12 March 1956

To the Graduate Council:

I am submitting herewith a thesis written by Henry Andrews entitled "Some Effects of Electrical Treatment of Seed." I recommend that it be accepted for nine quarter hours of credit in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Lawrence N Skold
Major Professor

We have read this thesis
and recommend its acceptance:

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SOME EFFECTS OF ELECTRICAL TREATMENT OF SEED

A THESIS

Submitted to
The Graduate Council
of
The University of Tennessee
in
Partial Fulfillment of the Requirements
for the degree of
Master of Science

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by

Henry Andrews

March 1956

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CHAPTER I

INTRODUCTION

Ever since Benjamin Franklin took it seriously when someone told him to go fly a kite, man has attempted to determine the relationship between electric energy and life. Various studies of the effects of electric fields on plants have been conducted with conflicting results reported. The experiments reported herein were designed to detect agronomic differences resulting from exposing certain seeds to fields of electric energy. Whereas many earlier results were based on observations and opinions, this work was designed so that the data could be analyzed statistically.

CHAPTER II

REVIEW OF LITERATURE

As early as 1783, Bertholon (3)[1] supposedly collected atmospheric electricity with an antenna, transmitted it to plants growing in the field, and reported an increase in growth of these plants treated with his "electro-vegetometer." In 1844, Ross (20) buried a large copper plate in the soil. It was connected by an above ground wire to a zinc plate buried two hundred feet away. Ross stated that potatoes grown between the two plates were larger than those not grown in this galvanic cell. Solly (23), in 1845, performed a similar experiment by growing grains, vegetables, and flowers between the electrodes. He concluded that electricity had no marked effect on plant growth.

Another type of "electro-culture" mentioned by Lund (14) was the use of a wire net held above an experimental plot by insulated supports. One terminal of a battery or generator was connected to the net, and the other terminal was grounded. Both alternating and direct currents were used and conflicting results were reported.

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[1]Number in parenthesis refers to literature cited.

Lemstrom (11,12), Priestly (18), Newman (16,17), and Dudgeon (6) reported an increase in growth rate from such treatments. Gerlach and Erlwein (7) found no increase in growth rate.

Briggs (4) described, in a thirty-four page bulletin, what is probably one of the most extensive studies of growing crops under an electrically charged network. His work commenced in 1907, and was carried through until 1918. He concluded that no sensible differences in yield, transpiration rate, and water requirements of plants were obtained by growing them under a highly charged network.

Cherry (5) mentioned that Butterfield and Barclay experimented with electrically treated seeds in South Australia. Barclay reported an increase in yield of forty per cent on sixty acres with treated seed. He did not specify what seeds were used. Cherry remarked, "Strangely enough, though he is reported to have treated his whole crop in the following year, no particulars of the result appear to have been made available." The machine used to treat the seed was described as a "medical coil set" such as was used to treat rheumatism.

Russell (21) reported the use of the Wolfryn process of electrolytic treatment of seeds. The details of the treatment are as follows:

> The grain is placed in a solution of 2½-5 per cent. (that is, 4-8 oz. to the gal.) of household salt, in a rectangular water-tight tank made of wood or cemented brick. Both ends of the tank are completely covered inside with a plate of

sheet iron about 1/8th in. thick. To each iron plate a terminal is attached for affixing the wires which conduct the electric current. A tank of the following dimensions is a convenient size in which to treat up to 12 bush. at one time, viz., 6 ft. 6 in. long by 3 ft. broad by 1 ft. 6 in. deep inside measurements.

The solution is first prepared in the tank in the proportion of about 5 gal. to 1 bush. of grain, sufficient well to cover the grain, which should be occasionally turned over during treatment. Oats need 5½ gal.

After the solution has been made ready in the tank, the grain is placed therein and submitted to an electric current of 8 watts per gal. of solution (400 watts for 50 gal., i.e., 2 amperes at 200 volts, or 4 amperes at 100 volts, and so on.)

When large quantities of grain are required to be treated at one time, several tanks are connected in series, and with increased voltage the same electric current will pass through the whole series.

After the treatment is completed the solution is run off and the grain removed from the tanks, and dried at a temperature of from 90 deg. to 100 deg. F. After the moisture has been driven out of the grain, it still remains in a swollen condition, for which due allowance must be made in drilling, otherwise a smaller quantity will be per acre than of the corresponding untreated grain.

In soil deficient in lime a solution of 5 per cent. calcium chloride (8 oz. to the gal.) may be used instead of a solution of household salt.

He stated that no real differences were obtained by use of these treatments. Russell called the reader's attention to the fact that the treatment consisted of three parts: soaking the seeds in a salt solution, submitting them to an electric current, and drying them at 110°F. He raised the question that the increase in yield obtained by Mercier (15) by the use of this process might be due to either the drying at 110°F, or soaking the seed in the salt solution.

Since no differences were observed in his pot tests, Russell did not conduct field trials. He did report on field results obtained by Robb during 1918 to 1919. Table I shows such little difference in yield that there appears to be no significant difference between the treated and the untreated. Leighty and Taylor (10), also reported no significant differences.

Shutt (22), in 1917, discovered a slight decrease in yield of seed wheat when treated by the Wolfryn method; however, he attributed some of the difference to lack of soil uniformity and to weed competition. He concluded that no economic value was gained from the treatment.

In 1920, Sutton (25) conducted a series of tests subjecting seeds of mangold, swede, cattle cabbage, and carrot to treatment by the Wolfryn process and found no distinct differences.

Riccioni (19) published a 127 page pamphlet reporting his work done in Italy, under the regime of Mussolini, in which he claims to have obtained increases in yield of wheat with seeds treated by passing them near an electrical discharge. However, his data were not subjected to statistical analysis and are difficult to evaluate.

In 1940, Ark and Perry (1) presented an extensive review of literature and concluded that numerous investigations showed that insect pests, fungi, and bacteria may be destroyed by heat induced by the passage of electric

TABLE I

DATA OBTAINED BY ROBB[1] AT THE AGRICULTURAL COLLEGE OF WYE IN EXPERIMENTS WITH SEED BARLEY AND OATS TREATED ELECTROCHEMICALLY

Crop	Bushel Yield Per Acre	
	Untreated	Treated
Barley	35.75	34.75
Oats (Abundance)	38.12	36.75
Oats (Black Tartarian)	33.00	34.75

[1]As reported by Russell (21).

energy without damaging the seeds. They also mentioned that McKinley noted a decrease in germination when seeds of Golden Bantam sweet corn were exposed for five minutes or more, while exposures of from thirty to forty seconds resulted in accelerated growth during the early germination period.

Kikuchi and Ikeuchi (9) found that cotton seeds irradiated for twenty minutes with 100 milliamperes at 1500 volts with a wave length of three meters resulted in a taller plant. However, they had only two replications of four plants each.

In a more recent publication, Iritani and Woodbury (8) declared that germination was increased from less than thirty per cent to approximately forty-five per cent after hard seeds of alfalfa and red clover were subjected to an exposure of 4500 volts for two minutes and thirty-seven seconds. They felt that the heat generated played some part in altering the permeability of the seed coat.

Baker, Wiant, and Taboada (2) stated that electromagnetic radiation had two main effects on biological tissue. Radiation with wave lengths longer than about 2880 angstroms had essentially heating effects, while shorter wave lengths caused ionization in atoms which produced chemical changes.

Considering that many of the earlier studies had no replications and were not designed to be analyzed statistically, too much confidence cannot be placed in their conflicting results. As a result of this brief review of literature, it seemed that an experiment lending itself to statistical analysis would be mandatory in order to measure any agronomic differences that might occur.

CHAPTER III

METHODS AND PROCEDURES

Laboratory Methods and Procedures

Electrical Treatment

The seeds to be electrically treated were placed in a glass discharge tube one inch in diameter. Iron electrodes, similar to those used in neon signs, were sealed in each end of the tube fourteen inches apart. A vacuum pump was used to evacuate this tube to below atmospheric pressure. A vacuum gage was not available at the time these treatments were performed, consequently the pressures attained were not recorded. A variable voltage, sixty cycle power source was used to apply voltage of peak value sufficient to excite the gas molecules within the tube, causing the gas to become conducting and forming a glow discharge. Oscillograms showed that the voltage used was not sinusoidal. Therefore, the effective voltages indicated by the voltmeter were of no value in determining the peak voltages applied, and were not reported. Variations were made in both duration of treatment and amount of current. Figure I shows corn being irradiated by this method.

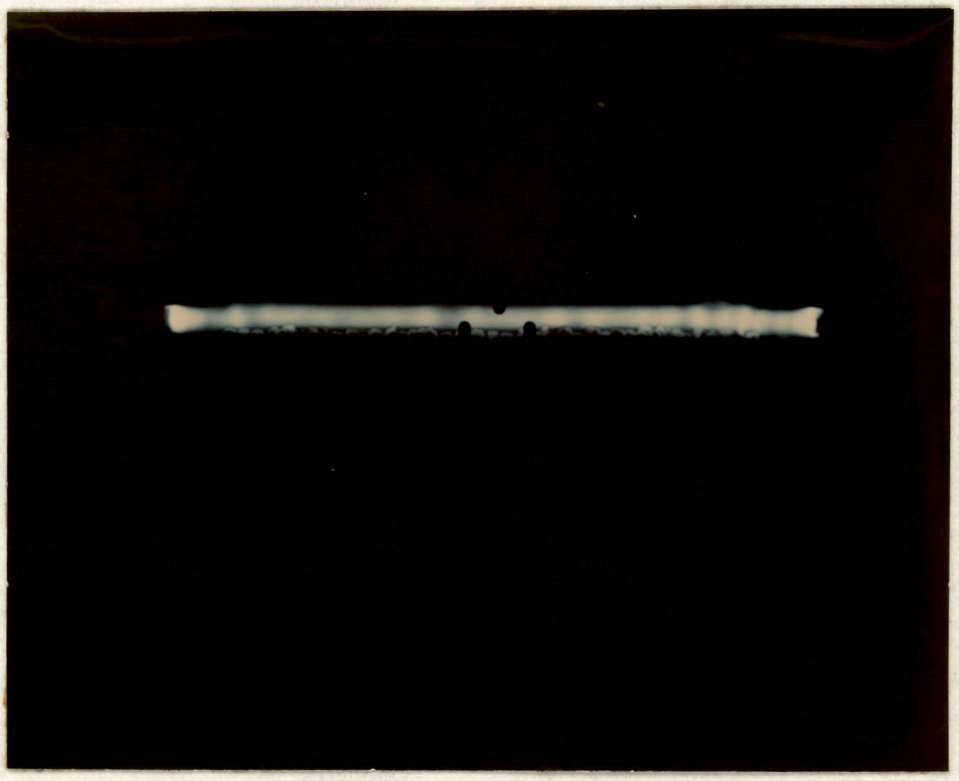


Figure 1. Seed corn being irradiated in the glass discharge tube.

Germination

Small quantities of grade six, long, flat seeds of foundation single cross (T18 x T14) white field corn[1] were treated as described above. Three ten-seed samples, treated for five minutes at four, eight, and sixteen milliamperes, respectively, were placed on filter paper in separate petri dishes and each moistened with ten milliliters of distilled water. An additional untreated sample was used as a control. Observations were made of germination under a regulated temperature of 74° Fahrenheit. Similar treatments of ten seeds each, along with a control sample, were placed on moist blotters and germinated at 80° Fahrenheit in a germinator.

Water Sorption

The rates of water sorption by treated and untreated seeds were determined. Specific quantities of graded seeds were given various treatments, placed in beakers and covered with distilled water for specific periods of time. The water was drained off rapidly and the seeds were placed on top of two crumpled filter papers in centrifuge tubes. Excessive water was then removed by centrifuging until a speed of 2,000 revolutions per minute was reached. The seeds were then placed in weighing dishes, weighed, and the per cent of weight increase calculated. The original dry

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[1]All references to corn seed will be of this grade and variety unless otherwise indicated.

weight was used as a base. The seeds were again placed in beakers, covered with water and this process repeated until the seeds had been immersed in water for a total predetermined period of time.

In order to measure the accuracy of this technique, four untreated samples of corn, consisting of fifty seeds each, were treated as described above with weights recorded after being immersed in water for five, fifteen, thirty, and sixty minutes.

Two lots, each containing fifty kernels of corn, were exposed to radiation in the discharge tube for ten minutes with fifteen milliamperes of sixty cycle current. The rates of water sorption for these lots were calculated as well as for two untreated lots as controls. Measurements were made over periods of four, six, and twenty-three hours. A similar experiment, in which seeds were exposed to radiation for ten minutes at fifteen milliamperes, was performed with weights recorded after one-half, five, ten, and fifteen minutes in water.

Another experiment was conducted in which rates of water sorption were determined using four lots of corn, each containing fifty seeds. The first was irradiated for ten minutes at fifteen milliamperes, sixty cycles. A second was killed by suspending the seeds above water in a sealed container which was placed in an oven maintained at 140° Fahrenheit for three hours. The seed was allowed

to dry and then treated with fifteen milliamperes, sixty cycles, for ten minutes. The third was immersed in boiling water for fifteen seconds to alter the permeability of the seed coat without harming the embryo. This was allowed to dry before conducting the water sorption test. The fourth sample was a control. Weights were recorded after five, fifteen, forty-five, and ninety-five minutes in water.

Another test was conducted in which two samples were irradiated at fifteen milliamperes, sixty cycles for ten minutes. One of these samples was scarified after irradiation by scraping off a major portion of the pericarp with a knife. A third sample was scarified only, with the fourth sample left as a control. Periodic measurements were made until the seeds had been in water for a total of three hours.

A similar test was run in which one sample was scarified before receiving the electrical treatment as outlined above, another sample was scarified after treatment. A third was scarified only and the remaining sample was used as a control. The test was conducted for a total submersion time of three hours.

To determine if any correlation existed between rates of water sorption and intensity of electrical treatment, three samples were given a geometric series of four, eight, and sixteen milliampere dosages, respectively, for five minutes with sixty cycle current. The fourth sample again was a check and the sorption test covered a three hour period.

A similar experiment was conducted with Ogden soybeans using 100 bean samples. Two were untreated and one of the remaining was exposed to radiation for five minutes at five milliamperes of current. The fourth was treated with ten milliamperes of current for the same length of time. Again the current was sixty cycles per second. Weights were recorded after seeds had been submersed for five, fifteen, and thirty minutes.

Seedling Growth in Flats

In order to observe possible effects on germination and seedling growth of corn, various electrical treatments were given to samples of twenty seeds each. The treated seeds were planted in standard eighteen by fourteen inch wooden flats. They were planted ten seeds to a row with the embryos up and covered with one inch of soil. Each flat contained a control and two treatments, all in duplicate and arranged at random. Observations were made of germination and seedling heights until the plants were approximately one foot tall.

A similar planting was made using seeds that had been irradiated with four, eight, and sixteen milliamperes of current for five minutes.

First generation (open pollinated) progeny, from seeds irradiated with four, eight, and sixteen milliamperes for five minutes at sixty cycles, were also planted along

with F_1 seeds that had been re-treated in the same manner as their parents. The seeds were planted in flats and observed as those mentioned previously.

Root Development

To observe root growth, glass fronts were installed on containers that were approximately eighteen inches wide, twelve inches deep and four inches in thickness. Seed corn was given the four, eight, and sixteen milliampere treatment for five minutes at sixty cycles per second. Seeds were planted next to the glass front and spaced one inch apart. Three untreated seeds were planted as controls at the left end of the container with three seeds of one treatment to the right of these controls. These were followed by three additional untreated seeds and three more seeds with the same electrical treatment. All seeds were covered with one inch of soil. A separate box was prepared for each of the three treatments. Three additional boxes were planted in the same manner except that vermiculite was used as a planting medium instead of soil. The glass fronts were covered to prevent light from reaching the roots. Observations of root development were made when the seedlings were one inch tall and again when they were three inches tall.

Barley and Vetch Treatments

Uniform seeds of Jackson Number 1 Barley and Hairy

Vetch were irradiated separately for five minutes at five, ten, and fifteen milliamperes with sixty cycle current. They were planted in eighteen by fourteen inch flats filled with soil. Two replications, each consisting of twelve seeds of each treatment, were planted in rows, along with two rows of untreated seeds as controls. The seeds were planted on 24 October 1955, and the flats were placed outside to allow germination under field temperature and moisture conditions.

Field Methods and Procedures

In order to measure some of the effects of electrical treatments on seed corn more accurately, a replicated field experiment was conducted at the University of Tennessee Agricultural Experiment Station's Morgan Farm, located at Knoxville. The level site selected was on an apparently uniform Etowah silt loam. After a soil test was made the fertility level was adjusted for a potential yield of 100 bushels per acre. A seedbed was prepared and laid off with twenty-two rows spaced thirty-two inches apart. Rows were divided into four ranges, each twenty-seven feet in length. They were separated by alleyways two feet wide. The planting plan was a randomized block design with three treatments and two controls, each replicated sixteen times. Each range was subdivided into four blocks that contained one plot of each

of the three electrical treatments, plus two plots of the control.

A plot consisted of one row with twenty-four hills, spaced fourteen inches apart. The end hills were used as borders, leaving a total of twenty-two hills from which the various data were collected. The two outside rows were used as borders. Figure 2 shows the planting diagram.

Seed Selection

Since plants of uniform genotype would be necessary in order to measure accurately any agronomic differences caused by the electrical treatments, a single cross hybrid (T18 x T14) was selected. This white field corn is the male parent of Tennessee 10, a commercially available hybrid.

Seed Treatment

Numerous preliminary treatments were conducted in order to obtain background information to determine proper treatments for field conditions. As a result of tests with treated seeds planted in flats, geometric series of dosages, four, eight, and sixteen milliamperes for five minutes with sixty cycle current were selected as the electrical treatment to be used for the field plantings. The seeds were treated as described at the beginning of this chapter. The treatments were made on the same day the seeds were planted.

Planting

The seeds were planted on 5 May 1955. A jab type

	Range			
Block	I	II	III	IV
A	0	4	0	0
	16	0	0	4
	8	16	4	8
	4	8	8	0
	0	0	16	16
B	8	16	0	8
	16	0	4	16
	4	0	8	4
	0	4	16	0
	0	8	0	0
C	0	0	0	4
	4	0	0	0
	16	8	16	0
	0	4	8	16
	8	16	4	8
D	0	0	16	8
	0	16	0	16
	4	8	4	4
	8	4	0	0
	16	0	8	0

Figure 2. Planting diagram used with corn (T18 x T14) at Knoxville, Tennessee, 1955. Numbers indicate location of plots containing seeds receiving 0, 4, 8, 16 milliamperes of sixty cycle current for five minutes.

hand planter was used to drop two grains of corn in each hill approximately two inches below the surface of the soil.

Stand Counts and Thinning

Stand counts were made as soon as the plants emerged. The first count was recorded on 12 May 1955, and the second eight days later on 20 May. The stand was thinned on 26 May to one plant per hill. To prevent bias, thinning was achieved by pulling up the plant in the hill to the north or west. If one of the two plants was obviously damaged or diseased, it was pulled, leaving the one that appeared to have the better chance of survival.

Plant Heights

Plant heights were measured from the soil surface to the tallest part of the plant when the leaves were held upright. Measurements to the nearest half-inch were taken on 3 June and 16 June. Only plants that had other plants in adjacent hills were measured in order that results would not be affected by unequal root competition.

Sidedressing and Cultivation

A sidedressing application of ammonium nitrate at the rate of sixty pounds of nitrogen per acre was administered on 6 June when the plants were approximately two feet tall.

A hand operated push plow was used for three shallow cultivations to control weeds. Extreme care was taken to

cultivate neither close to the plant nor deep in the soil in order to keep root pruning at a minimum.

Tasseling and Silking

Counts were made on 13 July of all the competitive plants with tassels open. Five days later on 18 July a count was made of all competitive plants on which silks were visible. It should be reemphasized that plant height, tasseling, and silking observations were recorded only from plants that were in competition with adjacent plants. If a plant was missing, the plant on either side was considered a border plant and disregarded as a source of data.

Harvesting and Yields

The corn plants, with the exception of border plants located at each end of the row, were cut and shocked on 23 and 24 August. Stalks were cut approximately one foot above ground and all plants from one plot were wired together in a single bundle. The shocks were dried in the field for one month.

The total plant weight of each plot was recorded before the ears were removed. After allowing sufficient time for the corn to reach a moisture equilibrium, the weight of ear corn was recorded along with the moisture content at the time of weighing. The corn was then shelled, and the weight and moisture content of the grain recorded.

CHAPTER IV

RESULTS

Laboratory Results

Germination

Figure 3 shows the effects of irradiating seed corn with four, eight, and sixteen milliamperes of current on germination in petri dishes where free water was available. The radicles of the treated seeds (B, C, and D) are slightly longer than those of the control (A). There are no observable differences in the lengths of radicles among seeds receiving the three levels of treatment.

Results of germination on blotters that held the moisture in tension as in contrast to the free water in petri dishes are shown in Figure 4. Again row A is the control and rows B, C, and D were irradiated with four, eight, and sixteen milliamperes of current respectively. There is little or no difference in the length of radicles between untreated seeds and the seeds receiving the various treatments.

Water Sorption

Rates of water sorption of four samples of untreated seed corn are shown in Figure 5. Percentages of weight increase are similar, indicating that the technique used



Figure 3. Effects on germination in petri dishes of seed corn (T18 x T14) irradiated with four (B), eight (C), and sixteen (D) milliamperes of sixty cycle current for five minutes. Dish A contains the untreated seeds.

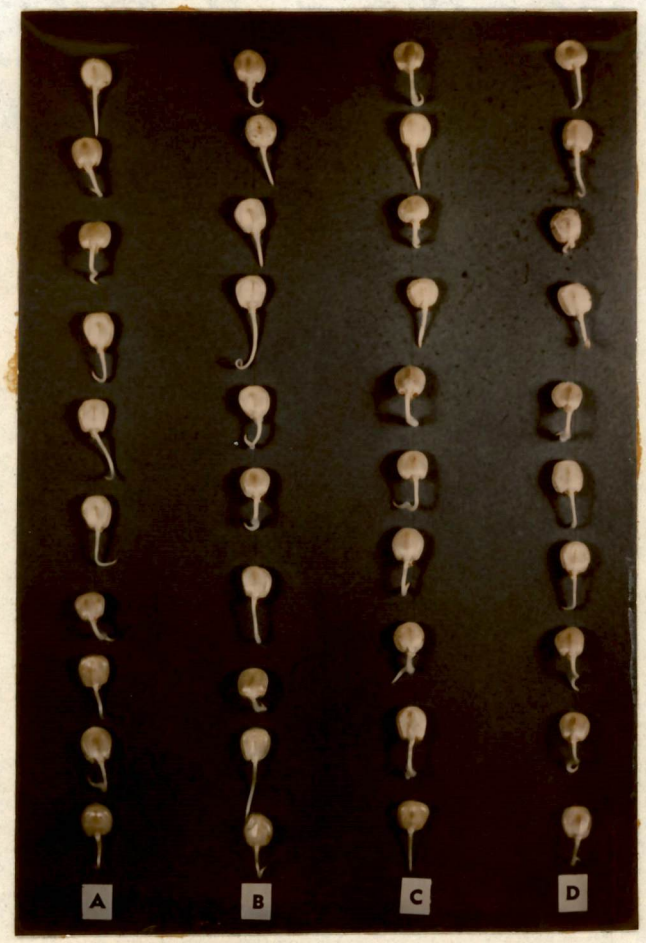


Figure 4. Effects on germination on blotters of seed corn (T18 x T14) irradiated with four (B), eight (C), and sixteen (D) milliamperes of sixty cycle current for five minutes. The untreated seeds are in row A.

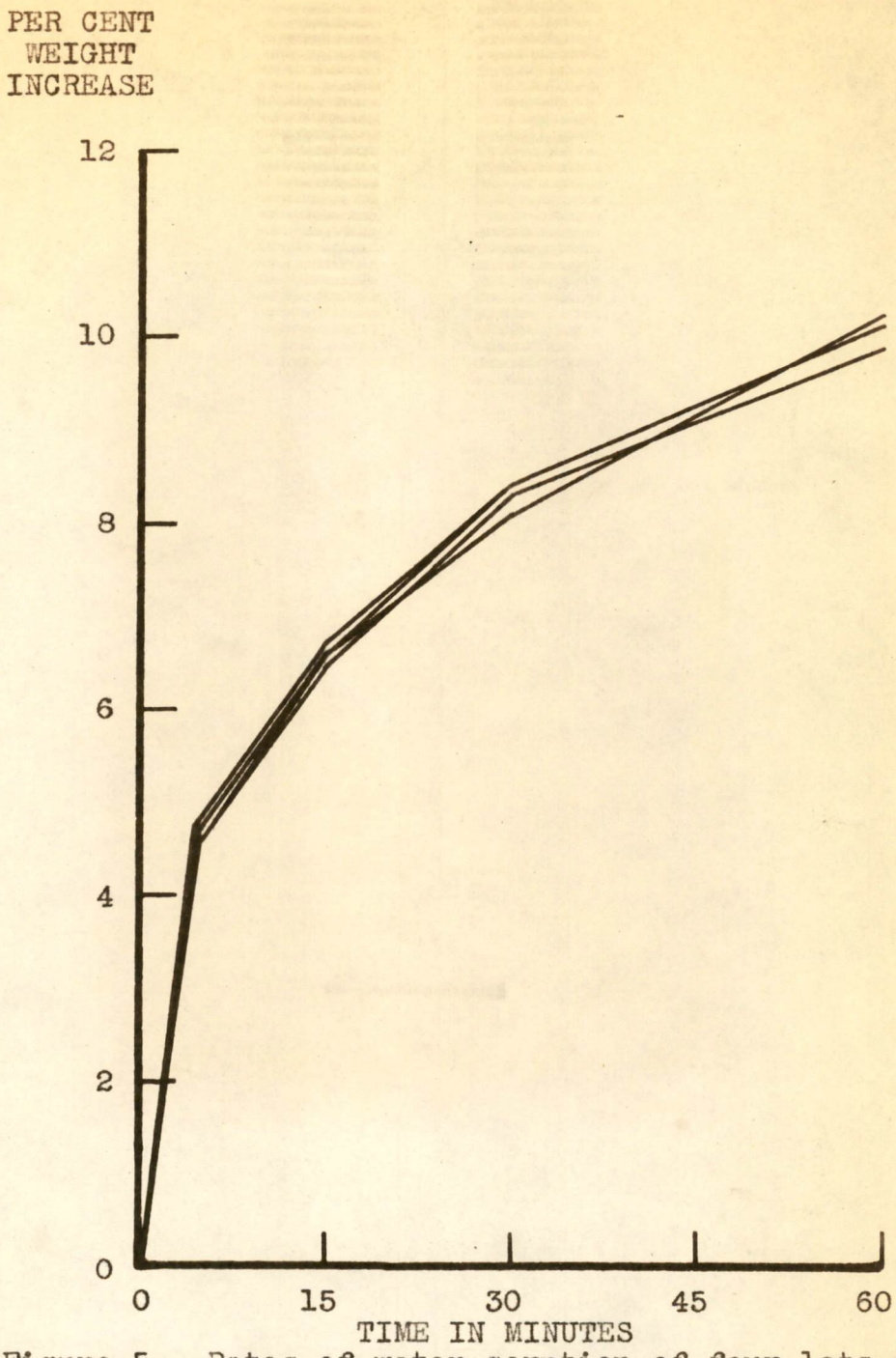


Figure 5. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water.

gives reproducible results.

Comparisons of rates of water sorption between treated and untreated seeds are shown in Figures 6 through 9. Figure 6 shows results of a submersion time of four hours, and Figures 7 and 8 are results from six and twenty-three hours submersion time respectively. In all cases, these differences were apparent when the first weights were recorded. Another test was conducted (Figure 9) over a period of fifteen minutes in which the first weighing was accomplished after the seeds were in water for only thirty seconds. Again differences in rate of water sorption were present.

Rates of water sorption of seeds electrically irradiated; seeds that had been killed prior to treatment; seeds that had been immersed briefly in boiling water; and untreated seeds are shown in Figure 10. Both lots of irradiated seeds had similar rates of water sorption that were greater than that of the control. This indicates that the rate of water sorption is a physical function which does not depend on living tissue. Viable seeds in the lot immersed in boiling water had a rate of water sorption similar to that of the controls.

Figure 11 shows the rates of water sorption of seeds that had been electrically irradiated; electrically irradiated then scarified; scarified only; and the untreated control.

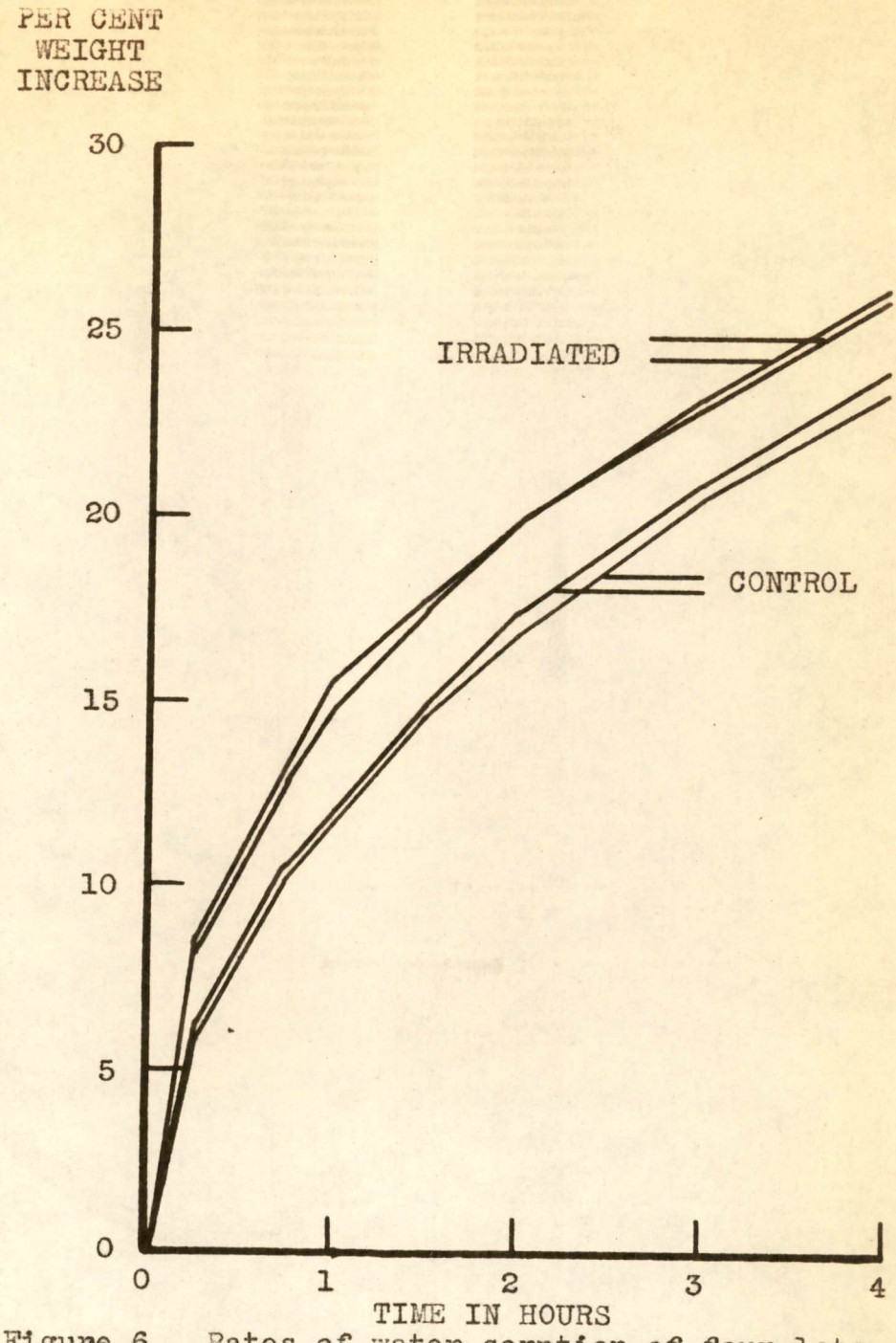


Figure 6. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Two lots were irradiated for ten minutes with fifteen milliamperes of sixty cycle current in a glow discharge tube.

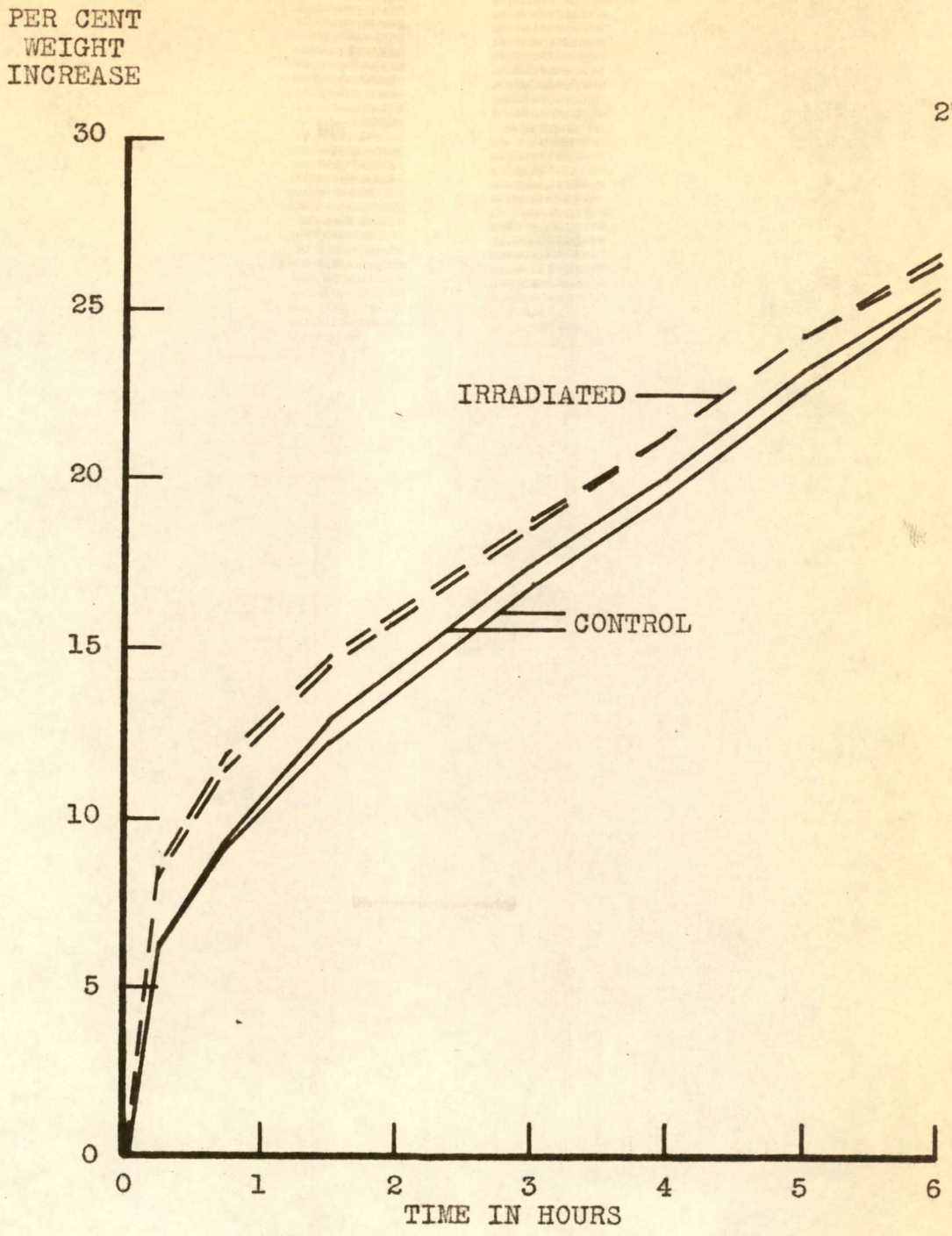


Figure 7. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Two lots were irradiated for ten minutes with fifteen milliamperes of sixty cycle current in a glow discharge tube.

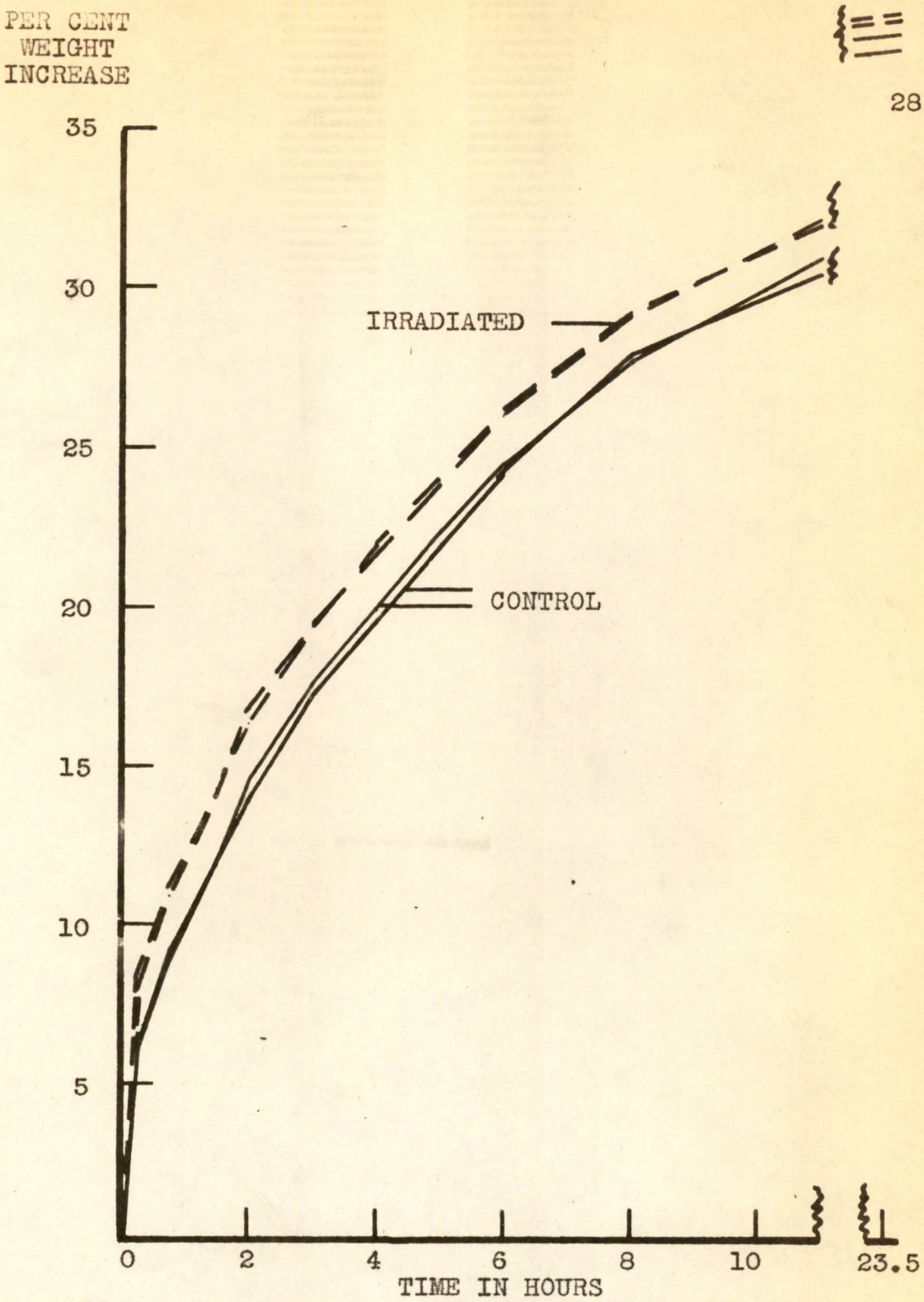


Figure 8. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Two lots were irradiated for ten minutes with fifteen milli-amperes of sixty cycle current in a glow discharge tube.

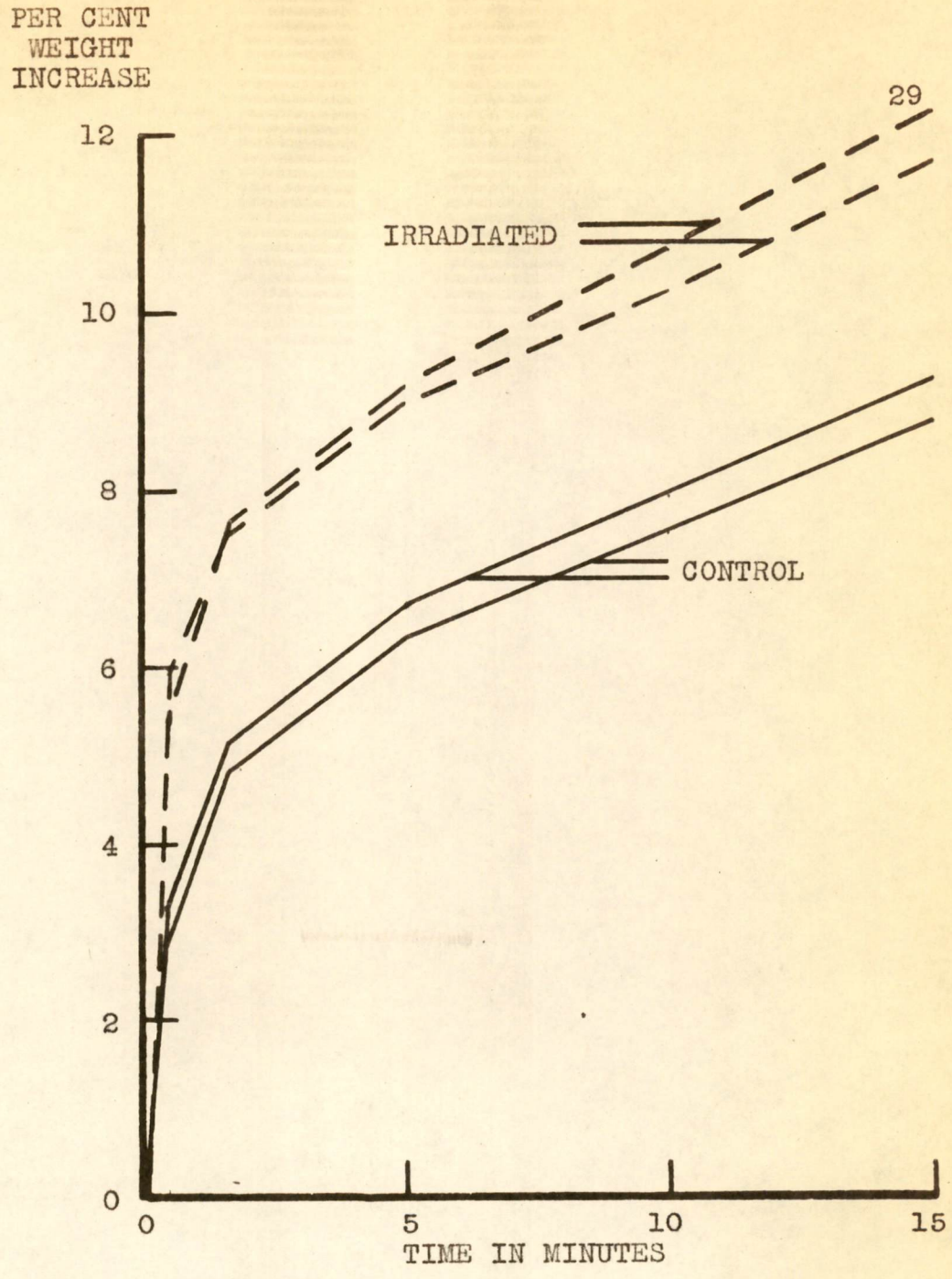


Figure 9. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Two lots were irradiated for ten minutes with fifteen milliamperes of sixty cycle current in a glow discharge tube.

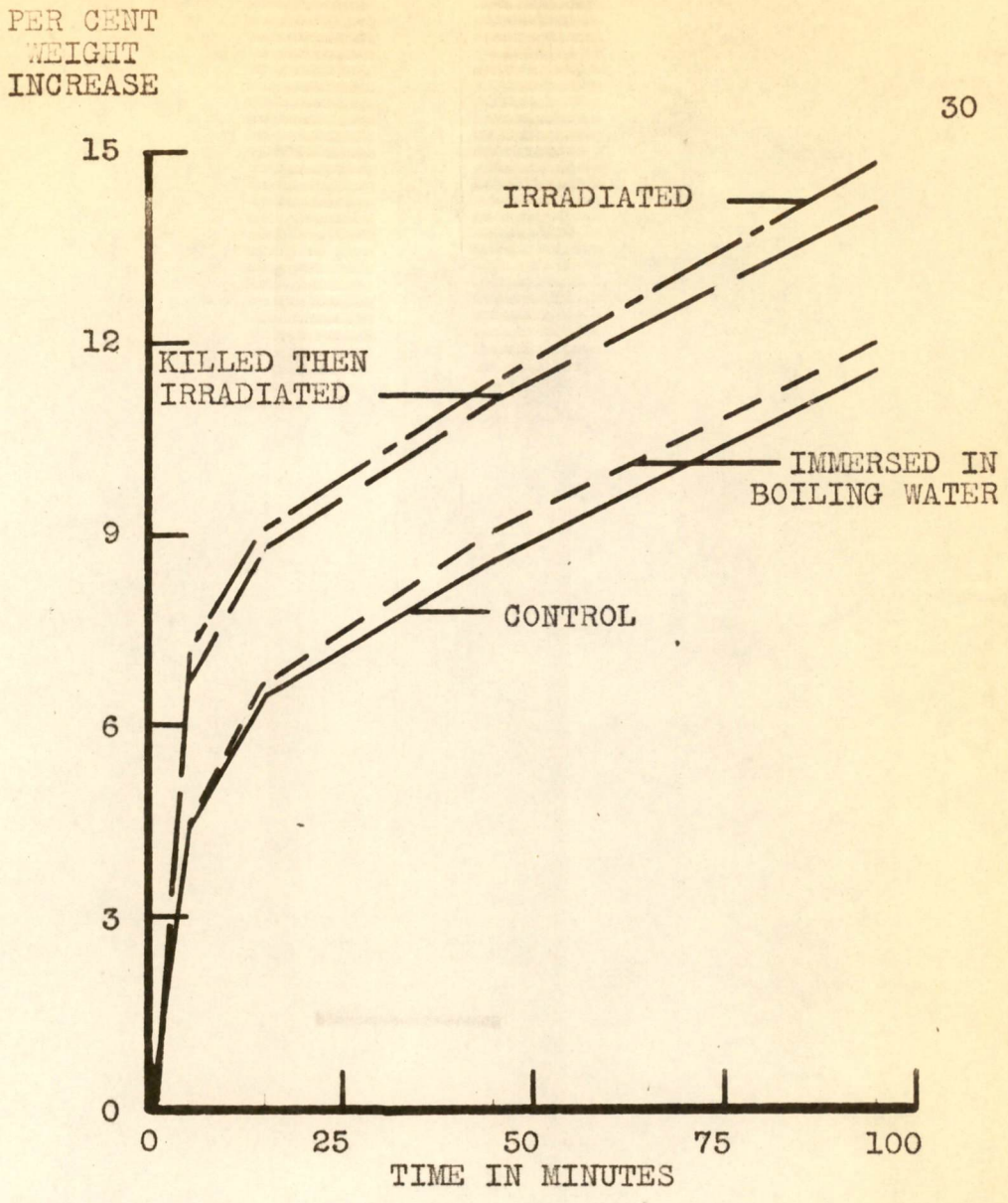


Figure 10. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. One lot received fifteen milliamperes of sixty cycle irradiation for ten minutes in a glow discharge tube. The second lot was killed prior to receiving this same level of irradiation. The third lot was immersed in boiling water for fifteen seconds, and the remaining lot was a control.

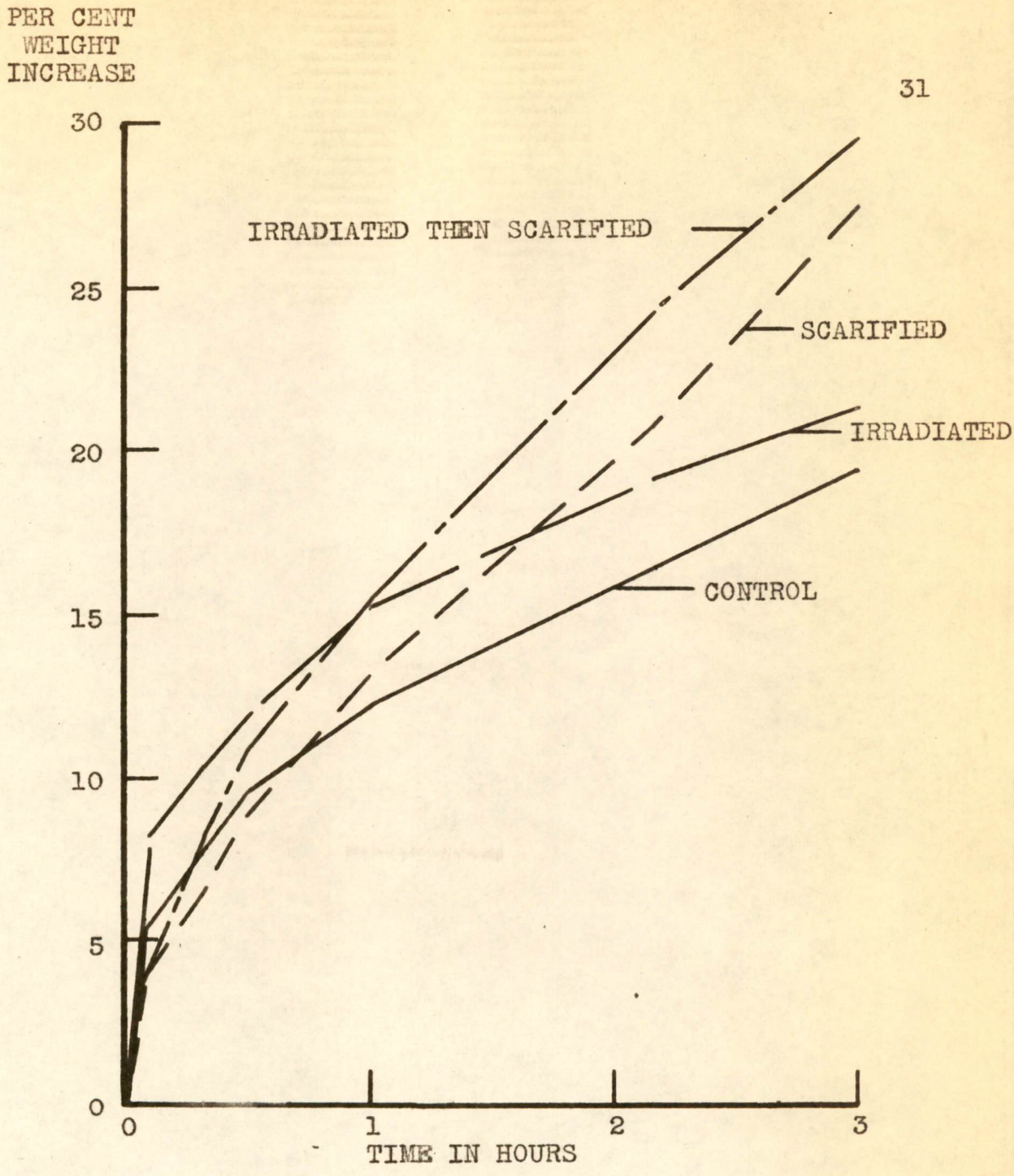


Figure 11. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Two lots received fifteen milliamperes of sixty cycle irradiation for ten minutes in a glow discharge tube. One of these samples was then scarified. A third sample was scarified and not irradiated while the fourth sample was a control.

Electrically irradiated and scarified seeds had a rate comparable to those scarified only. Both rates were higher than the rate of the irradiated lot, and all three had higher rates than the control.

Results of a similar test that included lots that were scarified then irradiated; irradiated then scarified; scarified only; and the control, are presented in Figure 12. Irradiation apparently had no effect on rates of water sorption with lots of scarified seeds.

Results of the tests with different intensities of electrical irradiation are given in Figure 13. Again no difference appeared among lots receiving these different intensities of irradiation.

The rates of water sorption by soybeans are illustrated in Figure 14. These rates indicated that rates of water sorption by soybeans are affected in much the same manner as by corn. After thirty minutes in water, irradiated beans were so soft that the test was terminated.

Seedling Growth

Observations of germination and growth of corn seedlings in flats showed little differences among the various treatments. No seedlings from irradiated seed had a higher rate of germination or taller growth than those from untreated seeds. The only significant trend observed was in the maximum treatments where germination percentage

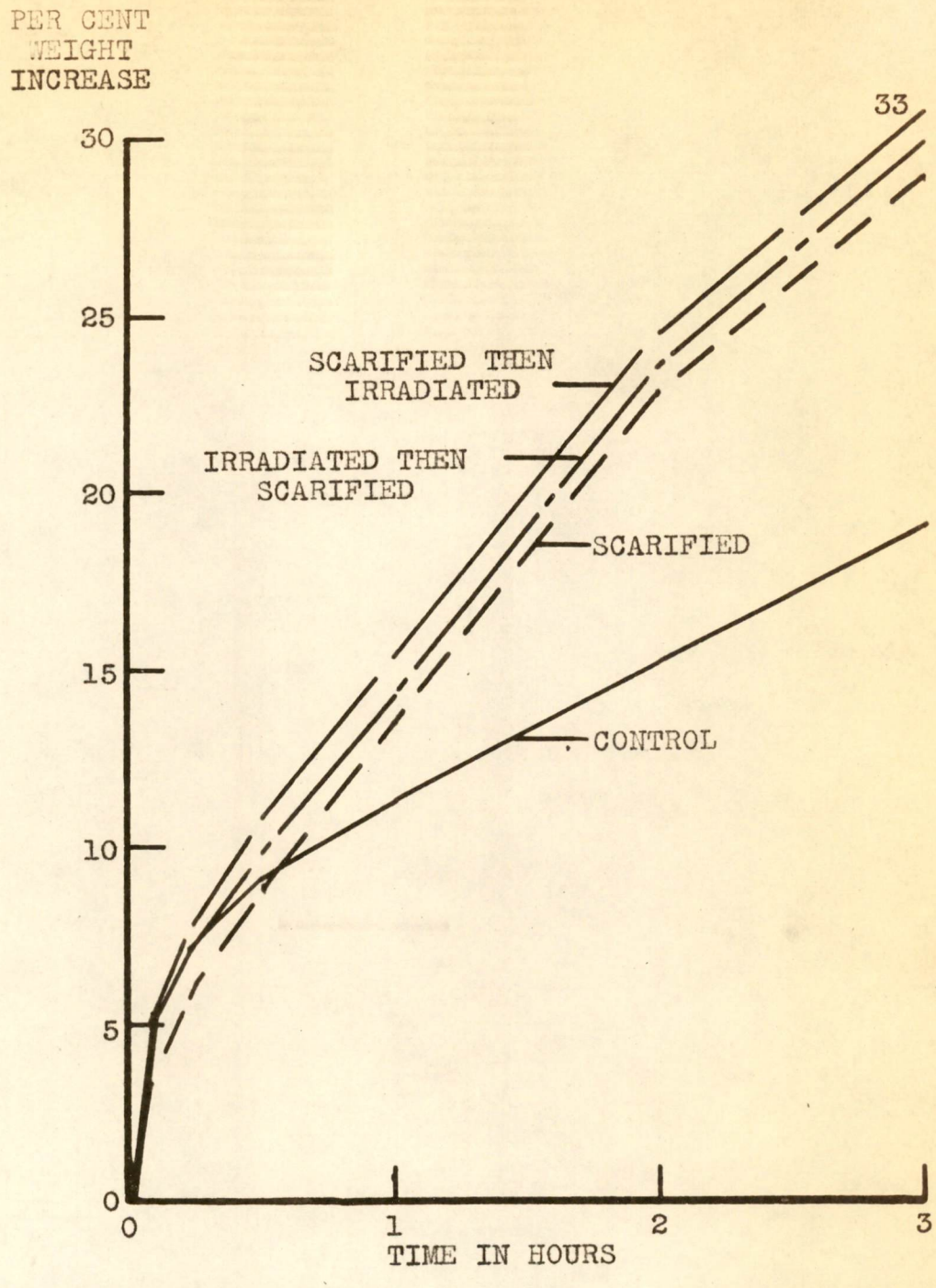


Figure 12. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. One lot was irradiated with fifteen milliamperes of sixty cycle current for ten minutes in a glow discharge tube and then scarified. A second lot was scarified prior to irradiation. The third lot was scarified only, and the fourth lot was the control.

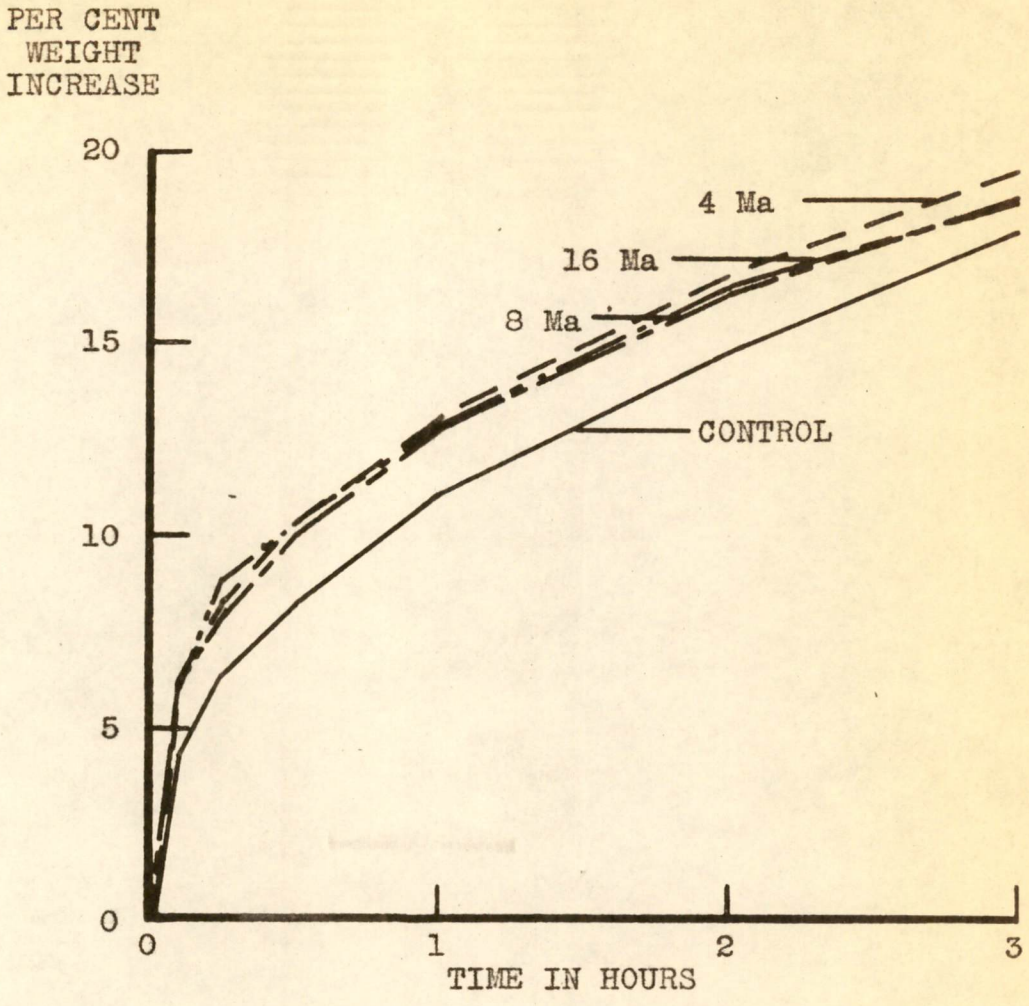


Figure 13. Rates of water sorption of four lots of fifty seeds each of corn (T18 X T14) immersed in water. Three lots received four, eight and sixteen milliamperes of sixty cycle current respectively, for five minutes in a glow discharge tube. The fourth lot was a control.

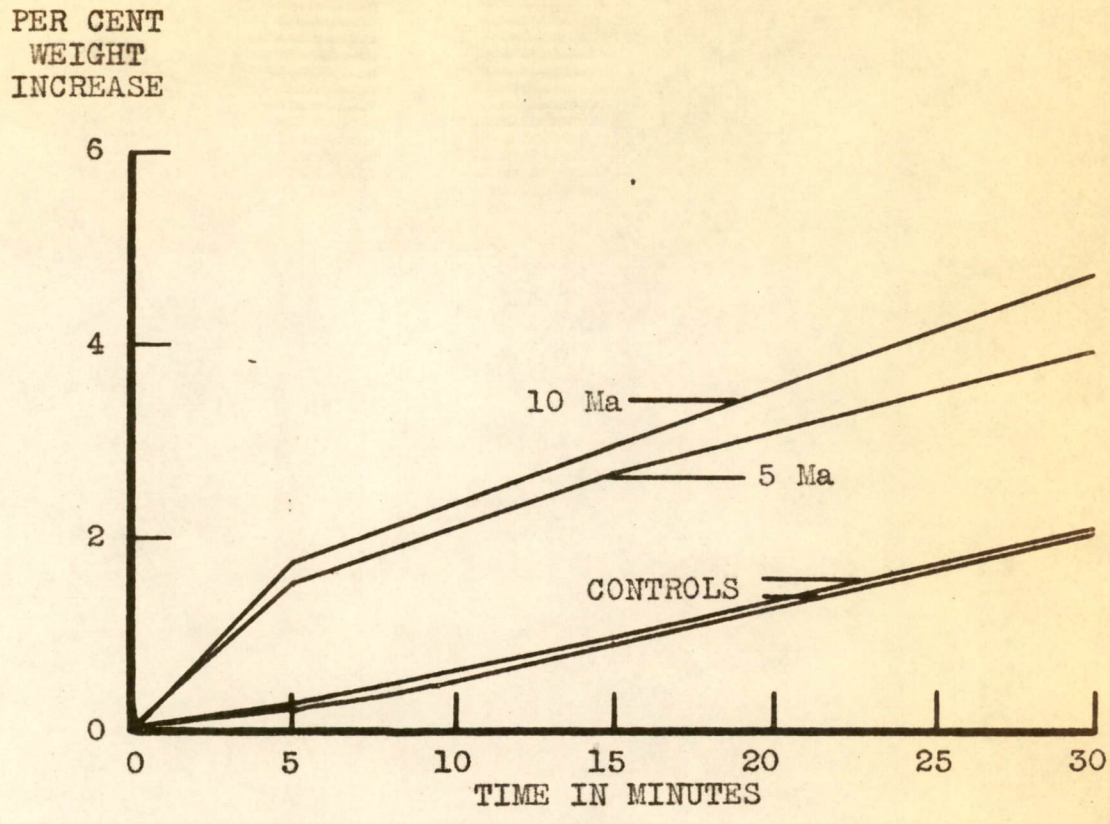


Figure 14. Rates of water sorption of four lots of 100 seeds each of Odgen Soybeans immersed in water. Two lots received ten milliamperes and five milliamperes respectively, of sixty cycle current for five minutes in a glow discharge tube. The other two lots were controls.

was reduced and shorter plants resulted. Seeds treated with thirty milliamperes of current for five minutes had a germination percentage of approximately one half that of controls and other electrically irradiated seeds. Plants produced from these seeds were only about three quarters as tall as the controls and the other seedlings. Seeds receiving thirty milliamperes of current for ten minutes did not germinate. Figure 15 shows a flat containing seeds that received these treatments. Rows marked C were controls. Treatment 6 was of five minutes duration, and treatment 5 for ten minutes. The second replication of treatment 5 is on the extreme right.

Plants from seeds receiving the four, eight, and sixteen milliamperes of current were not different from the controls.

Also, no significant differences in growth or rate of germination were noticed in the F_1 generation, or in the plants from F_1 seeds that had been exposed to the same electrical irradiation as their parents.

Root Development

No major trends or differences were evident in observations made of root growth of seedlings in either soil or vermiculite. Figure 16 represents a typical result.

Barley and Vetch Treatments

Barley seedlings had a uniform appearance both in



Figure 15. Corn seedlings (T18 x T14) from seeds irradiated with thirty milliamperes of sixty cycle current for five minutes (rows 6), and ten minutes (rows 5; the second replication of row 5 is on the extreme right). Rows marked C were controls.



Figure 16. Root growth of corn (T18 x T14) from seeds irradiated with sixteen milliamperes of sixty cycle current for five minutes. The two groups of three plants marked 5 are from treated seed and the two groups of three plants marked C are controls.

germination and plant growth. Figure 17 shows the flat containing the uniform seedlings of barley. No noticeable differences were observed in the flats containing vetch.

Field Results

Stand Counts

Stand counts are presented in Tables II and III. Plots receiving the maximum treatments of sixteen milliamperes had a highly significant reduction in stand. However, plants from seeds receiving this treatment were not visibly different than plants from seeds receiving other treatment.

Plant Heights

Records of plant heights appear in Tables IV and V. No significant differences were found between treatments. Plant heights were extremely uniform on both dates. A highly significant difference was evident between replications, which indicates that the south end of the area was more favorable for plant growth. The distribution of plant heights presented in Figure 18 shows no trend or differences. Figures 19 and 20 show the uniformity of plant height.

Tasseling and Silking

Percentages of plants with open tassels on 13 July are recorded in Table VI. No significant differences between treatments were present.

Table VII shows the percentages of plants having silks

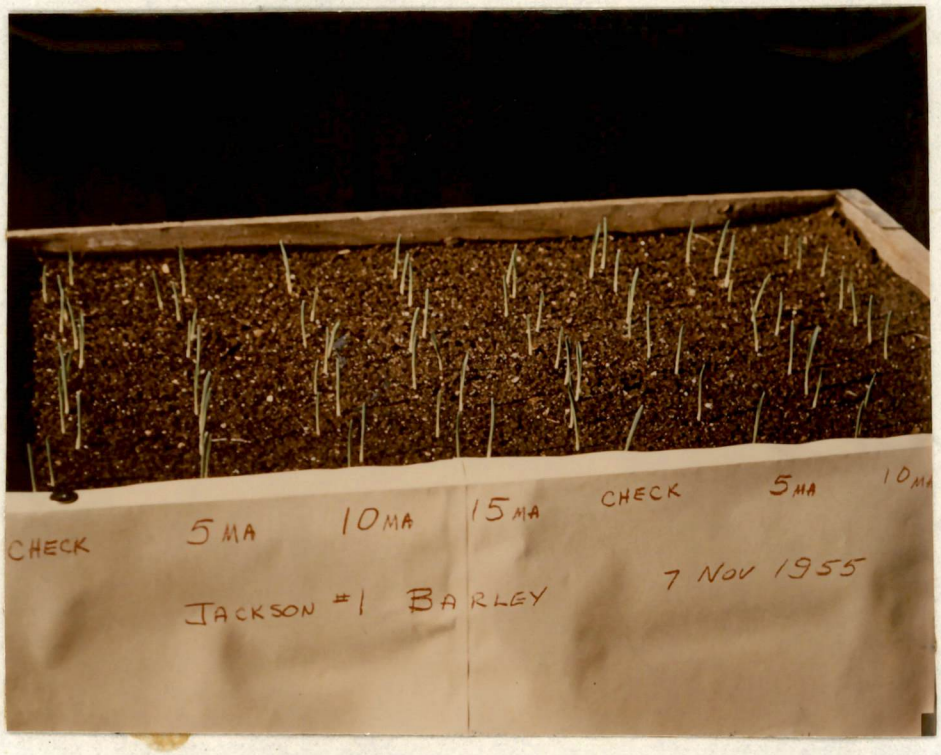


Figure 17. Flat containing Jackson Number 1 Barley from seeds irradiated for five minutes with sixty cycle current. The second replication of the fifteen milliamperes treatment is on the extreme right.

TABLE II

STAND COUNTS OF CORN (T18 x T14) ON 12 MAY 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, KNOXVILLE, TENNESSEE[1]

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	33	33	37	36	34
2	38	39	39	38	23
3	39	38	38	40	31
4	37	31	34	40	24
5	38	36	35	37	29
6	32	38	31	37	24
7	33	39	32	40	26
8	40	40	31	36	31
9	30	31	34	32	24
10	35	37	39	43	27
11	33	38	36	38	28
12	37	40	40	37	27
13	32	33	39	31	33
14	42	43	39	38	29
15	40	41	39	42	31
16	35	38	43	36	27
Mean	36.55		36.67	37.66	28.00
$LSD_{5\%}$	2.12				
CV	9%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	1,893.80		
Treatments	3	1,006.14	335.38	37.47**
Replications	15	341.80	22.79	2.55**
Error	61	545.86	8.95	

[1]Forty-four seeds per plot planted on 5 May 1955, on an Etowah Silt Loam soil.

**Double asterisk refers to significance at 1% level, single asterisk, 5% level.

TABLE III

STAND COUNTS OF CORN (T18 x T14) ON 20 MAY 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, KNOXVILLE, TENNESSEE[1]

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	40	43	41	40	33
2	43	44	44	43	29
3	41	40	42	43	37
4	42	41	43	43	34
5	43	42	42	42	37
6	40	42	43	42	32
7	40	41	40	44	35
8	44	44	39	41	37
9	39	41	38	41	31
10	44	44	43	44	33
11	40	41	39	42	33
12	41	43	43	42	35
13	41	39	42	40	37
14	43	42	40	43	32
15	42	42	43	43	36
16	43	41	43	43	35
Mean	41.75		41.56	42.25	34.12
$LSD_{5\%}$	1.16				
CV	4%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	994.34		
Treatments	3	763.65	254.55	94.63**
Replications	15	66.34	4.42	1.64
Error	61	164.35	2.69	

[1]Forty-four seeds per plot planted on 5 May 1955, on an Etowah Silt Loam soil.

TABLE IV

AVERAGE PLANT HEIGHT (IN INCHES) OF CORN (T18 x T14) ON 3 JUNE 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	23.6	21.2	22.2	22.4	22.0
2	19.3	20.4	21.5	21.4	20.6
3	22.0	19.6	20.7	22.3	20.6
4	21.7	22.0	22.6	21.3	18.2
5	23.5	20.6	23.5	23.3	21.8
6	21.0	20.9	19.1	20.5	20.8
7	21.2	18.9	21.1	22.0	21.6
8	20.6	22.0	21.8	23.1	22.5
9	22.4	23.6	21.2	22.7	20.7
10	20.5	22.4	21.8	22.2	19.8
11	22.3	21.6	24.7	23.2	21.7
12	23.3	22.6	24.2	21.9	23.7
13	25.8	23.7	25.6	24.7	24.3
14	24.6	24.4	24.5	22.6	23.6
15	25.0	26.5	24.0	25.2	23.4
16	25.2	20.0	25.3	25.3	24.4
Mean	22.26		22.74	22.76	21.86
CV	5%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	249.69		
Treatments	3	9.12	3.04	2.17
Replications	15	155.12	10.34	7.39**
Error	61	85.45	1.40	

TABLE V

AVERAGE PLANT HEIGHT (IN INCHES) OF CORN (T18 x T14) ON 16 JUNE 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	37.5	38.8	40.2	39.6	38.6
2	36.2	36.8	38.1	37.2	38.4
3	40.5	36.3	38.3	40.1	38.2
4	39.2	39.1	40.6	37.4	33.4
5	40.7	37.1	42.0	41.7	40.2
6	38.0	38.1	36.6	37.1	39.2
7	38.8	35.6	38.5	40.4	39.6
8	37.6	40.8	39.3	40.7	40.7
9	41.1	41.3	38.9	40.6	38.8
10	37.9	40.6	38.7	40.2	36.8
11	41.3	39.7	43.1	41.7	40.8
12	41.1	40.6	41.4	38.2	42.8
13	44.2	42.7	44.2	43.4	43.1
14	43.0	43.9	43.7	41.0	41.8
15	45.1	46.2	43.3	43.9	42.1
16	36.1	43.1	43.1	43.4	43.6
Mean	39.96		40.65	40.48	39.87
CV	4%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	515.12		
Treatments	3	7.96	2.65	0.90
Replications	15	327.49	21.83	7.40**
Error	61	179.67	2.95	

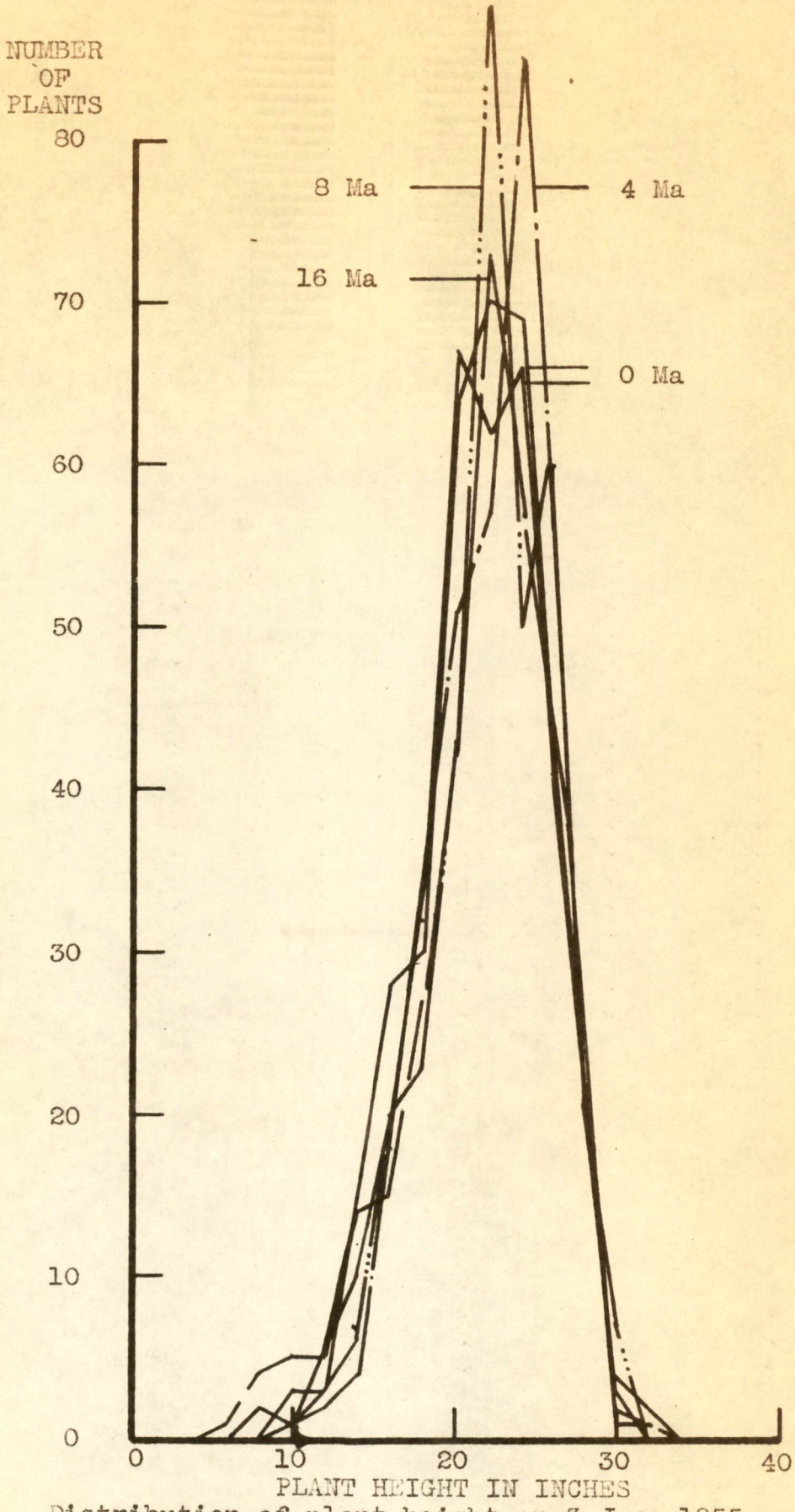


Figure 18. Distribution of plant height on 3 June 1955, of corn (T18 X T14) from seeds receiving four, eight, and sixteen milliamperes respectively of sixty cycle irradiation for five minutes in a glow discharge tube. Seeds were planted 5 May 1955, on an Etowah Silt Loam, Knoxville, Tennessee.



Figure 19. Corn (T18 x T14) on 26 May 1955, from seeds electrically irradiated and planted on 5 May 1955, Etowah Silt Loam, Knoxville, Tennessee.



Figure 20. Corn (T18 x T14) on 13 July 1955, from seeds electrically irradiated and planted on 5 May 1955, Etowah Silt Loam, Knoxville, Tennessee.

TABLE VI

PERCENTAGE OF CORN (T18 x T14) PLANTS PER PLOT WITH OPEN TASSELS ON 13 JULY 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	27.3	50.0	54.5	40.9	33.3
2	27.3	27.3	45.0	40.9	36.8
3	60.0	28.6	33.3	54.5	47.6
4	40.9	66.7	45.5	33.3	9.1
5	63.6	40.9	81.8	81.8	40.9
6	63.6	45.5	59.1	63.6	70.0
7	68.2	45.5	68.2	72.7	52.4
8	54.5	59.1	45.5	68.2	59.1
9	77.3	66.7	59.1	50.0	47.4
10	40.9	72.7	63.6	68.2	47.6
11	63.6	61.9	80.0	77.3	95.5
12	77.3	59.1	63.6	27.3	68.2
13	81.8	75.0	86.4	85.0	66.7
14	86.4	86.4	81.0	68.2	68.4
15	85.7	95.5	77.3	81.8	81.0
16	31.8	100.0	90.9	81.8	68.2
Mean	60.35		64.68	62.22	55.76
CV	24%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	30,075.77		
Treatments	3	683.70	227.90	1.11
Replications	15	16,820.75	1,121.38	5.44**
Error	61	12,571.32	206.09	

TABLE VII

PERCENTAGE OF CORN (T18 x T14) PLANTS PER PLOT WITH VISIBLE SILKS ON 18 JULY 1955, FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	77.3	81.8	95.5	77.3	85.7
2	54.5	72.7	85.0	90.9	78.9
3	75.0	71.4	85.7	86.4	76.2
4	86.4	85.7	86.4	66.7	40.9
5	86.4	81.8	100.0	95.5	95.5
6	86.4	95.5	81.8	77.3	85.0
7	90.9	72.7	95.5	86.4	90.5
8	68.2	100.0	95.5	86.4	100.0
9	100.0	95.2	86.4	81.8	84.2
10	86.4	90.9	68.2	100.0	76.2
11	90.9	85.7	90.0	90.9	90.9
12	86.4	90.9	90.9	81.8	90.9
13	100.0	100.0	95.5	90.0	95.2
14	95.5	95.5	100.0	81.8	84.2
15	100.0	100.0	90.9	100.0	90.5
16	77.3	100.0	95.5	90.9	90.9
Mean	86.92		90.18	86.51	84.73
CV	13%				

ANALYSIS OF VARIANCE[1]

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	8,574.69		
Treatments	3	287.37	95.79	1.15
Replications	15	3,227.21	215.15	2.59**
Error	61	5,060.11	82.95	

[1]Percentage data converted to angle(13).

visible on 18 July. Again, no significant differences between treatments existed.

Yields

No significant differences of total plant weight per plot existed between the control plots and plots receiving electrical treatments. However, as indicated by Table VIII, average plot weights of plants receiving the sixteen milliampere treatment were significantly lower than the weights of plots receiving the other two treatments.

Pounds of ear corn per plot are presented in Table IX. Yields from plots receiving the maximum treatments had a significantly lower average yield than other plots. To determine if the differences in yields per plot could be a result of reduced stand, yields were calculated on a basis of pounds of ear corn per plant (Table X), and plots receiving the sixteen milliampere treatment were again significantly lower in yield per plant.

The average yield of shelled corn was significantly less for the sixteen milliampere treatment (Table XI).

TABLE VIII

TOTAL PLANT WEIGHT IN POUNDS PER PLOT OF CORN (T18 x T14)
FROM SEEDS RECEIVING ELECTRICAL IRRADIATION,
ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	17.8	18.6	18.8	18.0	14.8
2	17.6	18.4	16.8	18.4	16.2
3	17.8	14.4	17.8	15.8	15.8
4	16.0	15.4	16.6	14.6	13.4
5	16.8	17.6	17.8	18.2	18.4
6	19.2	18.4	19.2	20.4	17.4
7	18.4	15.2	18.4	20.6	18.6
8	16.0	20.2	18.8	19.2	20.6
9	18.2	17.6	17.6	18.0	15.0
10	17.0	19.2	17.8	17.8	16.0
11	18.8	17.0	16.8	19.4	19.6
12	19.8	18.2	19.2	17.2	18.8
13	21.6	20.6	21.4	20.8	17.2
14	19.2	18.6	18.6	19.4	16.8
15	17.6	19.8	22.0	19.4	18.6
16	17.6	18.6	18.0	18.6	17.6
Mean	18.04		18.48	18.49	17.18
$LSD_{5\%}$	.90				
CV	7%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	225.98		
Treatments	3	18.20	6.07	3.79*
Replications	15	110.11	7.34	4.59**
Error	61	97.67	1.60	

TABLE IX

YIELD IN POUNDS OF EAR CORN (T18 x T14) PER PLOT FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE, 1955[1]

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	7.6	7.5	7.5	7.4	6.3
2	6.7	7.4	7.0	7.4	6.0
3	6.8	6.1	6.6	6.7	6.1
4	6.7	6.3	6.9	6.3	5.0
5	6.9	6.2	7.6	6.8	7.1
6	7.7	6.8	7.1	7.8	7.1
7	8.3	6.3	7.4	8.3	7.6
8	7.1	8.6	8.5	8.3	8.7
9	8.3	7.4	7.9	6.8	5.9
10	6.8	7.1	6.5	6.8	5.9
11	7.7	6.3	7.4	8.0	7.3
12	7.8	8.0	8.2	7.5	7.7
13	8.3	10.3	9.5	9.3	7.4
14	7.5	8.1	8.4	7.9	7.3
15	7.7	7.7	8.7	8.8	8.1
16	8.8	9.1	8.9	8.4	8.0
Mean	7.50		7.76	7.66	6.97
LSD 5%	0.40				
CV	8%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	70.55		
Treatments	3	5.91	1.97	6.16**
Replications	15	45.09	3.01	9.41**
Error	61	19.55	0.32	

[1] 10.6% Moisture

TABLE X

YIELD IN POUNDS OF EAR CORN (T18 x T14) PER PLANT FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE[1]

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	.35	.34	.34	.34	.30
2	.31	.34	.35	.35	.32
3	.32	.29	.31	.30	.29
4	.30	.30	.31	.30	.23
5	.31	.28	.35	.31	.32
6	.35	.31	.32	.35	.36
7	.38	.29	.34	.38	.36
8	.32	.39	.39	.38	.40
9	.38	.34	.38	.31	.31
10	.31	.32	.31	.31	.28
11	.35	.30	.37	.36	.33
12	.35	.36	.37	.34	.35
13	.40	.52	.43	.47	.37
14	.34	.37	.42	.38	.38
15	.37	.35	.40	.40	.39
16	.40	.43	.41	.38	.36
Mean	0.346		0.362	0.354	0.334
$LSD_{5\%}$	0.02				
CV	8%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	0.166		
Treatments	3	0.008	0.0027	3.6*
Replications	15	0.112	0.0075	9.38**
Error	61	.046	0.0008	

[1]10.6% Moisture

TABLE XI

YIELD IN POUNDS OF SHELLED CORN (T18 x T14) PER PLOT FROM SEEDS RECEIVING ELECTRICAL IRRADIATION, ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE, 1955[1]

Replication	Milliamperes of 60 Cycle Current				
	0	0	4	8	16
1	6.4	6.2	6.1	6.2	5.2
2	5.6	6.1	5.8	6.0	5.0
3	5.7	5.1	5.5	5.6	5.1
4	5.6	5.3	5.8	5.3	4.2
5	5.7	5.1	6.3	5.7	6.0
6	6.5	5.6	5.9	6.4	5.9
7	7.0	5.2	6.1	7.0	6.4
8	5.9	7.2	7.2	7.0	7.3
9	6.9	6.1	6.6	5.6	4.9
10	5.6	5.9	5.4	5.6	4.9
11	6.4	5.1	6.1	6.7	6.1
12	6.5	6.5	6.9	6.2	6.5
13	6.9	8.7	8.0	7.9	6.2
14	6.1	6.8	7.0	6.4	6.0
15	6.5	6.4	7.2	7.4	6.7
16	7.3	7.6	7.5	7.0	6.7
Mean	6.23		6.46	6.38	5.82
LSD5%	0.35				
CV	8%				

ANALYSIS OF VARIANCE

Source	Degrees of Freedom	Sum of Squares	Variance	F Value
Total	79	52.03		
Treatments	3	3.91	1.30	5.20**
Replications	15	32.83	2.19	8.76**
Error	61	15.29	0.25	

[1] 8.68% Moisture

CHAPTER V

DISCUSSION

The effects of radiation on seeds could be better interpreted if we knew to what type of radiation the seeds were exposed. In addition to the electron beam and to longer wave length radiations generated, radiation of wave lengths covering the electromagnetic spectrum from infra-red through visible light to ultraviolet were present. When electrons pass between two electrodes, the impact causes heating of the seeds, as well as other radiations. It is probable that varying amounts of any of these types of radiation including electrons or a combination of them were absorbed by the seeds. Since electrons flow on the surface, no internal effects would be expected.

The temperature of the discharge tube rose, making it uncomfortable to handle. It was not determined to what degree the seeds were heated because they absorbed energy at a different rate than the discharge tube, thermometer, or thermocouple.

The fact that irradiated seed corn germinated slightly faster than the controls when placed in petri dishes and did not germinate more rapidly than the controls on blotters could be due to an increase in the rate of water sorption. This is substantiated by the tests determining the rates of water sorption where seeds were immersed in water.

However, when germination was on blotters that held the water in tension, no observable differences in rates of germination occurred. When irradiated seed corn was planted in soil holding the moisture in tension, these increases in rates of germination or seedling growth were not observed. This indicated that a supply of free water must be present for more rapid water sorption and germination. Stone and Juhren (24) suggested that the permeability of the seed coat could be changed by heat. Also they stated that heat might destroy a chemical inhibitor in the seed and could alter the metabolism of the embryo. They concluded that the heat-induced increase in percentage of germination of seeds of sugar bush (Rhus ovata Wats.) was due to an increase in permeability of the seed coat caused by cracking, which permitted water to enter. Again it is stressed that heat was generated in the electrical treatments used in the experiments described in Chapter III.

Iritani and Woodbury (8) reported that scarification of seed coats of field bindweed increased the germination from approximately twenty-seven per cent to eighty-nine per cent, while radio frequency heat treatment increased the rate of germination to fifty-five per cent. In the tests determining rates of water sorption, removal of the pericarp of corn had essentially the same effect as electrical irradiation on the rates of water sorption. This indicated that the increased rate of water sorption

could be correlated with the permeability of the pericarp. As would be expected from the results discussed above, no observable differences in root growth existed in either soil or vermiculite since both media held the moisture in tension. The only visible differences of seedling growth in flats were the reduction in growth and destruction of the viability of seeds receiving maximum levels of irradiation. Similar results were obtained from the field experiments. The germination percentage and total plant weight per plot were significantly reduced only by the sixteen milliampere treatment. Also, the grain yields were significantly lower in both pounds of grain per plot and pounds of grain per plant in the plots receiving treatments of the highest energy level.

CHAPTER VI

SUMMARY

Seeds of a single cross hybrid field corn were exposed to radiation in a glow discharge tube. Studies were conducted to determine the effects of this radiation on germination, water sorption, and growth in the field.

When placed in petri dishes containing free water, irradiated seeds germinated slightly faster than seeds not exposed to this radiation. No differences in germination were visible when these seeds were germinated on blotters or in soil or vermiculite that held water in tension.

When placed in free water, rate of water sorption of the irradiated seeds was greater than that of the control seeds.

In free water, rates of water sorption of irradiated seed corn were similar to rates of water sorption of seed corn that had the pericarp removed. This increase in germination and rate of water sorption of irradiated seeds could be caused by heat generated during the electrical irradiation or by effects of electron beams. When planted in soil, irradiated seeds had no visible increase in growth as compared to untreated seeds. However, the highest levels of treatment produced a decrease in both germination percentage and plant height.

In a field experiment with T18 x T14 white field corn, only the highest energy level treatment, sixteen milliamperes for five minutes, resulted in significant agronomic differences. Germination percentage, total plant weight, yield of grain per treatment and per plant were significantly lower than from any other treatment. No significant differences were manifested in plant heights or percentages of plants with tassels or silks.

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LITERATURE CITED

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APPENDICES

APPENDIX A

DAILY WEATHER REPORT DURING FIELD CORN GROWING SEASON AT KNOXVILLE, TENNESSEE, 1955

Month	Day	Minimum Temp.	Maximum Temp.	Rain Fall (inches)
May	1	48	82	
	2	48	84	
	3	49	85	
	4	53	89	
	5	57	90	
	6	53	84	
	7	58	87	
	8	58	81	
	9	46	81	
	10	49	84	.06
	11	58	84	
	12	60	76	1.38
	13	63	79	.25
	14	60	77	
	15	60	78	
	16	56	70	
	17	56	82	
	18	56	83	
	19	60	81	
	20	58	85	.61
	21	64	81	
	22	64	78	.39
	23	64	83	
	24	67	78	
	25	66	82	.65
	26	62	88	
	27	65	89	
	28	66	88	.44
	29	65	77	.02
	30	56	73	
	31	50	76	
				total 3.80

APPENDIX A

DAILY WEATHER REPORT DURING FIELD CORN GROWING SEASON AT KNOXVILLE, TENNESSEE, 1955 (continued)

Month	Day	Minimum Temp.	Maximum Temp.	Rain Fall (inches)
June	1	51	82	
	2	54	84	
	3	54	85	
	4	55	85	
	5	62	88	
	6	64	85	.26
	7	63	72	.45
	8	54	60	.93
	9	54	74	
	10	62	71	.82
	11	59	73	
	12	58	72	.04
	13	58	70	
	14	56	75	
	15	52	80	
	16	55	84	
	17	58	88	
	18	59	86	
	19	64	86	.02
	20	64	87	
	21	64	90	
	22	63	87	.36
	23	62	78	.20
	24	60	86	.20
	25	66	78	.87
	26	62	83	
	27	60	84	
	28	63	80	
	29	66	83	
	30	66	86	
				total 4.15

APPENDIX A

DAILY WEATHER REPORT DURING FIELD CORN GROWING SEASON AT KNOXVILLE, TENNESSEE, 1955 (continued)

Month	Day	Minimum Temp.	Maximum Temp.	Rain Fall (inches)
July	1	64	87	
	2	66	91	
	3	66	94	
	4	68	91	1.19
	5	68	87	
	6	68	87	
	7	72	87	
	8	71	78	
	9	69	86	
	10	70	90	
	11	70	90	
	12	70	76	.38
	13	70	86	.30
	14	70	86	
	15	72	78	.24
	16	70	84	
	17	68	90	
	18	70	91	
	19	70	94	
	20	72	90	
	21	68	90	.56
	22	70	88	
	23	68	87	
	24	70	84	.56
	25	72	90	.61
	26	72	94	
	27	72	97	
	28	72	97	
	29	70	93	
	30	72	93	
	31	70	93	
				total 3.84

APPENDIX A

DAILY WEATHER REPORT DURING FIELD CORN GROWING SEASON AT KNOXVILLE, TENNESSEE, 1955 (continued)

Month	Day	Minimum Temp.	Maximum Temp.	Rain Fall (inches)
August	1	70	93	
	2	72	94	
	3	70	95	.05
	4	71	95	
	5	70	94	.02
	6	72	94	
	7	72	96	
	8	72	91	.07
	9	73	92	.76
	10	70	92	
	11	70	91	
	12	72	88	
	13	66	92	
	14	67	88	.12
	15	68	81	
	16	70	93	
	17	70	93	
	18	70	94	
	19	72	98	
	20	71	99	
	21	71	95	
	22	70	90	1.19
	23	70	90	.13
	24	66	92	
	25	67	92	
	26	67	90	
	27	68	94	
	28	65	94	
	29	68	94	
	30	72	90	
	31	70	87	.70
			total	3.04

APPENDIX B

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. (SEE FIGURE 5.)

Time in Water (Hours)	Per Cent Weight Increase			
	Lot 1	Lot 2	Lot 3	Lot 4
1/12	4.59	4.62	4.66	4.80
1/4	6.59	6.53	6.56	6.73
1/2	8.16	8.08	8.14	8.26
1	10.09	9.91	10.25	10.07

APPENDIX C

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. TWO LOTS WERE IRRADIATED FOR TEN MINUTES WITH FIFTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT IN A GLOW DISCHARGE TUBE. (SEE FIGURE 6.)

Time in Water (Hours)	Per Cent Weight Increase			
	Control	Control	Irradiated	Irradiated
1/4	6.19	5.85	8.54	8.33
1/2	8.41	8.04	10.99	10.45
3/4	10.52	10.13	13.17	12.93
1	12.04	11.73	15.58	14.88
1 1/2	14.93	14.71	17.83	17.67
2	17.49	16.98	19.90	19.91
3	20.82	20.48	23.14	23.00
4	24.01	23.49	26.03	25.94

APPENDIX D

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. TWO LOTS WERE IRRADIATED FOR TEN MINUTES WITH FIFTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT IN A GLOW DISCHARGE TUBE. (SEE FIGURE 7.)

Time in Water (Hours)	Per Cent Weight Increase			
	Control	Control	Irradiated	Irradiated
1/4	6.06	6.24	8.51	8.43
3/4	9.15	9.31	11.87	11.47
1 1/2	12.21	12.80	14.88	14.67
3	16.76	17.49	18.72	18.64
4	19.54	20.05	21.21	21.29
5	22.56	23.30	24.02	24.14
6	25.30	25.59	26.59	26.34

APPENDIX E

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. TWO LOTS WERE IRRADIATED FOR TEN MINUTES WITH FIFTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT IN A GLOW DISCHARGE TUBE. (SEE FIGURE 8.)

Time in Water (Hours)	Per Cent Weight Increase			
	Control	Control	Irradiated	Irradiated
1/4	6.27	6.13	8.00	8.24
3/4	9.01	8.93	10.96	11.20
1 1/2	11.72	11.77	14.15	14.25
2	13.93	14.50	16.76	16.39
3	17.14	17.52	19.49	19.48
4	19.50	19.95	21.68	21.86
5	21.90	22.33	23.84	23.93
6	24.10	24.49	26.00	26.03
8	27.95	27.78	29.10	29.12
10 1/2	30.44	30.92	32.10	31.97
23 1/2	37.33	37.85	38.18	38.37

APPENDIX F

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. TWO LOTS WERE IRRADIATED FOR TEN MINUTES WITH FIFTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT IN A GLOW DISCHARGE TUBE. (SEE FIGURE 9.)

Time in Water (Minutes)	Per Cent Weight Increase			
	Control	Control	Irradiated	Irradiated
1/2	2.91	3.34	5.91	5.57
2	4.83	5.19	7.52	7.66
5	6.34	6.77	9.00	9.19
10	7.56	7.96	10.21	10.72
15	8.78	9.23	11.74	12.25

APPENDIX G

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. ONE LOT RECEIVED FIFTEEN MILLIAMPERES OF SIXTY CYCLE IRRADIATION FOR TEN MINUTES IN A GLOW DISCHARGE TUBE. THE SECOND LOT WAS KILLED PRIOR TO RECEIVING THIS SAME LEVEL OF IRRADIATION. THE THIRD LOT WAS IMMERSED IN BOILING WATER FOR FIFTEEN SECONDS, AND THE REMAINING LOT WAS A CONTROL. (SEE FIGURE 10.)

Time in Water (Minutes)	Per Cent Weight Increase			
	Control	Irradiated	Immersed in Boiling Water	Killed then Irradiated
5	4.24	7.07	4.39	6.67
15	6.40	9.03	6.69	8.79
45	8.60	11.35	9.00	11.07
95	11.55	14.85	11.95	14.05

APPENDIX H

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. TWO LOTS RECEIVED FIFTEEN MILLIAMPERES OF SIXTY CYCLE IRRADIATION FOR TEN MINUTES IN A GLOW DISCHARGE TUBE. ONE OF THESE SAMPLES WAS THEN SCARIFIED. A THIRD SAMPLE WAS SCARIFIED AND NOT IRRADIATED WHILE THE FOURTH SAMPLE WAS A CONTROL. (SEE FIGURE 11.)

Time in Water: (Hours)	Per Cent Weight Increase			
	Scarified	Control	Irradiated	Irradiated and Scarified
1/12	3.87	5.34	8.20	5.53
1/4	6.31	7.69	10.36	8.19
1/2	8.78	9.52	12.36	10.84
1	13.07	12.03	15.07	15.17
2 1/6	21.72	16.37	19.07	24.39
3	27.41	19.43	21.27	29.53

APPENDIX I

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. ONE LOT WAS IRRADIATED WITH FIFTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT FOR TEN MINUTES IN A GLOW DISCHARGE TUBE AND THEN SCARIFIED. A SECOND LOT WAS SCARIFIED PRIOR TO IRRADIATION. THE THIRD LOT WAS SCARIFIED ONLY, AND THE FOURTH LOT WAS THE CONTROL. (SEE FIGURE 12.)

Time in Water (Hours)	Per Cent Weight Increase			
	Scarified	Control	Scarified then Irradiated	Irradiated then Scarified
1/12	3.72	5.00	5.37	4.74
1/4	6.15	7.12	7.88	7.19
1/2	8.88	9.07	10.70	9.93
1	13.54	11.39	15.41	14.37
2	22.93	15.25	24.53	23.52
3	28.95	19.03	30.69	29.87

APPENDIX J

RATES OF WATER SORPTION OF FOUR LOTS OF FIFTY SEEDS EACH OF CORN (T18 x T14) IMMERSED IN WATER. THREE LOTS RECEIVED FOUR, EIGHT AND SIXTEEN MILLIAMPERES OF SIXTY CYCLE CURRENT RESPECTIVELY, FOR FIVE MINUTES IN A GLOW DISCHARGE TUBE. THE FOURTH LOT WAS A CONTROL. (SEE FIGURE 13.)

Time in Water (Hours)	Per Cent Weight Increase			
	Control	4MA	8MA	16MA
1/12	4.42	6.34	6.20	6.43
1/4	6.48	8.42	8.25	8.92
1/2	8.26	10.40	10.08	10.32
1	11.03	13.13	12.79	12.95
2	14.74	16.71	16.21	16.44
3	17.98	19.50	18.89	18.83

APPENDIX K

RATES OF WATER SORPTION OF FOUR LOTS OF 100 SEEDS EACH OF ODGEN SOYBEANS IMMERSED IN WATER. TWO LOTS RECEIVED TEN MILLIAMPERES AND FIVE MILLIAMPERES RESPECTIVELY, OF SIXTY CYCLE CURRENT FOR FIVE MINUTES IN A GLOW DISCHARGE TUBE. THE OTHER TWO LOTS WERE CONTROLS. (SEE FIGURE 14.)

Time in Water (Minutes)	Per Cent Weight Increase			
	Control	Control	5MA	10MA
5	.24	.23	1.58	1.78
15	.97	.91	2.66	2.90
30	2.08	2.04	3.90	4.71

APPENDIX L

DISTRIBUTION OF PLANT HEIGHT ON 3 JUNE 1955, OF CORN (T18 X T14) FROM SEEDS RECEIVING FOUR, EIGHT AND SIXTEEN MILLIAMPERES RESPECTIVELY OF SIXTY CYCLE IRRADIATION FOR FIVE MINUTES IN A GLOW DISCHARGE TUBE. SEEDS WERE PLANTED 5 MAY 1955, ON AN ETOWAH SILT LOAM, KNOXVILLE, TENNESSEE. (SEE FIGURE 18.)

Plant Height in Inches	Number of Plants				
	0MA	0MA	4MA	8MA	16MA
6	0	0	0	0	1
7	0	0	0	0	0
8	1	1	1	0	1
9	0	1	1	0	3
10	0	0	1	2	3
11	1	1	0	1	2
12	1	1	2	1	2
13	2	2	0	2	3
14	4	5	3	5	8
15	8	5	1	1	6
16	20	11	11	11	9
17	8	9	7	9	6
18	20	20	19	15	13
19	10	14	13	8	14
20	34	43	29	22	22
21	30	24	22	21	20
22	41	40	31	60	50
23	29	22	26	34	23
24	44	46	51	33	27
25	25	20	34	27	30
26	31	30	42	45	28
27	12	11	14	15	10
28	12	13	22	18	21
29	9	9	4	3	3
30	3	4	21	5	1
31	0	0	1	2	0
32	0	2	1	0	1