ALTERATIONS OF THE BIOSPHERE BY SHADING AND THE RESULTING EFFECT ON TWO VEGETABLE CROPS[1]

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Approximately 5,000 acres of cigar-wrapper tobacco are grown under shade cloth in northwest Florida. The alteration of the biosphere by shade cloth could possibly offer solutions to some of the vegetable production problems now present in this area. One of the problems is poor plant stands and rather low yields in the fall vegetable season. Frequently high summer temperatures, insolation, and rapid evapotranspiration result in plant wilting even though soil moisture is adequate. High soil surface temperatures drastically reduce stands of some seedlings. A study of the effects of shading upon the growth, development and productivity of vegetable crops was begun at the North Florida Experiment Station in 1959, and instrumentation was added during the summer of 1962. The following report concerns the effects of shading on the biosphere and on two vegetable crops in the fall of 1962.

REVIEW OF LITERATURE

There have been a number of studies regarding the effects of shade on the phytoclimate but most of these studies related to the production of tobacco under shade cloth. Historically, the use of shade in the production of a Sumatra type wrapper leaf dates back to about 1898 in the Quincy area in Florida and to 1900 in the Connecticut River Valley in Connecticut. 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 physical 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 probably resulted in more shade than the cloth. The first attempt at quantitative measurement of the micro-climatic effect of the shade was made by Stewart (2) in 1907. He showed increased relative humidity, reduced evaporation and higher soil moisture under the shade tent. Street (3 and 4) in 1934 and 1935 took first measurements of the reductions in insolation caused by the shade cloth and reported reductions ranging from 30 percent to 60 percent. Waggoner *et al.* (5), in a rather comprehensive study in 1959, reached the following conclusions: On sunny days the shade cloth reduced incoming radiation by one third but on cloudy days only one-fifth. Evaporation was reduced by 20 percent but "the changes in air and soil temperatures and in humidity seem slight relative to the other changes noted and relative to the changes required to evoke a response in plants." By observations in an empty shade tent, he measured the wind at a height of one meter, and compared these to observations outside the tent. The relationship between the two was summarized as follows: (1) When the wind velocity in the open was less than 25 meters per minute, it was calm in the tent; (2) when the outside velocity was between 25 and 30 meters per minute, it ranged from zero to 4 meters per minute inside the tent; (3) when the outside velocity, U_p, was over 50 meters per minute, the velocity inside, U_t, was approximated by the relation $U_t = 0.67 (U_p - 50)$.

Purdy (6) reported that on very warm days shade reduced temperature from 1 to 5 degrees but on cool days no significant differences were recorded.

Trotter and Griffiths (7) found that the average humidity under shade was significantly higher, and that soil moisture at both the 2 and 4-inch levels was higher under shade. Soil moisture at the 2-inch level showed the greatest variation.

Work by Young (8) at the North Florida Experiment Station showed that the light intensity did not appear limiting under shade, and that unshaded plants often wilted in the afternoon despite adequate soil moisture. In general, shaded vegetable plants had longer internodes and larger leaves. The succulent, vigorous vegetable growth suggested high humidity and a reduction in evaporation from the soil surface. Soils in shaded plots following heavy rains remained light and loose, while compaction occurred in the unshaded plots.

MATERIALS AND METHODS

An area 400 feet long and 50 feet wide was divided into ten 40 x 50-foot sections. Alternate

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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. Micro meteorological 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; (5) a remote recording soil thermograph placed at the 2-inch soil level; (6) maximum and minimum air thermometers; and (7) a continuous recording wet bulb thermometer. Exposed on the top of each shelter were sets of Livingston black and white atmometer bulbs. Figure 1 shows the instrument shelter and instruments.

Figure 1. Instrument shelter and instruments.

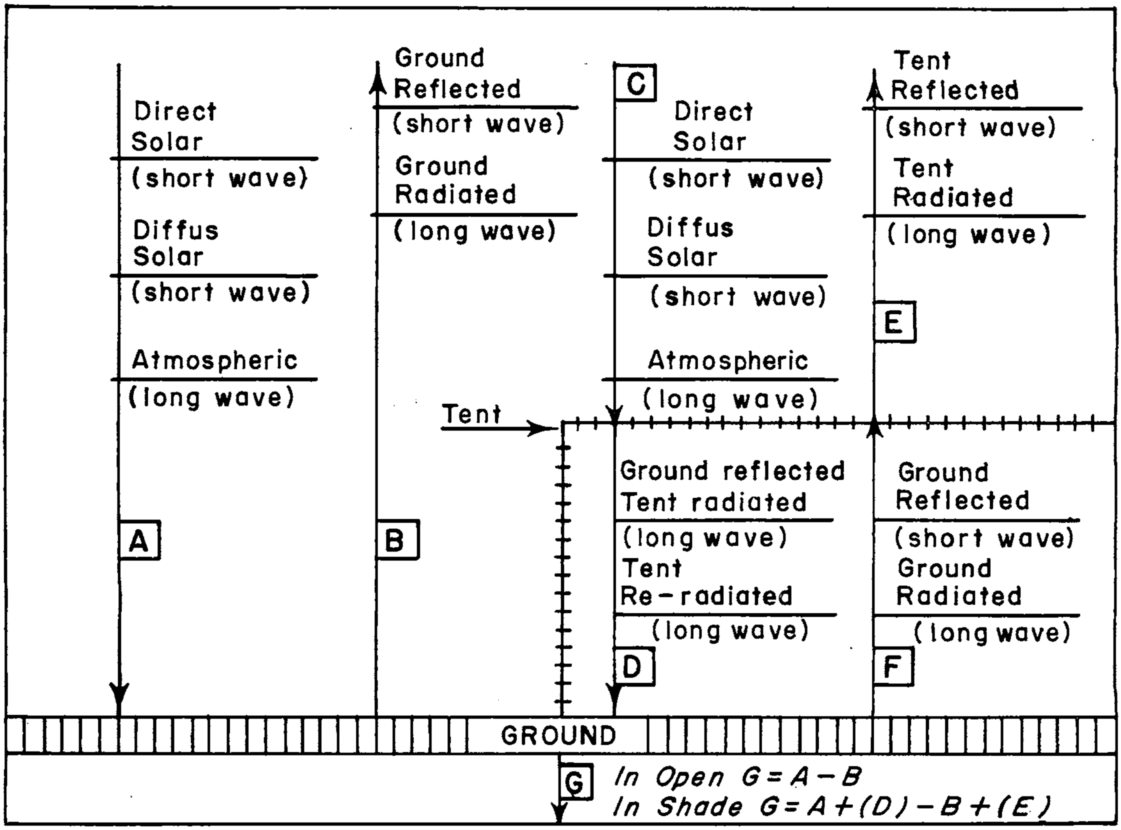

FIGURE 1b ENERGY DISTRIBUTION

Ashley cucumbers and Kentucky Wonder 191 pole beans were seeded in 4-foot rows on August 2 and August 10, respectively, and were subsequently thinned to about one plant per foot. Both crops were trained to string which was suspended from overhead wires.

Both shaded and open plots were treated with equal amounts of fertilizer in accordance with present recommendations for the area. Weekly applications of insecticides and fungicides were made to control insects and diseases. When irrigation was used the water was applied equally to both treatments. The harvesting period extended from September 24 to October 31 for the cucumbers, and from October 1 to November 5 for the pole beans.

Results

Insolation.—Incoming radiation in the open is composed of solar and atmospheric radiation, while under the shade tent there is also tent reflected and tent radiated energy, less the incident energy which is reflected and radiated by the top of the shade back into the atmosphere. Figure 1b 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 by the clouds and other atmospheric impurities. Both direct and diffuse radiation are in the short wave lengths. Diffuse radiation is that short wave energy which is absorbed by 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 reradiated out as long wave energy. Outgoing energy from bare soil is mostly ground radiated long wave with some 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.

Incoming radiation during the month of October (Figure 2) totaled 12,774 Langleys in the open as compared to 7,304 Langleys in the shade.

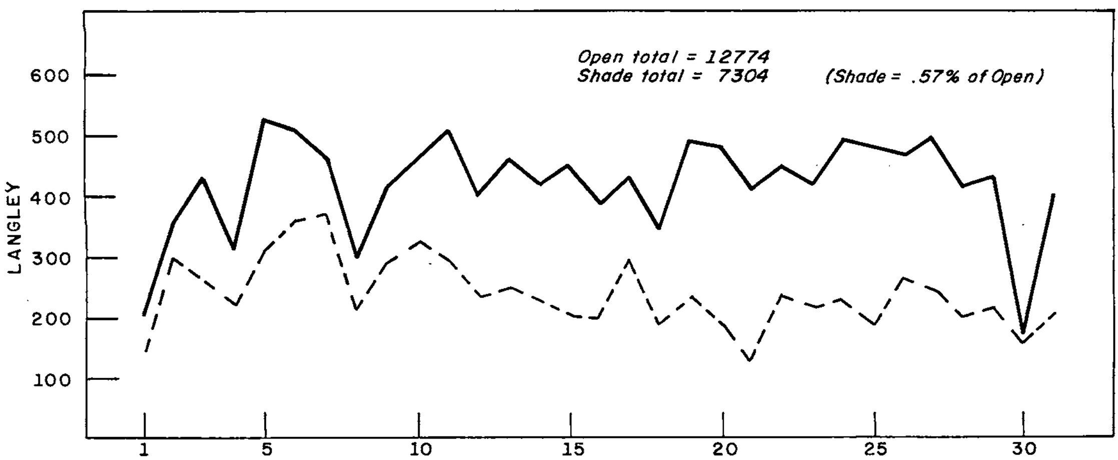

FIGURE 2a TOTAL INCOMING RADIATION IN LANGLEYS OCTOBER 1962

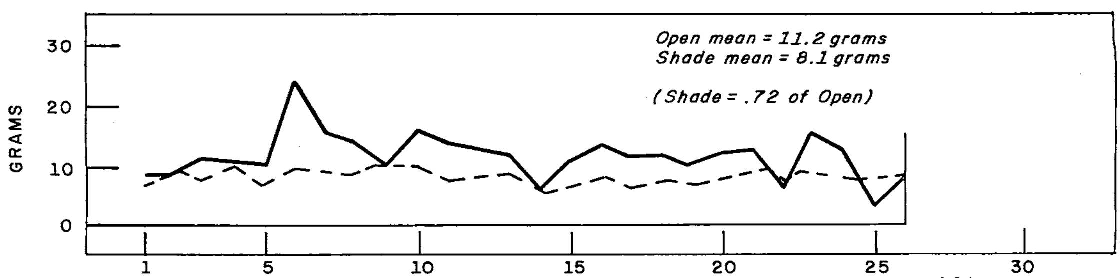

FIGURE 2b BLACK MINUS WHITE BULB EVAPORATION OCTOBER 1962

This represents about 43 percent reduction in incident energy for the entire month. However, using daily cloud cover data from the Weather Bureau Airport Station, Tallahassee (20 miles to the East Southeast), further analysis shows that on days with cloud cover averaging more than 5 tenths the reduction averaged 36 percent, while on days with less than 5 tenths cloud cover the reduction averaged 58 percent. Of interest are the totals recorded on October 30, a completely overcast day with thick cirrus overcast and broken altocumulus. Total incoming radiation under the shade on this cloudy day was 92 percent of that in the open.

Air Temperatures.—The October mean monthly temperature under shade averaged 68.1° F., compared to the open mean temperature of 69.5° F., a reduction under shade of 1.4° F. Mean monthly maximum temperature under the shade was 72.1° F. which was 3.3° F. lower than the open average maximum 75.4° F. Mean monthly minimum temperatures were 0.5° F. higher under the shade, 64.1° F. compared to the open mean of 63.6° F. Although during the month shade temperatures averaged 1.4° F. lower than the open, a comparison of the difference of shade versus open on a sunny day (Figure 4a) and a cloudy day (Figure 4b), show the cloudy day to be 1.6° F. cooler in the shade, but on the sunny day the shade averaged 0.3° F. warmer. A graph of the average hourly temperature for October 1962 (Figure 3) shows that the hours from 0100 through 1100 inclusive were warmer under the shade, while the hours from 1200 through 2400 inclusive the open temperatures were higher. The hourly march of temperature during the day was more symetrical under the shade than in the open and followed more closely the hourly march of incoming radiation.

Relative Humidity.—Monthly averages showed that the relative humidity in the shaded plots averaged about 5 percent higher than in the open. Using October 5th as an average sunny day (Figure 4a) and October 30 as an average cloudy day (Figure 4b), striking differences in relative humidity values were observed. On October 5th the relative humidity under shade averaged 88.3 percent compared to 83.7 percent in unshaded plots. During the period from about 0800 through 1500, the relative humidity under shade averaged 10 percent or more higher than in the open. During the period from 0600 to 1200, the temperatures under the shade also averaged higher than in the open. This indicated a higher actual water vapor content of the air under the shade. To show the higher water vapor content of the air under the shade, hourly values of dew point were compared (Figure 5a and 5b). Dew point is a conservative property of an air mass and is relatively unaffected by the temperature of the air in the temperature ranges under consideration. Thus, a significant change in dew point usually means either a change or modification of air mass. Again the sunny day showed the greatest difference between the open values and those under the shade. The 2.1° F. higher dew point average under shade was also associated with a smaller hourly departure from

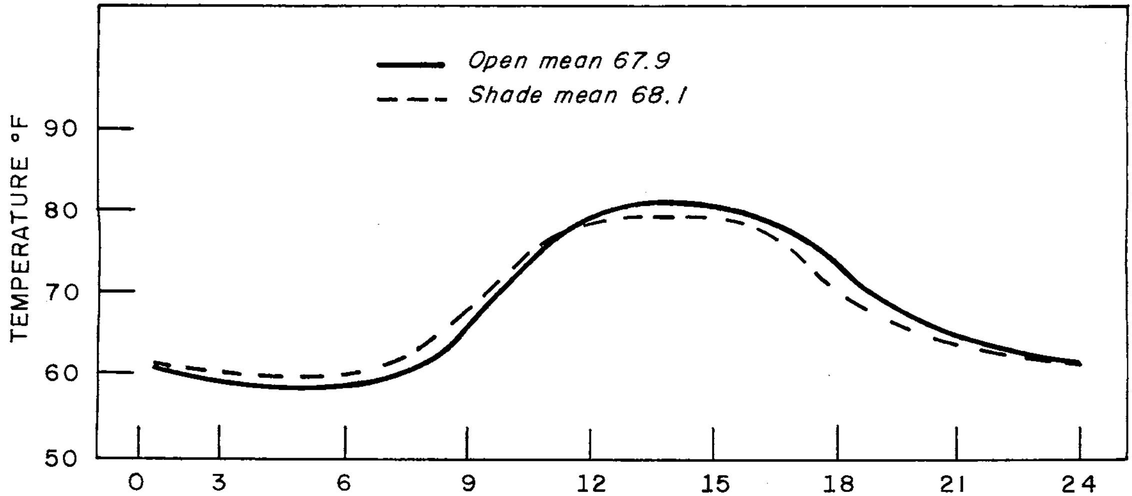

FIGURE 3 HOURLY AVERAGES OF TEMPERATURE OCTOBER 1962

the mean than in the open. The implications of these facts are numerous.

Evaporation.—Evaporation from Livingston black bulb (Figure 6a) and white bulb (Figure 6b) atmometers clearly shows the influence of the reduction in incident energy. Evaporation losses from the black bulb under the shade were only 78 percent of that of the open unshaded bulb, while the white bulb losses under shade averaged 85 percent of the open bulb. Figure 2b shows the difference in loss between the black bulb and white bulb atmometers which is a function of the net radiation. Risk of freezing temperatures required the removal of the atmometers on October 27.

A further indication of lower moisture stress on the plants was vapor pressure differences. The saturation vapor pressure deficit under the shade during the early morning hours was .091 inch compared to the open of .197 inch.

Soil Temperature.—Maximum soil temperatures at 4 inches (Figure 7) show a difference under the shade and again are a reflection of the available energy. The mean maximum tem-

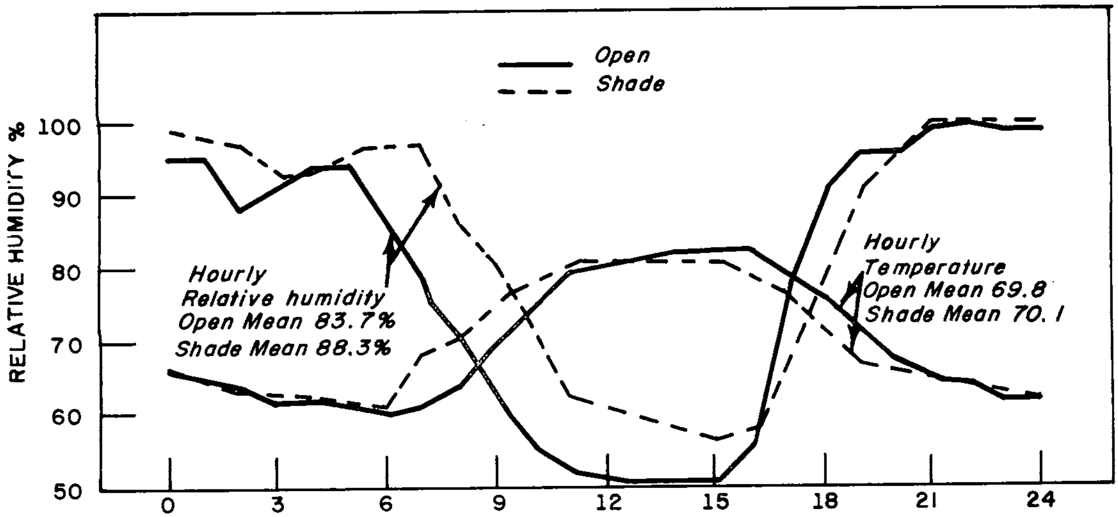

FIGURE 4a HOURLY RELATIVE HUMIDITY OCTOBER 5, 1962

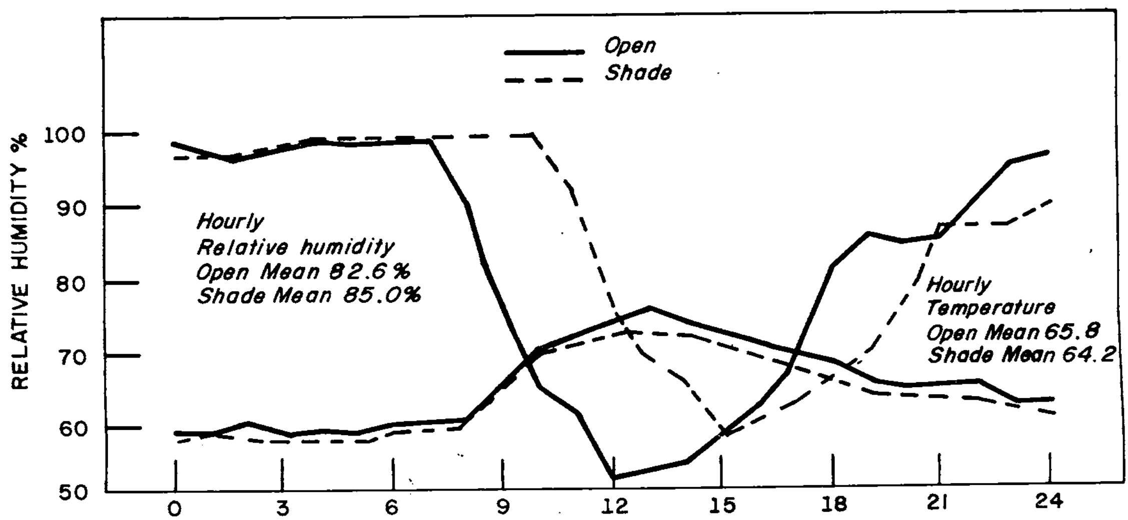

FIGURE 4b HOURLY RELATIVE HUMIDITY OCTOBER 30, 1962

perature under the shade was 5.7 degrees lower than in the open. Reduction in evaporation from the soil surface as a result of the lower incident energy under the shade caused higher soil moisture under 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.

Crop Results.—Table 1 indicates that Kentucky Wonder 191 pole beans produced an increase in total and marketable yields of pods under the shade; however, there was also a larger yield of unmarketable pods (crooked, missing seeds and spurs). There were no large differences in the percentages of either marketable or unmarketable pods between treatments but differences in plant stands were observed. Plant stands in the open were only 79 percent compared to stands under the shade of 99 percent.

In Table 2 the data indicate that Ashley cucumbers in the shaded plots produced an increase in total yield as well as in yield of marketable fruit. Also, the yield of all cull and misshapen fruit was greater under the shade. There was no large difference in fruit losses due to *Rhizoctonia* lesions. Considering the percentages of

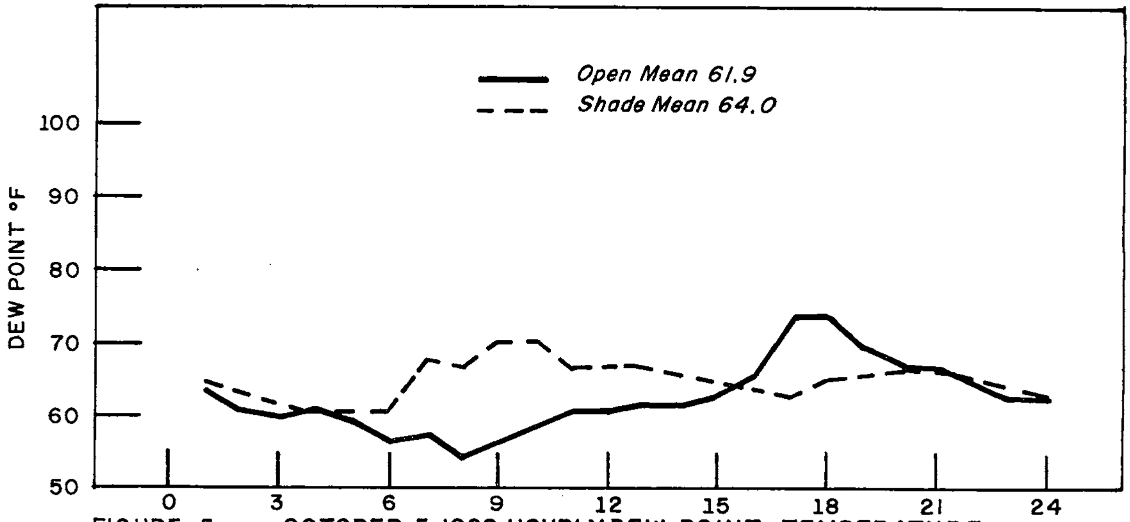

FIGURE 5a OCTOBER 5, 1962 HOURLY DEW POINT TEMPERATURE

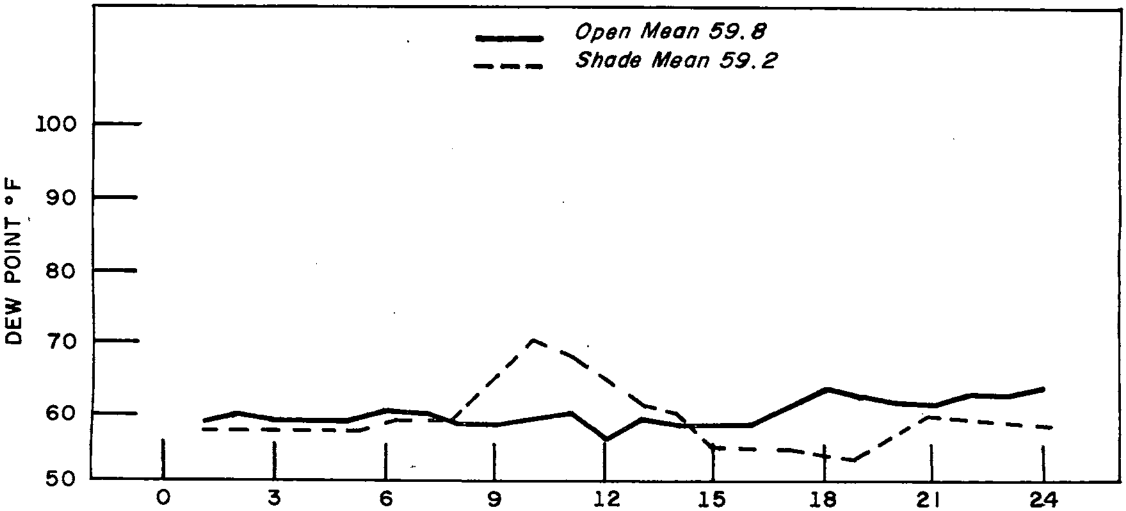

FIGURE 5b OCTOBER 30, 1962 HOURLY DEW POINT TEMPERATURE

fruit in each category the results were less apparent. The open plant stands were 58 percent compared to the shade stands of 96 percent.

Discussion and Conclusions

A maximum temperature reduction of 3.3° F. by the shade together with higher soil moisture produced lower moisture stresses on the plants in the shade. This would also contribute to better plant survival.

Evaporation rates from the black bulbs indicate lower rates of evaportranspiration in the shaded plots. Soil temperature differences recorded at the 4-inch level would indicate that

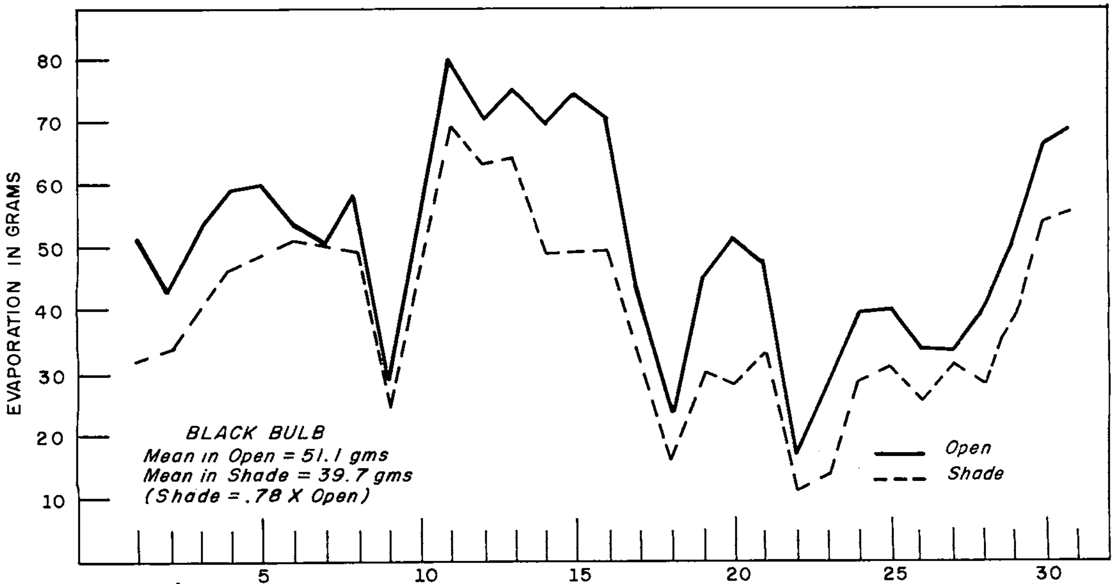

FIGURE 6a AUGUST 1962 DAILY EVAORATION FROM LIVINGSTON ATMOMETERS (gms)

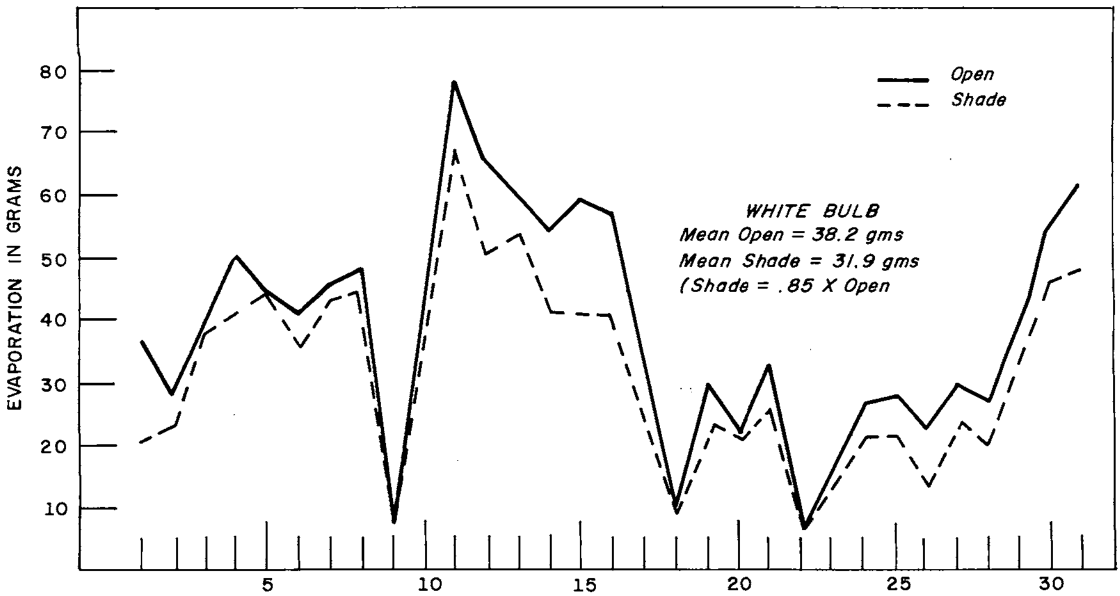

FIGURE 6b AUGUST 1962 DAILY EVAORATION FROM LIVINGSTON ATMOMETERS (gms)

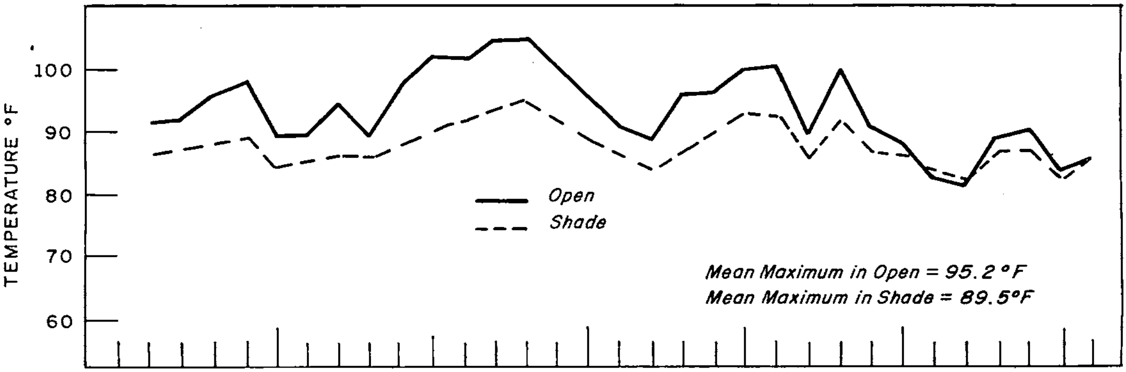

FIGURE 7 FOUR INCH MAXIMUM SOIL TEMPERATURES JULY 1962

plant roots were subjected to lower temperatures in the shaded plots.

Reduction in incident energy under the shade cloth of the order measured should produce a physiological response in plants. Since the rate of photosynthesis depends in part on the intensity of the light reaching the plants, a slower growth rate might be expected. However, at the intensities observed, sufficient light for phytosynthetic saturation was available and the compensation point was probably lowered due to the low leaf surface temperatures and consequent slower respiration. Shade interference with air exchange from higher levels probably tends to limit CO_2 replenishment, and at low concentrations of CO_2, light intensity is not usually considered limiting on photosynthesis.

The overall effect of shade induced temperature changes on plant growth would be difficult to delineate because the temperature is intimately related to insolation and, during the period of study, air temperature was not a growth limiting factor.

Plant stands were probably the most significant factor resulting in increased yields of both cucumbers and pole beans as reported in this experiment. The higher survival rates under the shade are likely the result of factors changed by the reduction in light intensity. There were no differences in the incidence of *Rhizoctonia* or other disease organisms between the shaded and open plots. The 43 percent reduction in incident energy on the soil under the shade produced lower soil temperatures and observably higher soil moisture.

Table 1. Yields of Kentucky Wonder 191 Pole Beans in Shaded and Open Plots at Quincy, Florida in the Fall of 1962

Treatment	Total Yield (Bus./A.)	Marketable Yield Bus./A.	%	Crooked Pods Bus./A.	%	Pods with missing seeds Bus./A.	%	Spurs Bus./A.	%	Plant Stand %
Shaded	610.4	151.9	24	244.9	40	205.8	32	7.8	4	99
Open	423.2	96.6	23	162.1	36	157.6	36	6.9	5	79

Table 2. Yields of Ashley Cucumbers in Shaded and Open Plots at Quincy, Florida in the Fall of 1962.

Treatment	Total Yield (Bus./A.)	Marketable Yield Bus./A.	%	All Unmarketable fruit Bus./A.	%	Misshapen Fruit Bus./A.	%	Rhizoctonia * Damage Bus./A.	%	Plant Stand %
Shaded	1241	779	61	462	39	279	23	249	21	96
Open	964	547	53	417	47	195	17	258	29	58

* Some fruit both misshapen and with Rhizoctonia lesions.

SUMMARY

A study of the effects of shading upon the biosphere and upon the growth and productivity of vegetable crops begun in 1959 was continued with added instrumentation in 1962.

Results indicate that the use of shade reduced incoming insolation, soil temperatures, and evapotranspiration. Although temperatures under shade averaged slightly lower, relative humidity was higher during the morning and early afternoon hours.

Evapotranspiration rates were reduced by the use of shade, with resulting higher soil moisture. Higher soil moisture, together with lower vapor pressure deficit, contributed to lower moisture stress on plants in the shade.

Soil temperatures, especially maximum, indicated sharp reduction under shade, resulting in lower temperatures in the root zone.

Pole beans and cucumbers produced increased total and marketable yields under shade. These increased yields were directly related to better plant stands which can be attributed to the modification of the biosphere by the shade.

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SELECTED ASPECTS OF TOMATO AGRIBUSINESS IN DADE COUNTY, FLORIDA

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INTRODUCTION

Agricultural leaders have long felt the need for improving the public image of agriculture. This need has been especially desirable in Dade County in recent years. The unique subtropical climate and easy access to water, plus good markets, have encouraged local farmers to produce an abundance of vegetables during the fall, winter and spring months. The same attributes—climate and water—have encouraged urban expansion. This expansion in Dade County, as elsewhere, has been accompanied by a lack of understanding of the mutual dependence existing between farm and urban people (1, 2).

The term "Agribusiness," coined approximately ten years ago by John H. Davis of the Graduate School of Business at Harvard University, presents a mechanism which can be of assistance in bridging the gap of understanding between farm and city people. Agribusiness is defined as the sum of all operations involved in the manufacture and distribution of farm supplies; production operations on the farm; and the storage, processing and distribution of farm commodities and items made from them (3). The concept of agribusiness developed from an effort to understand the interrelationships of farming with certain other business activities.

An effort to initiate a study of agribusiness relationships was begun several years ago by personnel of the Dade County Agricultural Extension Service staff because of the need to develop a closer understanding of the common interest of agricultural and urban people in Dade County. This effort, because of a combination of factors, did not result in the generation of all the data which had been intended. However, much background material relative to various components of these relationships was developed (4). This information will be very useful in the future conduct of agribusiness studies.

AGRIBUSINESS STUDY

The current study, "Selected Aspects of Tomato Agribusiness in Dade County, Florida" is the first phase of an intensive study of various components of Dade County agribusiness relationships. The purpose of this paper is: (1) to present pertinent data which explains in detail the relative importance of Dade County tomato

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