for May were 79.2° F. in the shade compared to 80.6 in the open, a reduction of 1.4 F.; for June 84.2° F. in the open, 81.6° F. in the shade, a reduction of 2.6° F; for July 85.4° F. in the open, 83.7° F.

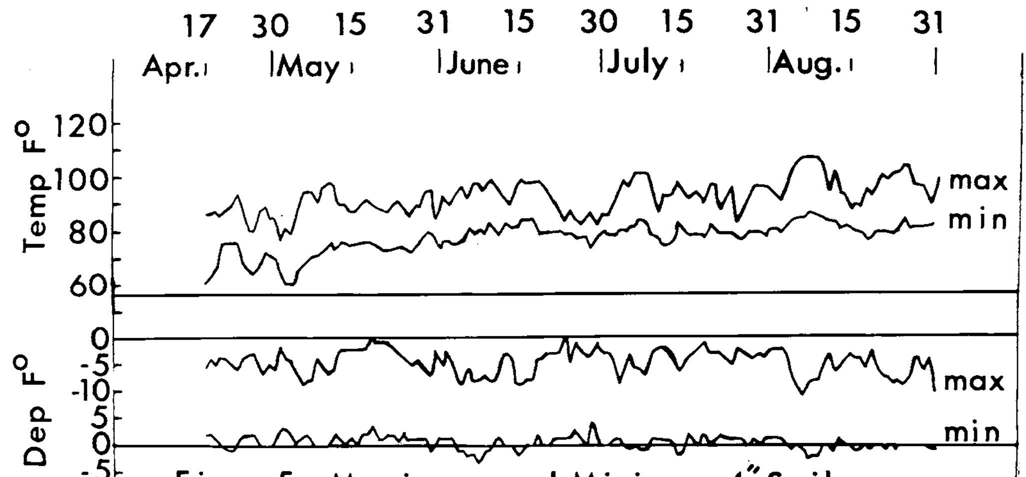

Figure 5. Maximum and Minimum 4" Soil Temperatures in the Open and Departures from Open in the Shade. April 17–Aug.31

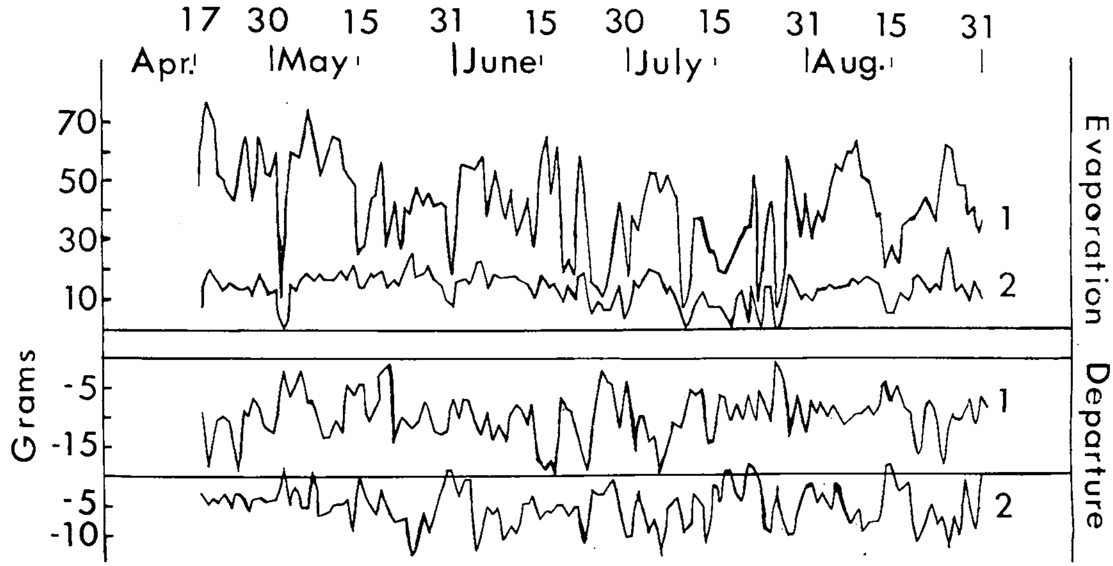

Figure 6. Black Bulb(1); Black Minus White Bulb(2); Atmometer Evaporation in Open and Departure from Open in Shade. April 17 - Aug 31

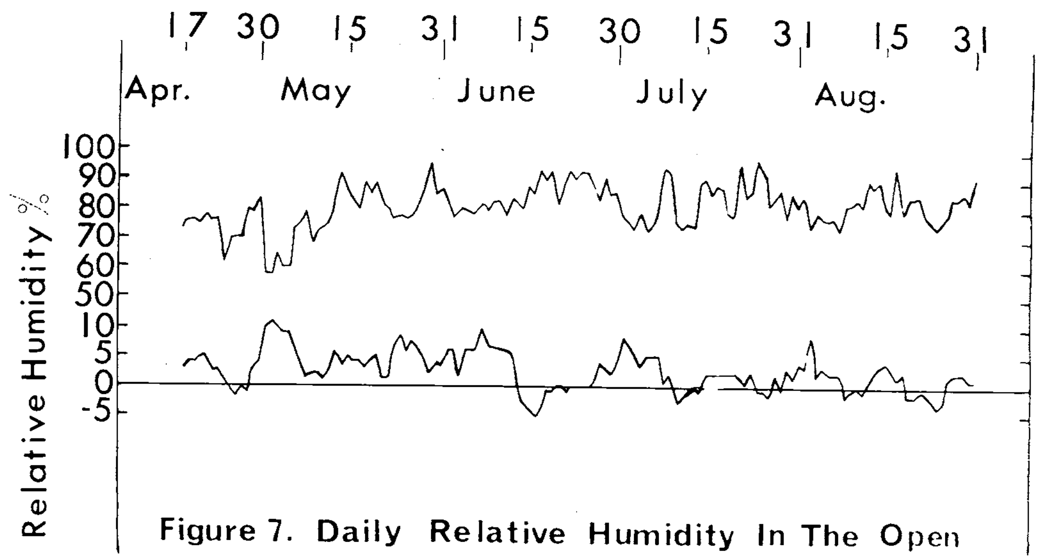

Figure 7. Daily Relative Humidity In The Open And Departure In Shade. April 17 – Aug. 31, 1963.

in the shade, a reduction of 1.7° F. and in August 88.8° F. in the open, 85.5° F. in the shade, a reduction of 3.3° F. For the entire period of April 17 through August 31, 1963, mean maximum temperatures averaged 90.8° F. in the open, which was 4.7° higher than the average of 86.1° F. in the shade tent. For the same period minimum temperatures averaged 75.7° F. in the open which was only 0.3° F. lower than the tent average of 76.0° F.

Relative Humidity

Daily mean relative humidities in the open and departures from the open in the shade are shown in Figure 7. Mean monthly relative humidity in the shade averaged about 3 percent higher than in the open for the entire period. Spot measurements of relative humidity in the vegetable foliage were made with an aspirated psychrometer on June 7, 1963. In bean foliage at about 6 inches measurements averaged 58 percent in the shade compared to 62 percent in the open. At a level of 4 feet the shade average was 72 percent compared to 61 percent in the sun. At 7 feet the shade value was 54 percent while in the open it was 60 percent. As indicated, the relative humidity was quite uniform at all levels in the open, while shade values were notably higher in the middle levels. Possibly the diminished wind within the shade decreased mixing and vertical motion. Measurements taken in cucumbers were more erratic.

Evaporation

Evaporation from Livingston black bulbs and white bulbs shows the reduction in incident energy. For the total period of April 17 through August 31 evaporation water loss from the black bulb under shade was 79 percent of that of the open unshaded black bulb. Evaporation water loss from the shaded white bulb was 95 percent of that of the open unshaded white bulb. Figure 6 shows the difference in loss between the black bulb and the white bulb atmometers. This difference is a function of the net radiation. The differences under shade were only 70 percent of the open differences. This difference in evaporation data is a reflection of reduced radiation energy under shade.

Soil Temperatures

Maximum soil temperatures at 4 inches under shade were reduced and again are a reflection of available energy. The mean maximum temperature under the shade was 86.7 degrees, which was 4.7° F. lower than the 91.4° F. mean maximum temperature in the open. As previously noted, evaporation water losses were smaller under the shade. Consequently, soil moisture remained higher in the shade, and therefore shaded soil would have a higher specific heat. This could account in part for the observed difference in days with similar incident energy. Mean minimum temperatures for the period were 76.0° F. in the shade compared to 75.7° F. in the open, an increase of 0.3° in the shade.

Crop Results

Table 1 shows that Ashley cucumbers grown in shaded plots produced larger marketable yields and a lower percent of cull fruit than plants grown in the open. Rhizoctonia was more extensive in the open and accounted for the difference in percent of culls from shaded and open plots. Plant stand, total number of fruit and fruit size of cucumbers were not affected by shading in the spring of 1963.

Table 2 shows that Kentucky Wonder 191 pole beans grown in the shade yielded considerably less than those grown in the open. Pod

Table 1. Yields of Ashley Cucumbers in Shaded and Open Plots at Quincy, Florida, in the Spring of 1963.

Treatment	Total Fruit Number (Thousand)	Marketable bu./A.	Yield %*	Fruit Size lb.	Culls %*	Rhizoctonia %*
Shaded	102	446	51	0.45	49	24
Open	102	386	42	0.47	58	36
L.S.D. at 5% Level		143				

*Percent of total number of fruit.

Table 2. Yields of Kentucky Wonder 191 Pole Beans in Shaded and Open Plots at Quincy, Florida, in the Spring of 1963.

	Marketable	Pod Characteristics**					
	Yield	Weight	length	width	thickness	seed	missing seed
Treatment	bu./A*	g	inches	mm	mm	number	number
Shaded	219	16	7.3	13.5	9.5	9.0	0.5
Open	327	14	6.9	12.8	9.1	9.2	0.7
L. S. D. at 5% Level	94						

*Plots were harvested on 5/27, 6/6 and 6/13 and averaged 16, 149 and 109 bushels per acre, respectively.

**Weighed means from a 10-pod sample from each plot on each harvest date.

weight, length, width and thickness were slightly larger and the number of missing seed in pods were slightly less in the shade plots. Plant stands were not affected by shading in the spring of 1963, however, in a Kentucky Wonder 191 pole bean crop planted in August, 1963, shaded plots and open plots had 89 percent and 40 percent plant stands, respectively. No crop records were taken on the fall crop because an early freeze occurred before maturity.

Discussion and Conclusions

Reduction of Maximum air temperatures by 4.7° F. under shade, when combined with the higher soil moisture under the shade, would produce a lower moisture stress on the shaded plants. The higher soil moisture under shade was indicated by the reduced rates of evaporation in shaded plots. Reduction of maximum four inch soil temperatures by the shade averaged 4.7° F. This would indicate that plant roots were subjected to lower temperatures in the shaded plots. Reductions in the incident energy received by the plants under the shade should cause a physiological response in plants. The rate of photosynthesis depends in part upon the intensity of light reaching the plants. Therefore, a slower growth rate might be indicated. However at the intensities observed, sufficient light for photosynthetic saturation was available, and the compensation point was probably lowered due to the lower leaf surface temperatures and consequent slower respiration. Shade interference with horizontal and vertical air motion probably tends to limit CO_2 replenishment, and at low concentrations of CO_2, light intensity is not usually considered limiting on photosynthesis. The total effects of shade induced air temperature changes on plant growth would be difficult to filter out because temperature is so closely related to isolation. Also, during the period of study air temperatures were not a growth limiting factor. Although spring seeded plant stands were not affected by shading, pole beans seeded in August produced stands of 89 percent and 40 percent in the shaded and unshaded plots respectively. Rhizoctonia was more extensive in the non-shaded cucumbers and accounted for the difference in percent of culls between the shaded and unshaded plots.

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