STUDIES ON THE EFFECTS OF SUPPLEMENTARY LIGHT FOR INCREASING THE GROWTH RATE AND YIELD OF LEAF LETTUCE

By

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1954

Submitted to the Faculty of the Graduate College
of the Oklahoma State University
in partial fulfillment of the requirements
for the Degree of
MASTER OF SCIENCE
August, 1969

STUDIES ON THE EFFECTS OF SUPPLEMENTARY

LIGHT FOR INCREASING THE GROWTH RATE

AND YIELD OF LEAF LETTUCE

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ACKNOWLEDGEMENTS

During the course of this study the author has had much help and advice from several members of the Horticulture Department, Oklahoma State University.

Sincere thanks is due Professor F. A. Romshe, my major professor, for his patient assistance and suggestions, and whose encouragement, boundless enthusiasm, and continued cooperation made possible the completion of this thesis.

Grateful appreciation is also due to Professor W. R. Kays, the department head, for his initial guidance and cooperation.

Acknowledgement is made to Mr. Bobby Burk for donating some of the lettuce plants used and technical assistance provided.

Further acknowledgement is made to the faculty members of the Horticulture Department for their help and friendship during my studies at this university.

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CHAPTER I

INTRODUCTION

In the study of lettuce production in greenhouses, some of the problems need to be investigated. These problems are: how to improve the cultural methods, how to increase the quality, how to shorten the growing period and, finally, what is the best combination of practices to increase production.

Lettuce growing in greenhouses is usually practiced in the cool season. The aim of vegetable growers in greenhouses is to obtain greater production in a shorter growing period. Space in greenhouses should be used efficiently. However, the photoperiod in winter is shorter than in summer and plants make slower growth in winter than in summer. Consequently, the time required to grow lettuce plants in winter is longer than that in summer.

The purpose of this study is to try to find a better method for growing lettuce seedlings.

According to the theory of Meyer (17), the energy stored by green plants in the molecules of carbohydrates during photosynthesis can be supplied only by light. Photosynthesis will occur in the presence of electric light, or other sources of illumination, if the lights are of sufficient intensity. Therefore, electric lights are often used in experimental work on photosynthesis and to some extent in greenhouses as supplementary sources of illumination.

Studies herein are to use supplementary light treatments on lettuce during germination and seedling stages in order to stimulate vegetative growth. Supplementary light could serve the purpose of reducing length of the growing period, and of obtaining a higher yield per unit of area.

The photoperiod in spring is shorter than in summer. The second part of this study is to use supplementary light treatments on lettuce seedlings during spring in order to study the effects on growth rate.

The major emphases of this study are as follows: (1) The growth rate of lettuce in its seedling stage may be stimulated by supplementary light. (2) The growing period for lettuce may be reduced by supplementary light. And therefore, (3) The yield of lettuce may be increased during a given period of time.

If we could obtain some positive results from these experiments, the method of using supplementary light in stimulating the growth of lettuce seedlings will be introduced for the lettuce growers.

CHAPTER II

REVIEW OF LITERATURE

This research problem is concerned with the effects of supplementary light on the growth rate and production of lettuce. Investigators (4, 5, 8, 11, 14, 19, 25) have published reports of supplementary light studies on germination and growth, and on the effects of photoperiod on growth of some plants.

In 1930, Haut (8) reported: "The experiments of Garner and Allard and other investigators have shown that the relative length of day is an important factor influencing the vegetative and reproductive development of plants."

Laurie (13) reported: "Although the first record of effects of light upon plants dates back to 1686 when John Ray, in Historia Plantarum, observed differences due to light variation, it was fully two and one-half centuries later that any comprehensive research along this line was undertaken. Since then many of the fundamentals have been established and empirical practices classified. Wiesner, Siemens, Bailey, Rane, Irons, McArthur, Popp, Denny, Gourley, Nightingale, and others may well be included in the list of workers who have been responsible for the earlier development."

Supplementary Light Studies

In 1947, Withrow (31) suggested: "The problem of producing vigorous plant growth, therefore, is one of increasing the irradiances as well as, in many cases, increasing the photoperiod. The use of high irradiances is economical for increasing the rate of growth of seedlings and young plants that can be closely spaced or for improving growth in special crops. Since light is a factor in plant culture we should solve this problem before we go on. The different sources of light should be analyzed by the spectroscope to determine their respective, and, especially, their predominating composition."

In 1905, Clark (4) reported that the actinic rays promoted flower development. He contends that red light is most favorable to leaf growth. Intense light very much decreases leaf growth, making the leaf small and thick. Besides, the texture of leaves grown in weak light is soft. Moreover, on theoretical grounds, blue light might prove to be a practice applicable to leaf growth. Leaf buds are formed only under relatively high intensity of light. It is a fair hypothesis that blue light would promote vegetative bud formation more than red light does.

In 1953, Learner and Wittwer (14) reported that tomato seedlings, grown in midwinter in an environment in which the photoperiod was extended to 16 hours by using 300 foot candles of white fluorescent light, had significantly greater heights and dry weights of foliage and roots than did plants grown under natural photoperiods.

Light on Germination

The seeds of all species of plants require at least three external conditions before germination can occur: (1) water; (2) a suitable temperature; and (3) oxygen. A fourth factor, light affects the germination of the seeds of some species.

Negbi (19) reported that the action of prolonged far-red irradiation on seed germination was studied in Lactuca sativa, lettuce variety, Grand Rapids. Germination promoted either by red light, GA3, or thiourea, depended upon the occurrence of certain processes which proceed in darkness, independently of any of these factors. Devlin (6) found that seeds vary considerably in their response to light with respect to germination. Some seeds have an absolute requirement for light to germinate. Red light promotion of lettuce seed germination could be reversed if far-red irradiation immediately followed red light treatment. If the seeds were again treated with red light, germination would again be promoted. In other words, the system is repeatedly reversible.

Miller (18) found that lettuce seeds were frequently sensitive to light, thus, the germination of these seeds has attracted much attention. Miller suggested: "According to Shuck, lettuce seed is in a physiologically unstable condition that makes it particularly sensitive during germination to the effects of light, moisture, and temperature. In the laboratory, germination is promoted by the exposure of lettuce seeds to light, by the use of a very moist substratum, and by starting the germination at a low temperature. The light requirement may be satisfied by continuous exposure to light under germinating condition or by exposing the moist seeds to light before placing them in a dark chamber."

Strafford (23) suggested that most of the work on light-sensitive seeds has been done with lettuce seeds and, by the use of optically pure filters, it has been possible to obtain action spectra. In general, light-sensitive seeds show the following characteristics: germination is inhibited by blue as well as by infra-red light, while germination is promoted by red light.

Light on Growth

Devlin (6) mentioned: "One can imagine that it was easily demonstrated that a plant could not grow in the dark, that light was essential." Auchter (1) reported that in his study of lettuce, it was found that the plants treated by electric light were larger and had broader leaves with better color than those in any of the other plots.

Clark (4) found that a plant grown in an environment exposed only to red rays, which are physically most closely allied to the heat rays, partakes much of the nature of a plant grown entirely with the aid of heat light; but with the exception that the red light somewhat inhibits stem growth and promotes leaf growth.

Hemphill (11) reported that in all cases as light increased, up to a certain point, the fruit yield in tomatoes increased also. Most individuals recognize that light is necessary for the growth of chlorophyll-containing plants, but there is little data in the literature indicating how closely yields of horticultural crops are correlated with total solar radiation. In the production of greenhouse tomatoes, where optimum nutrient supply, moisture supply and temperatures can be maintained, data presented in his report indicate that light becomes an important factor in determining yields. As the total amount of sunlight increased, yields increased.

Withrow (31) reported that seventy days from the beginning of the radiation treatments, the spinach plants were largest, and the flowering spike longest under fluorescent light

Photoperiod on Growth

Many investigators (6, 8, 10, 13, 14, 25) have studied the effects of photoperiod upon the vegetative phases of horticultural plants.

Hegwood (10) reported: Investigators have found that photoperiod may influence the vegetative phase of plant growth by increasing or decreasing the period of vegetative activity and the amount and extent of vegetative extension including plant height and weight, leaf area, and number and length of lateral branches.

Devlin (6) suggested that flowering, vegetative growth, internode elongation, seed germination, and leaf abscission were examples of photoperiodic responses that had been discovered in plants. Much of the early work on photoperiodism was aimed at establishing which part of the plant receives the photoperiodic stimulus. The organs of the plant receiving the most attention were the leaves and buds. Meyer (17) suggested that the foundation of our knowledge of photoperiodism was laid in 1920 when Garner and Allard observed the behavior of plants of the Maryland Mammoth variety of tobacco growing in a greenhouse during the winter months. Furthermore, long photoperiods were obtained during the winter months by supplementing the natural day length with the necessary number of hours of illumination. Relatively low intensities of supplemental light had been found adequate to induce photoperiodic reactions in many plants.

CHAPTER III

MATERIALS AND METHODS

The studies reported here were conducted in the greenhouse of the Department of Horticulture at the Oklahoma State University, during the winter and spring of 1969.

One variety of lettuce (Lactuca sativa) was used in these trials. It is a dark green selection out of U. S. #1 strain of Grand Rapids.

The principal objectives of these experiments were to try to find a better method for growing lettuce seedlings, to determine the effects of mist and supplementary light on stimulating vegetative growth of leaf lettuce plants, to find the effects of supplementary light on reducing length of the growing period and of obtaining a higher yield per unit of area on greenhouse-grown leaf lettuce.

Experiment I

The main objectives of experiment I were to determine the effects of misting and supplementary light on the growth rate during germination and seedling growth stages, the effects of transplanting and direct seeding on the growth rate of leaf lettuce, and the effects of misting and supplementary light on the yield of leaf lettuce during winter time.

Treatments 1, 2, 4, and 5 were to sow the seeds directly in cell-paks. One cell-pak unit was used by one treatment for sowing seeds. Cell-paks are multi-cell plant growing containers made of white semi-rigid plastic. The size used had individual cells of 1" x 1½" at the top and 2" deep, with appreciable taper from top to bottom. The taper and flexibility of the plastic made it easy to remove plants. Twelve cells were contained in a small unit and eight of these units are slightly joined together to form a large unit. The large unit fits a "Handi-Flat," a plastic tray, for ease in handling; therefore, there were 96 spaces in which to grow plants.

The growing medium used in the cell-paks was composed of equal parts of shredded peat moss, perlite, and sterilized soil. The medium was maintained only moderately moist due to the excellent drainage. The size of lettuce seeds is about 1/8 inch in length and quite slender. Being quite small and light in weight, it is hard to plant individual seeds on the surface of soil. A good method is to put the seeds in a small coin envelop, press the edges together enough to form a trough of the lip, tilt and tap the envelop so that one or two seeds go into each division. There is no need to cover the seed when germinated under mist.

Following seeding certain treatments were placed under mist. Misting occurred for nine seconds of each six minutes from overhead deflective nozzles including nighttime. Germination required three to five days at a day temperature of 85° F. The supplementary light used in this experiment was from a double tube fluorescent fixture with four foot, 40 watt, "Grolux" tubes, suspended 12 inches above the plants. The supplementary lights were applied 33 days for treatment 1, 28 days for treatments 2 and 3, and five days for treatment 4.

Five to six days after seeding, the seedlings in the cell-paks needed thinning. At that time the seedlings were between 2/3 to 3/4 inch high. The seedlings in experiment I were thinned on February 5, six days following seeding.

Six treatments: Lettuce seeds of these six treatments were sown in cell-paks in six "Handi-Flats" on January 30, 1969.

Treatment 1, ML-L: Seeds were dropped on the surface of the growing medium, in cell-paks, and placed under mist and lights for germination. After germination the containers were transferred to a growing room. The seedlings were placed under lights at night and on dark cloudy days. ML before the hyphen denotes to apply mist and light during germination stage. L after the hyphen denotes to apply supplementary light during the seedling growth stage.

Treatment 2, M-L: The seeds in cell-paks were placed under mist for germination. After germination the containers were transferred to a growing room. The seedlings were placed under lights at night and on dark cloudy days.

Treatment 3, TP-L: The seedlings were transplanted one time. TP denotes transplanting. The seeds were sown in vermiculite and seedlings transplanted into cell-paks when cotyledon leaves had expanded. Seedlings were placed under lights at night and on dark cloudy days during the seedling growth stage.

Treatment 4, ML-O*: The seeds in cell-paks, were placed under mist and light for germination. After germination the containers were transferred to a growing room. The seedlings were not placed under lights.

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*O = No supplementary light during seedling growth stage.

Treatment 5, M-O: The seeds in cell-paks were placed under mist for germination. After germination the containers were transferred to a growing room. The seedlings were not placed under lights.

Treatment 6, TP-O (CK): The seedlings were transplanted one time. The seeds were sown in vermiculite and seedlings transplanted into cell-paks when cotyledon leaves had expanded. Seedlings were not placed under lights.

Six treatments were established with four replicates, each plot containing fifteen plants. The plants were spaced 8" x 8" when set into the ground-bed.

Experiment II

The objectives of experiment II were to determine the effects of supplementary light on the photoperiod of leaf lettuce during the spring season of growth, and determine the effect of treatment on yield at the time of harvest in May.

Lettuce seeds were sown in cell-paks in two "Handi-Flats" on March 13, 1969. Both containers were placed in the greenhouse room under mist for germination. The maximum temperature ranged from 85° to 95° F. during the day.

Following germination the containers were transferred to the growing room on March 18, 1969. Treatment 1 (L) was placed under lights during night starting March 18 and ending April 10. Treatment 2 (NL*) was not treated by supplementary light. Each treatment contained 96 seedlings. The seedlings of experiment II were thinned on March 20. One seedling was left in each cell.

*NL = No supplementary light during the seedling growth stage.

Twenty plants were set in each plot. The plants were spaced 8" x 8" when set in the ground-bed. The replications were arranged in two blocks. Each block contained two replications of each treatment, or four plots. Extra plants were used for a buffer to protect the trials and were set at both ends of the blocks.

CHAPTER IV

RESULTS

Experiment I

This work was started during winter. The daylength was short, thus supplementary light might be expected to have a beneficial effect on the growth of lettuce seedlings.

The seeds were sown January 30, 1969. After three to four days they had germinated. All of the flats were moved February 4 to the growing room in the greenhouse. On February 10, the seedlings for treatments 3 and 6 were transplanted. These seedlings were transplanted to cell-paks from a germination flat.

The height of the seedlings of six treatments was measured February 24. Twenty seedlings at random, were measured from each treatment.

Photographs were taken February 25, (Figs. 3-7) to show comparative heights of plants of each treatment.

The lettuce plants were set in the ground-bed in the greenhouse March 4. Lettuce in experiment I was harvested April 17, 77 days after sowing the seed.

Data on the effect of treatment on plant height are given in Table I.

TABLE I

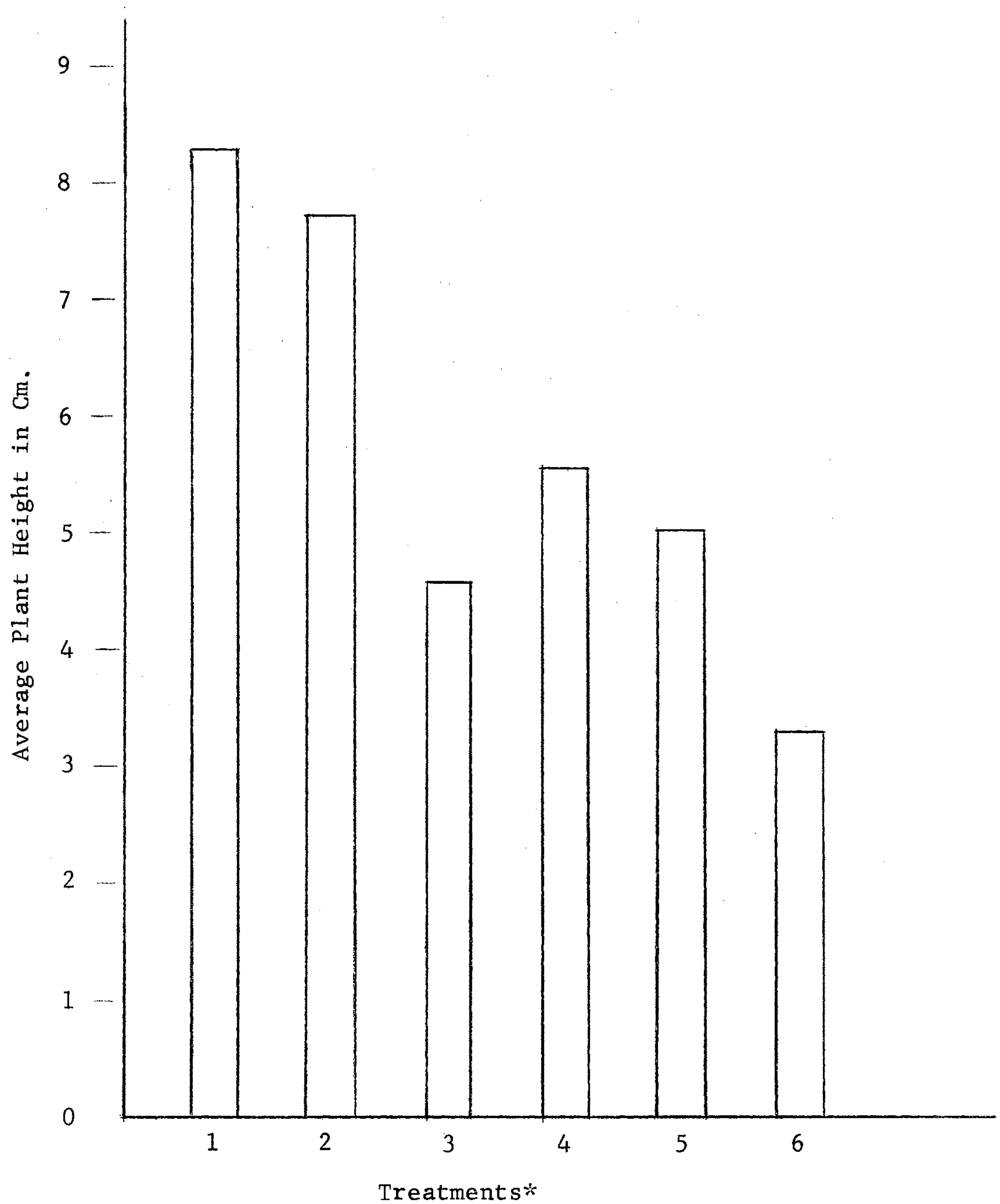
HEIGHT OF LETTUCE SEEDLINGS FROM SIX TREATMENTS, TWENTY FIVE DAYS AFTER SEEDING

Treatments	1 ML-L	2 M-L	3 TP-L	4 ML-O	5 M-O	6 TP-O(CK)
Total height of twenty seedlings (CM.)	165.6	154.1	90.2	111.8	101.2	65.0
Average (CM.)	8.26	7.70	4.51	5.59	5.06	3.26
Percentage increase over check	154.7	136.7	38.7	72.0	55.6	

Data in Table I show that treatment 1 (ML-L) produced the tallest plants. Lettuce seedlings in treatment 1 grew very rapidly. Plants from this treatment averaged 157 percent greater in height than those of the check treatment.

A graphic representation of plant height is shown in Figure 1.

Figure 1. The effect of various treatments on the average height of leaf lettuce plants, twenty five days following seeding.



*Treatments

1.	ML-L	Mist and light, plus light all night.
2.	M-L	Mist, plus light all night.
3.	TP-L	Transplanting, plus light all night.
4.	ML-0	Mist and light, no light during night.
5.	M-0	Mist, no light during night.
6.	TP-0	Transplanting, no light during night.

In Figure 1, treatment 1 and 2 had the higher growth while treatment 6 (CK) was the shortest in growth.

Data on the effect of treatment on plant weight are shown in Table II.

Fifteen lettuce plants were harvested April 17 from each plot, combined and weighed.

TABLE II

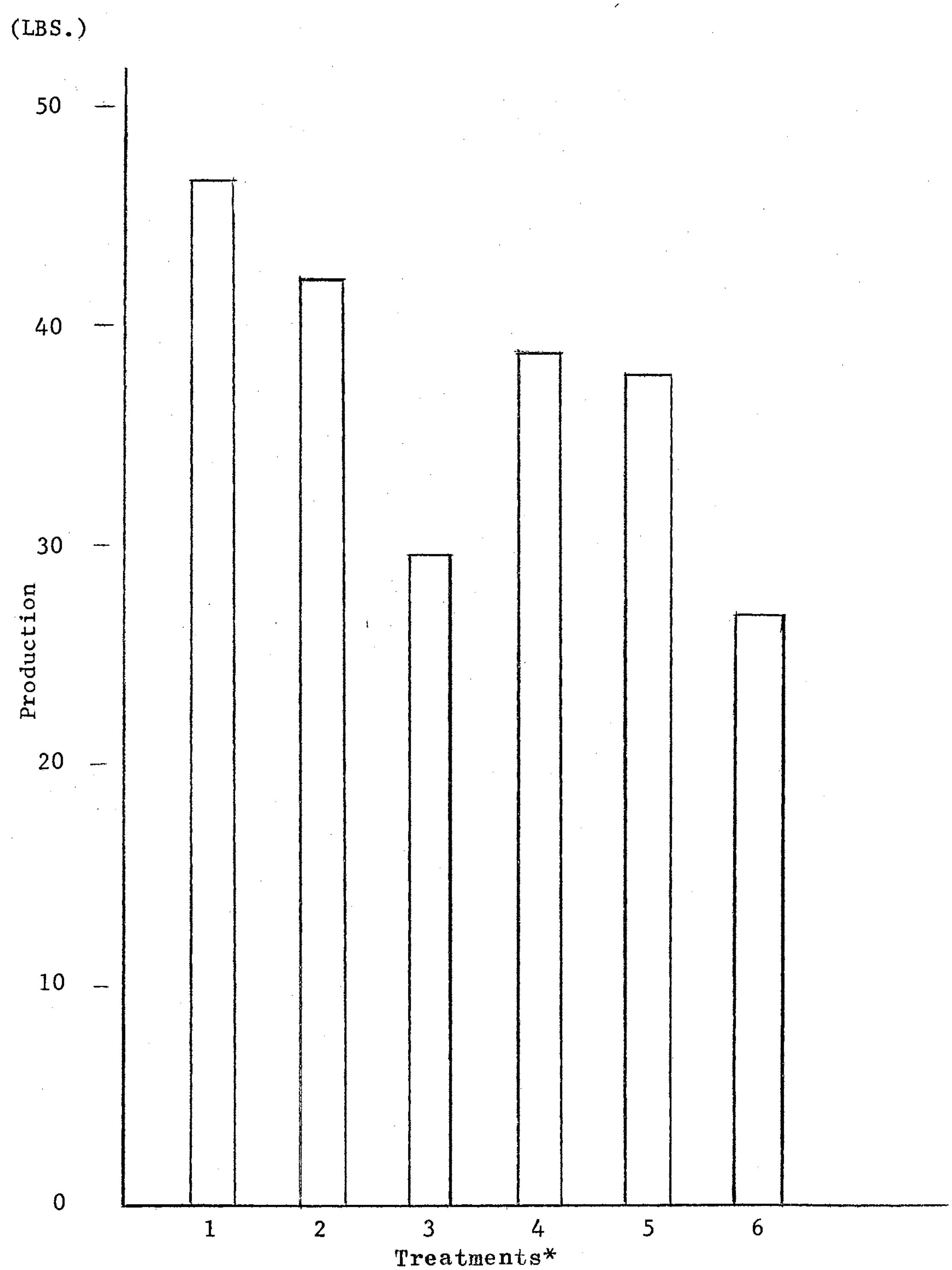
THE EFFECT OF VARIOUS TREATMENTS ON THE PRODUCTION OF LEAF LETTUCE PLANTS, 77 DAYS FOLLOWING SEEDING (WEIGHT IN POUNDS)

Replication	Treatments 1	2	3	4	5	6 (CK)	Total
I	12.19	12.44	9.44	11.06	10.56	6.75	62.44
II	13.50	9.19	6.56	9.75	10.56	7.06	56.63
III	10.75	9.38	7.35	8.88	10.38	7.56	54.31
IV	9.44	10.31	6.31	9.13	6.31	5.75	47.25
Total	45.88	41.31	29.69	38.31	37.81	27.13	220.63
Percentage increase over check	69.12	52.30	9.45	43.09	39.40		

Data in Table II show that the highest yield in experiment I was treatment 1. The second highest was treatment 2. The third was treatment 4, and the lowest yield came from treatment 6 (CK).

The data in Table II are shown in Figure 2 as a histogram to compare treatments.

Figure 2. The comparison of various treatments on the production of leaf lettuce plants eleven weeks following seeding.



*Treatments

1. ML-L
2. M-L
3. TP-L
4. ML-O
5. M-O
6. TP-O

Data in Table II were analyzed by the method of AOV. The results are shown in Table III.

TABLE III

THE ANALYSIS OF VARIANCE FOR THE EFFECT OF VARIOUS TREATMENTS ON THE PRODUCTION OF LEAF LETTUCE IN EXPERIMENT I

Source of Variation	d.f.	S.S.	M.S.	F
Replication	3	19.7324	6.5774	
Treatment	5	62.9949	12.5989	9.4281**
Error	15	20.0447	1.3363	
Total	23	102.7720		

** F value = 9.4281 (highly significant)

Since calculated treatment F value is larger than tabulated F value we can say that there are significant differences among treatments. We compare further by using Duncan's new multiple-range test. The results are shown in Table IV.

TABLE IV

THE RESULTS OF DUNCAN'S NEW MULTIPLE-RANGE TEST
FOR SIX TREATMENTS ON THE PRODUCTION
OF LEAF LETTUCE IN EXPERIMENT I

6	3	5	4	2	1
27.13	29.69	37.81	38.31	41.31	45.88
					———
				———	
		———	———		
	———				

Any two means underscored by the same line are not significantly different. Therefore, treatment 1 is the best among six treatments and is significantly better than the other five treatments. Treatments 4 and 5 are significantly better than treatments 3 and 6. Finally, treatment 3 is better than treatment 6.

Experiment II

In experiment II the lettuce seeds were sown on March 13, 1969. The main purpose of this part was to investigate the influence of supplementary light in spring on the growth and yield of lettuce.

Treatment 1 was geven supplementary light at night during seedling growth stage. The other treatment was not exposed to supplementary light.

The lettuce plants were set in the ground-bed in a greenhouse on April 10.

Five weeks, or thirty-five days after transplanting, on May 15, the lettuce in experiment II was harvested and weighed. The total growing period of the lettuce in experiment II was nine weeks.

Production from the two treatments are shown in Table V.

TABLE V

THE EFFECT OF SUPPLEMENTAL LIGHT ON THE YIELD OF LEAF LETTUCE IN EXPERIMENT II

	Treatments		
	1	2	
Replications	(L)*	(N L)**	Total
I	15.0	15.8	30.8
II	15.0	14.1	29.1
III	15.5	15.4	30.9
IV	15.1	14.6	29.8
Total	60.6	59.9	120.6

It is apparent from the production data that no response resulted from the light treatment.

The photographs taken of experiment I are shown in figures 3 to 7 in the next pages.

*L = Treated by supplementary light during seedling growth stage.

**NL = Not treated by supplementary light during seedling growth stage.

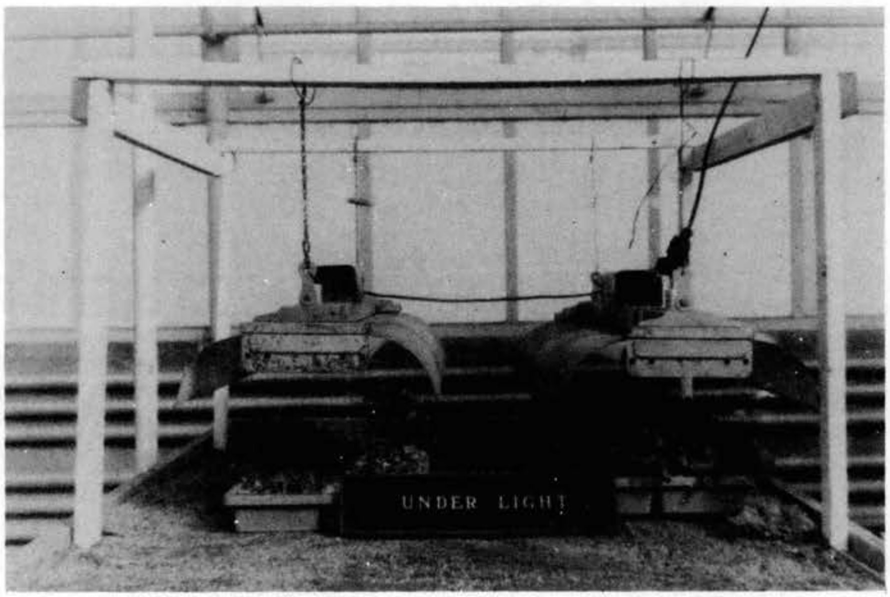


Figure 3. The effect of supplemental light all night on seedling plants of leaf lettuce prior to final transplanting.

Plants at right were from treatment 1 (ML-L), and at left from treatment 3 (TP-L).

Figure 4. The effect of mist plus supplemental light (4, ML-O) and mist plus light, plus supplemental light all night (1, ML-L) during seedling stage on leaf lettuce, 26 days following seeding.

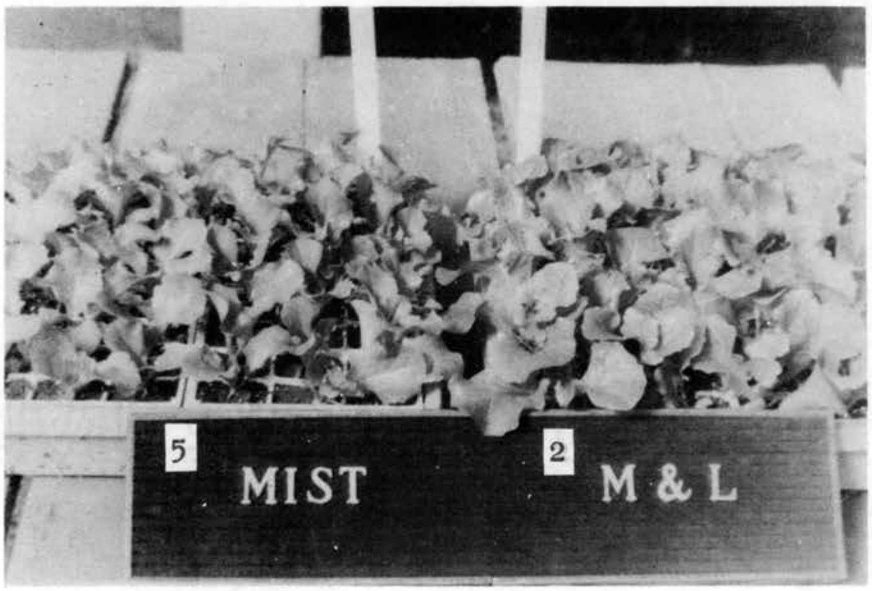


Figure 5. The effect of mist (5, M-0) and mist plus supplemental light (2,M-L) during the seedling stage on leaf lettuce, 26 days following seeding.

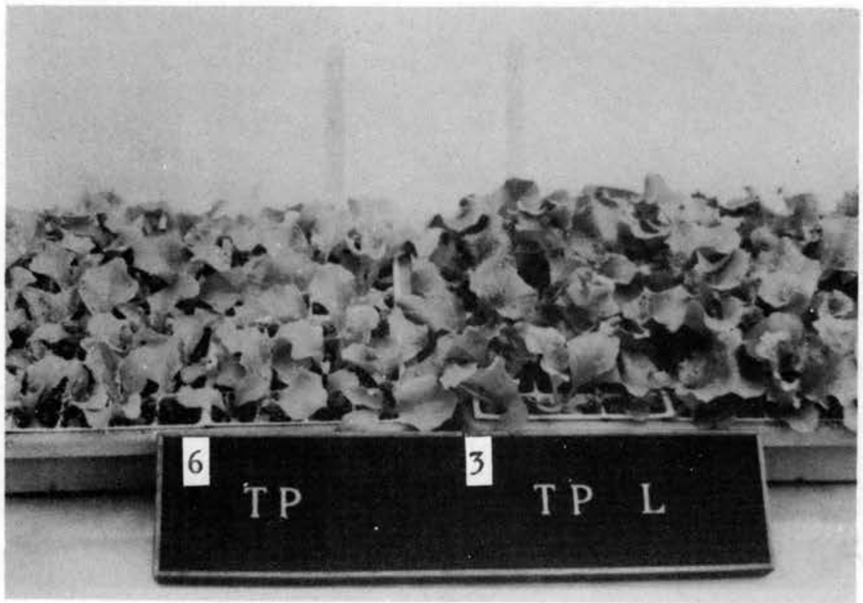


Figure 6. The effect of transplanting (6, TP-O) and transplanting plus supplemental light all night (3, TP-L) during the seedling stage on leaf lettuce, 26 days following seeding.

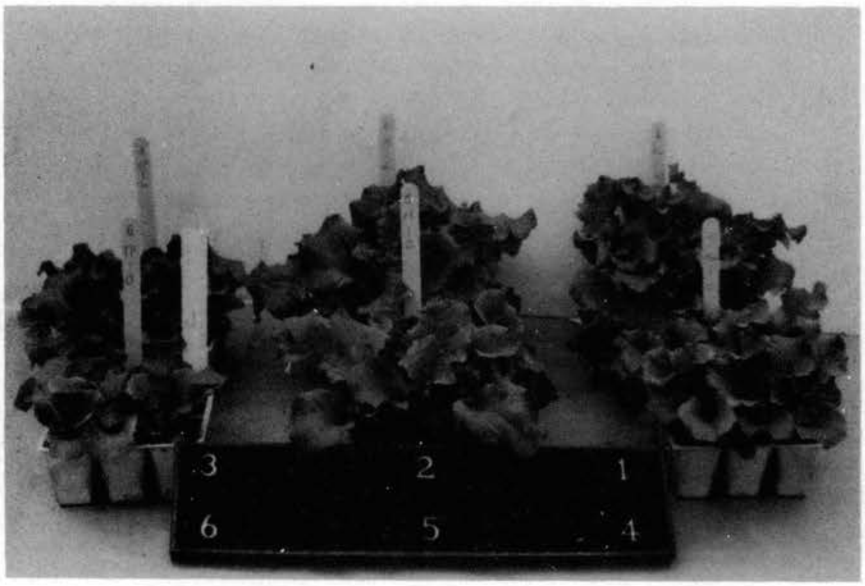


Figure 7. The comparison of the size of lettuce seedlings with different treatments in experiment I.

1. ML-L	2. M-L	3. TP-L
4. ML-O	5. M-O	6. TP-O

CHAPTER V

DISCUSSION AND CONCLUSION

The most satisfactory treatment in experiment I with respect to plant height and plant weight was number 1-intermittent mist plus supplementary light during germination and supplementary light during seedling development. The average height of twenty seedlings in treatment 1 was 8.26 cm., twenty five days following seeding. If treatment 6 (CK) is considered as 100 percent, the percentage of seedling height over the check in treatments 1 to 5 is 154.7 percent, 136.7 percent, 38.7 percent, 72 percent, and 55.6 percent respectively. Apparently, treatments 1 (ML-L) and 2 (M-L) were very effective because of the supplemental light treatment.

The objective in growing leaf lettuce is to get a good crop in a short period of time. In treatment 1 (ML-L), the lettuce seedlings obtained more light than the other five treatments, and responded by making faster growth.

Results of weight from different treatments in experiment I show that in treatment 6 (CK) the total yield was 27.1 pounds. But in treatment 1 the yield was 45.8 pounds. The percentage over check of treatment 1 in experiment I was 69.1%. The percentage over check of treatment 2 was 52.3 percent. The weight increase in treatments 1 to 5 could be supported by the theories advanced by James (12). He suggested: "The speed at which photosynthesis goes on depends upon the concentration of available carbon dioxide, the quantity of chlorophyll, the intensity of light, temperature, and other factors. An increase in any one of them may cause a faster rate. If a brighter light was used, there was a greater response to increase in the concentration of carbon dioxide. During photosynthesis, light is taken up quantitatively and is therefore called one of the conditioning factors of the process."

Data in Table III show the analysis of variance for the production in different treatments in experiment I. The F value is 9.4281 which indicates a great difference among treatments. Furthermore the data in Table II was analyzed by Duncan's new multiple-range test, the order of the production shown in Table IV follows: Treatment 1 is the best among the six treatments and is significantly better than the other five treatments. Treatment 2 was better than the other four treatments (4, 5, 3, and 6). Treatments 4 and 5 were at the same level, but were better than treatments 3 and 6. Treatment 3 was better than treatment 6. Treatment 6 (CK) was the lowest in yield.

Results from treatments 1 and 2 of experiment I might be supported by Meyer's (17) conception: "Photosynthesis will occur under electric light, or other artificial sources of illumination if it is of sufficient intensity. Electric lights are often used in experimental work on photosynthesis and to some extent in greenhouses as supplementary sources of illumination."

In experiment I the lettuce was harvested on April 17, 1969, which was only 77 days after sowing. In the fall of 1968, the author made another test entitled, "A Study of the Effect of Different Methods of Growing Seedlings on Lettuce Production." In that test, the lettuce was harvested on December 23, 1968 and January 8, 1969. These dates were 87 days and 92 days after sowing, respectively.

Data in Table V show the production of two treatments of lettuce in experiment II.

In treatment 1 (L) the yield was 60.6 pounds and the yield in treatment 2 (NL) was 59.9 pounds.

The production of these two treatments was very close to each other. The fact that there was no difference might be due to the photoperiod, which is longer in spring than in winter. The lettuce seedlings that were treated with supplemental light during the night were not visibly different in height.

A very small amount of botrytis rot was evident at harvest time in experiment II. Damage was minor and apparently did not influence results.

CHAPTER VI

SUMMARY

The studies made herein concern the effects of supplementary light on the growth of lettuce seedlings. Six treatments were included in experiment I and two treatments were included in experiment II.

It was evident from the experiments that the height of lettuce seedlings treated by supplementary light grew higher than those in the regular treatment. The greatest height of lettuce seedlings in experiment I was treatment 1 (mist and light plus light during night). The smallest height of lettuce seedlings in experiment I was treatment 6 (CK) (transplanted and no light during the night).

Comparison of the weights among six different treatments in experiment I showed that the greatest yield in production was from plants grown in treatment 1 (ML-L) and the smallest yield in production was treatment 6 (TP-0). Treatment 2 takes the second place in production.

Due to the results shown from treatment 1, 2, 4, and 5 of experiment I the supplementary light was effective in increasing the growth rate for lettuce crops, which were grown in a greenhouse during the winter time.

The growing period of leaf lettuce in experiment I from sowing to harvesting was only 11 weeks. In experiment I, treatments 1, 2, and 4 had the three top figures in production.

The analysis of variance of the production in experiment I indicates that there are great differences among treatments.

The yields of treatments 1 and 2 in experiment II were similar. The production data indicated that there was no appreciable difference in yield between the two treatments--supplemental light during the seedling stage vs no supplemental light.

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