THE INFLUENCE OF PLANT DENSITY ON LIGHT TRANSMISSION, LATERAL DEVELOPMENT, AND FRUITING PATTERN OF THE TOMATO (Lycopersicon esculentum, Mill.)

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ABSTRACT

THE INFLUENCE OF PLANT DENSITY ON LIGHT TRANSMISSION, LATERAL DEVELOPMENT, AND FRUITING PATTERN OF THE TOMATO (*Lycopersicon esculentum*, Mill.)

By

Michael James Taylor

The effects of plant density and relative light intensity on the lateral development and fruiting patterns of the tomato plant, *Lycopersicon esculentum*, Mill., were studied. Three approaches for analysis of these effects were used: controlled environment studies, field growth studies, and once-over destructive harvest studies.

Controlled environment studies were conducted to investigate the effect of light intensity in the area of a leaf on the development of a lateral at the leaf's axil. Application of 2 different light intensities to a leaf or its axillary bud gave results suggesting that the leaf and not the bud is the receptor of any stimulus to lateral development that occurs with increased light intensity in the area of the leaf. Lateral growth was significantly greater when leaves were illuminated at the higher light intensity. Possible roles of the leaf as a receptor of this light intensity stimulus are discussed.

Michael James Taylor

Field studies conducted at 3 plant spacings resulted in greater lateral development with decreasing density. An increase in light transmission through the plant canopy resulted with decreasing density. Positive correlations were obtained between light transmission to a leaf and the length of a lateral arising from the leaf's axil.

Field studies at 3 spacings with root environment held constant by means of growing all plants in 6" pots gave results similar to the above field studies. A decrease in density resulted in greater lateral development and greater light transmission. A positive correlation was obtained between the light transmission to a leaf and the length of the lateral arising from the leaf's axil at the last date of measurement.

Yield studies at 3 spacings harvested for once-over harvest showed a significant effect of density on the fruiting pattern of the tomato plant. Weight per fruit, number of fruit per plant, and total weight of fruit per plant were reduced by increasing density. Increasing density increased both the percentage of fruit borne on the main stem and the percentage of ripe fruit. Yield per acre of ripe fruit was also increased by increasing density.

The importance of the concentration of fruit set and increase in early ripening of fruit resulting from increasing density are discussed in light of the advent of a once-over destructive type harvest of tomatoes.

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Michael James Taylor

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INTRODUCTION

Adjustment of plant densities to maximize production of vegetative or reproductive plant parts has been the object of many research programs. In the practical sense, present concerns with maximization of yield, uniformity of maturity, earliness of maturity, and the advent of a once over type of harvest have increased the importance of understanding the effects of density on plant populations.

The majority of past studies have been concerned with the response of a plant population as a whole to density changes rather than a concern with the effect of density changes on the individual plants within the population. These studies have examined the effect of density on such parameters as yield, earliness of production, and uniformity of production. The effects of changing density on the requirements of the population as changing water, nutrient, and light requirements have also been studied.

To better understand the effects of plant density on the plant population as a whole, we must understand the effects on the individual plants which make up that population. Changes occurring among individuals will be reflected as changes in the population as a whole.

Furthermore, if the response of a plant to increasing density is due to increasing limitations on essential factors to the plant such as water, nutrients, or light, it is important to understand the individual contributions of these factors.

This study is restricted to the effect of changing plant populations of the tomato, *Lycopersicon esculentum*, Mill., on the availability of light to the leaves of individual tomato plants within a population, and the relative growth of laterals from the main stem of the tomato. Because these laterals are potential carriers of fruit, the extent of this lateral growth is an important variable affecting yield per plant, and therefore, yield per acre.

Relative light transmission and lateral development are compared in order to correlate light intensity at a particular leaf to lateral development at that axil.

The relationship of plant density to production of fruit on both the main stem and the laterals is discussed, especially as these factors affect yield, concentration of maturity, and earliness of maturity.

LITERATURE REVIEW

General Effects of Plant Density

The interaction of individual plants within a plant community is considered to be a competitive effect, with more than one plant competing for one or more limited resources (3,10). Clements (3), in his book "Plant Competition: An Analysis of Community Functions", published in 1929, states "competition in short is a combined need in excess of supply". When plants compete for "room" or "space", it is apparent that this "space" really stands for, as Clements terms them, "the raw materials, energy, and working factors that it contains" (3).

The most common response of higher plants to increasing competition is a decrease in fresh weight per plant (3,7,10, 19). Kira, Ogawa, and Sakazaki (19) found that the fresh weight per plant of soybean, radish, turnip, and Chinese cabbage decreased as plant density was increased. The authors summarize this "competition-density" effect by the equation: $\omega d^{a-1} = K$, where ω is plant weight, d is density, and a and K are constants.

Donald (7) found marked decreases in the fresh weight of wheat, buckwheat, subterranean clover, and corn with increasing plant density.

In general, the total yield of dry matter produced per unit area tends to increase to a constant plateau with increasing density of plants (7,10).

Effect of Plant Density on Plant Parts

As competition affects the total weight of plants, it also affects the weight and/or frequency of plant parts (3,5,7,8,10,12,19,29,32). The competitive effects of increasing density have been most widely studied on the reproductive parts of plants, since these are often responsible for economic yield.

Kira, Ogawa, and Sakazaki (19) found that seed weight per plant in experiments with lettuce and soybean followed the same "compensation-density" effect as did total fresh weight, decreasing with increasing density.

Increasing the density of broadbean plants had the effect of decreasing the number of pods per plant, with no significant change in the number of seed per pod, thus decreasing seed production per plant. Hodgson and Blackman (12), found that a yield of 29.7 grams per plant at a wide spacing was reduced to 9.3 grams at a closer spacing which gave maximum yield per unit area.

Puckridge (29), working with wheat plant densities ranging from 1.4 plants to 447 plants per square meter, noted a great decrease in the yield of grain per plant with increasing density from 33.2 grams at 1.4 plants to 0.42

grams at 447 plants per square meter. The factors contributing to this decrease were: a marked decrease in grains per ear, ears per plant, seeds per plant, and a slight decrease in weight per grain with increasing density. Donald (7) showed the same trend of density effects on the seed production of Wimmera ryegrass, subterranean clover, wheat, and corn. He found that the weight per grain was only slightly affected, while the number of grains per plant was markedly decreased with increasing density.

Duncan (8) grew corn at an infinite number of densities by use of a wagon wheel design, with rows planted as spokes to converge at the center of a hub. Progressing from the low density (outside of the wheel) toward the center caused a very regular decrease in the grain yield per plant. Ears were smaller, with fewer ears per plant at the higher densities. Tillering also decreased as density increased.

Scott, working with sugar beets, found that closer row widths resulted in smaller seed clusters, while wider spacing in the row or wider spacing between rows increased weight per seed (32).

Effect of Plant Density on Branching

Increasing density may decrease the amount of branching by a plant (5,7,12). Donald (5), found that Wimmera ryegrass produced fewer tillers per plant as density was increased. He had an average of 82 tillers per plant at the lowest density contrasted to 1.96 tillers at the highest density. In a similar experiment (7), wheat plants averaged 40.5 tillers at 1.4 plants per square meter, and only 1.2 tillers at 694 plants per square meter.

Hodgson and Blackman (12) found a highly significant reduction in the total number of stems produced by each plant in the growth of broadbean seedlings. The average number of stems per plant decreased from 2.66 at 10.7 plants per square meter to 1.36 at 41.9 plants per meter in field experiments.

Responses of the Tomato Plant to Changes in Plant Density

Responses of the tomato plant to changing density patterns have also been studied, especially as these patterns relate to fruit yield, earliness of yield, fruit size, and fruit number (9,25,26,27,30,33,34).

Moore, Kattan, and Fleming (25) using the processing varieties Indark and Moreton Hybrid, found that decreasing the amount of soil per plant from 30 square feet to 9 square feet was associated with a reduction in number of fruits per plant, average weight per fruit, and average weight of total fruit per plant. This occurred both for early harvest and total harvest.

In a similar field experiment with the canning variety Garden State, Reeve and Schmidt (30) found a trend toward slightly smaller fruit size with closer spacing with both transplanted and direct seeded plants. Total and early yields per acre were increased by decreasing the area per plant from 21 to 7 square feet per plant.

Pennhart, a determinate variety, and Rutgers, an indeterminate variety, showed no significant change in fruit size in work by Odland (27). There was a trend toward smaller fruit size at increased density. Both varieties produced greater total yield and early yield per acre at the closest spacing, 8 square feet per plant, than at 12, 16, or 25 square feet per plant.

Nicklow and Downes (26), in studies with New Yorker, a determinate, early maturing variety, and Heinz-1630, a more vigorous, less determinate, and later maturing variety, found that increasing plant density generally resulted in a decrease in average fruit size.

Studies by Vittum and Tapley with both a paste type tomato, Red Top (34), and a determinate type tomato, Gem (33), showed an increase in yield per acre and a decrease in yield per plant when plant density was increased from 15 square feet to 10 square feet per plant. Fruit size was not significantly affected by density.

Fery and Janick (9) provide the most comprehensive report on the response of the tomato to population pressure. They used a range from 3000 plants per acre to 100,000 plants per acre, with five distinctive vine types. Early yield, yield concentration, number of marketable fruit per acre, and number of flowers per acre all increased with increasing density for all vine types. Marketable fruit size, number of marketable fruit per plant, number of clusters per plant, number of flowers per plant, and vine weight per plant decreased with increasing density for all vine types. The number of branches per plant also decreased as density was increased.

Effects of Density on Light Transmission

Plant density has been found to affect the transmission of light through a plant canopy (3,13,31). Several workers have applied Beer's Law to explain the exponential light interception by a canopy of leaves (4,14,23,24).

Applying the formula:

$$I = I_o e^{-KL}$$

where:

I = light intensity beneath a leaf area index of L;
I_0= light intensity above the crop;
L = leaf area index above the point of measurement;
K = coefficient of extinction;

gives a sharp decline in light intensity from the surface of a crop downward (6).

Work by Santhirasegram and Black (31) at two row spacings showed higher relative light intensities at ground level both beneath and between 14 inch rows than

beneath and between 7 inch rows. Within each row spacing, relative light intensity was higher beneath the low rate than beneath the high rate of sowing.

Broadbean populations of four densities (11, 22, 44 and 66 plants per square meter) were compared by Hodgson and Blackman (13) with respect to light transmission at various stages of canopy development from seedling to full flower. At the first stage recorded, 93% daylight was recorded at ground level at the lowest density compared with 41% daylight at the highest density. The relative differences in light penetration increased through the third date, with 67% daylight beneath the lowest density and 8% daylight at the highest density at this stage midway through the main growth period of the plants. At the time the plants were in full flower, transmission through the lowest density had dropped to 18% daylight, while transmission through the highest density remained at 8%.

Light Intensity as a Limiting Resource in Plant Production

When other factors required by green plants are available in non-limiting quantities, light becomes the ultimate limit on dry matter production (1,6). An increase in light intensity coupled with an increase in production and/or photosynthesis has been shown for many plant species (1, 11,13,21,28,35).

The effect of light intensity on the growth of the tomato plant has been recognized for some time because of its importance as a winter greenhouse crop (28,35). Porter (28), using average light intensities of 1139.9, 583.1, and 261.0 foot candles on greenhouse grown Grand Rapids Forcing tomato plants, found a positive relationship of fruit production and total plant production to light intensity. The percentage of dry matter, ash material, water, fresh weight, and photosynthate (dry weight minus ash weight) were found to correlate closely with the light intensity received by the plants. Light intensity accounted for 32.4 percent of the photosynthate variation between plants.

Went (35) grew young tomato plants at six light intensities and measured dry weight accumulation during a six day period. Results showed that dry matter production was exactly proportional to light intensity up to 1300 foot candles. Above 1300 foot candles, an increase in intensity had no effect. The compensation point, that light intensity at which respiration uses as much photosynthate as is formed, was found to be about 100 foot candles for the tomato.

The upper leaf of a plant may not utilize all of the light it receives, whereas a lower leaf may receive less light than that required to compensate for respiration (35). While an individual leaf of a crop may reach a maximum rate of photosynthesis at a light intensity of 1500 to 2000 foot candles for many crop species, the plant as a whole may have a rising photosynthetic rate to very high light intensities due to the heavy shading of some leaves (6,11,21).

Bremner, Saeed, and Scott modified the light transmission of potato and sugar beet plants by planting the plants individually in five gallon containers to provide identical root environments (2). Containers with potatoes were spaced 24 by 28 inches or 12 by 28 inches, while the sugar beets were spaced 23 by 18 inches or 11.5 by 18 inches. The resulting growth rate per plant was 10 percent less with close spacing than with wide spacing for both species, with mean net assimilation rates 20 percent less in potatoes and 30 percent less in sugar beets at the closer spacing. Wider spacing gave a significant increase in dry matter production per plant with both species.

Large (22) grew tomato seedlings of Minibelle, Craigella, and Warecross varieties in 4½ inch pots in the greenhouse. During propagation, increased spacing gave progressive increases in dry weight per plant at the time of transplanting. After transplanting all plants to a single density, early yield was highest for those plants which were grown at the widest spacing on the propagation bench. No significant differences were noted for total yield.

Knavel (20) used various spacings and pot sizes on tomato seedlings of the Heinz-1370 variety before transplanting to the field. A spacing of 8 by 8 inches before transplanting gave increased early yield over 4 by 4 or 6 by 6 inch spacing in all types of pots used.

Importance of Photosynthate Produced in Leaves to the Development of Other Plant Parts

The importance of the rate of photosynthetic activity in the various leaves of the tomato plant to the growth and development of other plant parts has been shown in several experiments (15,16,17,18,36).

Khan and Sagar conducted several studies on the movement of radioactive carbon through tomato plants of the Warecross variety (15,16,17,18). In one experiment, tomato plants were selected for uniformity so that each plant initially had 17 leaves and 3 trusses, truss 1 directly below the tenth leaf, truss 2 directly below the thirteenth leaf, and truss 3 directly below the sixteenth leaf (16). All leaves were treated with labeled CO_2; one leaf treated per plant. Results show that the lower leaves (1-9) as a group exported the majority of their radiocarbon upward while leaves 10-17 as a group exported most of their radiocarbon downward. A flexible "source-sink" relationship was found to exist, with truss 1 gaining more carbon from leaf group 7-9, directly below the truss, than from other leaf groups. Truss 2 showed the same type of relationship, with the lower leaves tending to supply a higher proportion of their export to that sink. The fruit trusses and stems were the major sinks for exported carbon from the leaves.

In a similar experiment (18), the tenth leaf of tomato plants in which the leaf occurred immediately below truss 1 was supplied with radioactive carbon labeled CO_2. Throughout the life of the tenth leaf, truss 1 remained the most important "sink" for the radiocarbon, although later other trusses imported radiocarbon from the tenth leaf.

Experiments by Yakushkina (36) with the variety Gruntovyi Gribovakiy support the findings of Khan and Sagar (15,16) suggesting that the leaves nearest a truss are most important for export of carbon compounds into the truss. In Yakushkina's experiments, a leaf nearest to the truss supplied more radiocarbon to the developing fruits than did a lower or higher leaf.

These "source-sink" relationships which appear to exist in the movement of carbon compounds through the tomato plant are not absolute and may change with time in the plant. Although certain leaves may provide carbon primarily to a single source, radiocarbon supplied to one leaf can be found in several "sinks" of the plant (15,15,17,18). Conversely, radiocarbon from several sources is found in a single "sink" in the tomato plant (15,16,17,18,36).

MATERIALS AND METHODS

I. Controlled Environment Studies

Experiments were conducted in a Sherer Gro-Lab growth chamber to determine the effect of the intensity of light reaching a main stem leaf of a tomato plant on the development of a lateral at that axil. Tomatoes of the Moto-red variety, an indeterminate, greenhouse variety, were direct seeded into 5" pots in the growth chamber and thinned to one plant per pot two days after emergence.

Lighting was by use of Westinghouse Cool White Flourescent bulbs (F48 T12/CW/SHO and F15 T12/CW/SHO) at a photoperiod of 16 hours. Lights were fixed approximately 36" above the base of the plant. All plants were grown at 550 foot candles until the plants were used for experimentation.

A day temperature of 25^{o}C. and a night temperature of 20^{o}C. were maintained before and during differential light treatments.

Fertilization was by addition of "Rapid-Gro" (23-19-17) to water once a week at the rate of one gram per plant per week beginning 10 days after emergence.

Differential light intensity treatments were started on the plants 45 tb 50 days after emergence, at the time the plants had 7 or 8 visible leaves. The light intensities were adjusted by varying the number of bulbs used, not through any adjustment of bulb height above the plant.

No flowers were present before or during the differential light treatments.

Experiment 1: Effect of Supplemental Light Applied to an Individual Leaf

In this experiment one leaf per plant was illuminated at a light intensity of either 2200 foot candles or 550 foot candles. The remaining parts of all plants, including the axils of leaves receiving illumination of 2200 foot candles, were under a light intensity of 550 foot candles. Figure 1 illustrates the apparatus used to separate the different light intensities.

Four trials were run, each at a separate date since only one growth chamber was used for all experiments. Two trials were run to determine light intensity effects on the third leaf; two were run on the fourth leaf. All four trials included 3 treatment plants and 3 control plants.

Lengths of all axillary buds or branches were measured at weekly intervals for a period of 2 weeks, the first measurement at the start of the trial.

Experiment 2: Effect of Supplemental Light Applied to Individual Axils

In this experiment, one axil of the main stem was illuminated with a 3/16 inch diameter circle of 2200 foot

Figure 1. Apparatus used for illumination of a single leaf of a tomato plant at 2200 foot candles (left), or 550 foot candles (right). Controlled environment experiment 1.

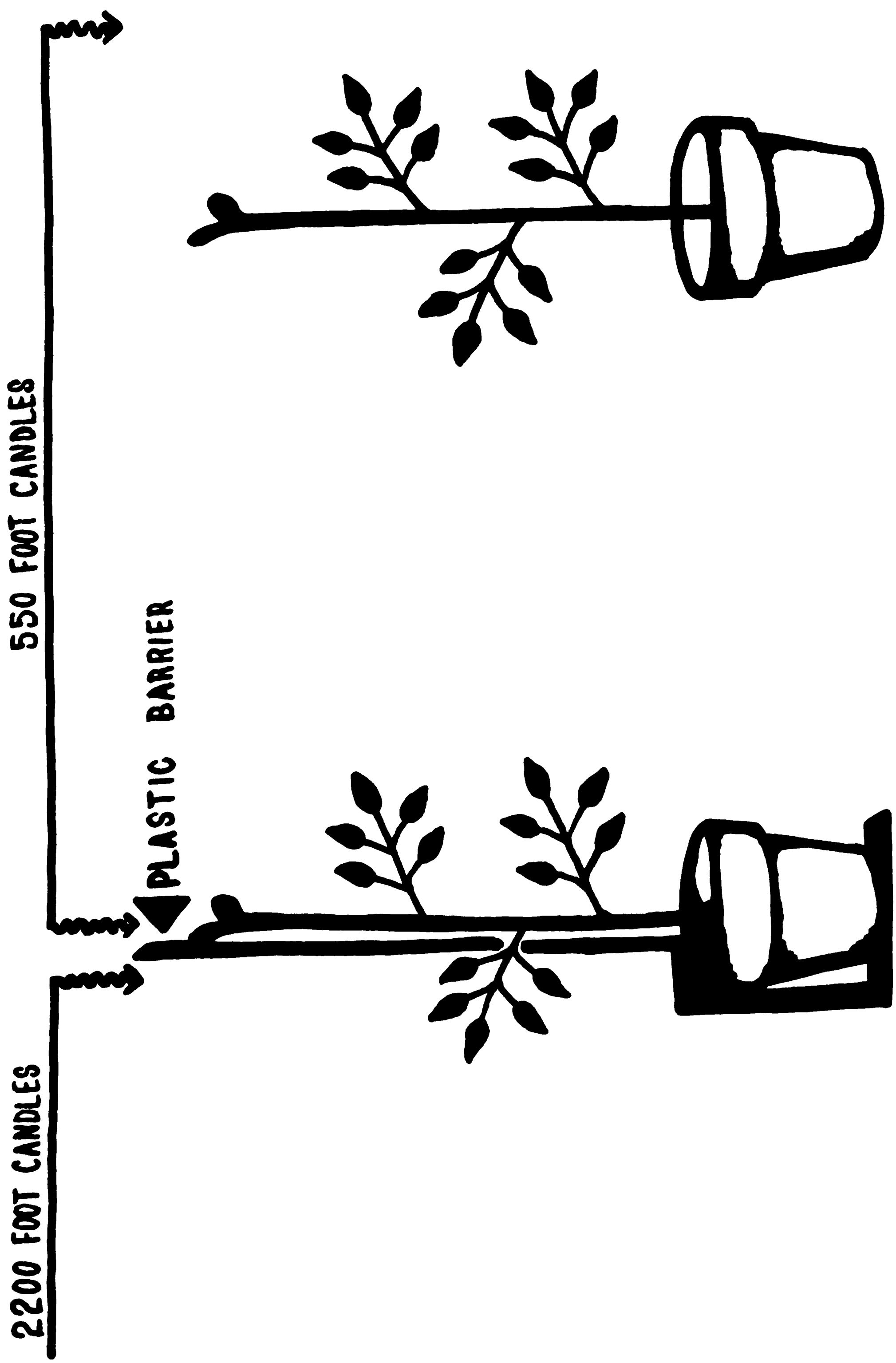


FIGURE 1

candles of light, while the remainder of each treated plant was exposed to 550 foot candles of light. Control plants were exposed only to light of 550 foot candles.

Two trials were run, each including 4 treated plants and 4 control plants. Supplemented light was given to the axil at the fourth leaf in both experiments. Lengths of axillary buds were measured after 10 days.

II. Field Studies

Experiment 1: Effect of Plant Density on Light Transmission and Lateral Development

A field study was conducted during the summer of 1971 at the Horticulture Research Center, Michigan State University, East Lansing, on a clay loam soil in order to determine the effects of plant density on the light transmission of tomato plants and the development of lateral branches arising from the axils of main stem leaves.

A. Cultural practices

Tomatoes were direct seeded 6, 12, or 18 inches between rows, then thinned to 6, 12, or 18 inches in the row three days after emergence to create an equal distance between all plants of a given density. Where plants were missing, a plant was transplanted into the area within ten days after emergence to insure a uniform density.

Diphenamid at 6 pounds active ingredient per acre was applied two weeks after emergence of the tomato seedlings.

A pre-plant fertilizer was applied at the rate of 380 pounds of 10-20-20 per acre. Additional fertilizer at the rate of 50 pounds per acre of 5-20-20 was broadcast July 12, 1971.

Sprinkler irrigation was applied at the rate of 1/4 inch per application whenever available moisture in any of the plots reached 50 percent of field capacity as measured by moisture blocks. The site was on a slope of approximately 5 percent to insure good drainage after rains or sprinkler irrigation.

B. <u>Experimental design and sampling technique</u>

A randomized block design was used, with 3 plant densities and 2 varieties. Plant densities used were 6" by 6", 12" by 12", and 18" by 18". Two determinate type tomato varieties, New Yorker and Heinz-1783, were used. All treatments were replicated 3 times.

Plots of unequal size were used for the 3 plant densities to give a constant number of plants per plot of 169. This configuration allowed 9 possible samples of 9 plants each to be removed periodically from each plot while maintaining a border row between each sample. In the course of the experiment, samples were taken from each plot at 4 dates at 10 day intervals, choosing four of the nine possible sample sites at random.

Each plant sampled was measured for lateral length at axil four and axil seven, height of plant, and number of leaves over four centimeters in length.

Two plants per plot were randomly selected to be used for light studies throughout the period of sampling. Light illumination readings at the surface of a leaf, as determined by a Weston Illumination meter--Model 756 equipped with a quartz filter, were made at 5 day intervals beginning July 12, 1971 and ending August 12, 1971, the main period of lateral elongation. Light measurements were taken at the fourth and seventh leaf of each plant between 11:30 A.M. and 12:30 P.M. Light readings were computed as percent full sunlight above the plant canopy.

All significant differences were compared by Tukey's ω-procedure.

Experiment 2: Effect of Plant Density on Light Transmission and Lateral Development with Root Environment Held Constant

A field study was conducted during the summer of 1971 at the Horticulture Research Center to determine the effects of plant density on the light regime and development of laterals arising from the axils of main stem leaves of tomato plants grown in 6 inch pots.

A. Cultural practices

Tomatoes were direct seeded on July 17 in the greenhouse in 6 inch clay pots containing a sterilized soil mix of: 2 parts peat, 2 parts soil, and 3 parts sand. The seedlings were thinned to one plant per pot 3 days after emergence. On August 2, ten days after emergence, the seedlings were moved outside to the Horticulture Research Center.

Plants were watered uniformly once a day or several times a day as the size of the plants increased. Each pot was fertilized weekly beginning one week after transfer to the Horticulture Research Center with 5 grams of "Rapid-Gro" (23-19-17).

B. Experimental design and sampling technique

A randomized block design was used with three plant densities of the New Yorker variety. Plant densities used were: 6" by 6", 12" by 12", and 18" by 18". All treatments were replicated three times.

Plots of unequal size were used for the three plant densities to give a constant number of plants per plot of 25. Measurements were made of the lateral length at the fourth and seventh axils of the main stem, and height of the plant, and the number of leaves over four centimeters in length for each of nine plants per plot at 10 day intervals beginning August 17, 1971 and ending September 6, 1971.

Two plants per plot were randomly selected to be used for light studies. Light illumination readings were made at the fourth and seventh leaf of each plant between 11:30 A.M. and 12:30 P.M. Light readings were computed as percent full sunlight above the plant canopy.

All significant differences were compared by Tukey's ω-procedure.

Experiment 3: Effect of Plant Density and Variety on Distribution, Relative Maturity, and Yield of Tomato Fruit

A field study was conducted during the summer of 1971 near Charlotte, Michigan to determine the effects of plant density and variety on the fruiting pattern of tomato plants, particularly density effects on the relative importance of lateral branches as carriers of fruit.

A. Cultural practices

Tomatoes were direct seeded 6, 12, or 18 inches between the rows on May 29, then thinned to 6, 12, or 18 inches in the row three days after emergence to create an equal distance between all plants of a given density. Where plants were missing, a plant was transplanted into the area within ten days after emergence to insure a uniform density.

Diphenamid at 6 pounds active ingredient per acre was applied on June 25 for weed control, 16 days after emergence of the tomato seedling.

The sandy loam soil, prior to application of any fertilizer, had 98, 292, 1673, and 450 pounds of available P (Bray P_1), K, Ca, and Mg, respectively per acre according to the Soil Test Laboratory at Michigan State University. The soil had 1.19 percent organic matter and a pH of 6.7.

Pre plant fertilizer at the rate of 500 pounds of 10-20-20 per acre and 50 pounds per acre of Mg as Epsom salts was applied before plowing. At the time of first flowers, July 27, 120 pounds of 33-0-0 was broadcast per acre.

Sprinkler irrigation was applied when available moisture in any plots reached 50 percent field capacity as measured by moisture blocks.

Harvest dates were determined by estimating the average ripeness of the fruit of a variety and attempting to maximize ripe yield without appreciable numbers of overripe fruit. New Yorker variety plots were all harvested September 14. Heinz-1783 plots were harvested September 25. Amounts of rotten fruit were negligible and were not recorded.

B. Experimental design and sampling technique

A randomized block design was used with 3 plant densities and 2 varieties. Plant densities used were: 6" by 6", 12" by 12", and 18" by 18". Two determinate type varieties, New Yorker and Heinz-1783 were used. All treatments were replicated two times.

The size of each plot was 81 square feet. At the time of once over harvest, 2 samples of ten plants each were selected at random from each plot, not including border row plants. Measurements were taken for number of ripe and green fruit on each lateral arising from the main stem, and for number of ripe and green fruit on the main stem of each plant. Weights were recorded on each ten plant sample for main stem ripe fruit, main stem green fruit, lateral ripe fruit, and lateral green fruit.

All significant differences were compared by Tukey's ω-procedure.

RESULTS

I. Controlled Environment Studies

Experiment 1: Effect of Supplemental Light Applied to an Individual Leaf on Axillary Development

Results are tabulated in Table 1 for mean lateral lengths for the 4 trials, 2 on leaf 3, and 2 on leaf 4. The first date listed for each trial is the date that different light intensities were first applied.

Means were not found to be significantly different in any of the trials at the first date. Marked differences were noted after one week in lateral lengths, with both leaf 3 and leaf 4. The higher light intensity resulted in significantly greater lateral length for all trials both one and two weeks after beginning the trial.

Axillary buds of the control plants receiving 550 foot candles showed very little or no development over the 2 week period in all 4 trials.

Experiment 2: Effect of Supplemental Light Applied to an Individual Axil on Axillary Development

Results from the 2 trials indicate that supplemental light at 2200 foot candles did not significantly affect axillary development compared to those axils held for the ten day period at 550 foot candles ($\alpha = .05$), Table 2.

Table 1. The effect of 2 light intensities, 550 and 2200 foot candles, applied to leaf 3 or leaf 4 on the length (cm.) of the lateral at the axil of the treated leaf. Measurements were taken at one week intervals for a period of 2 weeks. Each mean represents 3 plants. Controlled environment Experiment 1.

	Date	Mean length of lateral[1] 2200 f.c.	550 f.c.	
1. leaf 3	3/13	0.27	0.23	n.s.
	3/20	2.93	0.20	*
	3/27	10.50	0.20	*
2. leaf 3	3/29	0.13	0.17	n.s.
	4/5	2.33	0.20	**
	4/12	12.07	0.30	*
3. leaf 4	1/7	0.13	0.17	n.s.
	1/14	2.33	0.20	*
	1/21	13.10	0.20	*
4. leaf 4	2/28	0.30	0.40	n.s.
	3/6	2.97	0.40	**
	3/13	12.03	0.40	**

[1] n.s. = not significant at the 5% level.
* = significant at the 5% level.
** = significant at the 1% level.

Table 2. The effect of 2 light intensities, 500 and 2200 foot candles, applied to axil 4 on the length (cm.) of the lateral at the treated axil. Measurements were taken 10 days after differential light intensities were applied. Controlled environment Experiment 2.

Trial	Mean length of lateral[1] 2200	500	
1.	0.200	0.200	n.s.
2.	0.425	0.400	n.s.

[1] n.s. = not significant at the 5% level.

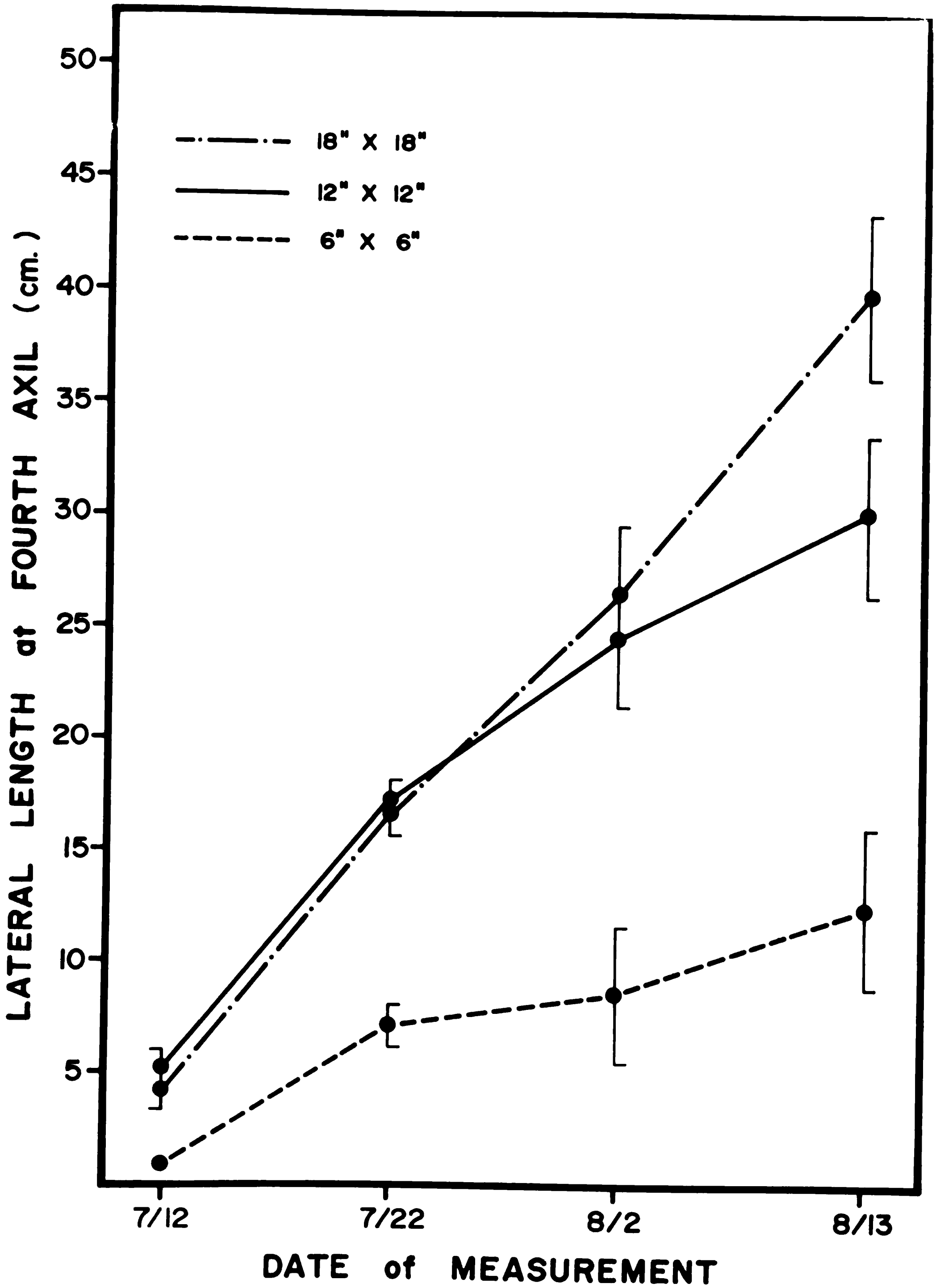
II. Field Studies

Experiment 1: Effect of Plant Density on Light Intensity and Lateral Development

A. Lateral lengths

The effect of plant density on lateral development is shown in Figures 2 and 3. The mean length of the lateral at axil 4 was significantly shorter (α = .05) for the 6" by 6" spacing compared to 12" by 12" and 18" by 18" spacings at all dates, Figure 2. Spacings 12" by 12" and 18" by 18" were not significantly different for the first 3 dates, but were significantly different at the fourth or final date (α = .05). The interaction between density and variety was significant at the last date (α = .05).

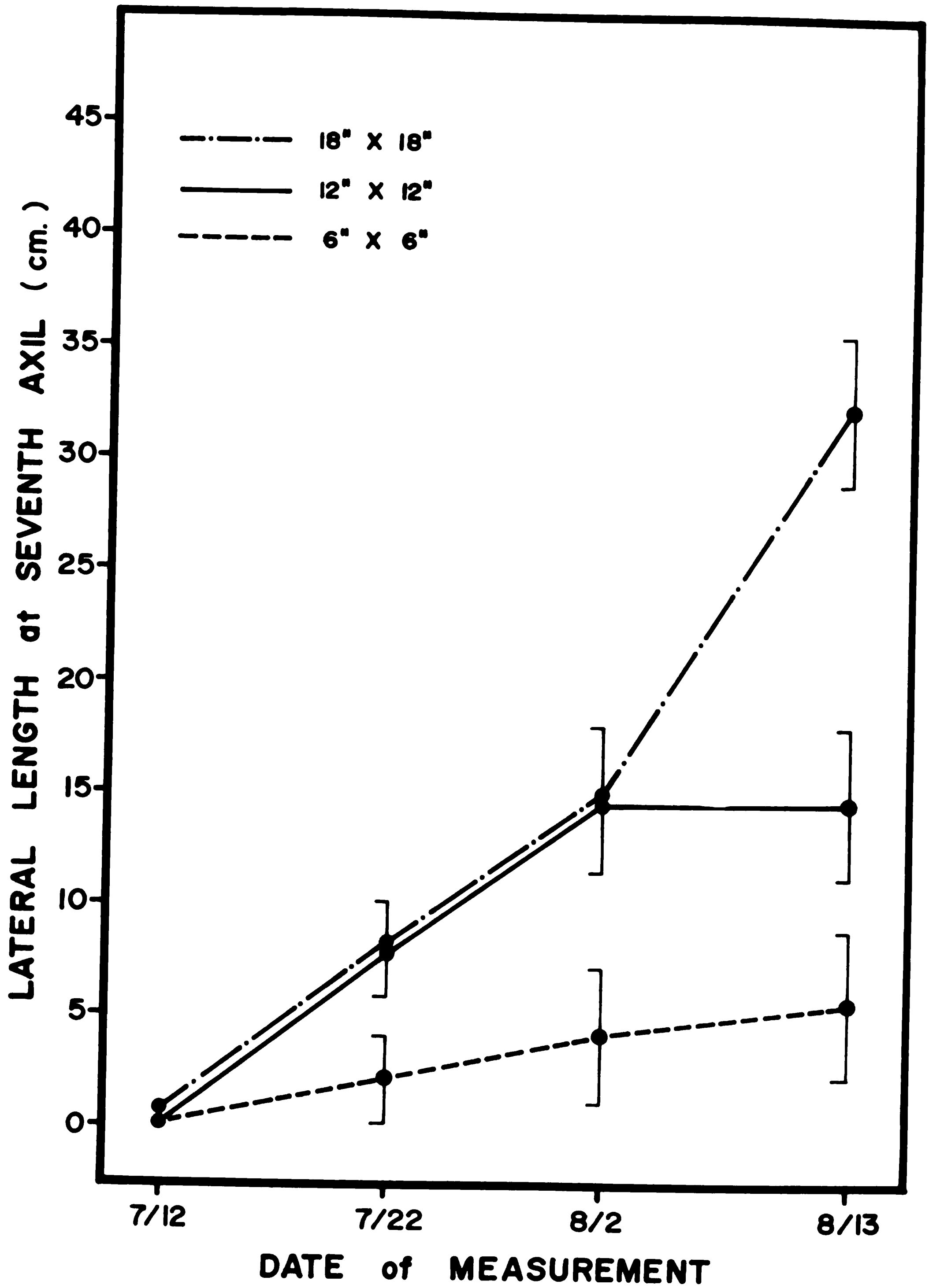
Figure 2. Mean lateral length at the fourth axil of tomato plants in field plots at 3 plant spacings over a 30 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field Experiment 1.



18" X 18"
12" X 12"
6" X 6"
LATERAL LENGTH at FOURTH AXIL (cm.)
50
45
40
35
30
25
20
15
10
5
7/12
7/22
8/2
8/13
DATE of MEASUREMENT

FIGURE 2

Figure 3. Mean lateral length at the seventh axil of tomato plants in field plots at 3 plant spacings over a 30 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 1.



18" X 18"
12" X 12"
6" X 6"
LATERAL LENGTH at SEVENTH AXIL (cm.)
0
5
10
15
20
25
30
35
40
45
7/12
7/22
8/2
8/13
DATE of MEASUREMENT

FIGURE 3

The mean length of the lateral at axil 7 was not significantly affected by density (α = .05) at date 1, Figure 3. At dates 2 and 3, the mean length was significantly shorter for the 6" by 6" spacing compared to both 12" by 12" and 18" by 18" spacings (α = .05). Spacings 12" by 12" and 18" by 18" were not significantly different at these dates (α = .05). At date 4, the mean length at each spacing was significantly different compared to mean lengths of all other spacings.

The mean length of laterals was significantly greater (α = .05) for New Yorker variety compared to Heinz-1783 variety at the fourth or final date at both the fourth and seventh axils.

B. Plant height

As seen in Table 3, mean plant heights were not significantly different (α = .05) for either spacing or variety for date 1 and 2. The mean height of the 18" by 18" spacing was significantly less (α = .05) than both the 12" by 12" and 6" by 6" spacings at date 3. The height of New Yorker variety was significantly greater than that of Heinz-1783 at date 3 (α = .01). The mean height of the 6" by 6" spacing was significantly greater than both the 12" by 12" and the 18" by 18" spacings (α = .05) at the fourth or final sampling date.

Table 3. The effect of 3 plant spacings and 2 varieties on the mean height (cm.) and number of leaves (over 4 cm.) of tomato plants grown in field plots. Field Experiment 1.

	Plant Height (cm.)[1]			Variety[2]		
Date	6"x6"	12"x12"	18"x18"	New Yorker	Heinz-1783	
7/12	17.89 a	20.04 a	19.77 a	19.63	18.83	n.s.
7/22	36.69 a	34.07 a	30.20 a	33.82	33.48	n.s.
8/2	43.56 a	46.70 a	38.83 b	44.70	41.36	**
8/12	50.26 a	45.78 b	45.65 b	47.70	46.75	n.s.
	Number of Leaves					
	6"x6"	12"x12"	18"x18"			
7/12	7.37 a	8.33 b	8.11 b	8.07	7.80	n.s.
7/22	8.06 a	9.31 b	9.46 c	8.89	9.00	n.s.
8/2	8.46 a	10.68 b	10.06 b	9.74	9.59	n.s.
8/12	8.65 a	10.44 b	11.02 b	9.84	10.23	n.s.

[1]Within a row, means above the same letter are not significantly different at the 5% level (Tukey's ω-procedure).

[2]n.s. = not significant at the 5% level.
* = significant at the 5% level.
** = significant at the 1% level.

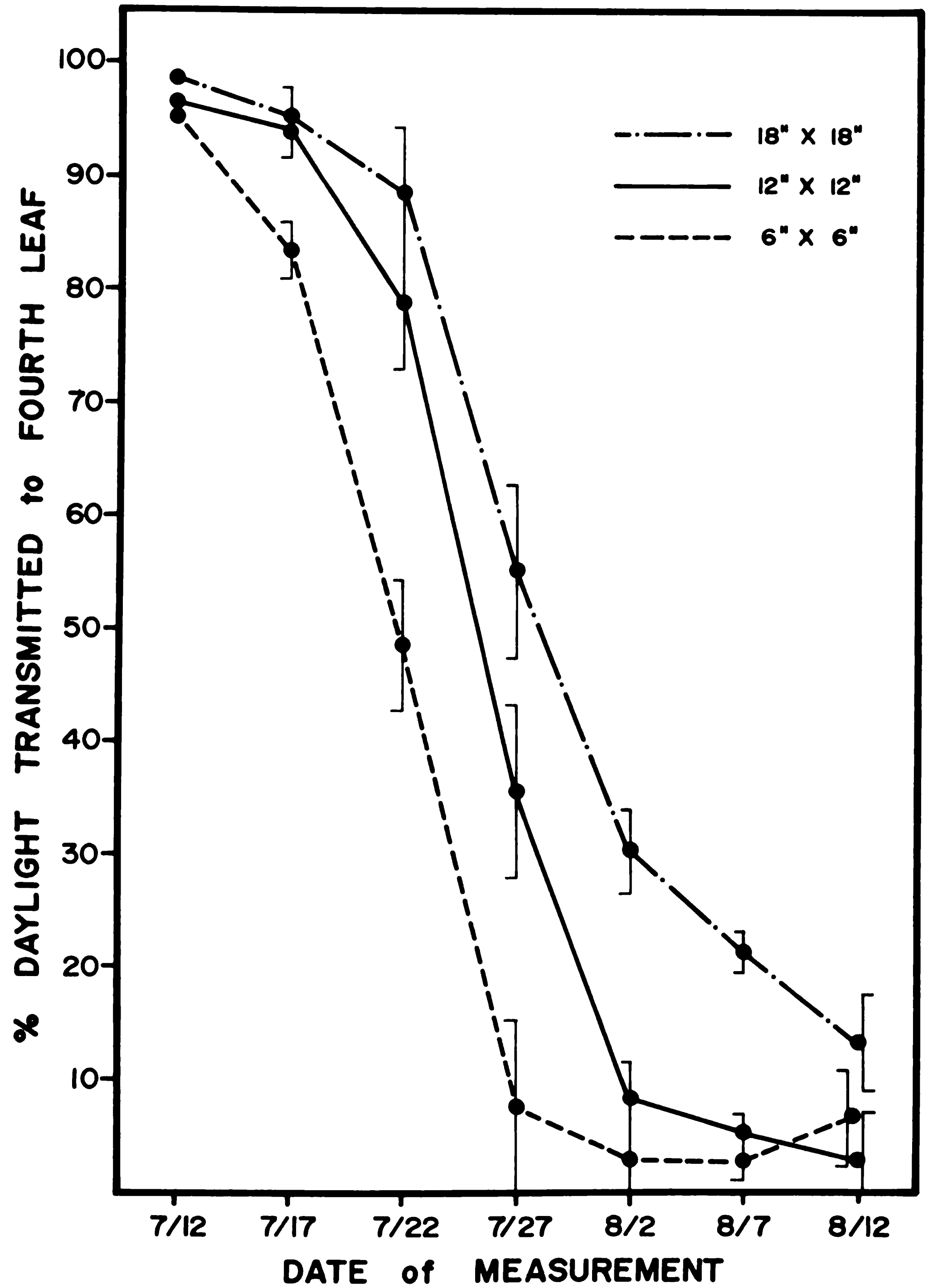
C. Number of leaves

The 6" by 6" spacing had a mean number of leaves significantly less than both 12" by 12" and 18" by 18" (α = .05) at date 1, Table 3. At date 2, the mean number of leaves was significantly different for each spacing. At dates 3 and 4, the mean number of leaves for the 6" by 6" spacing was significantly less than both the 12" by 12" and 18" by 18" spacings (α = .05). The mean number of leaves for the Heinz-1783 variety was not signigicantly different from the mean number of leaves for the New Yorker variety at any of the four dates (α = .05).

D. Effect of plant density and variety on light transmission to the fourth and seventh leaves

Figures 4 and 5 show the marked decrease in light transmission with increasing density. Means were significantly different (α = .05) for the densities for all but the first of seven dates taken during the main period of rapid growth. For dates 2, 3, and 4, light transmission was significantly lower (α = .05) for spacing 6" by 6" compared to spacings 12" by 12" and 18" by 18" for leaf 4, Figure 4, and leaf 7, Figure 5. For dates 5 and 6, spacing 18" by 18" transmitted more light to leaf 4 and leaf 7 than did spacings 12" by 12" or 6" by 6" (α = .05). At the seventh and final date, light transmission was significantly greater at spacing 18" by 18" than at 12" by 12" or 6" by 6" at leaf 7 (α = .05).

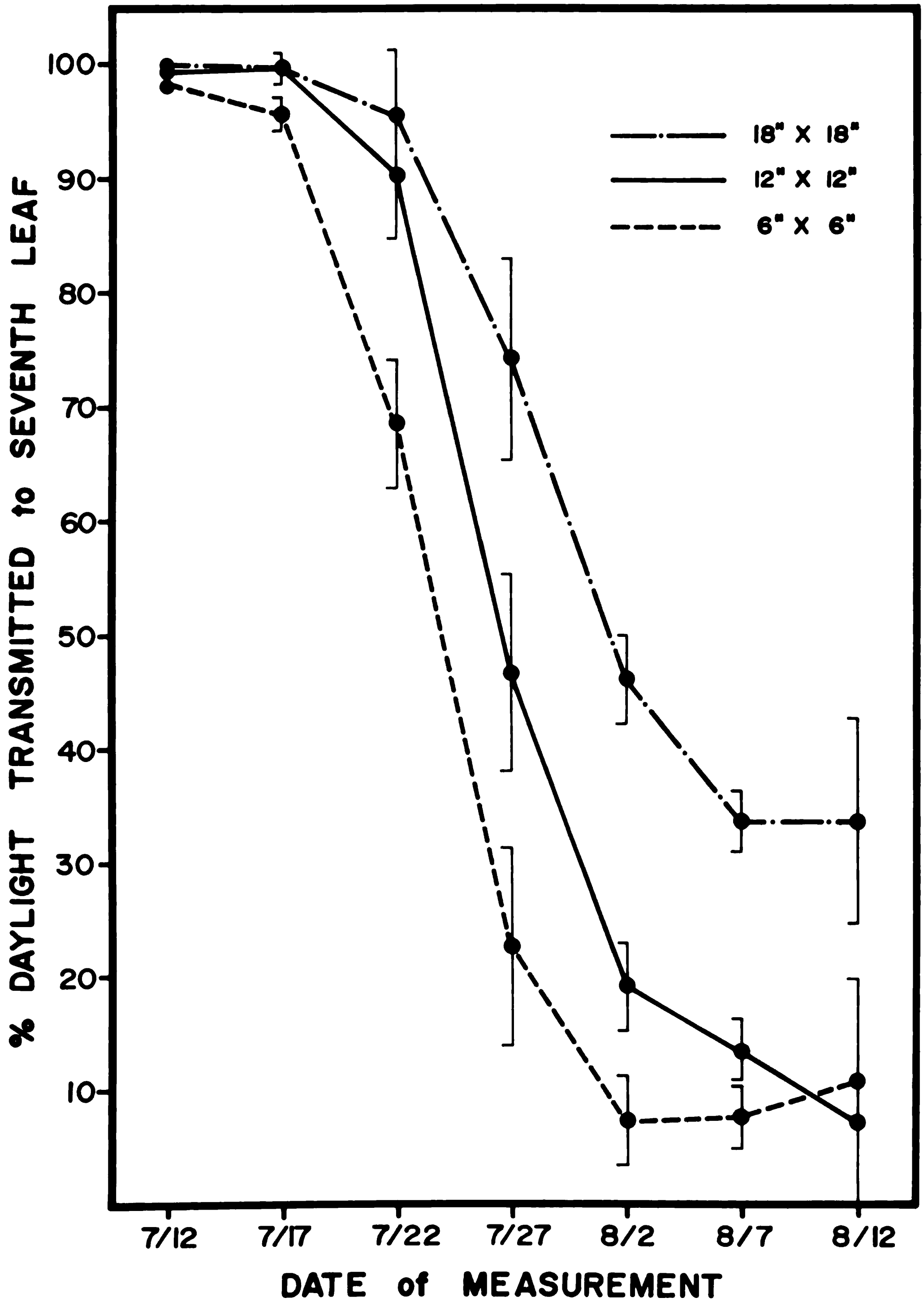
Figure 4. Mean percent daylight transmitted to the fourth leaf of tomato plants in field plots at 3 plant spacings over a 30 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 1.



100
90
80
70
60
50
40
30
20
10
% DAYLIGHT TRANSMITTED to FOURTH LEAF
18" X 18"
12" X 12"
6" X 6"
7/12
7/17
7/22
7/27
8/2
8/7
8/12
DATE of MEASUREMENT

FIGURE 4

Figure 5. Mean percent daylight transmitted to the seventh leaf of tomato plants in field plots at 3 plant spacings over a 30 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 2.



% DAYLIGHT TRANSMITTED to SEVENTH LEAF
100
90
80
70
60
50
40
30
20
10
18" X 18"
12" X 12"
6" X 6"
7/12
7/17
7/22
7/27
8/2
8/7
8/12
DATE of MEASUREMENT

FIGURE 5

E. Relationships between light transmission and lateral length

Least squares analysis of the relationship between the log of the lateral length and the light transmission to the corresponding leaf for the same or previous sampling dates was found to be significant (α = .05) at dates 2, 3, and 4 for both leaf 4 and leaf 7, Figures 6-12. Log values of lateral lengths were converted back to actual length values to plot Figures 6-12.

Light transmission at date 2 was positively correlated with the $\log_{10}$ of the lateral length at dates 2, 3, and 4 for leaf 4 and dates 3 and 4 for leaf 7. Light transmission at date 1 was positively correlated with the $\log_{10}$ of the lateral length at date 2 for both leaf 4 and leaf 7. The largest R^2 value was obtained by the correlation between light transmission at date 2 and $\log_{10}$ of the lateral length at date 4 for the fourth leaf, the light transmission at date 2 explaining 60.12 percent of the variability of the mean lateral length at leaf 4.

Experiment 2: Effect of Plant Density on Light Intensity and Lateral Development with Root Environment Held Constant

A. Lateral lengths

The effect of plant density on lateral development is shown in Figures 13 and 14. At date 1, the mean length at the fourth axil was significantly less at the 6" by 6" spacing compared to the 12" by 12" and 18" by 18" spacings (α = .05), Figure 13. At date 2, the mean length of

Figure 6. Least squares analysis of correlation of percent daylight transmitted to leaf 4 on July 12 with $\log_{10}$ of the lateral length at leaf 4 on July 22. Field experiment 1.

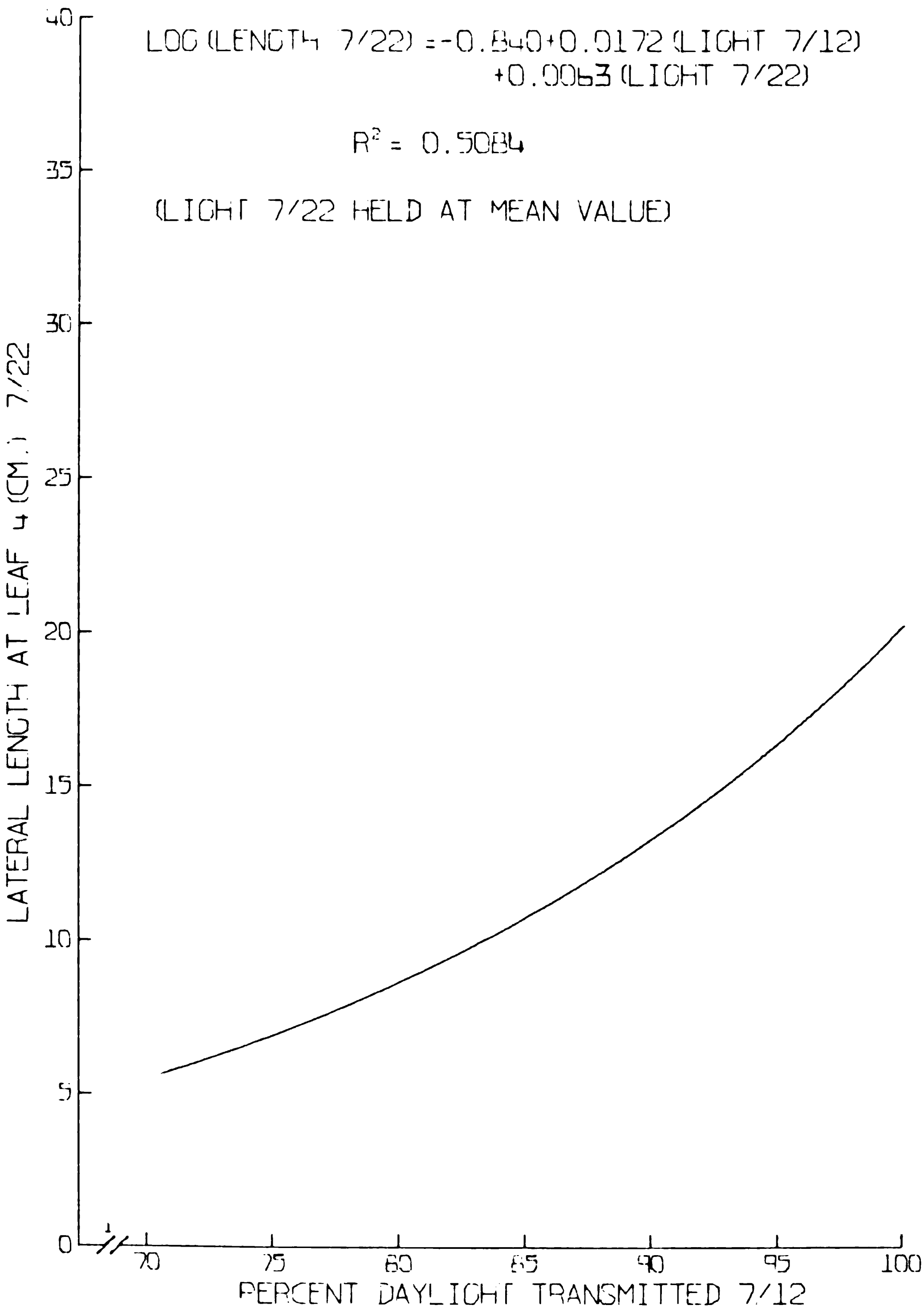

LOG (LENGTH 7/22) = -0.840 + 0.0172 (LIGHT 7/12)
+0.0063 (LIGHT 7/22)
R² = 0.5084
(LIGHT 7/22 HELD AT MEAN VALUE)
LATERAL LENGTH AT LEAF 4 (CM.) 7/22
PERCENT DAYLIGHT TRANSMITTED 7/12
0
5
10
15
20
25
30
35
40
70
75
80
85
90
95
100

FIGURE 6

Figure 7. Least squares analysis of correlation of percent daylight transmitted to leaf 4 on July 22 with $\log_{10}$ of the lateral length at leaf 4 on July 22. Field experiment 1.

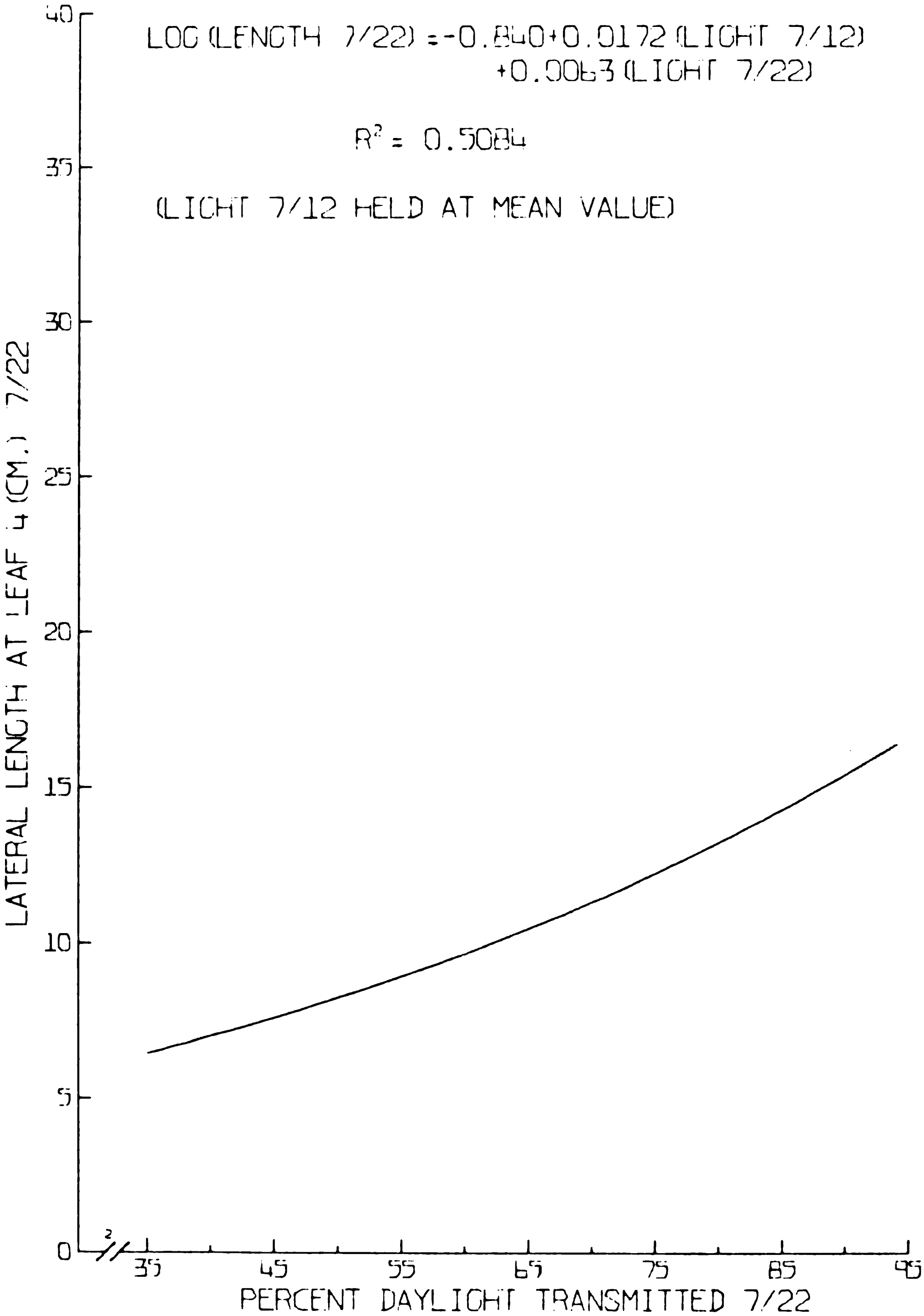

LOG (LENGTH 7/22) = -0.840+0.0172 (LIGHT 7/12)
+0.0063 (LIGHT 7/22)
R² = 0.5084
(LIGHT 7/12 HELD AT MEAN VALUE)
LATERAL LENGTH AT LEAF 4 (CM.) 7/22
0
5
10
15
20
25
30
35
40
35
45
55
65
75
85
95
PERCENT DAYLIGHT TRANSMITTED 7/22

FIGURE 7

Figure 8. Least squares analysis of correlation of percent daylight transmitted to leaf 4 on July 22 with $\log_{10}$ of the lateral length at leaf 4 on August 2. Field experiment 1.

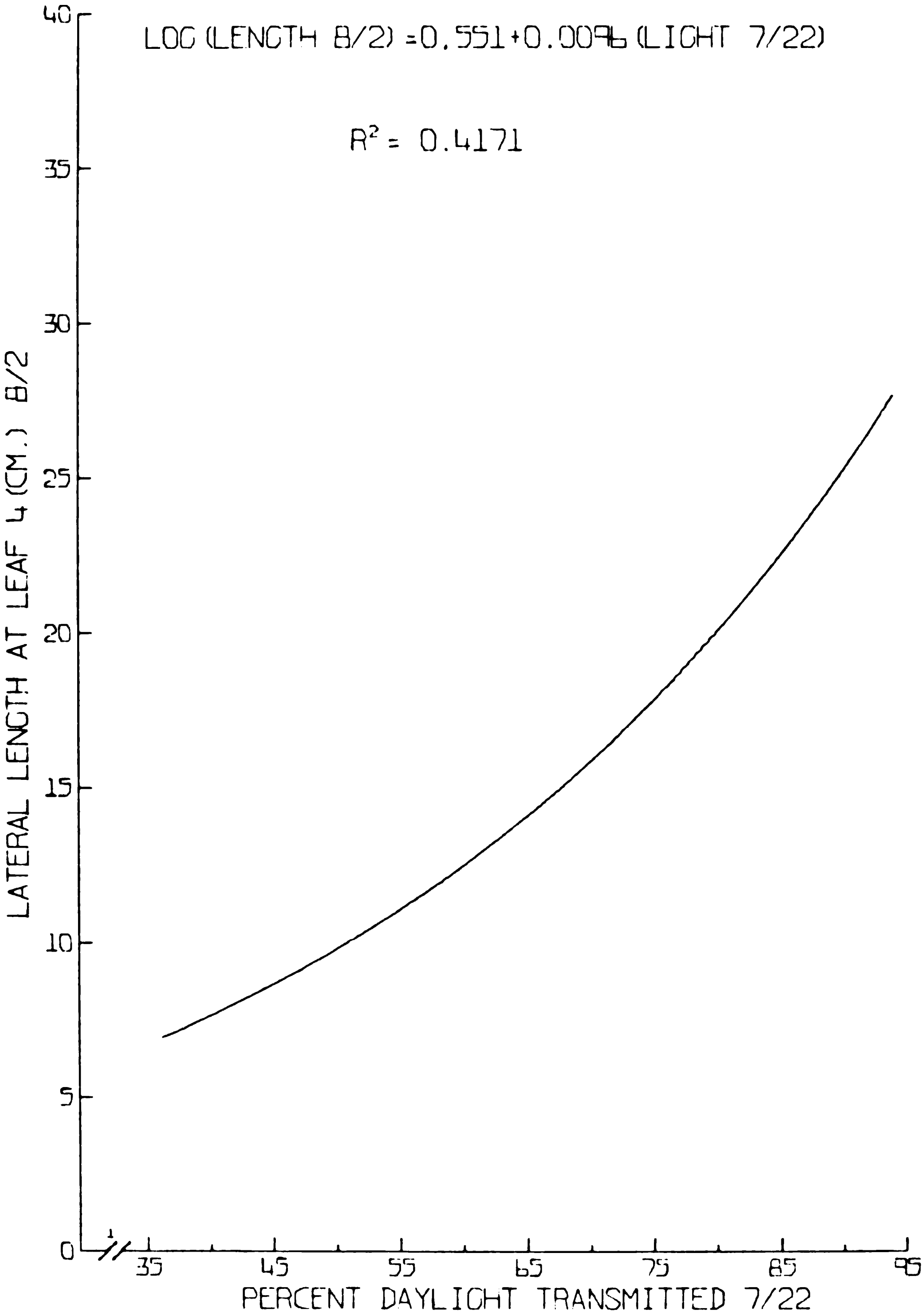

LOG (LENGTH 8/2) =0.551+0.0096 (LIGHT 7/22)
R^2 = 0.4171
LATERAL LENGTH AT LEAF 4 (CM.) 8/2
PERCENT DAYLIGHT TRANSMITTED 7/22
0
5
10
15
20
25
30
35
40
35
45
55
65
75
85
95

FIGURE 8

Figure 9. Least squares analysis of correlation of percent daylight transmitted to leaf 4 on July 22 with $\log_{10}$ of the lateral length at leaf 4 on August 12. Field experiment 1.

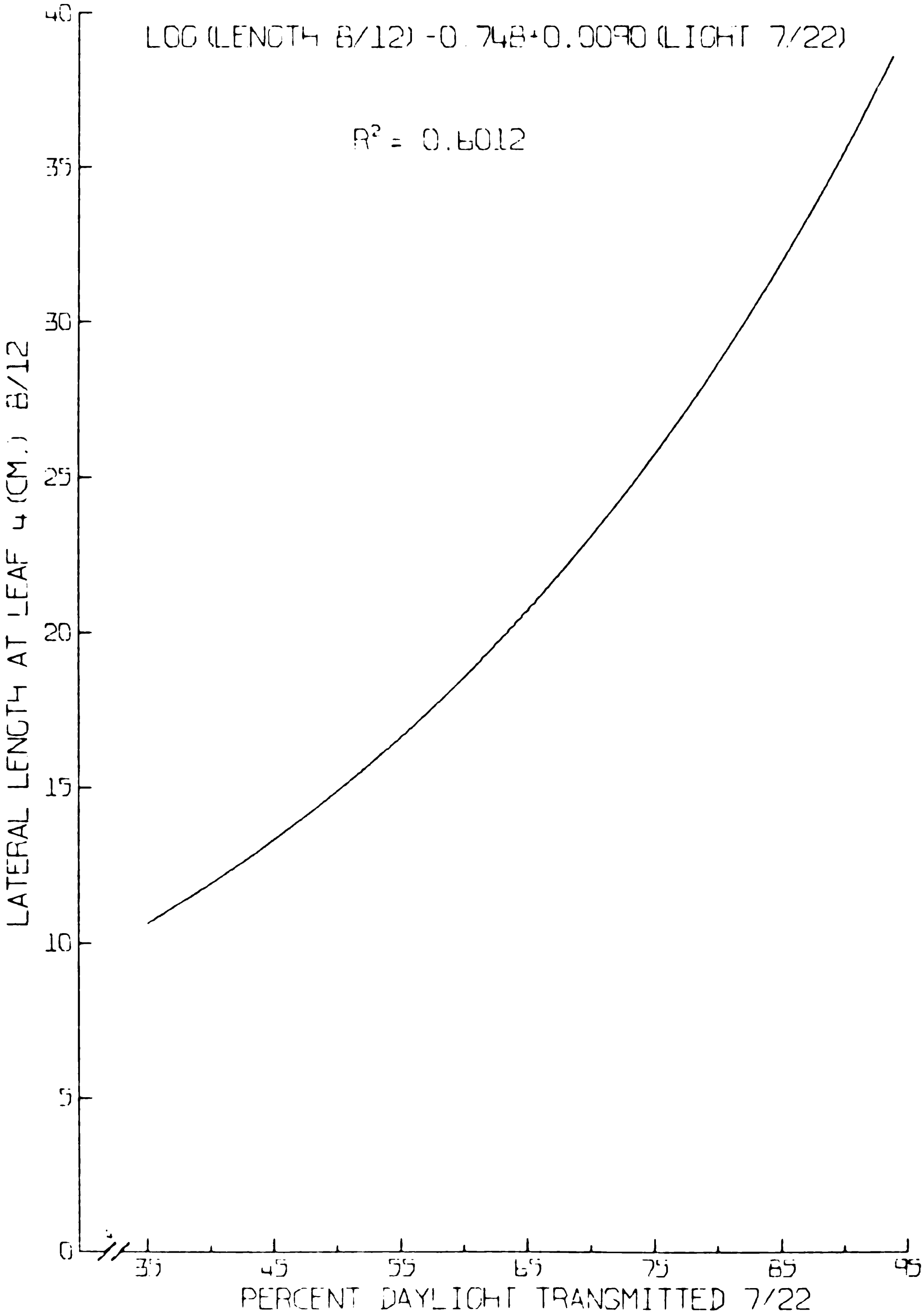

LOG (LENGTH 8/12) -0.748+0.0090 (LIGHT 7/22)
R² = 0.6012
LATERAL LENGTH AT LEAF 4 (CM.) 8/12
PERCENT DAYLIGHT TRANSMITTED 7/22
0
5
10
15
20
25
30
35
40
35
45
55
65
75
85
95

FIGURE 9

Figure 10. Least squares analysis of correlation of percent daylight transmitted to leaf 7 on July 12 with $\log_{10}$ of the lateral length at leaf 7 on July 22. Field experiment 1.

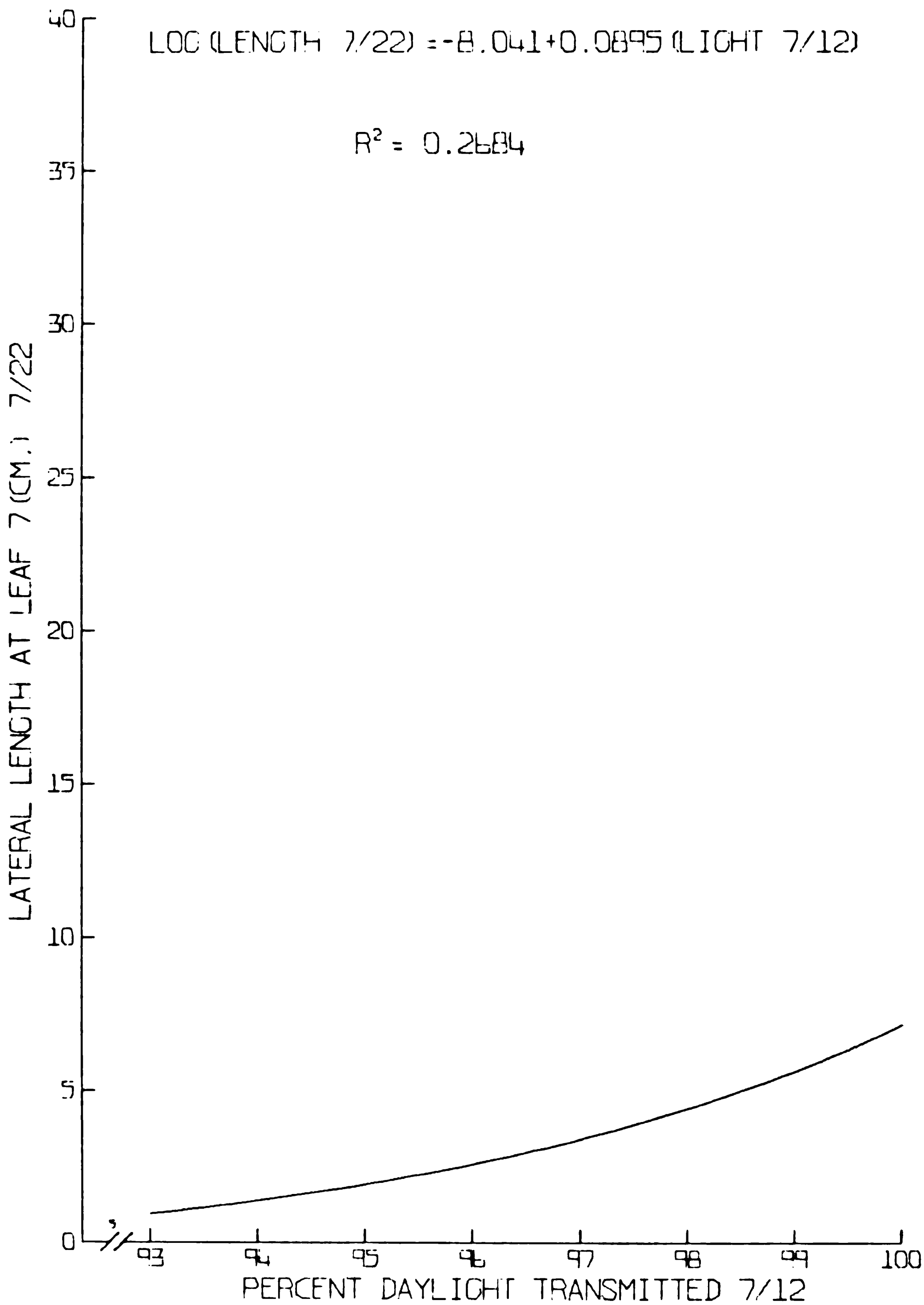
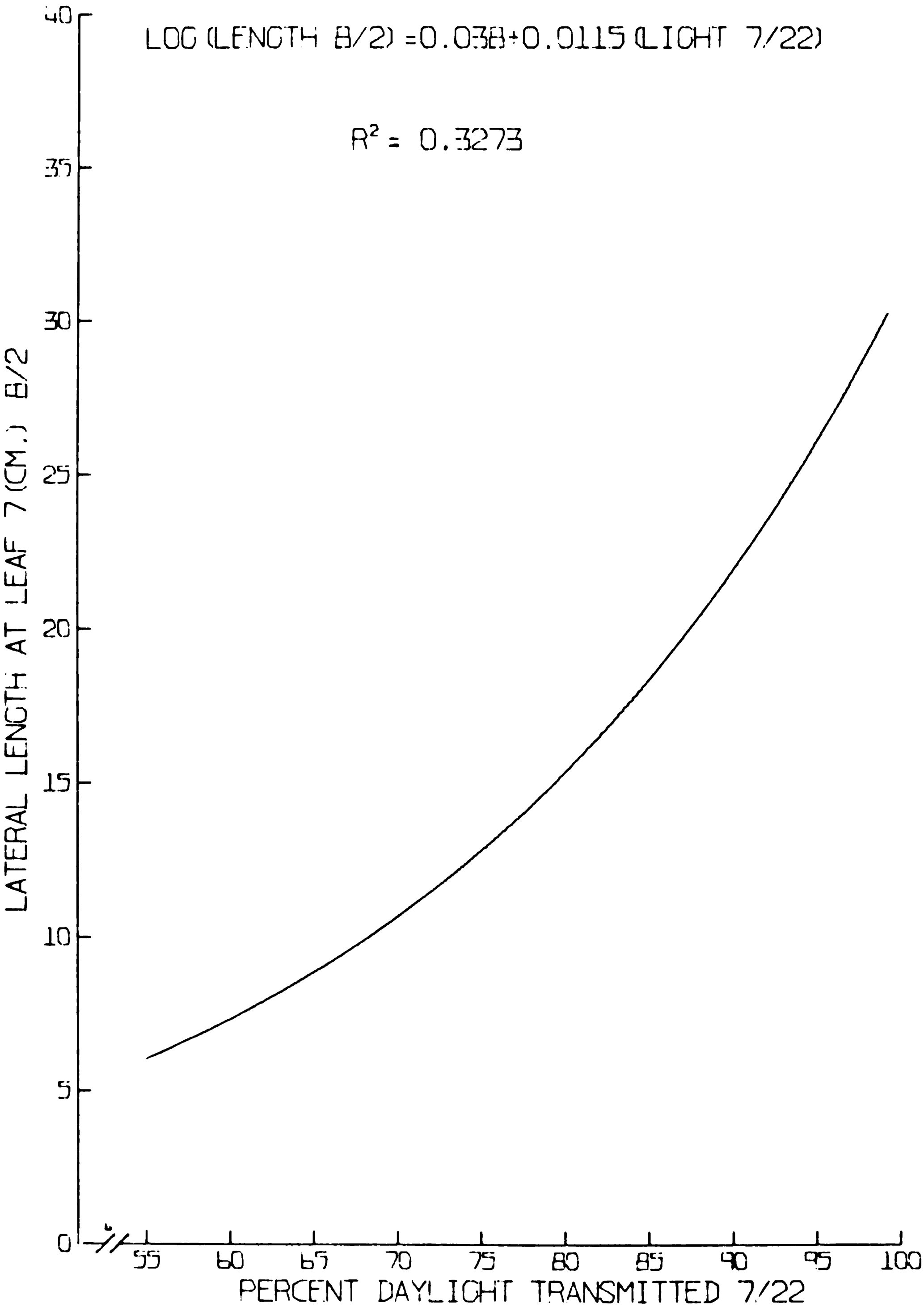

LOG (LENGTH 7/22) = -8.041+0.0895 (LIGHT 7/12)
R² = 0.2684
LATERAL LENGTH AT LEAF 7 (CM.) 7/22
PERCENT DAYLIGHT TRANSMITTED 7/12
0
5
10
15
20
25
30
35
40
93
94
95
96
97
98
99
100

FIGURE 10

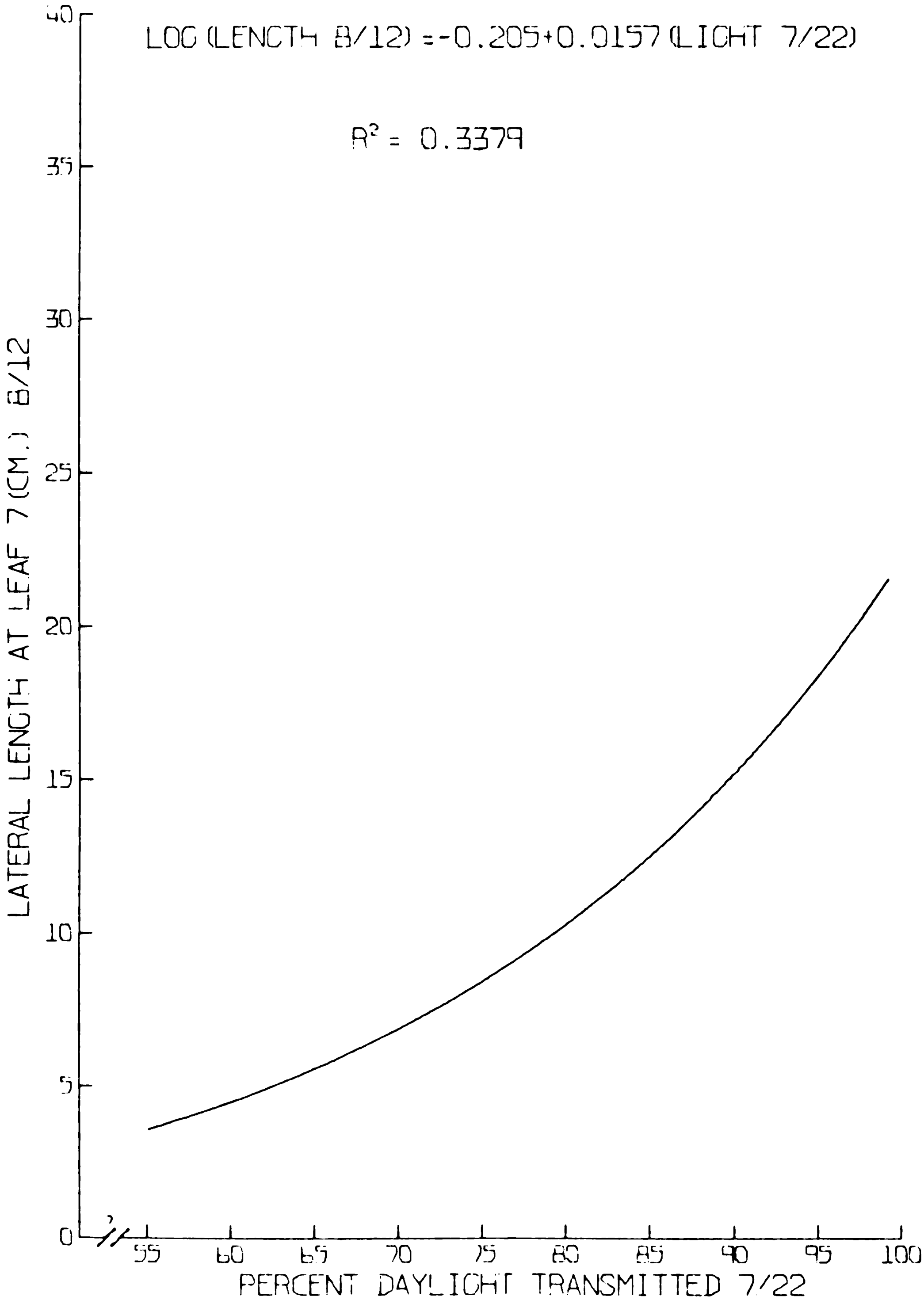
Figure 11. Least squares analysis of correlation of percent daylight transmitted to leaf 7 on July 22 with $\log_{10}$ of the lateral length at leaf 7 on August 2. Field experiment 1.



LOG (LENGTH B/2) =0.038+0.0115 (LIGHT 7/22)
R² = 0.3273
LATERAL LENGTH AT LEAF 7 (CM.) B/2
40
35
30
25
20
15
10
5
0
55
60
65
70
75
80
85
90
95
100
PERCENT DAYLIGHT TRANSMITTED 7/22

FIGURE 11

Figure 12. Least squares analysis of correlation of percent daylight transmitted to leaf 7 on July 22 with $\log_{10}$ of the lateral length at leaf 7 on August 12. Field experiment 1.



LOG (LENGTH 8/12) = -0.205+0.0157 (LIGHT 7/22)
R² = 0.3379
LATERAL LENGTH AT LEAF 7 (CM.) 8/12
PERCENT DAYLIGHT TRANSMITTED 7/22
0
5
10
15
20
25
30
35
40
55
60
65
70
75
80
85
90
95
100

FIGURE 12

Figure 13. Mean lateral length at the fourth axil of tomato plants in pots at 3 plant spacings over a 20 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 2.

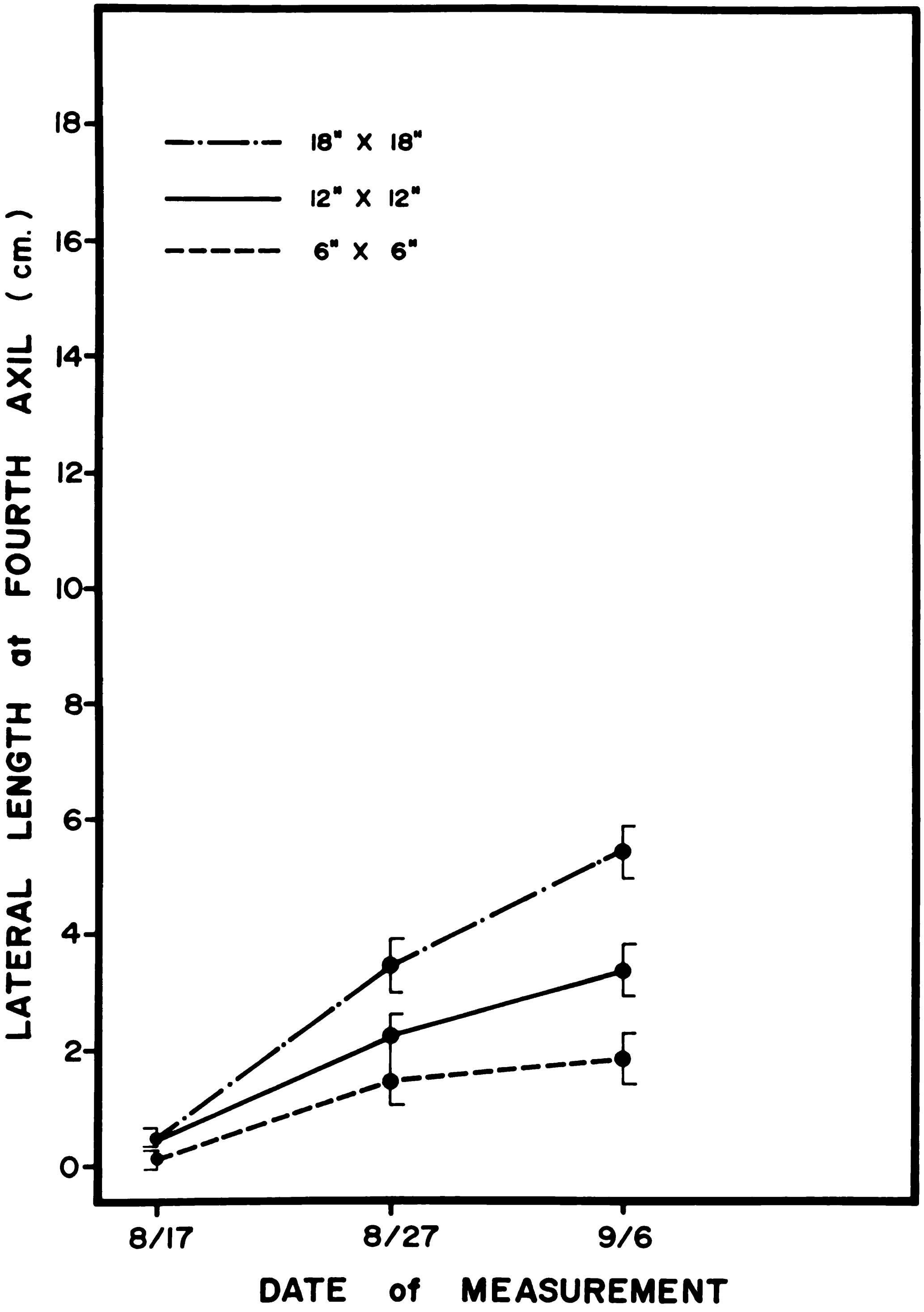
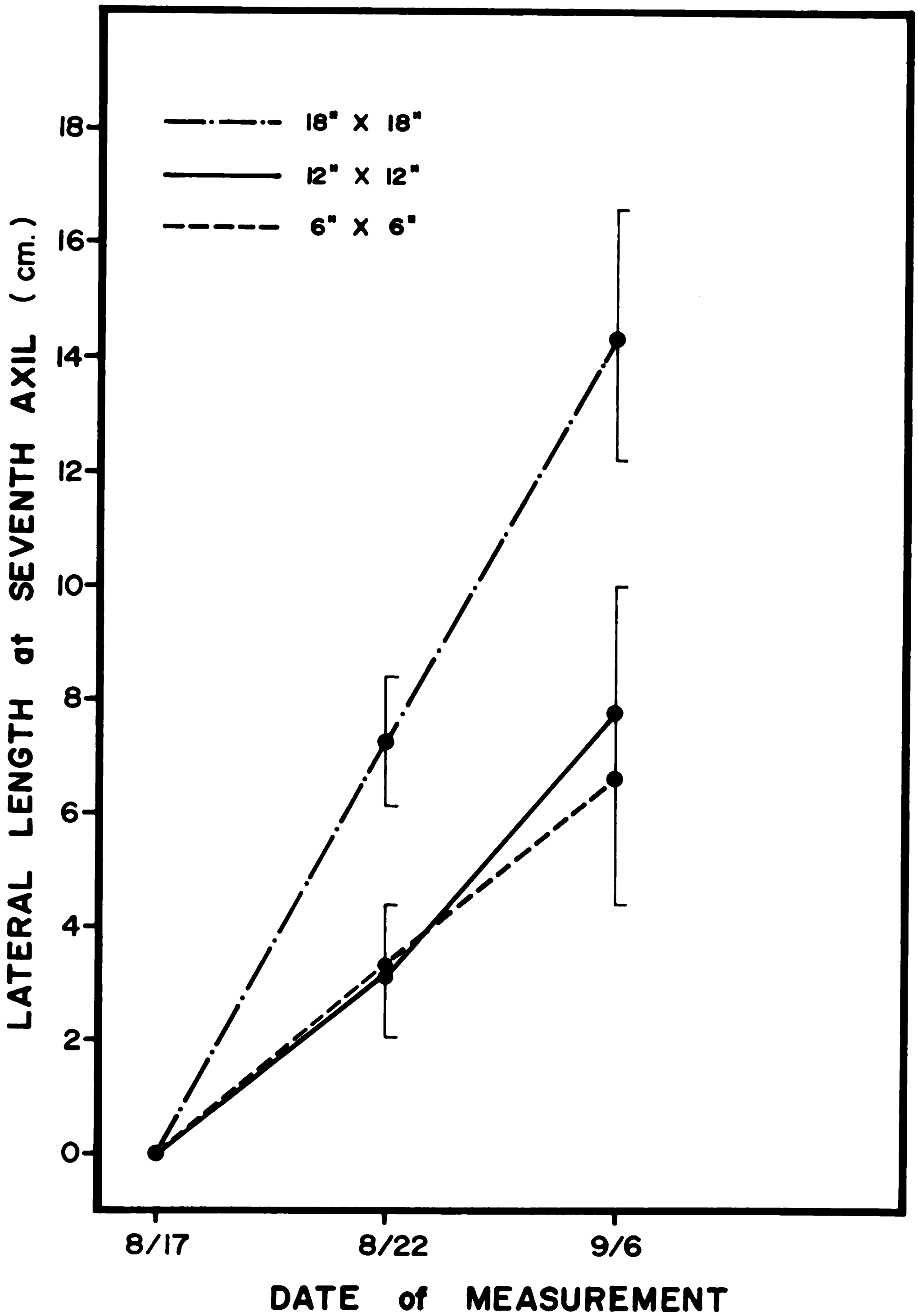

18" X 18"
12" X 12"
6" X 6"
LATERAL LENGTH at FOURTH AXIL (cm.)
0
2
4
6
8
10
12
14
16
18
8/17
8/27
9/6
DATE of MEASUREMENT

FIGURE 13

Figure 14. Mean lateral length at the seventh axil of tomato plants in pots at 3 plant spacings over a 20 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 2.



18" X 18"
12" X 12"
6" X 6"
LATERAL LENGTH at SEVENTH AXIL (cm.)
0
2
4
6
8
10
12
14
16
18
8/17
8/22
9/6
DATE of MEASUREMENT

FIGURE 14

laterals at leaf 4 and leaf 7 were significantly greater for spacing 18" by 18" compared to 12" by 12" and 6" by 6" spacings (α = .05). At date 3, the mean length at each spacing was significantly different (α = .05). Spacing 18" by 18" was significantly greater than 12" by 12" spacing or 6" by 6" spacing at leaf 7 (α = .05), Figure 14.

B. Plant height

Plant height was not significantly different at date 1 between spacings (α = .05), Table 4. At date 2, spacing 6" by 6" was greater in height compared to spacing 12" by 12" (α = .05). At date 3, spacing 6" by 6" was greater in height than both 12" by 12" and 18" by 18" spacings (α = .05).

C. Number of leaves

The number of leaves on the main stem greater than 4 centimeters in length was significantly less at date 1 for the 6" by 6" spacing compared to 12" by 12" or 18" by 18" inch spacings (α = .05), Table 4. Spacing was not significantly different for number of leaves at date 2 or 3 (α = .05).

D. Effect of plant density on light transmission to the fourth and seventh leaves

The effect of increasing plant density on light transmission is shown in Figures 15 and 16. Spacing did not significantly affect light transmission to leaf 4 or leaf 7 at date 1 (α = .05). Light transmission to leaf 4 at

Table 4. The effect of 3 plant spacings on the mean height (cm.) and number of leaves (over 4 cm.) of tomato plants grown in 6" pots. Field Experiment 2.

Date	Plant Height (cm.)		
	6"x6"	12"x12"	18"x18"
8/17	14.60 a	15.48 a	15.39 a
8/27	29.37 a	26.15 b	27.59 a b
9/6	47.85 a	40.67 b	39.85 b
	Number of Leaves		
	6"x6"	12"x12"	18"x18"
8/17	6.96 a	7.74 b	7.89 b
8/27	9.71 a	9.70 a	9.59 a
9/6	10.33 a	10.33 a	10.93 a

[1]Within a row, means above the same letter are not significantly different at the 5% level (Tukey's ω-procedure).

Figure 15. Mean percent daylight transmitted to the fourth leaf of tomato plants in pots at 3 plant spacings over a 25 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 2.

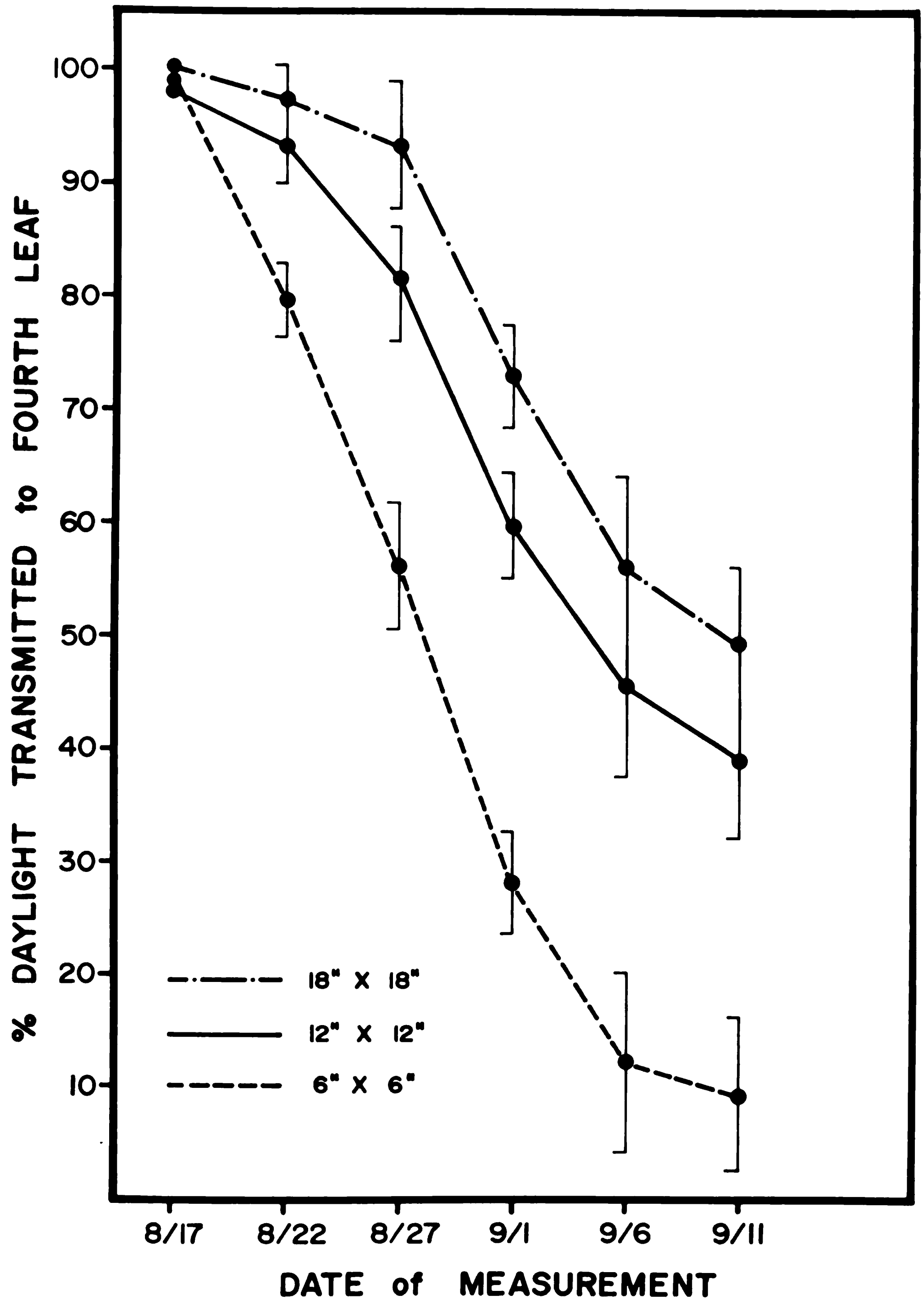

% DAYLIGHT TRANSMITTED to FOURTH LEAF
100
90
80
70
60
50
40
30
20
10
18" X 18"
12" X 12"
6" X 6"
8/17
8/22
8/27
9/1
9/6
9/11
DATE of MEASUREMENT

FIGURE 15

Figure 16. Mean percent daylight transmitted to the seventh leaf of tomato plants in pots at 3 plant spacings over a 25 day period. The distance from point to nearest bar is equal to 1/2 the significant difference at the 5% level by Tukey's ω-procedure. Means not significantly different are joined by a straight line. Field experiment 2.

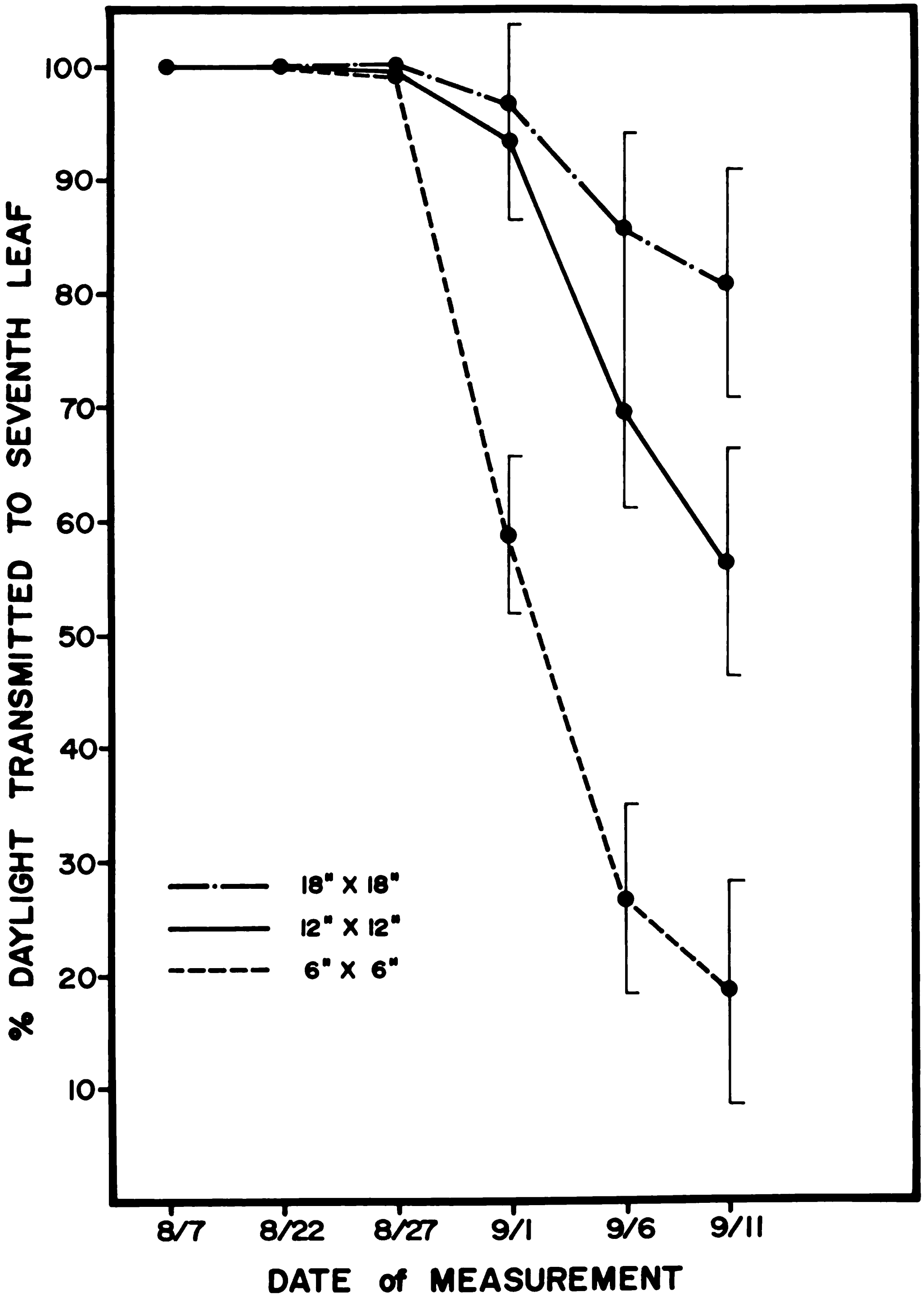

100
90
80
70
60
50
40
30
20
10
% DAYLIGHT TRANSMITTED TO SEVENTH LEAF
18" X 18"
12" X 12"
6" X 6"
8/7
8/22
8/27
9/1
9/6
9/11
DATE of MEASUREMENT

FIGURE 16

spacing 6" by 6" was significantly less than at spacings 12" by 12" or 18" by 18" at the second and all later dates (α = .05). Light transmission to leaf 4 at spacing 12" by 12" was significantly less than at spacing 18" by 18" at dates 3 and 4 (α = .05).

At dates 4 and 5, spacing 6" by 6" had a lower light transmission to leaf 7 compared to spacings 12" by 12" and 18" by 18" (α = .05). At date 6, light transmission to leaf 7 was significantly different for each spacing (α = .05).

E. Relationship between light transmission and lateral length

Least squares analysis of the relationship between the $\log_{10}$ of the lateral length and the light transmission at the corresponding leaf for the same or previous sampling dates was found to be significant at leaf 7 at the last sampling date, September 6 (α = .05), Figure 17. The light transmission at September 6 explained 52.48 percent of the variability of the log of lateral length at date 3. Log values of lateral lengths were converted back to actual length values to plot Figure 17.

Experiment 3: Effect of Plant Density and Variety on the Distribution, Relative Maturity, and Yield of Tomato Fruit

A. Effect of spacing and variety on fruit production

The mean weight of fruit per plant, as seen in Table 5, increased markedly with wider spacing from 6.15 oz. per

Figure 17. Least squares analysis of correlation of percent daylight transmitted to leaf 7 on September 6 with $\log_{10}$ of the lateral length at leaf 7 on September 6. Field experiment 2. (pots)

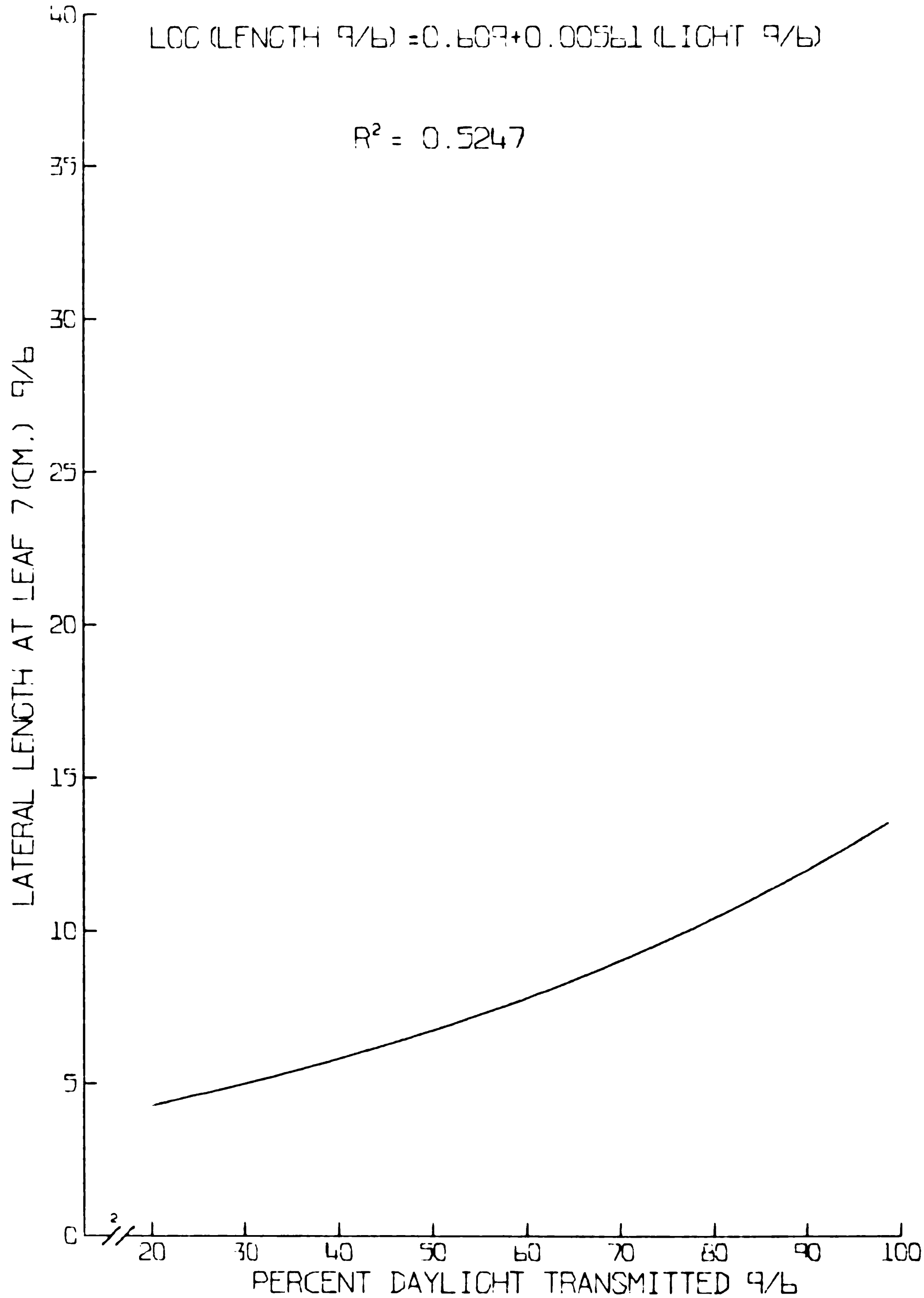

LOG (LENGTH 9/6) =0.609+0.00561 (LIGHT 9/6)
R^2 = 0.5247
LATERAL LENGTH AT LEAF 7 (CM.) 9/6
PERCENT DAYLIGHT TRANSMITTED 9/6
0
5
10
15
20
25
30
35
40
2
20
30
40
50
60
70
80
90
100

FIGURE 17

Table 5. The effect of 3 plant spacings and 2 varieties on the mean weight per fruit (oz.), number of fruit per plant, weight of fruit per plant (oz.), and weight of fruit per acre (lbs/acre) of tomato plots harvested for once over harvest. Field Experiment 3.

	Spacing (inches)[1]			Variety[2]		
	6"x6"	12"x12"	18"x18"	New Yorker	Heinz-1783	
Weight per fruit (oz.)	1.80 a	2.32 a b	2.62 b	2.93	1.44	**
Number of fruit per plant	3.42 a	11.67 b	19.94 c	10.59	18.04	**
Weight of fruit per plant (oz.)	6.15 a	27.08 b	52.25 c	31.02	25.97	**
Ripe fruit per plant (oz.)	4.26 a	14.23 b	28.51 c	16.95	14.38	**
Green fruit per plant (oz.)	1.89 a	12.85 b	23.74 c	14.07	11.58	**
Weight of fruit per acre (lbs.)	66,974 a	73,712 b	63,223 a	72,718	63,220	**
Ripe fruit per acre (lbs.)	46,419 a	38,728 b	34,500 b	42,244	37,520	*
Green fruit per acre (lbs.)	20,555 a	34,984 b	28,722 c	30,474	25,700	**

[1]Within a row, means above the same letter are not significantly different at the 5% level (Tukey's ω-procedure).

[2]n.s. = not significant at the 5% level.
 * = significant at the 5% level.
 ** = significant at the 1% level.

plant at 6" by 6" spacing to 52.25 oz. per plant at 18" by 18" spacing. This increase was due to 2 factors: a significant increase in weight per fruit and a significant increase in the number of fruit per plant with wider spacing ($\alpha = .05$). New Yorker variety had significantly greater weight per fruit, and weight of fruit per plant compared to Heinz-1783 variety ($\alpha = .01$). Number of fruit per plant was significantly less for New Yorker variety compared to Heinz-1783 variety ($\alpha = .01$). The interaction between variety and spacing was significant ($\alpha = .01$) for weight of fruit per plant.

The amount of ripe fruit per plant and the amount of green fruit per plant increased significantly with increasing spacing between plants as expected from the increase in total weight per plant ($\alpha = .05$). New Yorker variety had significantly greater weight of both green and ripe fruit per plant ($\alpha = .01$). The variety-spacing interaction was significant for both green and ripe weight per plant ($\alpha = .01$).

The total yield of fruit per acre was significantly greater at the 12" by 12" spacing (73,712 lbs.) compared to 6" by 6" (66,974 lbs.) or 18" by 18" (63,223 lbs.) ($\alpha = .05$). New Yorker variety yield of 72,718 pounds per acre was significantly higher than the Heinz-1783 yield of 63,220 pounds per acre ($\alpha = .01$). Ripe yield per acre of 46,419 pounds for the 6" by 6" spacing was significantly greater than the yields of 38,728 pounds for 12" by 12" spacing or 34,500 pounds for 18" by 18" spacing (α = .05), Table 6. The yield of green fruit per acre was significantly different for each spacing compared to all other spacings, spacing 6" by 6" having significantly less green yield compared to the other spacings (α = .05). The variety-spacing interaction was significant for both ripe and total yield (α = .01).

B. Effect of spacing and variety on relative maturity

Spacing 6" by 6" had a significantly greater percentage of ripe fruit at the date of once over harvest than either of the wider spacings (α = .05), Table 6. Almost 70 percent of the fruit was ripe at the 6" by 6" spacing compared to about 52 percent at spacing 12" by 12" and 54 percent at 18" by 18". The difference in percent ripe or green was not significant between varieties (α = .05). This may have been due to the method chosen for harvest, since all plots of a single variety were harvested on the same day, but the Heinz-1783 variety was harvested 11 days later than New Yorker with the intention of obtaining an approximately equal maturity at time of harvest for both varieties.

C. Distribution of fruit as affected by spacing and variety

The relative importance of main stem and lateral stems as carriers of fruit at different spacings and varieties is shown in Table 7. Percent of total fruit on the main

Table 6. The effect of 3 plant spacings and 2 varieties on the yield of ripe and green fruit (lbs/acre and percent of total yield) of tomato plots harvested for once over harvest. Field Experiment 3.

	Spacing (inches)[1]			Variety[2]		
	6"x6"	12"x12"	18"x18"	New Yorker	Heinz-1783	
Lbs/acre ripe fruit	46,419	38,728	34,500	42,244	37,520	*
	a	b	b			
Percent of total fruit	69.30	51.91	54.06	57.76	59.09	n.s.
	a	b	b			
Lbs/acre green fruit	20,555	34,984	28,722	30,474	25,700	**
	a	b	c			
Percent of total fruit	30.70	48.09	45.94	42.24	40.91	n.s.
	a	b	b			

[1]Within a row, means above the same letter are not significantly different at the 5% level (Tukey's ω-procedure).

[2]n.s. = not significant at the 5% level.
* = significant at the 5% level.
** = significant at the 1% level.

Table 7. The effect of 3 plant spacings and 2 varieties on the distribution of fruit between main and lateral stems (as percent of total fruit) of tomato plots harvested for once over harvest. The relative maturity of fruit borne on the maturity of fruit borne on the main or lateral stems is expressed as percent ripe or green of the total fruit on that stem. Field Experiment 3.

	Spacing (inches)[1]			Variety[1]		
	6"x6"	12"x12"	18"x18"	New Yorker	Heinz-1783	
Percent of total fruit on main stem	82.93 a	67.21 b	58.46 c	77.00	62.06	**
Percent ripe on main stem	69.78 a	62.00 b	71.86 a	67.21	68.56	n.s.
Percent green on main stem	30.22 a	38.00 b	28.14 a	32.79	31.44	n.s.
Percent of total fruit on lateral stems	17.07 a	32.79 b	41.54 c	23.00	37.94	**
Percent ripe on lateral stems	56.34 a	30.30 b	29.03 b	33.27	43.84	**
Percent green on lateral stems	43.66 a	69.70 b	70.97 b	66.73	56.16	**

[1]Within a row, means above the same letter are not significantly different at the 5% level (Tukey's ω-procedure).

[2]n.s. = not significant at the 5% level.
* = significant at the 5% level.
** = significant at the 1% level.

stem and percent of total fruit on the laterals were significantly different for each spacing (α = .05). New Yorker variety had a significantly greater percentage of fruit borne on the main stem at each of the 3 spacings (α = .01). The spacing-variety interaction was significant for the percentage of fruit borne on the main stem (α = .05).

The percentage of green fruit on the main stem was significantly greater for spacing 12" by 12" compared to percentages for the other 2 spacings (α = .05). The percentage of green fruit on the main stem did not differ significantly between varieties (α = .05).

The percentage of green fruit on the laterals was significantly less at the 6" by 6" spacing compared to percentages for the other 2 spacings (α = .05). The percentage of green fruit on the laterals was significantly less for the Heinz-1783 variety compared to the New Yorker variety (α = .01).

DISCUSSION

The results obtained in controlled environment studies (Tables 1 and 2) suggest that the light intensity on a leaf influences the rate of lateral growth at the leaf's axil. The failure of light intensity at the axillary bud to influence the rate of lateral growth (Table 2) points toward the leaf as the receptor of a light intensity stimulus for lateral development.

The tomato leaf's role as a receptor may be through the increase in photosynthesis rate at that leaf with increasing light intensity. Went (35) has shown that photosynthesis, expressed as dry matter production, is exactly proportional to light intensity up to 1300 foot candles. This relationship would suggest a higher production of photosynthetic products in leaves receiving the greater light intensity in the controlled environment study. Khan and Sagar (15,16) and Yakushkina (36) have shown that the leaves nearest a lateral are mainly responsible for the flow of carbon compounds into the lateral. An increase in the production of these carbon compounds due to an increase in photosynthesis at higher light intensities may induce a greater flow of carbon compounds to the lateral. The rate of flow of carbon compounds to the developing lateral may then influence the rate of growth of the lateral. An increase in light intensity on the leaf may also affect growth regulating compounds present in the leaf, causing a greater flow of carbon compounds out of the leaf.

The concept of the leaf as a receptor of the light stimulus may be used to explain the positive correlations found in field experiments between lateral development and relative light intensity on the corresponding leaf (Figures 6-12, and 17). At a high plant density, leaves below the plant canopy receive a lower light intensity on a given leaf compared to a leaf at a wider plant spacing. A lower light intensity on the leaf at the higher density may restrict lateral development due to a decrease in the flow of carbon compounds from the leaf to the lateral.

The use of pots to minimize other density effects on lateral development such as availability of nutrients or water did not remove the positive correlation of lateral development with relative light intensity (Figure 17). This correlation suggests that one factor responsible for the restriction of lateral development with increasing density is the decrease in light intensity on leaves below the canopy at high densities. The use of larger root containers to allow continuation of the experiment over the normal growth period of the tomato plant may have resulted in similar or greater correlations at later dates. A similar experiment by Bremner, Saeed, and Scott (2), using potato and sugar beet plants grown individually in five gallon containers, resulted in significant increases in dry matter production with both species at wider spacings. These results support the general conclusion that the effect of plant density on the growth rate and pattern of growth of plants is partially through the effect of plant density on light transmission.

The importance of lateral development as an influence in the production of tomato populations can be seen in the change of the percent fruit borne on lateral stems as the plant density is varied (Table 7). In the range of plant densities studied, percent of total fruit carried on the laterals decreased from 41.54 at the 18" by 18" spacing to 17.07 at the 6" by 6" spacing.

The increase in early yield and concentration of yield which resulted with increased plant density (Tables 6 and 7) is in agreement with other spacing studies conducted on the tomato by Fery and Janick (9), Odland (27), Reeve and Schmidt (30), and Vittum and Tapley (33,34). The influence of lateral development on relative earliness of maturity and concentration of maturity of the tomato plant is apparent in this study (Tables 6 and 7). The fruit set on the laterals occurs after the set on the main stem, creating two distinct stages of maturity. A higher percentage of fruit on the main stem will promote a more concentrated fruit maturity for the plant since the fruit on the main stem would become more dominant, decreasing the effect of the later set on the laterals. This is the case with the 6" by 6" spacing, in which 82.93 percent of the fruit was borne on the main stem.

Another factor increasing relative earliness of maturity and concentration of maturity with increasing density is the change in relative maturity of fruit borne on the laterals (Table 7). The percent ripe fruit of the total fruit borne on laterals was significantly greater at the 6" by 6" spacing compared to 12" by 12" and 18" by 18" spacings.

The higher percentage of main stem fruit and the greater relative maturity of lateral fruit is reflected in the greater percentage of ripe fruit and higher ripe yield per acre for spacing 6" by 6" compared to the wider spacings. Fery and Janick (9) also recorded a decrease in the number of branches per plant with an increase in early yield and yield concentration at higher plant densities.

With the advent of a once over type harvest of tomatoes, the concentration of fruit set through an increase in plant density appears to be an advantage in maximizing usable yield. In regions where the length of the growing season is marginal for tomatoes, an increase in the earlier main stem fruit set through increased plant density may be an important method to promote an earlier relative maturity.

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