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The effect of electro-magnetic radiation on certain varieties of soybean seeds

Arunachalam Lakshmanan

To the Graduate Council:

I am submitting herewith a thesis written by Arunachalam Lakshmanan entitled "The effect of electro-magnetic radiation on certain varieties of soybean seeds." I have examined the final electronic copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Agronomy.

Horace C. Smith, Major Professor

We have read this thesis and recommend its acceptance:

Henry Andrews, Rufus, Beamer

Accepted for the Council:
Carolyn R. Hodges

Vice Provost and Dean of the Graduate School

(Original signatures are on file with official student records.)

August 15, 1961

To the Graduate Council:

I am submitting herewith a thesis written by Arunachalam Lakshmanan entitled "The Effect of Electro-Magnetic Radiation on Certain Varieties of Soybean Seeds." 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.

Horace C Smith Jr.
Major Professor

We have read this thesis
and recommend its acceptance:

Rufus W. Beamer

Henry Andrews

Accepted for the Council:

W. E. Spivey
Dean of the Graduate School

THE EFFECT OF ELECTRO-MAGNETIC RADIATION ON CERTAIN VARIETIES OF SOYBEAN SEEDS

A Thesis
Presented to
the Graduate Council of
The University of Tennessee

In Partial Fulfillment
of the Requirements for the Degree
Master of Science

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by
Arunachalam Lakshmanan
August 1961

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CHAPTER I

INTRODUCTION

Ever since electricity was discovered, man has attempted to study its effect on plant and animal life. Different principles and methods have been employed to improve crop plants with electricity, but the reported results are contradictory except in the case of seed germination. An increase in rate and per cent germination of seeds with hard coats, like alfalfa, due to electrical treatment have been reported by several workers. Treatment of certain other seeds including soybeans, cotton and corn have been reported to give a faster rate of germination although the final germination per cent was not always affected.

Earlier studies at the University of Tennessee by the Farm Electrification Research Branch, Agricultural Research Service, indicated that electrically treated seeds of soybeans showed a higher and faster adsorption of water when placed in contact with free water than the untreated seeds. It was also reported that the treated seed germinated faster, but the final per cent germination in the laboratory and field conditions were not greatly influenced by electrical treatment. Also no difference in yield was reported.

Experiments reported here were conducted to further determine the effects of electrical treatment of soybean seed and to determine the response of various varieties of soybeans to electrical treatment including seed germination, respiration, and growth.

CHAPTER II

REVIEW OF LITERATURE

The earliest recorded experiment of the influence of electricity on plants was that of Maimbray, a Scotch scientist, in 1746 whose work was reported by Cherry (10). He conducted experiments on the influence of electricity, collected from the atmosphere, on myrtle trees. Ricioni (26) reported the work of Abbe Nollet in 1747, who applied electrical energy to seeds by the use of friction apparatus.

Bertholan, a French scientist, in 1783 used an antenna arrangement to collect and transmit electricity to plants growing in the field. Cherry (10) and Lund (22) reported an increase in growth of plants treated with Bertholan's "electro-vegetometer."

In 1884, Ross (27) buried large zinc and copper plates in the soil 200 feet apart and connected them with above ground wires. Potatoes grown between the plates were reported to be larger than potatoes not grown in his "glavanic cell."

Solly, in 1845 conducted similar experiments, using a variety of plants including grains, vegetables and flowers. He obtained conflicting results and concluded that electrical treatment had no positive effect on growth.

Increase in growth and other favorable effects due to electrical treatments were reported by Lemstrom (20), Priestly (25), Newman (24) and Dudgeon (12). In 1902, Lemstrom (20) reported increases in yield of strawberries by 50 to 128%, corn by 35 to 40%, potatoes by 20% and beets by 26%.

Cherry (10) has reported the experiments conducted by Sir Oliver Lodge in 1907. The treatment in this case consisted of having a network of wires above the plants through which electricity was passed. Increases in yield of 40% and 30% for two varieties of wheat were reported from the treatment.

In 1924, Blackman (6) and Blackman and Legg (7) reported the results of their field and pot culture experiments conducted over a period of 4 years. They concluded that, in general, electrical treatment increased the dry weight of the plants in the pot culture and increased the yield of wheat in the field experiment.

In 1926, Briggs et al. (8) published a bulletin describing experiments conducted over a period of 11 years. These tests showed no difference between the treated and control plants with respect to yield, transpiration rate, and water requirements of the plants grown under a highly charged network of wires with a potential of approximately 50,000 volts.

DeWolf and Fry (28) patented a process of electrical treatment of seeds in England and brought it in to use in 1917. The process consisted of soaking the seeds in household salt solution of 2.5 to 5%, passing an electric current of 8 watts through the solution and drying the seeds at 110°F. The process was given wide publicity in Canada, United States, and Australia.

Russel (28) conducted controlled pot tests in 1915 and 1919 at the Rothamstead Experiment Station using the "Wolfryn" process stated above. He found no real difference between plants from treated and untreated seeds. Hence he did not conduct any field trials. The process used, involves three distinct independent steps namely, soaking the seed in salt solution, passing electric current through the seed and drying them at 110°F. Russel suggested that any increase in yield obtained may be due to any one of the three steps.

Experiments with the "Wolfryn process" were conducted in Canada in 1917 by Shutt (29) and in 1922 by Sutton (31). They found that the process was of no real value for increasing the yield of crop plants. In the United States, Leightly and Taylor (19) conducted experiments at the Arlington experimental farm using this process and found no noticeable difference in plant vigor, appearance or yield.

In recent years a number of experiments have been conducted to study the effect of high frequency seed irradiation on insect and diseases infesting the seed in storage. High frequency irradiation according to Baker, Waint and Taboada (5) causes two main effects on tissue namely, a heat effect, and a chemical effect. They stated that radiation with wave lengths longer than about 2880Å is essentially heating. The control of insects and diseases infesting seeds in storage is considered primarily as an effect of heating. Ark and Parry (2) reported that the effect of such treatment on seed germination indicated a definite stimulation effect. Quoting the work of Sinuik and Frolore, they reported increased germination of carrot and onion seeds.

High frequency treatment has been reported to have given higher germination by Leao in 1922 (18) in Brazil. He also reported that the treatment did not affect the nutritive value of plants.

Cotton seeds were irradiated by Kikuchi and Ikeuchi (16) at 100 millamperes, 1500 volts and a wave length of 3 meters for a period of 20 minutes. They reported that the treated plants were taller than the controls. However, their report was based on only two replications of four plants each.

In 1954, Iritani and Woodbury (14) working with high frequency heat treatment on some seeds like alfalfa with hard seed coats found that the seeds with 28% germination, when irradiated at 4000 - 4500 volts for a period of 2 minutes and 37 seconds gave approximately 43% germination. Since high frequency electrostatic radiation causes internal heating, they considered the effect on hard seeds of such a treatment as a heat effect.

In Italy, Ricioni (26) developed a method for electrical treatment of seeds, in 1946 which perhaps is the first type to be applied on a large commercial scale. A plant for treating the seeds in the method advocated by him is located at Terni, Italy. The treatment consists of passing the grain between two spheres where a spark discharge was occuring 1000 times per second. It was reported that the treated seeds definitely produced higher yields than the control without affecting the quality of the grain.

In experiments conducted by Andrews (1) and Lingerfelt (21) seeds were treated in an evacuated glass tube 1 inch in diameter and 14 inches long with an iron electrode in each end as found in neon lights. The tube was evacuated to the desired pressure and an electrical potential was applied between the electrodes thus producing a current in the circuit.

> Brown, Stone and Andrews (9) stated, "At low potentials the current is the result of the movements of free charged particles. As the potential is increased a point is reached where the velocity of the free electrons is great enough to exite the gas molecules with which they collide causing these molecules to radiate light-energy. When ionization occurs, the inner volume of the partially evacuated tube is almost entirely filled with a luminous region known as the plasma."

They found that radiation of the above type increased the rate of water adsorption of seeds and decreased the time required for the germination of seed in a petri dish containing free water. They also found that if the radiation is made sufficiently intense the seeds are killed. These workers also expressed the opinion that the radiation effects may have ecomomic values. Since the seeds are made more permeable to water, they suggested that the seeds irradiated in an electromagnetic discharge would be more easily dried.

Andrews (1) reported no visible differences in the length of the radicle of electrically treated and untreated seeds germinated on blotters. He slso reported that untreated corn seeds had a lower rate of water adsorption than viable treated seeds, unviable treated seeds, treated then scarified seeds and scarified seeds. Seeds that were both irradiated and scarified and seeds that were scarified only had a higher rate of water adsorption than seeds that were only irradiated. He reported that the rates of water adsorption of soybeans were affected by electrical treatment in much the same manner as corn.

Tests conducted by Andrews in flats with treated and untreated corn showed no increase in germination, seedling height or root development from irradiation. Similar plantings of vetch and barley with treated and untreated seeds showed no visible differences.

Andrews also reported results of a field planting of corn in which treated and untreated seeds were used. The treatments used were 4, 8, and 16 milliamperes for 5 minutes. He found no significant differences in height or time of silking and tasseling of plants between treated and untreated seeds. Seeds receiving the 16 milliampere treatment were significantly lower in germination percentage and plots planted with seed receiving this treatment had significantly lower yields.

Lingerfelt (21) treated Ogden soybeans seeds in the same method as Andrews and placed them in petri dishes in the presence of free water. He reported an increased rate of water adsorption from the treatment. Lingerfelt (21) reported an increase in the amount of soluble amino-nigrogen in electrically treated seeds over untreated seed. He reported an increase ranging from 10.2% to 27.4% depending upon the intensity of the treatment. He suggested that the increase in soluble amino-nitrogen in treated seeds was due to protein hydrolysis during the electrical treatment, which, in the case of untreated seeds, happens only when they come in contact with water. He suggested that the treated seeds with larger amount of soluble amino-nitrogen contributed to the earlier germination of the treated seed.

Many studies have clearly indicated that the amount of moisture in seeds is one of the factors affecting the intensity of respiration.

Kolkwitz (17) found that barley kernels containing 10 to 11% of moisture liberated only 0.33 to 1.5 mg. of carbon-dioxide per g. per hour. After they had absorbed 33% moisture, 2,000 mg. of carbon-dioxide were liberated in a similar period.

The increase in the respiration rate due to changes in the moisture content was observed in wheat by Bailey and Gurjar (4) to be as follows:

When the per cent moisture increased from 12% to 13% the increase in respiration was 0.16%, from 13% to 14% it was 0.17%, from 15 to 16 it gave 1.41% increase and from 16 to 17 a rise of 3.02% was observed.

Bailey and Gurjar (4) observed that respiration of corn seed became marked when the moisture content exceeded 13%. When the moisture content was raised to 15 or 16% an increase in the respiration rate of 400% was obtained.

The reason for the accelerated respiration with increased moisture content given by Bailey and Gurjar is as follows:

> "In the case of grains, the colloids of the cells inbibe water and form elastic gels and if sufficient water is supplied, the gels become more and more dilute. Diffusion through the stronger gels is relatively slow, while through the dilute gels it is relatively rapid. Increasing the moisture content thus results in progressively less viscous gels and a corresponding increase in the rate of diffusion. It is assumed that the rate of respiration depends upon the rate of diffusion between the various cells of the tissues, so that the less viscous the gels of these cells, the more rapid the rate of respiration."

Observation similar to those which have been mentioned in regard to the relation of the moisture content to respiration have been made by Coleman, Rothgeb and Fellows (11), Duvel (13) and Babcock(3).

Jacquot and Mayer (15) reported the rate of carbon-dioxide production per unit of moist weight of corn and peanut seed increased with water content up to 30 to 35% when the rate began to fall off, while in the case of beans, the respiration rate increased with moisture up to 60% before it began to decline.

The work at the University of Tennessee under the Farm Electrification program[1] also indicated that electrically treated Ogden soybeans showed an increased rate of respiration than the untreated and the maximum difference in rate of respiration was reported at the second hour after contact with water.

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[1]Unpublished Annual report for year ending March 31, 1961, Line Project AE - d4 - 4: Farm Electrification Research Branch, Agricultural Research Service.

CHAPTER III

METHODS AND PROCEDURES

I. LABORATORY METHODS AND PROCEDURES

Electrical Seed Treatment

Soybean seeds were electrically irradiated by placing them in a straight glass tube, 1 inch in diameter and 14 inches long, with iron electrodes of the type used in neon signs sealed in each end. The tube was evacuated to a pressure of 3 mm.Hg. and electrical potential of 40 milliamperes applied between the electrodes for 5 minutes. All the varieties of soybean seeds used in the experiment were given the above treatment. A detailed description of the appartus used is given by Brown, Stone and Andrews.(9)

Germination Equipment and Methods

The germination equipment employed for several of the experiments reported here was constructed from a refrigerator cabinet of approximately 64 cubic feet capacity. A temperature cycle of 30°C for 8 hours followed by 20°C for 16 hours was used. The temperature within the cabinet was controlled automatically by thermostats. The free flowing water, which ran down the back of the cabinet, maintained almost a 100% relative humidity. The ferminator was equipped with perforated stainless steel trays.

Germination Tests

Soybean seeds of Odgen, Lee, Hood and Hill varieties were irradiated in the method previously described. Untreated samples were also included. Four folds of paper towels were moistened and the excess moisture was rolled out by a roller. Fifty seeds each of the treated and untreated samples were placed in between towel folds. These towels were placed over moistened towels on the germination experiment. Germination counts were taken for 5 consecutive days.

Germination at Various Soil Moisture Levels

Huntington fine sandy loam soil was passed through a 2 mm. sieve and dried in the oven at 105°C for 3 days. Moisture was added to the oven dry soil to obtain 5, 10 and 15% by weight. The moist soil (450 g.) was placed in a plastic bag which was placed in a small can. Ten seeds were uniformly sown at a depth of 0.75 inch and the plastic bag was tied securely to prevent evaporation of moisture. The cans were placed in a growth chamber with a light period of 16 hours followed by a dark period of 8 hours. The temperature in the growth chamber was maintained at 63°F. with a relative humidity of approximately 45% through out the experimental period. Four replications were used. Emergence counts were taken for 8 days following the date of planting.

Germination at Various Osmotic Pressures

Sucrose was employed for regulating osmotic pressure in distilled water at 3, 6 and 9 atmospheres, with distilled water as control. Minute quantity of thymol was dissolved in the water and solutions to control fungus growth. Ten seeds were placed on No. 40 Whatman filter paper in 9 cm. petri dishes. Three ml. of the solutions or water was added to each of the dishes. Each treatment was replicated four times. The dishes were placed in the germinator described above. Germination counts were taken daily for 5 consecutive days.

Germination in Vermiculite and Measurement of Root and Stem Growth of Seedlings

The length of primary root and stem of soybeans seedlings from treated and untreated seeds were determined. Plantings were made in vermiculite in glass dishes with one quart of vermiculite placed in the bottom of each dish with 50 seeds uniformly planted over it. The seeds were covered with vermiculite. Water was added to keep the medium moist. The dishes were placed in the growth chamber. The temperature, humidity and light were the same as those previously described.

At the end of 5 days, the seedlings were carefully removed and the root and stem length measured.

Respiration Studies

Respiration studies during germination of electrically treated and untreated seed were conducted in a Warburg manometer. Manometric techniques recommended by Umbreit, Buttis and Stauffer (32) were followed. The respiration of treated and untreated seeds of Lee, Ogden, Hood and Hill varieties were determined.

Three seeds weighing about 0.5 g. was used for each sample. In the center well of the flask, 0.2 ml. of 20% KOH was placed with a strip of filter paper to absorb the carbon dioxide produced during respiration. Two ml. of water was added to the seed. The volume of the manometer was kept constant and pressure change due to uptake of oxygen by the germinating seeds was measured. The temperature during the experiment was maintained at 30°C. in the water bath of the apparatus. Each treatment was replicated three times. Hourly readings were taken for 8 hours after placing the seed in contact with water and the results calculated as $\mu l\ O_2$ per g. dry matter.

II. FIELD METHODS AND PROCEDURES

Sowings were made with the four varieties of soybeans to determine the effect of electrical radiation on germination and emergence in the field. This experiment was conducted at the University of Tennessee Agricultural Experimental Station, Knoxville on Huntington fine sandy loam soil.

A split plot design was used with seed treatments as the main plots and varieties as the sub-plots. Each sub-plot was a row containing 100 seeds. Eight replications were used in the experiment.

The soybeans were planted by placing them in holes bored one inch apart in a narrow section of plywood placed over furrow. The seed were covered to a depth of approximately 1.5 inches.

Counts were taken from the fourth day after planting when the first emergence was observed, to the tenth day.

CHAPTER IV

RESULTS AND DISCUSSION

Germination in Paper Towel

The rate of germination of electrically treated and untreated seed of Lee, Ogden, Hood and Hill varieties of soybeans are presented in Table I and Figures 1 through 4. The untreated seeds of all varieties did not germinate after 24 hours of contact with water and after 48 hours the average germination was only 9.4%. The electrically treated seeds had an average germination of 16.4% after 24 hours of contact with water and 39.1% after 48 hours. As seen from the photographs, the untreated seeds considered as germinated were just beginning to germinate after 48 hours of contact with water, while the radicles of the treated seed have grown to a considerable length. The seed of Lee had the highest germination per cent and the germinated seed produced longer radicles than the seed of the other three varieties after 48 hours, followed by Ogden, Hood and Hill.

On the third and subsequent days the average germination per cent was approximately the same for treated and untreated seed. The untreated seed of Hill and Hood, however, had a slightly higher germination per cent than the treated seed after the second day. The treated seed of Lee and Ogden had a somewhat higher per cent germination than the untreated seeds after the second day. The differences were small, with the exception that the treated seed of Ogden had a germination of 81% compared to only 66% for the untreated on the third day. The effect

TABLE I

GERMINATION OF FOUR VARIETIES OF SOYBEANS IN GERMINATOR AS AFFECTED BY ELECTRICAL TREATMENT

	Germination, %[a] Days after planting				
Variety	1	2	3	4	5
			Electrically Treated		
Lee	28.5	56.5	97.0	99.5	99.5
Ogden	18.0	40.5	81.0	95.5	96.5
Hood	11.5	39.0	88.5	96.0	96.0
Hill	7.5	20.5	60.5	70.5	74.5
Mean	16.4	39.1	81.8	90.4	91.6
			Untreated		
Lee	0.0	18.5	91.0	97.0	97.0
Ogden	0.0	3.5	66.0	91.0	91.0
Hood	0.0	9.5	91.0	99.5	99.5
Hill	0.0	6.0	72.0	72.0	77.0
Mean	0.0	9.4	80.0	89.9	91.1

[a]Values are means of 4 replications of 50 seeds each.

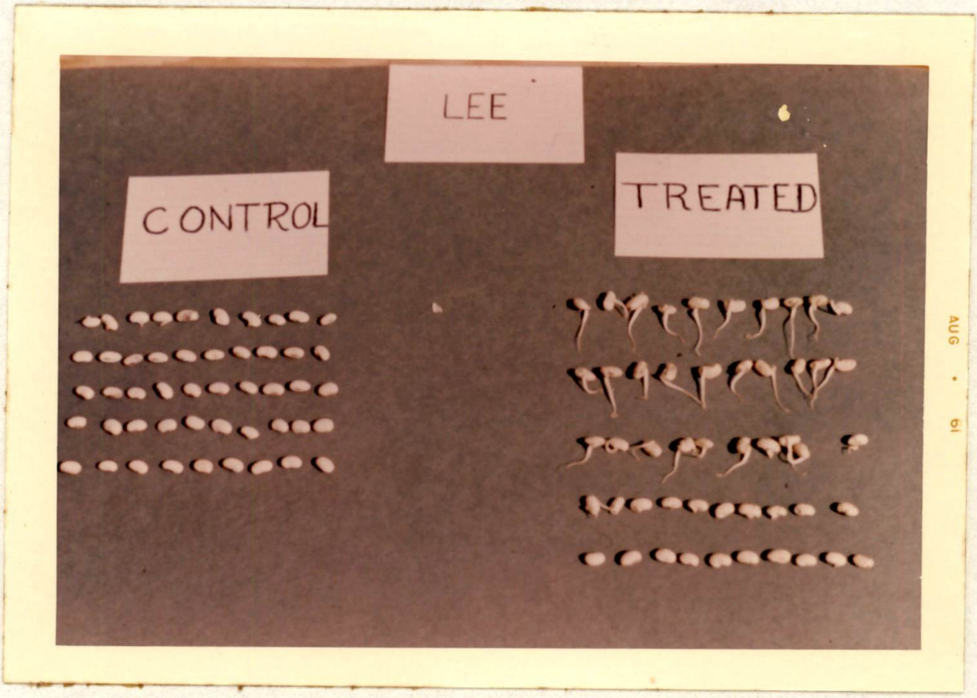


FIGURE 1

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED
(CONTROL) SEED OF LEE SOYBEANS AFTER
48 HOURS OF CONTACT WITH WATER

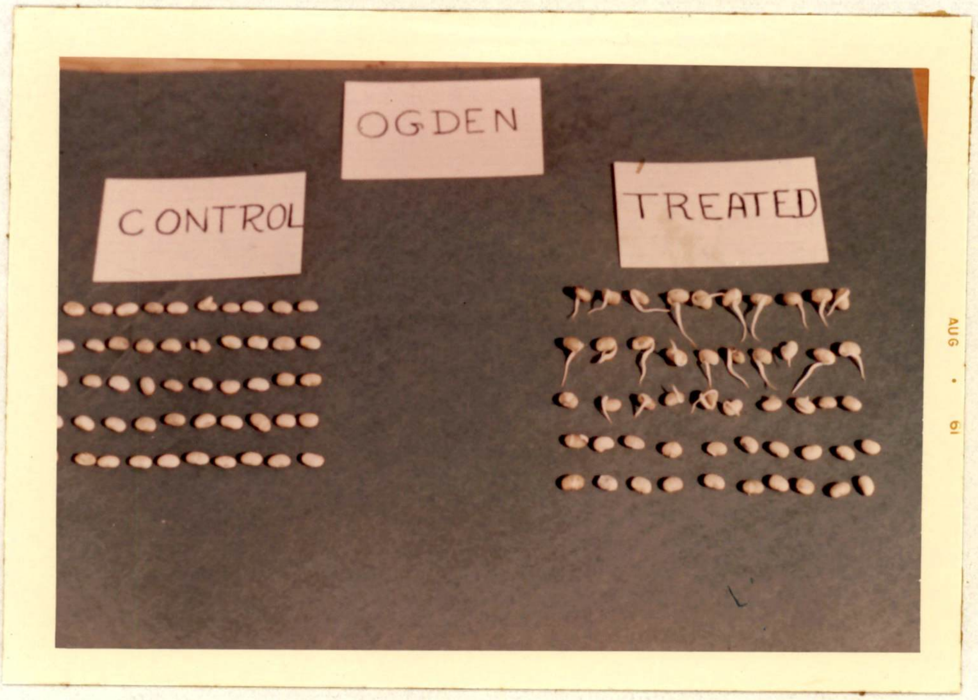


FIGURE 2

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED (CONTROL)
SEED OF OGDEN SOYBEANS AFTER 48 HOURS
OF CONTACT WITH WATER

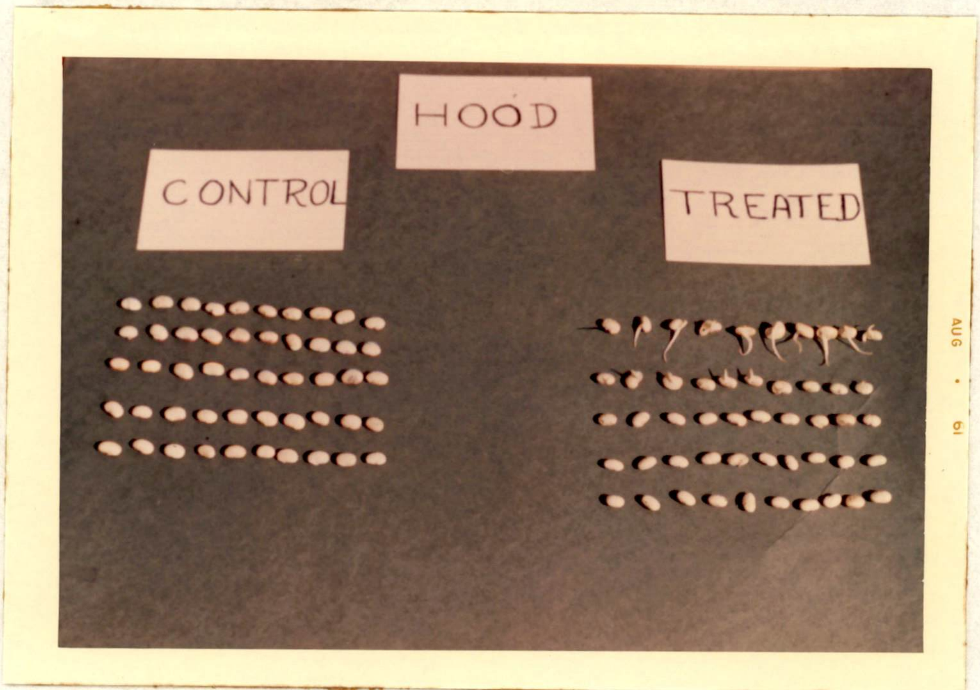


FIGURE 3

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED (CONTROL) SEED OF HOOD SOYBEANS AFTER 48 HOURS OF CONTACT WITH WATER

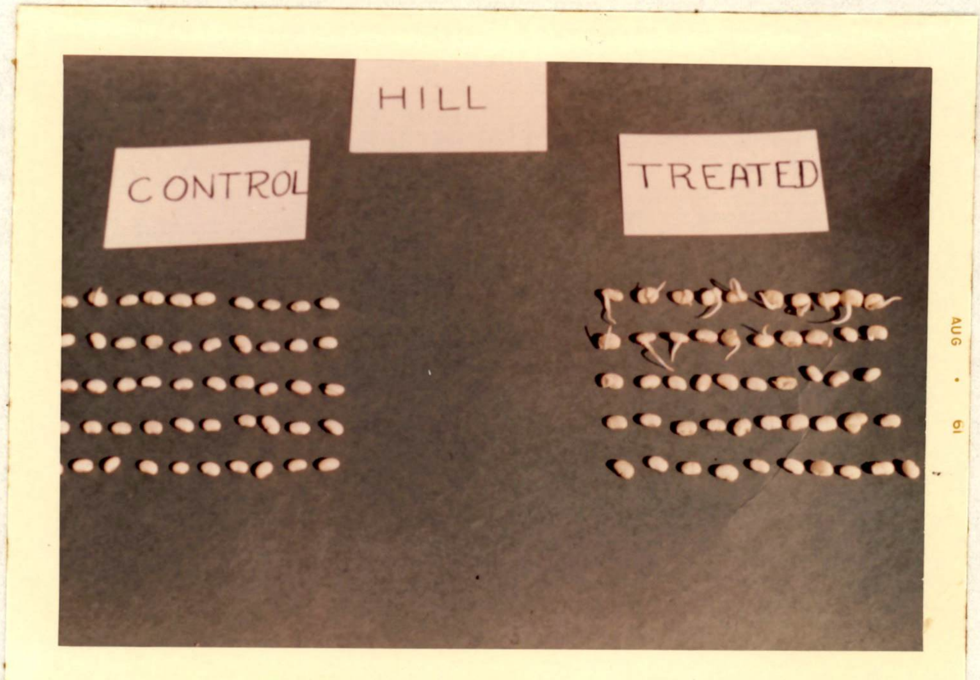


FIGURE 4

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED (CONTROL)
SEED OF HILL SOYBEANS AFTER 48 HOURS
OF CONTACT WITH WATER

of electrical treatment on the four varieties are similar except with Hill. Treatment increased the germination only 14.5% after 48 hours compared to an increase of about 30% for the other three varieties.

The rate of germination of four varieties tested in the above experiment viz. Ogden, Lee, Hood and Hill obtained from two sources are presented in Tables II and III.

Treated seeds of source I gave a germination of 18.1% the first day while source II gave only 11%. On the second day, the per cent germination of source II showed a 35% increase while source I showed only 22%. The untreated sample of source II also gave a slightly higher per cent germination on the second day. On the third and subsequent days, the difference between source I and source II for both treated and untreated condition are small.

From the data it is seen that the general trend of rate of germination in both sources are similar except that the source I has given a higher germination per cent after 24 hours of contact with water while the source II gave the highest per cent germination after 48 hours of contact with water. The final germination in both the sources were slightly higher in the treated lot. The differences noticed among varieties in the previous experiment were also noted here. Hence, it was concluded that the differences in varieties obtained from irradiation are due largely to the response of the varieties to treatment and not to the source of seeds of the same variety.

Andrews (1) noticed the earlier germination in electrically treated corn when placed in petri dishes but not on blotters. He

TABLE II

GERMINATION OF FOUR VARIETIES OF SOYBEANS OF SOURCE I
AS AFFECTED BY ELECTRICAL TREATMENT

Variety	Germination, %[a] Days after planting 1	2	3	4	5
		Electrically Treated			
Lee	30.5	57.5	98.0	99.0	99.0
Ogden	19.5	43.0	84.0	94.5	96.0
Hood	13.5	39.0	91.5	96.0	98.5
Hill	9.0	23.0	63.0	69.0	75.0
Mean	18.1	40.5	84.1	89.5	92.1
		Untreated			
Lee	0.0	21.5	92.0	98.0	98.0
Ogden	0.0	4.0	70.5	88.0	92.0
Hood	0.0	11.0	83.5	85.0	93.5
Hill	0.0	7.5	70.0	72.5	76.0
Mean	0.0	11.0	79.0	86.0	90.0

[a]Values are means of 4 replications of 50 seeds each.

TABLE III

GERMINATION OF FOUR VARIETIES OF SOYBEANS OF SOURCE II AS AFFECTED BY ELECTRICAL TREATMENT

	Germination, %[a] Days after planting				
Variety	1	2	3	4	5
			Electrically Treated		
Lee	33.0	61.0	97.5	98.0	98.5
Ogden	17.0	42.5	88.0	96.0	96.5
Hood	19.5	48.0	96.0	97.5	97.5
Hill	15.0	31.5	76.0	82.0	87.0
Mean	11.0	46.0	89.5	93.6	95.0
			Untreated		
Lee	0.0	19.5	78.5	96.5	97.0
Odgen	0.0	7.5	72.5	91.0	93.0
Hood	0.0	26.5	97.0	99.5	99.5
Hill	0.0	9.5	72.0	79.5	80.0
Mean	0.0	16.0	80.0	91.5	92.5

[a]Values are means of 4 replications of 50 seeds each.

suggested that the faster germination of treated seeds was a result of an increase in rate of water adsorption. He related the increase in water adsorption with permeability of the pericarp, which he suggested might have occured due to electrical treatment.

On the other hand, Lingerfelt (21), noticing the same phenomenon in Ogden soybeans, suggested that electrical treatment might have caused protein hydrolysis, which in the case of untreated seed takes place only after it comes in contact with water. He theorized that the larger availability of soluble amino-nitrogen might have increased the germination rate.

Seedling Emergence in the field:

The rate of emergence of soybeans in the field is presented in Table IV. The germination of both treated and untreated seed of all varieties was slow and a relatively poor final stand was obtained. Lack of adequate moisture in the soil immediately after sowing probably was the primary cause of the poor stand.

The general trend of germination is similar to that obtained in the previous experiments, although, the treated seeds gave only a slightly higher per cent germination. The final average germination for all varieties is similar. Among varieties, Lee gave the highest final per cent germination, 60% and 59% for the treated and untreated respectively. The untreated seed of Hill gave the lowest germination (26%), while among the treated seeds Ogden gave the lowest germination (34%).

The untreated seed of Hood gave 8% higher final germination than

TABLE IV

PERCENTAGE EMERGENCE IN THE FIELD OF FOUR VARIETIES OF SOYBEAN AS AFFECTED BY ELECTRICAL SEED TREATMENT

	Emergence, %[a] Days of planting						
Variety	4	5	6	7	8	9	10
			Electrically Treated				
Lee	13	19	22	33	45	53	60
Ogden	4	15	17	19	23	28	34
Hood	7	16	19	21	28	38	43
Hill	9	18	20	21	24	32	37
Mean	8.3	17.0	19.5	23.5	30.0	37.8	43.5
			Untreated				
Lee	12	18	20	24	36	48	59
Ogden	3	9	11	12	21	31	37
Hood	6	16	19	22	31	43	51
Hill	4	8	9	10	14	22	26
Mean	6.3	12.8	14.4	17.0	25.5	36.0	43.3

[a]Values are means of 8 replications of 100 seed per plot.

the treated seed while the treated seed of Hill gave 11% higher germination than the untreated. The differences between treated and untreated seeds of the other two varieties are small.

The large differences between irradiated and untreated seed observed in the laboratory during the first 48 hours were not present in the field.

Germination at Various Soil Moisture Levels

The results of germination of Ogden and Lee seed at 10 and 15% soil moisture in the growth chamber are presented in Figure 5. Treated and untreated seeds of both the varieties did not germinate at 5% moisture. At the 15% moisture level, treated seeds of both varieties gave an earlier and higher final per cent germination than the untreated seed. At 10% soil moisture a higher per cent of the treated seeds germinated earlier than untreated seeds. At both moisture levels, the variety Lee gave a higher final germination than Ogden, and the difference, particularly at 10% moisture is considerable.

When the treated seeds that had not emerged at the 10% moisture level were examined after the final count, the radicles had emerged but the hypocotyls had not developed. However, in the case of untreated seeds, only swelling of the seeds was noticed and the radicles had not emerged. This suggests an increased activity of the treated seeds even when the moisture is in short supply.

Germination at Various Levels of Osmotic Pressures

The results of the germination of Ogden and Lee soybean seeds in

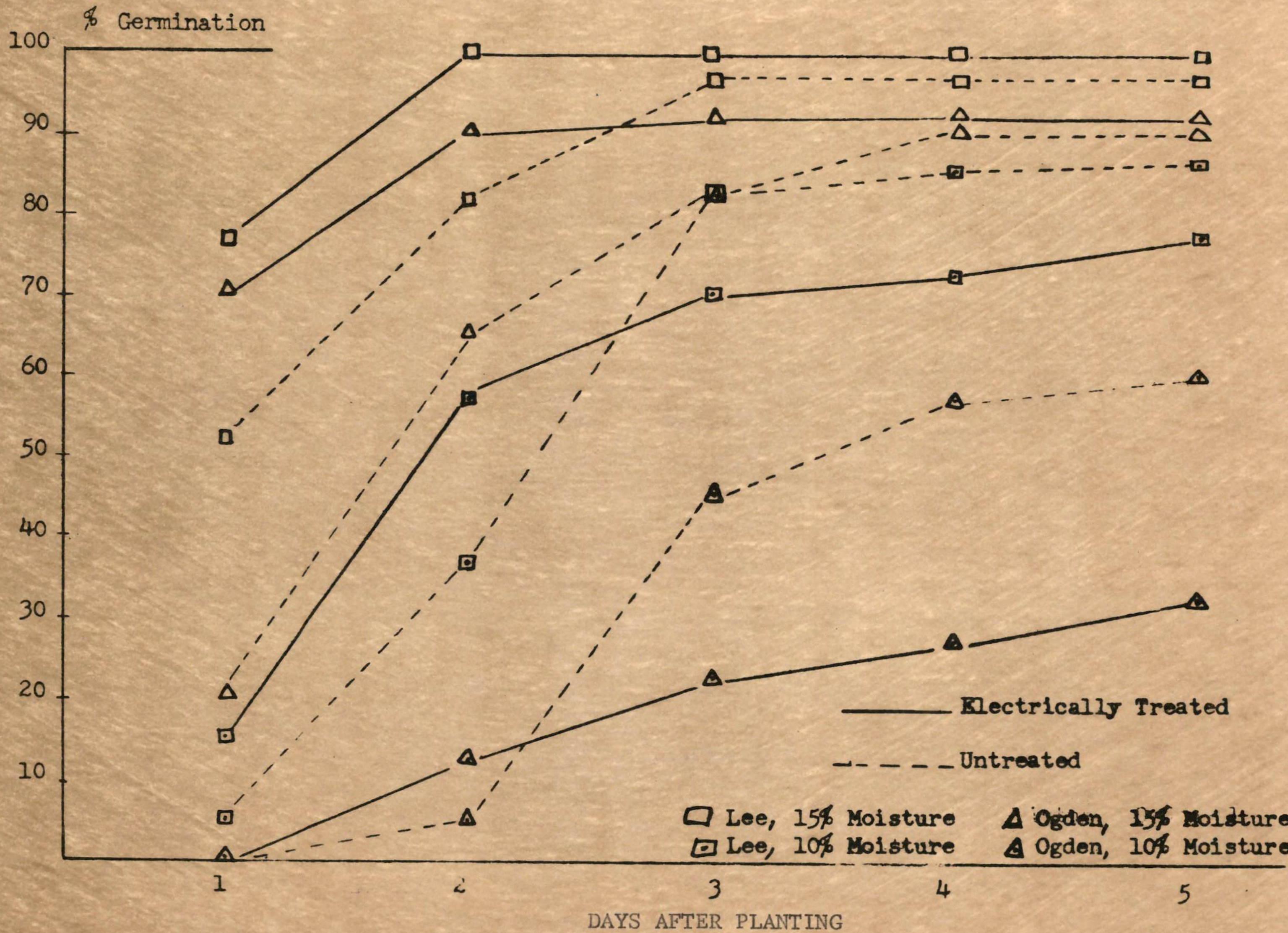


FIGURE 5

GERMINATION OF TWO VARIETIES OF SOYBEANS SEED AS AFFECTED BY ELECTRICAL TREATMENT AT TWO MOISTURE LEVELS solutions with osmotic pressures of 3,6 and 9 atmospheres and in water are presented in Figures 6 and 7.

The rapid imbition of water and quick germination of the treated seeds, observed in the experiments described previously, was absent in seed of both varieties when they were placed in the solutions. In most cases the untreated seeds gave a higher final percentage germination than the treated seeds, while the treated seeds showed a higher per cent germination in the first two days. Since rapid water adsorption by seed was significantly absent in osmotic solutions, it is supposed that the irradiation of seeds did not affect the capacity of the seed to imbibe water from solutions. In the solutions of 6 and 9 atmospheres, germination was observed only after the third day of contact with the solutions. The germination in distilled water was 80 to 90% at this time.

Among the varities, the treated and untreated seeds of Lee gave a higher percentage of germination at all osmotic pressures.

<u>Stem and Root Lenght of Soybeans Seedlings from Treated and Untreated Seed</u>

When treated and untreated soybeans seeds of the four varieties under test were germinated in vermiculite, there was no apparent difference in the rate of emergence.

The root and stem length of seedlings from treated and untreated seeds after 5 days of growth is presented in Table V. In case of Ogden, seedlings from treated seeds had a longer stem and root length, while with the other three varities, the treated seeds had a shorter root lenght. The stem length of seedlings from untreated seed of Lee had

TABLE V

ROOT AND STEM LENGTH IN MM. OF FOUR VARIETIES OF SOYBEAN AS AFFECTED BY ELECTRICAL SEED TREATMENT AFTER 5 DAYS OF GROWTH IN VERMICULITE

	Root Length[a]		Stem Length[a]	
Variety	Treated	Untreated	Treated	Untreated
Lee	6.1	8.2	6.3	6.6
Ogden	10.2	9.9	6.5	6.0
Hood	11.2	11.5	5.7	5.4
Hill	7.9	8.7	6.5	6.0
Mean	8.8	9.6	6.2	6.0

LSD (.05) Between Varieties	0.6	0.23
Between Treatment	0.9	0.16

[a]Values are means of 40 to 48 plants out of 50 seeds sown.

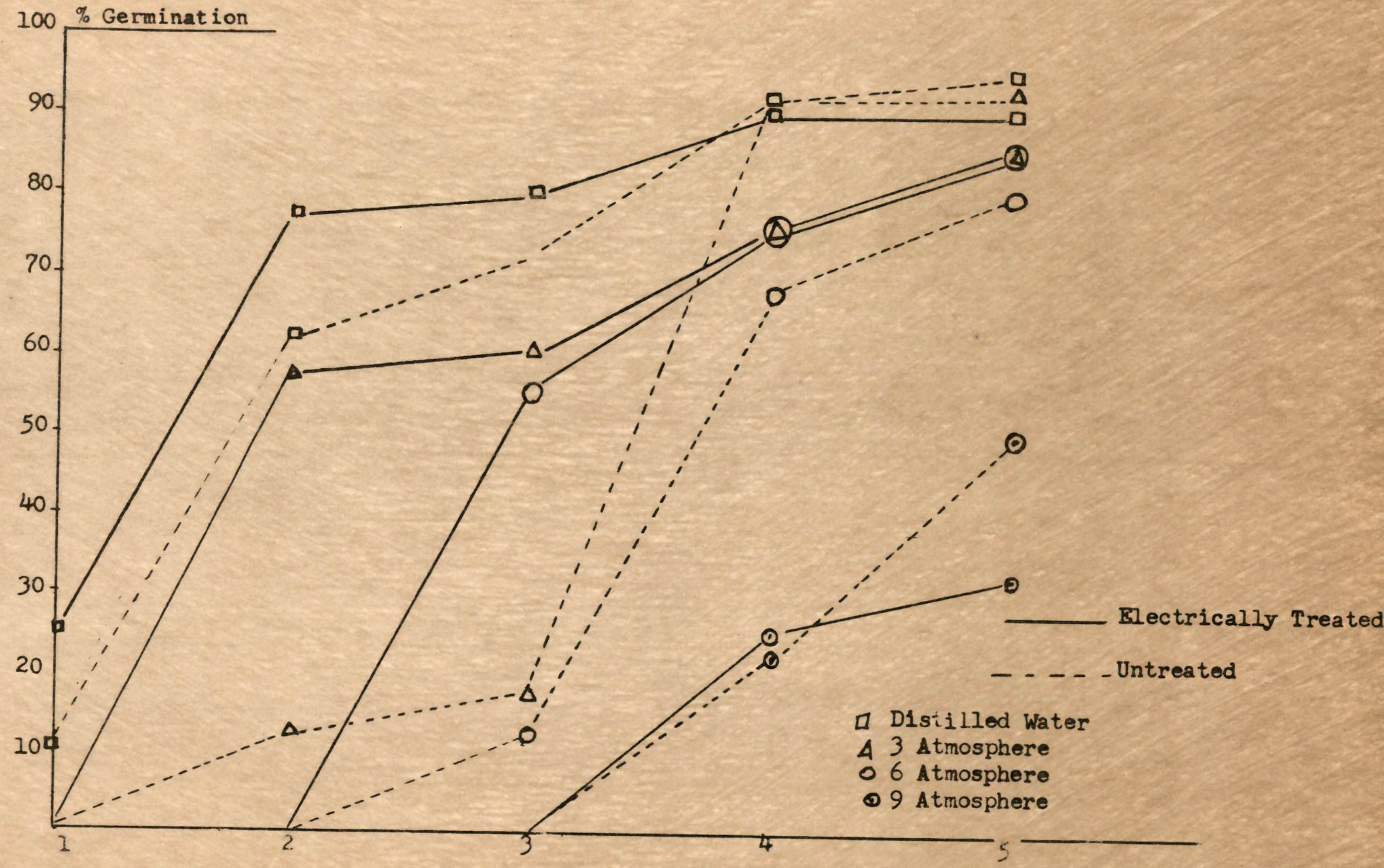


FIGURE 6

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED SEED OF LEE SOYBEANS IN VARIOUS OSMOTIC PRESSURE SOLUTIONS

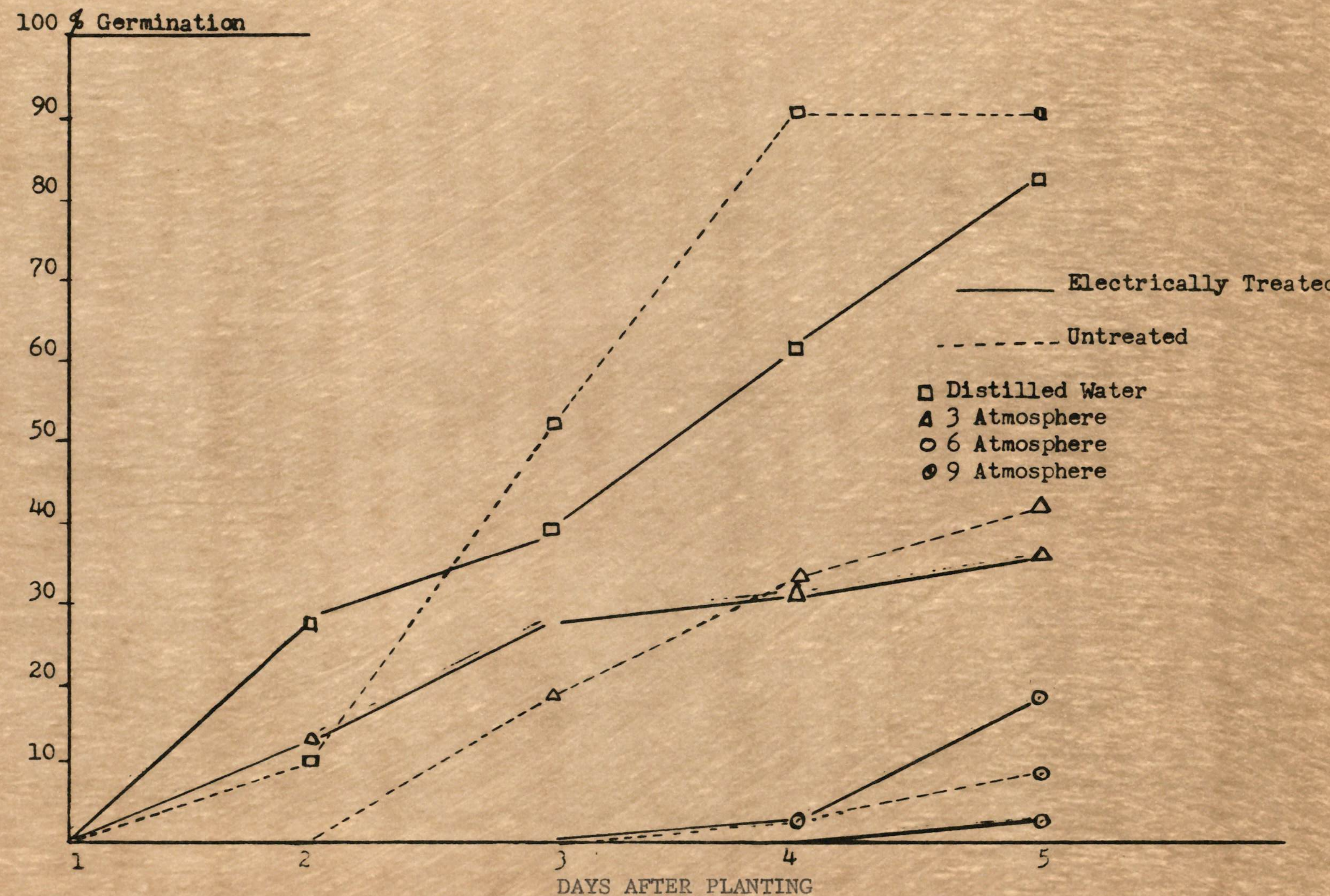


FIGURE 7

GERMINATION OF ELECTRICALLY TREATED AND UNTREATED SEED OF OGDEN SOYBEANS IN VARIOUS OSMOTIC PRESSURE SOLUTIONS

Longer stem growth than treated Lee, but in the other three varieties, seedlings from treated seeds gave significantly longer stem growth. The treated seeds gave an average root length of 8.8 mm.; the untreated gave an average of 9.6 mm. The stem length of treated seeds had an average of 6.2 mm. while the untreated gave 6.0 mm.

The variety Lee had the fastest rate of germination in all the experiments but had significantly shorter stem and root growth in comparison with the other three varieties. Of the four varieties under test, the seed size of Lee was the smallest, consequently a low food reserve. This probably is the reason for the short root and stem growth of seedlings of Lee.

Respiration of Germination Soybean Seed

The results of the experiment on the rate of respiration of the electrically treated and untreated germination seeds are presented in Table VI and Figure 8.

In all four varieties, the treated seeds had a higher rate of respiration throughout the experimental period of 8 hours, as measured by oxygen utilization, than the untreated. The variety Lee had the highest average rate of respiration followed by Odgen, Hood and Hill in the order mentioned.

Among the untreated seeds, the variety Lee had the highest average rate of respiration (140μl. of oxygen per g.) while Odgen gave the lowest)122μl. per g.), a significant difference of 18μl. per g. Oxygen uptake of Hood and Hill and other two varieties are not significant at 95% level of probability.

Among the treated seeds, Lee gave the highest rate of oxygen

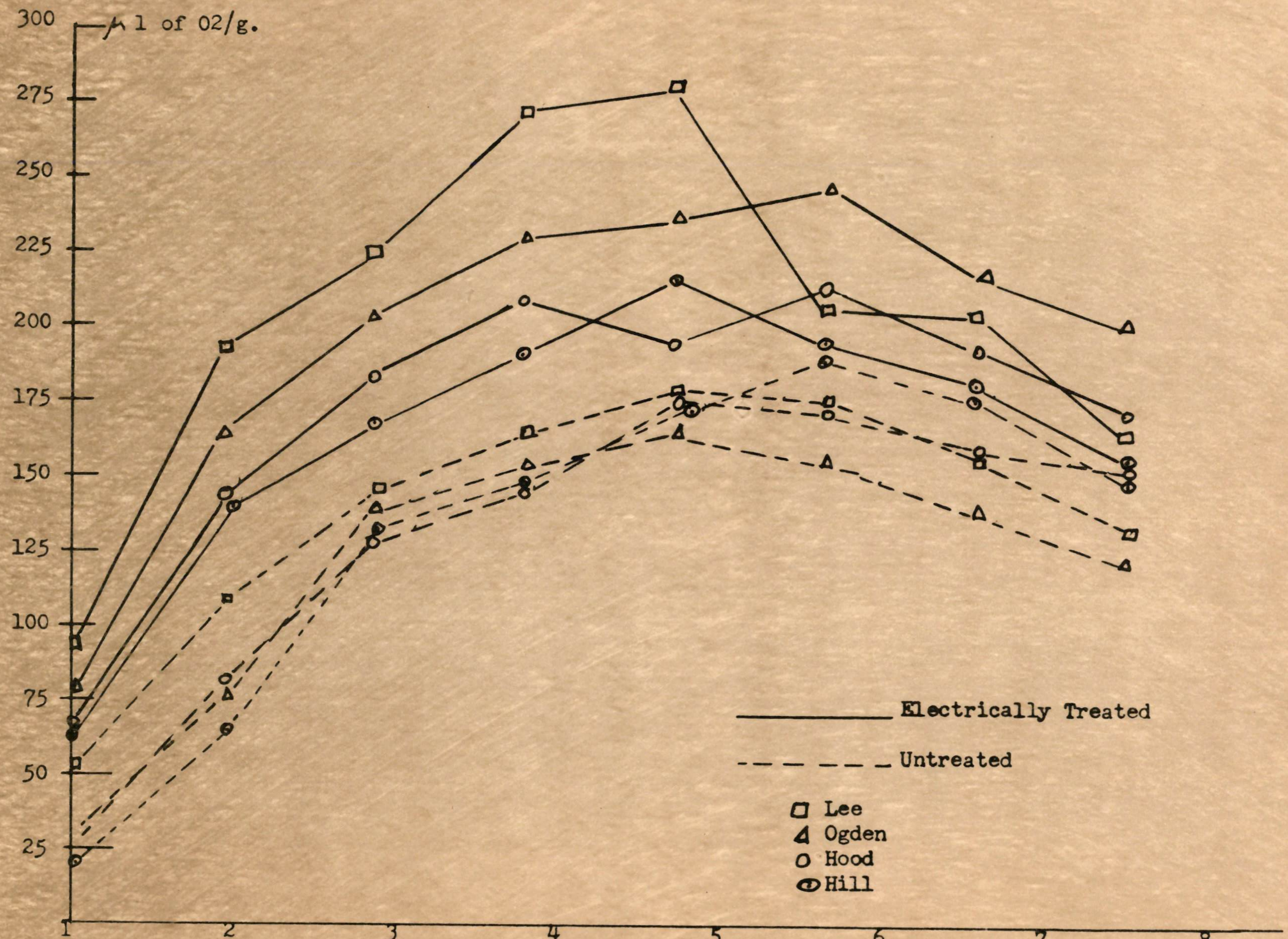
TABLE VI

AVERAGE RESPIRATION RATE (OXYGEN UPTAKE) OF FOUR VARIETIES OF SOYBEANS AS AFFECTED BY ELECTRICAL SEED TREATMENT

	Oxygen uptake, µl./g.[a]	
Variety	Electrically treated	Untreated
Lee	204	140
Ogden	195	122
Hood	170	130
Hill	163	132
Mean	183	131
LSD (.05)	21.0	11.0
(.01)	31.0	16.0

Between Variety Means (.05) 5.2 (.01) 7.0; Between Treatment Means (.05) 3.7 (.01) 5.0

[a]Values are means of 3 replications and 8 hourly readings.



HOURS OF CONTACT WITH WATER

FIGURE 8

RESPIRATION RATE OF FOUR VARIETIES OF SOYBEANS AS AFFECTED BY ELECTRICAL TREATMENT uptake, 204μl. per g. Hill had the lowest rate, 163μ l per g. The difference of 41μl. per g. was highly significant.

The untreated seed of Ogden which gave the lowest average rate of respiration showed the greatest increase (73μl. per g.) due to irradiation. The increases for the other varieties were: Lee, 63μl. per g.: Hood, 40μl. per g.; and Hill, 31μl. per g.

The rate of respiration in all cases increased progressively up to the fifth hour, except in the case of Ogden when maximum respiration was noticed on the sixth hour. After this time the rate of respiration decreased to the eighth hour when the experiment was terminated.

The rate of respiration of treated and untreated seeds have a close relationship to that of seed germination in the germinator. The higher respiration brought about by rapid intake of moisture by the treated seed probably resulted in quick release of energy resulting in faster germination of treated seeds.

CHAPTER V

SUMMARY AND CONCLUSIONS

Seed of Lee, Ogden, Hood and Hill, varieties of soybeans, were treated electromagnetically in an evacuated glass tube to 3 mm. Hg pressure at 40 milliampere for 5 minutes.

A higher per cent of all varieties treated as above germinated faster on the first two days than the untreated seed in paper towels, but the final germination was not influenced in any of the four varieties. The treatment also increased the emergence of soybean seedlings in the field, but the difference was small.

At 15% soil moisture level treated seeds of Ogden and Lee gave an earlier germination, while at 10% moisture the untreated seed gave a higher germination. The variety Lee gave a higher germination than Ogden at both moisture levels.

In osmotic solutions of 3,6 and 9 atmospheres, treated seeds did not germinate after 24 hours of contact with the solution. Hence, it is supposed that the electrical treatment did not affect the capacity of seed to imbibe water from osmotic solutions. The variety Lee gave a higher germination than Ogden at all levels of osmotic pressure.

The root and stem length of seedlings after five days growth from treated seeds of Ogden had significantly more root and stem growth, while seedlings from treated seeds of Lee had less root and stem growth. Treated seeds of Hood and Hill gave more stem growth and lower root growth than untreated seed.

The respiration rate of germinating treated seeds of all four varieties was higher than the untreated. The variety Lee, which gave an earlier germination in all the experiments, had the highest rate of respiration. The variety Ogden responded more to electrical treatment than the other three varieties in rate of respiration.

Since the treated seeds absorbed moisture rapidly, it is concluded that the accelerated respiration was brought about by higher intake of moisture. It is also theorized that the increased respiration rate accelerated the process of germination.

The effect of electrical treatment on soybean seeds varied to some extent from variety to variety, but in all cases an earlier germination is noticed although the final germination is not affected.

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