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Electro-horticulture with the incandescent lamp

F. Wm. Rane

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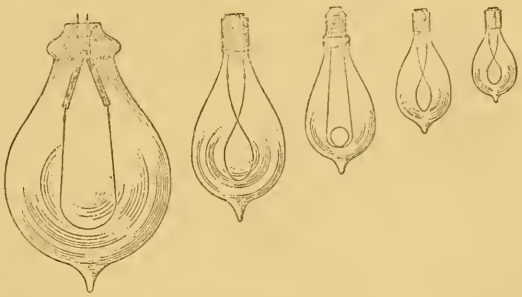

INCANDESCENT LAMPS

By F. WM. RANE.

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ELECTRO-HORTICULTURE

WITH

THE INCANDESCENT LAMP.

F. Wm. Rane, M. S.

Beginning with the fall of 1892, a series of experiments was inaugurated for testing the relations of the incandescent electric light to plants grown in the greenhouse. The experiments that had been carried on up to that time in this country had all been with the use of the arc lamp. *

In using the arc light, there are a number of things which may or may not effect the results obtained. These may be raised as points of variation in the different systems of arc lighting, that is, an experiment carried on with a low tension system may vary more or less from a similar experiment under a high tension system.

The unsteadiness sometimes noticed in arc lights is due to a variety of causes, the principal of which are the following :†

"1. Unsteadiness in the driving power, either arising from variations in the amount of power, or from the slipping of the driving belt.

"2. Imperfections in the working of the feeding mechanism of the lamp.

"3. Impurities in the carbon.

"Unless the carbons are carefully manufactured, they will contain minute portions of materials that are more readily volatilized than those forming the main body of the carbon. When such portions are reached, their sudden volatilization gives a marked variation in the intensity of the light."

"Much of the unsteadiness of the arc light is due to the traveling of the arc from one side of the carbon pencil to the other, so that an observer on one side of the lamp will at one moment see the intense light caused by the arc appearing on the side nearest to him, and at the next moment will be exposed to a much less brilliant light by the arc moving to the side furtherest from him. This is especially the case when the carbons are thicker than necessary."

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* Cornell Experiment Stations Bulletins, Nos. 30. 42 and 55.
† Electric Measurements, Houston. page 159.

Improvements are continually being made, and no doubt in time these inherent variations in the arc light will be overcome.

There are other points about the arc light which are somewhat objectionable when applied to practical and economic greenhouse work; some of which are as follows:

1. Expense.
2. They consume time keeping them in order.
3. Bulkiness.
4. More danger in handling in a regular series arc system but less in an incandescent arc system.
5. Unhandy to shift.
6. Often unpleasant, buzzing noises.
7. If placed inside the greenhouse, it must be more than 14 feet away from the growing plants, unless covered by an opal globe.*
8. If placed outside the glass roof difficulty is experienced with the film of moisture which condenses on greenhouse roofs at night and obstructs the passage of light. †

In reviewing the experiments already carried on with the arc light, it was suggested that there were points in the use of the incandescent light, provided it could be substituted in these experiments, which were preferable.

The first thing necessary was to make a study of the two systems of electric lighting-arc and incandescent, and state wherein they differed. This could extend over a wide range of the electric lighting science, but the essential difference concerned in the present paper is that in the arc light chemical rays predominate, while in the incandescent light, these are only slightly present. The supposition, therefore, is that the arc contains in its light properties that render it much nearer sunlight and therefore its action upon plant growth is superior to that of the incandescent lamp.

Prof. L. H. Bailey found in his first experiments* that the nearer the plant grew to the naked light, the greater was the acceleration. The plants "ran to seed" before edible leaves were formed, and were smaller and curled. When an opal globe was placed about the light† the effect of the plant's proximity to the lamp was overcome, and a beneficial effect was given lettuce, while the other plants continued to run to seed, although they showed a much healthier lateral growth.

In his second report,‡ the results of an experiment with the arc light placed outside of the glass roof, are given. In this experiment, the light was six feet above the nearest glass. The lamp carried a clear glass globe so that the light passed through two panes of glass—the globe and the roof—before reaching the plants. The results from this experiment were beneficial to almost all plants.

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* Cornell Station Bulletin No. 30, Page 91.
† Proc. Royal Soc. XXX. 210 and 293. Rep. British A. A. S. 1881, 474

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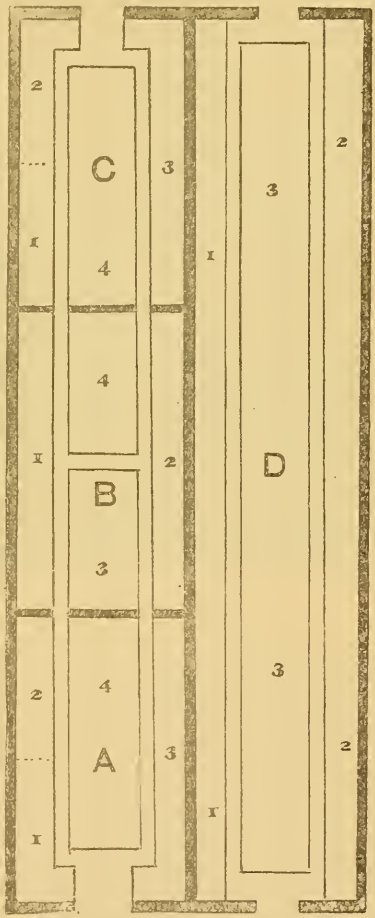
* Cornell Experiment Station Bulletin No. 30. p. 87.
† Cornell Experiment Station Bulletin No. 30. p. 96.
‡ Cornell Experiment Station Bulletin No. 42 p.

Experiments at the Station.

For the purpose of carrying on these experiments, houses A, B, & D (see plan) were wired and connected with the incandescent system of the city. Houses A & B are practically one, being separated by a glass partition only. Their width is twenty feet. The walks inside are 2 feet in width, leaving the side beds nearly 4, and the center bed 8 feet wide.

During the season of 1892 and '93, houses A & B were the only ones used. At first, the light was placed in house A, while house B was used as the dark house. In the latter part of the season the use of the houses was reversed. At night a curtain of rubber cloth hung over the glass partition served to keep one house in darkness. Both houses were heated and ventilated with the same apparatus, and the same soil was used in each. The houses are all ½ span and extend from north to south, bearing slightly to the N. E. and S. W. The beds in each house are represented by the figures 1, 2, 3, & 4, as shown in the diagram In each instance the light was suspended from the peak of the house, and hung two and one-half feet above the bed.

In the first experiment the light was directly over the center of bed 4, house A, during the fore part of the season, and over bed 4, house B, in the latter part. The light used the first seven weeks was a 16-candle power Buckeye. During the remaining time of experimentation a rosette of seven lights, similar to the above, was used. By this arrangement, we were enabled to use one light only, or any combination of the seven lights, each representing 16 candle power. Their combined strength was, of course, equal to 112 candle power, and we had the choice of either 16, 32, 48, 64, 96, or 112 (candle) power.



PLAN OF GREENHOUSE.

The number of hours the light ran during 1892-93 is as follows :

Dates.	Number Hours per Night.	Dates	Number Hours per Night.
January 9– 10	12	Febru'ry 15	12
" 11	3	" 16	6
" 12	12	" 17– 24	—
" 13	0	" 24-Apr. 7	12
" 14– 17	12	April 8–May 7	11½
" 18	0	May 8– " 11	10½
" 19	13	" 12 – " 14	0
" 20– 21	7½	" " " 15	10½
" 22	11½	" " " 16	0
" 23 - 26	8	" 17– " 20	10½
" 27– 29	12½	" 21– " 26	0
" 30–Feb. 10	13	" 27 - " 28	10½
Febru'ry 11– 14	0	" 29–June 4	11½

General Experiments.

Our selection of plants to be used in these experiments was partially governed by those already tried under the arc light. Therefore, such plants as lettuce, endive, beets, radishes, spinach, cauliflower and various ornamental plants were selected.

Lettuce.

On the 8th of December '92, the seed was sown. When sufficiently large, it was transplanted into trays, the plants being placed two inches apart. January 9, it was permanently put into beds 4, house A and 4, house B By this time, the plants contained from three to five leaves each. On the following day, a single lamp was suspended over bed 4, house A, in the manner described above. Cut 1, is a reproduction of a photograph taken to show the condition of the beds at the beginning of the experiment. The behavior of the plants was watched closely throughout and notes taken at various times. I neglected to say that two varieties of lettuce were used in each bed, the Black-seeded Simson and the Hanson. House A, contained 13 rows of Simpson and 14 of Hanson, while house B, contained 4 of Simpson and 15 of Hanson.

Cut 1. At The Beginning.

In comparatively few nights, it was thought that the lettuce in house A began to show the effect of the light. This was apparently more noticeable within a short radius of the lamp. The lettuce appeared more erect, although not so much difference was shown in its growth. This was at the end of the first week. From this time on the difference was easily detected by all who visited the houses. The lettuce in the dark house, notedly the Hanson variety, seemed to spread more, was of a deeper green in color, and was much different in appearance from that grown under electricity. The Simpson variety in the same bed stood up much better, but the contrast was not so great, although the same characteristics were presented.

On February 8, general notes were taken on both beds, and the crop of lettuce harvested in house A. As far as observation could determine, it was thought that the efficacy of the light terminated at a distance of 8 feet. From the centre of the bed, at which point the plants were highest, to its outer edges, there was a very gradual diminution in height. However, at the extreme edge of the bed, the plants

were very perceptibly smaller than those next to them. This may be due to one of several causes. Possibly those plants derived no benefit from the light on account of their distance from it, or having possibly been stunted in growth from the first by contact with the wearing apparel of persons passing through the houses, they were shaded by those next them, and therefore received no direct rays. They were also of a deeper green, similar to those grown in the dark house. This difference in coloring was probably caused by their stunted growth, and the absence of direct rays.

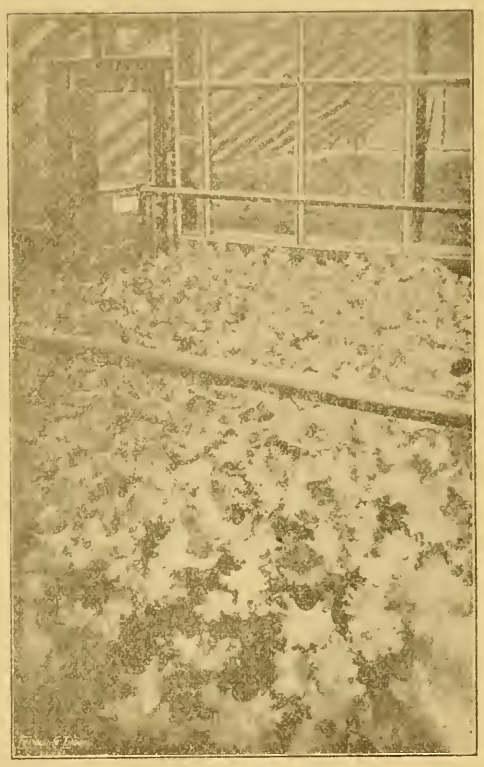
The average height of the Simpson lettuce in the dark house was 10, and the Hanson 9 inches. In the light house, the same varieties measured 11½ and 10½ inches respectively. The tallest plants were not taken in either case, only an average height. When transplanted the last time, they were placed 6x7 inches. The average weight of the crop in house A was as follows: Hanson 2 ounces, and Simpson 1.8 ounces per plant.

The lettuce in house B was harvested on Feb. 14. Hanson gave an average weight of 1.8 ounce, while Simpson, although of good appearance, weighed only 1.5 ounces per plant. Although the dark house was given six days more for maturing, yet the light house produced the greater weight per plant. The light was used in this experiment 300 hours.

The Second Crop.

After the first crop was harvested, the same beds were again put in order and filled with transplanted lettuce. These plants like those in the former experiment, were about six weeks old when transplanted, and had from three to five leaves. They were set the same distance apart, 6x7 inches. This time three varieties were used in each bed, viz: Grand Rapids, Hanson and Tennis Ball.

The light used was a cluster of seven bulbs, each similar in every respect to that used in the former experiment. We therefore had seven times as much light as in the former experiment, or 112 candle power instead of 16. It was not turned on until the plants had thoroughly established themselves, and were growing. This was on February 24. March 10, photographs of both beds were taken, from which cuts were prepared. See cuts 2 and 3. Cut 2, Dark House Bed, and 3, Light House. The difference in growth seen in the photographs is therefore due to the use of the light for exactly two weeks. The light was on regularly as in the former experiment, from 6 p. m. until 6 a. m., and consequently represents a light of 112 candle power running 168 hours.



Cut 2, Dark House.

On March 17, average measurements were taken of each bed. In house B, (Dark House) Grand Rapids measured 10, Hanson 6 and Tennis Ball 7, inches. In house A (Light House) Grand Rapids measured 13, Hanson 10 and Tennis Ball 9, inches.

Cut 3, Light House.

The growth in the light house, unlike the previous experiment, was very even throughout. The only plants that fell behind were one or two at the corners of the bed, which presented the same characteristics mentioned in the first experiment. Their condition is thought to be due to the same cause. The effect of the light seemed to be most beneficial to the Grand Rapids variety. It was more erect, and the soil was free from decaying or damping off leaves. The Hanson came next and lastly the Tennis Ball. This last variety matured prematurely; the leaves damped off and were sun-scalded; and it was necessarily harvested earlier than the other varieties. All the electric light lettuce was thought to be much more tender than that in the other house.

The Tennis Ball variety in house A was harvested on March 17. Fifty-six heads weighed 14 pounds, the average weight of each being 4 ounces. The same variety in house B was not mature at this time, and therefore was not harvested until March 29. Fifty heads weighed 14.4 pounds, the average weight of each being 4.6 ounces. The time between the two harvestings or twelve days represents, therefore, .6 ounces or an average of .05 ounce per day in favor of the dark house. The whole period of growth, or 43 days from the time of transplanting, February 14 to March 29, date of maturity, represents an average of nearly .1 ounce per day. We know that a lettuce plant increases in weight more rapidly in the latter days of its growth. Therefore, the excess in growth can not be represented by .05 ounce per day, but must have been far greater. Now if the 12 days time were given the light house toward another crop, a growth of 1.32 ounces would result, the ratio of growth being the same as before. Therefore, we must represent the comparative growths in house B and A by the ratio, 4.6 ounces: 5.3 ounces. In plainer terms, the light house was 1-6 better in weight. The electricity was used in this experiment 564 hours.

The Hanson variety was harvested in house A, March 22, and 54 heads weighed 16.9 pounds, averaging .5 ounces each. The same variety in house B was not harvested until 7 days later, when 34 heads weighed 9.4 pounds., averaging 4.6 ounces. Using the same method of computation as before, the growth in houses B & A is represented by the ratio 4.6 ounces: 5.9 ounces. In plainer terms, the weight under light is one fourth greater. Caused by 564 hours light.

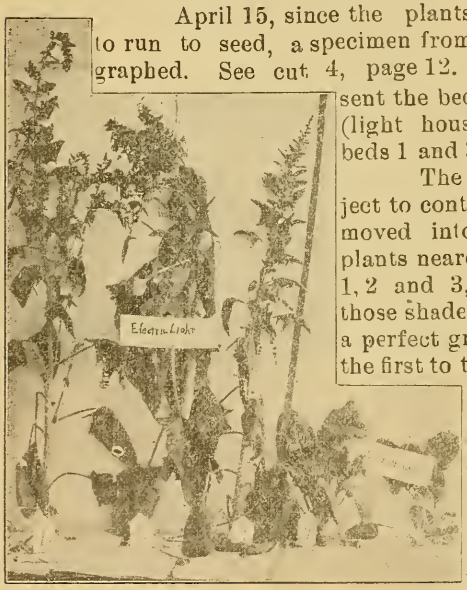
The Grand Rapids was first harvested in house A March 20 and the last was taken off March 25. 196 heads weighed 51.9 pounds, the average being 4.2 ounces per head. In house B, it was first harvested March 22, and the last was taken off April 1st. 135 heads weighed 31.7 pounds, the average for each plant being 3.7 ounces. The majority of the plants were taken off towards the latter date, and were consequently in the bed a longer time. Not taking this into account, the ratio 4.2 ounces: 3.7 ounces, represents the comparative growth in houses B and A; or the light house gave one-eighth more weight. This difference was due to the use of the light 516 hours, or until the last plants were harvested.

A third test of lettuce was commenced, but the experiment was not fully completed. Since the sun was very warm at the time of transplanting (April 8) tomato plants were made to serve a double purpose, both to protect the lettuce and to produce a crop of fruit. They were placed 18 inches apart, with the lettuce underneath. They were pruned at the base to give the lettuce growing space; but since trimming at the top would have ruined the fruit, the lettuce test was given up. However, it started off nicely in both beds; in fact, this was the first time the bed in house B came up to the standard. The beneficial effect of the light was very plainly evident.

Spinach.

On February 28, 1893, Round Summer Spinach plants were placed in both houses A and C. In house A, two rows were planted in each of beds 1, 2 and 3; and in house C, in beds 1 and 2.

The plants were started in the greenhouse from seed, and were put into two-inch pots before finally transplanted. The beneficial effect of the electric light was soon evident here also. March 21, measurements were first taken of the plants in each house with the following results: House C (dark), bed 1, 4 inches; bed 2, 4 inches. House A (light), bed 1, 7½ inches; bed 2, 11 inches; bed 3, 9 inches. One week later, March 28, measurements were again taken as follows: House C, bed 1, 6 inches, with no seed stalk; bed 2, 5 inches, with dark green foliage. House A, bed 1, 10 inches; bed 2, 16 inches; and bed 3, 11 inches.



CUT 4. SPINACH.

April 15, since the plants in house C had commenced to run to seed, a specimen from each of the beds was photographed. See cut 4, page 12. Numbers 1, 2 and 3 represent the beds of like numbers in house A, (light house) while 3 and 4 represent beds 1 and 3 in house C.

The plants in house A were subject to continuous light until it was removed into house B, April 8. The plants nearest the light in each of beds 1, 2 and 3, house A, were larger than those shaded by them. There was almost a perfect graduation of the plants from the first to the last. In bed 1, the tallest was 3 feet, the average, however, for 14 plants being 1 foot 3 inches. In bed 2, the tallest was 3 feet 6 inches, the average of 14 plants 3 feet. In bed 3, the tallest, 2 feet 10 inches, average 1 foot 6½ inches. Bed 2, in addition to the advantage of electric lighting, was watered by sub-irrigation, while the others were not. The plants in each bed of house C averaged from 5 to 6 inches and ran very evenly.

From these experiments, we conclude that spinach is particularly influenced by the electric light.

Cauliflower.

Cut 5,
Cauliflower in Light.

February 28, plants of Early Erfurt cauliflower were transplanted from pots into beds 1, 2 and 3, house A, and beds 1 and 2, house C. They were subjected to the same amount of light as the spinach; in fact, they occupied portions of the same beds. Measurements of these were taken on the same dates as the spinach with the following results.

	House A (Light).			House C (Dark).	
Date	Bed. 1	Bed. 2	Bed. 3	Bed. 1	Bed. 2
March 21	8 in.	13 in.	12 in.	8 in.	8 in.
March 28	11 in.	19 in.	15 in.	10 in.	10 in.

The first plant flowered in bed 1, house A, on April 16; the second, however, was in bed 1, house C, on the following day. From this time on, no regularity in time of flowering was evident in any of the beds; it was very even throughout. The plants nearer the light were more spindling and produced a much smaller flower head than those in the dark house, and also than those in the light house that were shaded. Cuts 5 and 6, pages 13 & 14 represent plants from the sub-irrigated beds, taken from similar positions in the beds of the light and dark houses respectively. In the ordinary surface-watered beds, there was the same contrast, although the plants were not so tall. The cauliflower, therefore, although its growth was taller in the light, did not produce as fine heads as that in the dark house and shaded portions of the light house.

Cut 6,-Cauliflower in Dark.

Beets.

On January 7, 1893, six rows of young Early Blood Turnip beets were transplanted into bed 3, house C, and four rows into bed 3, house A. They were allowed to grow until harvested on April 12. At this time the roots in the light (house A) were practically identical with those in the dark (house C) but the tops in house C were eight inches shorter than those in the other house. In proportion to the weight of the plant as a whole, the dark house contained the greater percentage of root In both houses, the plants were very tall, averaging 3 feet in house A, and 22 inches in house C.

February 28, the same day that both spinach and cauliflower were placed in beds 1, 2 and 3, house A, and beds 1 and 2, house C, one row of Eclipse beets was also transplanted into each of the same beds. Measurements taken at the same dates as the other plants were as follows :

Date.	Light House.			Dark House.	
	House A,			House C,	
	Bed 1.	Bed 2.	Bed 3.	Bed 1.	Bed 2
March 21	8 in.	9 in.	8 in.	8 in.	8 in.
" 28	10 in.	11 in.	10 in.	10 in.	11 in.

No great difference is shown. These beets were harvested April 21, and the average weights of the marketable beets in each bed were as follows:

Date.	House A (Light).						House C (dark).			
	Bed 1.		Bed 2.		Bed 3		Bed 1.		Bed 2	
	No. Beets	Av. Weight oz	No. Beets	Av. Weight, oz.	No. Beets	Av. Weight, oz	No. Beets	Av. Weight, oz.	No Beets.	Av. Weight, oz.
April 21	8	3 2	10	1.6	6	1.4	12	1.3	16	1.4

By the above table, we see that in the light house greater individual weight was secured in a few instances, but that in the dark house a greater number of average, marketable beets were found. When pulling the beets in the light house, we noticed that the plant on the outside edge of the bed and nearest to the light gave a larger root in each bed. Their weights were 6.4 oz., 2.4 oz. and 3.2 oz. in beds 1, 2 and 3 respectively. By comparing these with the tables, it will be seen that they exceed the average weight.

We then examined the plants in the dark house and found that the same difference existed here to a certain extent, although no electric light was present. The weight of the first beet at the outer edge of beds 1 and 2, house C, was 1.6 oz. and 2.4 oz. respectively. The position of the plant as regards both sunlight and electric light was important. The plants were doubtless too close together. Beets take considerable time to mature in the greenhouse, and hence are not a profitable crop as far as the vegetable itself is concerned.

Radishes

March 2, two rows each of Olive Carmine, Early Short Top, and Early Blood Turnip Radishes were planted in beds 1, 2 and 3, house A, (light) and in 1 and 2 (dark). They ran comparatively evenly in top growth, and on March 28 gave the following results:

Variety.	House A (Light).						House B (Dark).			
	Bed 1.		Bed 2		Bed 3.		Bed 1.		Bed 2.	
	No. Matured.	Av. Weight, oz.	No. Matured.	Av. Weight, oz	No. Matured.	Av. Weight, oz.	No. Matured.	Av. Weight, oz.	No. Matured.	Av. Weight, oz.
Olive Carmine..	55	5.1	50	4.8	40	3.2	29	3.8	50	4 1
Early Scarlet Short Top	16	1.6	5	2.2	16	1.4	7	1.6	13	2.2
Early Blood Turnip.....	23	1.1	12	.6	12	.5	26	.8	23	.8

No deductions can be made from this table to prove that the light was either especially beneficial or harmful. We now believe that if we had transplanted the plants into the beds instead of sowing the seed, the conditions would have been better for any possible difference to manifest itself. Besides the above, numerous other plants were carried into the light house at night, but there was no perceptible difference in these, due, we now think, to our not carrying on the experiment long enough.

Season 1893–4.

In October of this year arrangements were made to carry on the incandescent light experiments in House D. The wiring and other preparations were completed by November 1st. The cluster of seven lights used last year in Houses A and B was hung directly over bed 3 in the central portion of the front or south half of the house. A single sixteen candle power bulb was also hung directly under the bed. I neglected to state in explaining the plan of the houses that while the side beds in this house are at the usual height (2½ feet), bed 3 is placed at a height of 4 feet. This gives considerable space beneath the bed which receives some direct sunlight both in the morning and afternoon.

The north end of the house was shut off from the other, and consequently from the light both above and below the beds, by a curtain of black oilcloth, which was removed during the day. All the beds in this house were watered by the method of sub-irrigation, porous tile being used to convey the water, which was poured in at one end of the bed.

November 4. Bed 3 was mostly filled with lettuce, the varieties used being the Simpson and Grand Rapids, the seed of which was sown September 12. The plants were set 6x7 inches as in the previous experiments. One row of each of the following was planted in both the light and dark portions of bed 3:

November 9. Bliss American peas. From seed.
Thornburn's Early Refuge beans. From seed.
Prickly-seeded or Fall Spinach.

These were transplanted from the garden from seed sown October 2.

Endive transplanted from trays, the seed sown October 5.

November 10. White Box Radish. Transplanted from trays; seed sown October 28.

Cuttings of Coleus. These were started October 21.

On this date, also, two plants of the following varieties were selected from house B for this experiment; Martha Washington Geranium, Strabilanthes Anisophyllus, Echeveria, Heliotrope, Marguerite Daisy and Begonia. One was placed in the light, and one in the dark house as above. They were in 4 and 6-inch pots, and instead of being transplanted into the bed were placed upon boards. The plants were as near alike as possible, and if there was thought to be any difference the preference was given the dark side. The light was first turned on November 7. The following table gives the number of hours of its use throughout the experiment:

1893-4.

Date.	No. hours per night.	Date.	No. hours per night.
Nov. 7-10	13	Dec 1—Feb. 13	13
" 11	6½	Feb. 14	0
" 12-17	13	" 15—Mar. 12	13
" 18	6½	Mar. 13	0
" 19-28	13	" 14—28	13
" 29-30	0	" 29—Apr. 22	12½
		Apr. 23—May 4	12

The plants apparently started off nicely, and their condition appeared about the same However, when in a few days we found the peas and beans germinating in the dark portion of the bed, and no signs of any in the light, we investigated the matter, and found that nearly one-third of bed 3 was a trifle lower at the dark end than elsewhere. The caution given to make the beds level had been unheeded. This soil, therefore, contained considerable more moisture than the other portions of the bed. The tiles used in sub-irrigation were cemented part way up at the lower portion of their joining, which we found useless, as it did not allow of sufficient diffusion of water at these joints.

The bed was built of heavy iron framework, and, as it had been filled with dirt, it was impossible to remedy the matter; consequently the experiment was allowed to go on under these unequal conditions. While this excess of moisture was objectionable for those plants directly transplanted into the bed, it did not, of course, alter the conditions of those in pots.

Beans and peas germinated from three to four days earlier in the dark than in the light, and all made their appearance at about the same time. Those in the light were irregular in coming up.

November 27. Beans and peas were much more even in the dark, and were also in advance.

December 13. Average height of peas in dark, 6 inches; in light, only 5 inches. Beans in dark ready to bloom; in light, much behind.

December 18. Peas were advancing rapidly under light.

December 21. Beans began blooming in light; in dark, had been in bloom four days.

December 22. Peas in both light and dark began blooming. Those under light blossomed more profusely.

December 27. Beans in dark bearing freely; in light blossoming freely, but no marketable pods.

January 1. Beans in light began to bear.

January 3. Peas in light had more bloom, and larger pods set than in dark; also taller in light.

The beans under the light were not able to overtake those in the dark. The difference in moisture, therefore, had more effect upon their growth than the difference in light.

The peas under the light, although from 3 to 4 days behind in starting, overtook those in the dark and blossomed at the same time. They also gained on those in the dark and produced on the whole larger pods.

Spinach.

From the very first the row of spinach plants seemed to be affected by the light. Those under the light started to seed immediately, and on December 13, the light plants—17 in all—averaged 12 inches in height and were in blossom. At this time the plants in the dark were making a perfectly normal and finely solid growth.

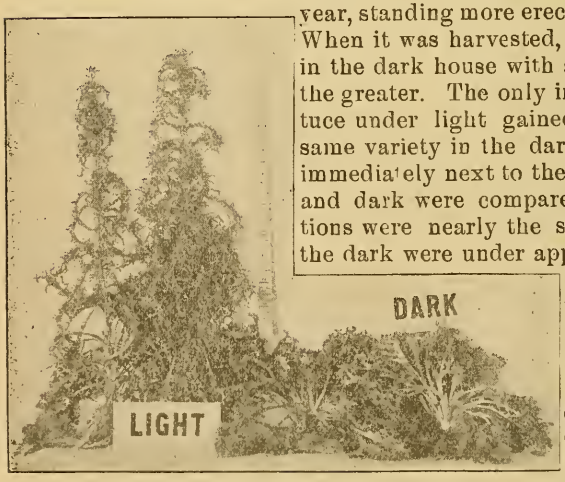
Endive.

The plants under the dark gave the best results throughout the experiment. They grew thick and massive, making a beautiful salad. Those in the light were more spindling, and were of a lighter color. Cut 7 represents the plants in the light and dark respectively. When that in light was in blossom the dark house endive had not started.

Endive is rather slowly affected by the light in comparison with the spinach, and even more slowly than lettuce, we think.

Lettuce.

The lettuce under the electric light assumed the same characteristic form and appearance as in the previous year, standing more erect and taller in growth. When it was harvested, however, the weight in the dark house with a few exceptions was the greater. The only instance where the lettuce under light gained in weight over the same variety in the dark was when the rows immediately next to the curtain in both light and dark were compared. Here the conditions were nearly the same. The plants in the dark were under approximately the same conditions as those in the light that were farthest from the lamp.



CUT 7. ENDIVE.

December 12, eighty-eight heads of Grand Rapids lettuce were harvested from the position stated above in both dark and light; the weight in the former being 20 pounds and in the latter 20 pounds 13 ounces.

The plants grown in other parts of the beds favored the dark side of the house; in some instances almost doubled in weight.

The question, therefore, of watering lettuce is even more important from an economic standpoint than that of lighting by electricity; but when both are favorable an ideal condition is approached.

Radishes.

The radishes in the dark far surpassed those in the light in every respect—smaller tops, a much larger root, earlier in maturity and of very even growth. Those in the dark were in the lowest and dampest soil of the bed, and proved conclusively that they flourish in a more moist soil. Moisture will do more toward maturing the White Box Radish than an ordinary bed+electric light.

Coleus Cuttings.

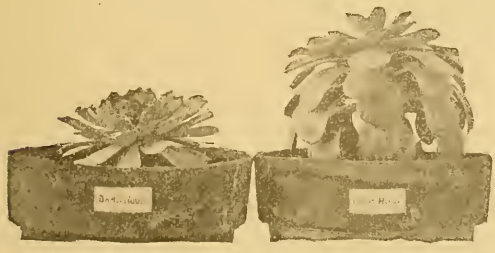
Those in the dark bed were taller and produced better plants. Their heights were as 7 is to 4. Like radishes, they enjoy a moist soil.

Potted Plants.

Heliotrope blossomed first under light on December 13, and not until January 3 in the dark.

Martha Washington Geranium, much advanced in light beyond that in the dark by the 13th. On December 18 it was in bud in the light, but was unable to blossom and the buds fell off. That in the dark house showed no signs of budding. The plants were removed about February 1, on account of their mammoth proportions; that in in the light was fully ⅓ larger. They were placed underneath the beds in the greenhouse, and in a short time the light plant began to bloom. The light was thought to show its effect quite plainly upon this plant.

The Daisy was in bud under the light December 13; none in dark. On January 3, the former was in full bloom, while the later was in bud for the first time. These plants were cuttings from the same plant made at the same time.



Cut 8. Echeveria glauca.

Verbenas blossomed first in light on January 3; no signs of blossoming in dark until a much later date.

Echeveria glauca. These plants showed a marked contrast. After having been under the light from November 10, until December 13, the light plant had made a far better growth than that in the dark Cut 8 is a photograph of the two plants taken the first of February.

Begonia. No preceptible difference. Both plants remained nearly equal.

Strobilanthes anisophyllus. The plant under light was in full bloom by November 27. That in the dark had not put forth a single

bud, nor had any of the numerous plants of the same in the other house. In order to test this plant more fully, another was paced under the light November 27. December 18, it began to bloom, while that in the dark had not yet expanded a single bud. The first plant was still blooming, and the bed beneath it was strewn with fallen petals. December 23. The plant in the dark first blossomed. The Strobilanthes anisophyllus, therefore, appeared to be particularly fond of the light.

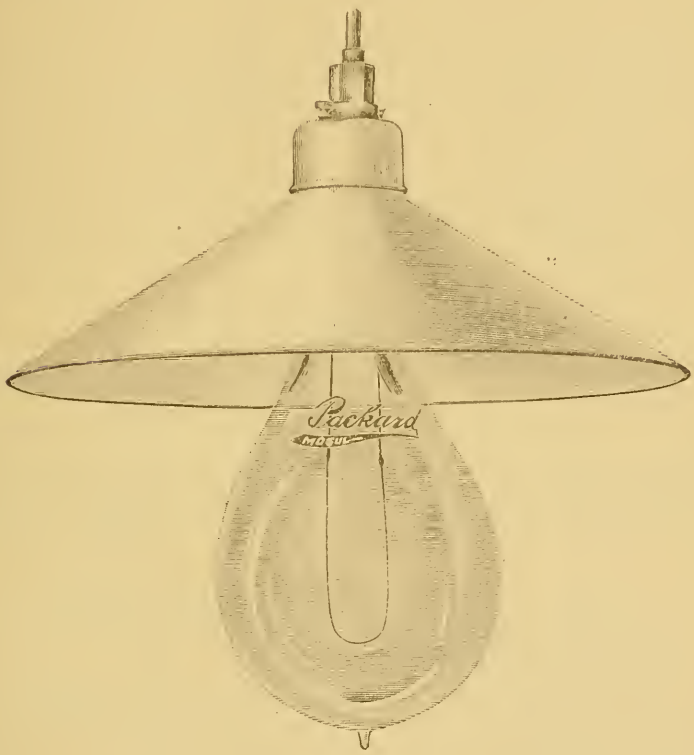
Experiments Under Bed 3.

It was thought that by raising the bed, a sufficient amount of sunlight would be admitted to grow many plants, such as rhubarb, asparagus, etc; and when wiring house D, it occurred to us that by the addition of electric light, such plants as mentioned could be grown with profit. Thus the space would be fully utilized. As already stated, a 16 candle power lamp was hung under the bed, and plants of lettuce, radishes and endive were placed in the soil on the ground the same distance apart as in the bed above. The light was turned on November 7.

The plants did not receive enough sunlight, and in every instance ran up spindling. The plants under the light were possibly not as good as those in the dark; therefore no beneficial results from the light were visible Further experimentation along this line will be carried on next year with a stronger light.

Range of Candle Power.

The range of candle power in incandescent lamps can be procured at present from as low as five-candle power up to that of 500 in a single lamp.



CUT 9: 500-CANDLE POWER.

Cut 9 represents a 500-candle-power lamp

*The points claimed for the high candle power lamps as compared with the 16 candle-power lamps are as follows:**

1. "The cost of lamp per candle power is less

2. "The cost of wiring per candle power is less.

3. "The saving in current will, on the average, pay for the renewal of the lamp.

4. "When burning at the same incandescence the life is longer.

5. "With the same dynamo and engine power, a third more light can be obtained.

*New York and Ohio Company's Catalogue, page 19 1894.

*The same lights compare with arc lamps in opal globes as follows:**

1. "Absolutely steady light.
2. "No dead resistance in circuit.
3. "Does not have to be burned two in series on 100 volts.
4. "The color of light is much pleasanter, and it casts no sharp shadows.
5. "Will give nearly two-thirds the light and a more satisfactory illumination *with the same expenditure of power.*
6. "Renewals will cost no more than the carbons and trimmings of an arc lamp.
7. "No carbons to replace every day, and requires no attention from the time it is installed until it burns out.
8. "Requires no special transformer to be used on alternating current, and is absolutely noiseless."

Experiments Elsewhere.

Before going further, it is thought best to give the recapitulations and conclusions reached by experimenters up to date.

"The first experiments to determine the influence of electric light upon vegetation made by Hervé-Mango in 1861.* This experiment showed that the electric light can cause the production of chlorophyll or the green color in plants, and also that the light can produce heliotropism, or the phenomenon of turning or bending toward the light."

In 1869 Prillieux* showed that the electric light, in common with other artificial lights, is capable of producing assimilation, or the decomposition of carbon dioxide and water.

Dr. C. W. Siemens in England carried on experiments‡ with the arc lamp both inside and above the greenhouse. When placed inside the house, he found the 4,000 candle power light harmful when naked, but when a clear glass globe was used, it was satisfactory. When a 1 400 candle power was placed outside and ten feet above the roof, similar results were secured. In all cases those plants exposed to both sources of light showed a decided superiority and vigor over all others, and the green of the leaf was of a dark, rich hue. Electric light appeared to be about half as effective as daylight. A difficulty was experienced when the lamp was outside the house by the film of moisture which condensed on the greenhouse roofs at night and obstructed the passage of the light. Dr. Siemens concluded that a lamp of 1,400 candle power produced a maximum beneficial result on vegetation at a distance of nearly ten feet above the glass, but the effect is nevertheless very marked upon plants at a greater distance."

*New York and Ohio Company's Catalogue, 1894, page 20.

*Compt. Rend. 53,243.
†Compt. Rend. 69,410.
‡Proc. Royal Soc. XXX. 210 and 293. Rep. British A. A. S. 1881, 474.

In reviewing Dr, Siemens, Prof. L. H. Bailey gives the following.* "At the close of his experiments Siemens was very sanguine that the electric light can be profitably employed in Horticulture, and he used the term "electro-horticulture" to designate this new application of electric energy. He anticipated that in the future "the Horticulturist will have the means of making himself practically independent of solar light for producing a high quality of fruit at all seasons of the year." He had shown that growth can be hastened by the addition of electric light to daylight, that injury does not necessarily follow continuous light throughout the 24 hours, that the electric light often deepens the green of leaves and the tints of flowers, and sometimes intensifies flavor, and that it aids to produce good seeds; and he thought that the addition of the electric light enabled plants to bear a higher temperature in the greenhouses than they otherwise could. But whatever may be the value of electric light to Horticulture, the practical value of Siemens' experiments is still great. They have furnished data in several obscure relations of light to vegetation."

Deherain's experiments † were conducted at the Exposition d' Electricite, Paris in 1889. A lamp of 2,000 candle power was used. His general conclusions of the influence of electricity upon plants are as follows:

"1. The electric light from lamps contains rays harmful to vegetation.

"2. The greater part of the injurious rays are modified by a transparent glass.

"3. The electric light contains enough rays to maintain full grown plants two and one-half months.

"4. The light is too weak to enable sprouting seeds to prosper or to bring adult plants to maturity.

Observations made on the influence of electric light upon plants in the winter palace at St. Petersburg* showed that in a single night ornamental plants turned yellow and then lost their leaves.

Bailey's experiments† were conducted at the Cornell University, Ithaca, N. Y. The experiments, which were carried on for a period of four years, have all been fully written up in three reports of the Cornell University Experiment Station. Each of his three reports contains a recapitulation, or summary, as follows:

First Report—Recapitulation. (Bailey)

"It is impossible to draw many definite conclusions from the above researches. The many conflicting and indefinite results indicate that the problems vary widely under different conditions and with different plants. Yet there are a few points which are clear: The electric light promotes assimilation, it often hastens growth and maturity, it is capable of producing natural flavors and colors in fruits, it often intensifies colors of flowers and sometimes increases the production of

*Cornell Exp. St. Bulletin No. 30, p. 118.

†Ann. Agronom. VII, 551, (1881.)

*Ann. Agronom XVI., 281, 1888.

†Cornell Exp. Sta. Bulletin Nos. 30, 42 and 55.

flowers. The experiments show that periods of darkness are not necessary to the growth and deveolpment of plants. There is every reason, therefore, to suppose that the electric light can be profitably used in the growing of plants. It is only necessary to overcome the difficulties, the chief of which are the injurious influences upon plants near the light, the too rapid hastening of maturity in some species, and in short, the whole series of practical adjustments of conditions to individual circumstances Thus far, to be sure, we have learned more of the injurious effects than of the beneficial ones, but this only means that we are acquiring definite facts concerning the whole influence of electric light upon vegetation; and in some cases, notably in our lettuce tests, the light has already been found to be a useful adjunct to forcing establishments.

The experiments suggest many physiological speculations upon which it is not the province of this bulletin to enter. Yet two or three of them may be mentioned. It is a common notion that plants need rest at night, but this is not true in the scense in which animals need rest. Plants have simply adapted themselves to the conditions of alternating daylight and darkness, and during the day they assimilate or make their food and during the night, when, perforce, assimilation must cease, they use the food in growth. They simply practice an individual division of labor. There is no inherent reason why plants can not grow in full light, and, in fact it is well known that they do grow then, although the greater part of growth is usually performed at night. If light is continuous, they simply grow more or less continuously, as conditions require, as they do in the long days of the arctic regions, or as our plants did under continuous light. There is no such thing as a plant becoming worn out or tired out because of the stimulating influence of continuous light.

It would seem, therefore, that if the electric light enables plants to assimilate during the night, and does not interfere with growth, it must produce plants of great size and marked precocity. But there are other conditions, not yet understood, which must be studied. Our radish plants, and many others were earlier, but smaller under the influence of the light. Observation and chemical examination showed that a greater degree of maturity had been attained. Perhaps they had assimilated too rapidly, perhaps the functions of the plant had been completed before it had time to make its accustomed growth. Perhaps the highly refrangible and invisible rays from the electric lamp has something to do with it. In fact, this latter presumption probably accounts for much, if not all of the injury resulting from the use of the naked light, for the effect of the interposition of a clear pane of glass is probably to absorb or obstruct these rays of high refrangibility. Good results which follow the use of a globe or a pane of glass show on the other hand, that the injury to plants can not result from any gases arising from the lamp itself, as has been supposed by some observers. In our own experiments, particularly with the Brush

lamp, there was no perceptible odor from the gases of combustion; and it may also be said that commercial forcing-houses, like our own, are not tight enough to hold sufficient quantities of these gases to injure plants."

"It is highly probable that there are certain times in the life of the plant when the electric light will prove to be particularly helpful. Many experiments show that injury follows its use at that critical time when the plantlet is losing its support from the seed and is beginning to shift for itself, and other experiments show that good results follow its later use This latter point appears to be contradicted by Deherain's results, but his experiments were not conducted under the best normal conditions.

On the whole, I am inclined toward Siemens' view that there is a future for electro-horticulture."

Second Report. Summary. (Bailey).

"1. The influence of the electric arc light upon greenhouse plants is greatly modified by the use of a clear glass globe or the interposition of a glass roof. Plants which are much injured by a naked light, may be benefitted by a protected light.

2. As a rule, plants are earlier under the electric light than when grown in ordinary conditions.

3. The light can be suspended above the house with good effect.

4. Lettuce is greatly benefitted by the electric light. An average of five hours of light per night hastened maturity from a week to ten days, at the distance of ten and twelve feet. Even at 40 feet, in only diffused light, the effect was marked. The light appeared to injure young newly transplanted plants.

5. Radishes were also benefitted by the light, but not to a great extent. When the light was hung in the house, however, whether naked or protected by a globe, radishes were injured.

6. Beets and spinach appeared to be slightly benefitted by the light.

7. Cauliflowers under the light tended to grow taller than in ordinary conditions, and to make fewer and smaller heads.

8. Violets and daisies bloomed earlier in the light house. This corroborates results obtained with other flowers in our earlier experiment.

9. The electric light does not appear to determine or modify the growth of lettuce and some other plants which have been studied in this particular. Plants which are benefitted, simply grow more rapidly during the customary periods.

10. I am convinced that the electric light can be used to advantage in the forcing of some plants."

Third Report. (Bailey.)

a. "Light Above the House. Cauliflowers."

"Review.—These averages are conflicting. The two strains of

Snowball gave much larger heads in the dark house, as shown by the average diameter of the heads. This corresponds with the results obtained a year ago. But the plants—or leaves—were also longer in the dark house, which is opposed to former results. In one instance the plants averaged heavier in the light house, and in the other instance the figures are reversed. With Erfurt, decidedly better results were obtained in the light house. The total average of the results shows that in size of head and length of leaves, the light and dark houses gave about equal results. It was noticeable, however, that the plants under the light held their leaves more erect than the others. It is probable that, under the conditions of this experiment, the electric light exercises very little pronounced influence upon cauliflowers."

b. "To What Distance Does the Influence of the Light Extend?" "The Lamp Inside the House."

"Review. While it is true that the very earliest heads were obtained from points far removed from the light, there dose not appear to be any uniform behavior, so for as these measurements go, in reference to the light. Plants near the light were much injured, and it is only until the fith or sixth rows are reached—or a distance of seven or ten feet—that plants and heads of normal size are procured. It must be said, however, that the lamp hung so low that beyond fifteen or twenty feet the plants were much shaded by their own leaves, and by plants in front of them, and that the influence of the rays was therefore much broken. The general results, therefore, seem to indicate that the baneful influence of the naked electric arc lamp, of this pattern, is dissipated, in cauliflowers, at a distance of about ten feet, and that beyond that point the light appears to exert little influence."

C. "Experiments with Color Screens."

"Review.—This experiment seems to show, therefore, that lights of different colors exert decided influences upon radishes and lettuce plants early in their growth; but these differences tend to disappear as the plants approach maturity The naked light, as usual, was very injurious to the plants; but in no other case was the influence of the light sufficiently marked to make any important difference in the value of the crop."

Summary.

The following deductions can be made from the experiments thus far carried on :

1. The incandescent electric light has a marked effect upon greenhouse plants.

2. The light appears to be beneficial to some plants grown for foliage, such as lettuce. The lettuce was earlier, weighed more and stood more erect.

3. Flowering plants blossomed earlier and continued in bloom longer under the light.

4. The light influences some plants, such as spinach and endive, to quickly run to seed, which is objectionable in forcing these plants for sale.

5. Proper watering appears to be more important with radishes, beans and cuttings than improper watering + and the electric light.

6. The stronger the candle power the more marked the results, other conditions being the same.

7. Most plants tended toward a taller growth under the light.

8. It is doubtful whether the incandescent light can be used in the greenhouse from a practical and economic standpoint on other plants than lettuce and perhaps flowering plants; and at present prices it is a question if it will pay to employ it for even these.

9. There are many points about the incandescent electric light that appear to make it preferrable to the arc light for greenhouse use. See page 22.

10. Although we have not yet thoroughly established the economy and practicability of the electric light upon plant growth, still I am convinced that there is a future for it.

F. Wm. Rane.