'InFolio'

REX RESEARCH
P O BOX 19250
JEAN
NV 89019
USA

NR. E8-EC1

TITLE: ELECTRO-CULTURE

#1

70 pp

SCI. NEWS v. 128 p. 88

Making rain while the sun shines

Some scientists have maintained that cloud seeding — the practice of dispersing chemicals into cumulus clouds in order to make rain — is about as effective as paying someone to do a rain dance. For midwestern farmers and water managers, however, cloud seeding has often seemed to offer hope in times of drought. North Dakota farmers, for instance, have had enough confidence in the procedure to target 6.6 million acres for the "store-bought" rain at the cost of 5¢ an acre, a state meteorologist estimates.

Skeptics have never doubted that when silver iodide seeding agents come into contact with a cloud's very cold moisture droplets, ice crystals — which become raindrops in warm weather — are formed; in laboratory cloud chambers this is known to happen. But could the process work in the field — or, perhaps more aptly in this case, in the sky — where the real clouds roam? The skeptics doubted that seeding agents dispersed at the base of a tall cumulus cloud could wend their way 5,000 to 12,000 feet up, to the part of the cloud that contains moisture droplets.

Last month, in a collaborative effort, scientists from the North Dakota Weather Modification Board in Bismarck and the National Oceanic and Atmospheric Administration (NOAA) in Boulder, Colo., took to the clouds in order to settle things once and for all. The researchers released a tracer gas — sulfur hexafluoride — simultaneously with the silver iodide, and then followed in a second plane equipped with detection equipment to monitor the tracer's dispersal.

"The stuff had a bit of a climb to make," says John Flueck, a NOAA research scientist, "but our preliminary guesses are that in at least one instance the seeding agent was successful in reaching the level where the cold water is." The researchers also tested silver iodide with sodium chloride. This combination, says Flueck, "works much more quickly — because the water in the cloud doesn't have to be as cold for it to work."

Scientists find new plant growth booster

BEAUMONT, TX ENTERPRISE 5/85

COLLEGE STATION (AP) — Scientists are studying a "plant tonic" they say could stimulate plant growth and revolutionize agriculture in the 21st century.

Preliminary studies under way at the Texas Agricultural Experiment Station indicate that a chemical "bioregulator" can increase plant growth and crop, officials said this past week.

The chemical, dichlorophenoxy-triethylamine, could be a shortcut to increasing crop yields without going through lengthy breeding experiments, says Dr. C.R. Benedict, a geneticist and plant physiologist with the Experiment Station.

"This bioregulator appears to have the potential for biochemical manipulation of plant growth and could have a profound impact on increasing the quantity and quality of crops," he said.

He and other researchers say they have found that DCPTA stimulates gene activity in the plant, speeding up the production of enzymes that in turn speed up the plant's metabolism.

They first discovered that DCPTA doubled the rubber production of guayule, a native desert plant that yields small quantities of high-quality natural rubber, Benedict said.

Researchers in Texas and elsewhere then began testing the bioregulator's effects on soybeans, wheat and cotton.

In greenhouse and laboratory experiments, a team of researchers from Texas and California has found that DCPTA increases growth of cotton plants.

"These observations look very encouraging," Benedict said. "The bioregulator stimulated growth in cotton and in preliminary studies, it looks like it has stimulated growth in soybeans."

But researchers say another growing season is needed to confirm the results.

The guayule results indicate that better crop yields are possible by other than genetic means, he said. And tests on DCPTA show no chance for producing mutant strains in plants.

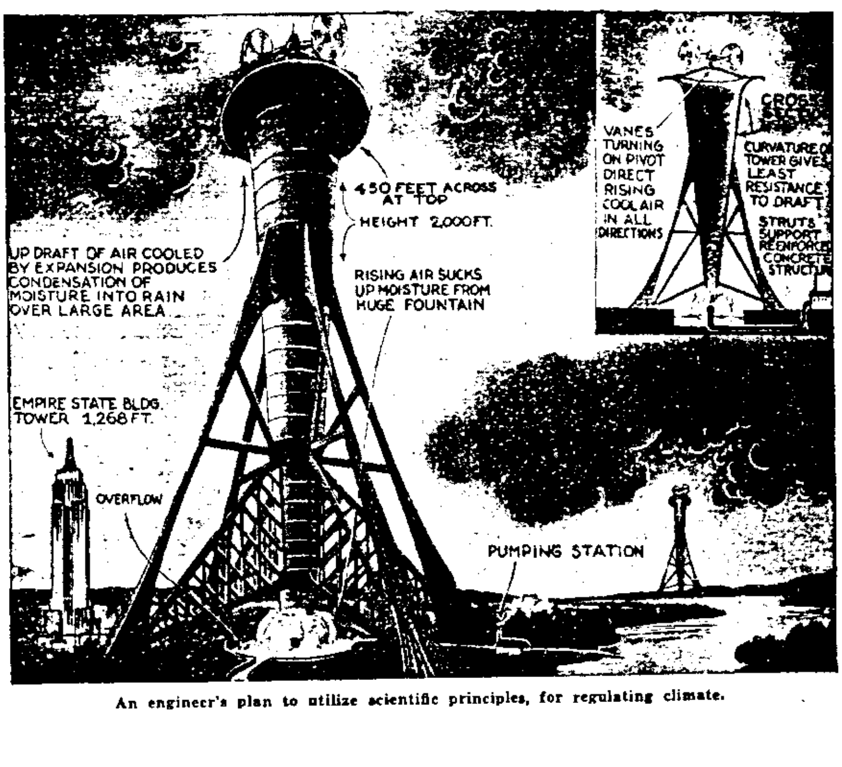
"Bioregulators give us the potential for manipulating the gene regulation of a plant," Benedict says, "and could have a profound impact on agricultural crop productivity and quality."

Sky-Scraping Towers to Make Rain

● RAIN is caused, as everyone knows, by the upper air's becoming too cold to hold any longer the water it contains. Consequently, the idea that rain can be made by firing bombs into the sky, to shake loose the water, is impractical.

A French meteorologist, Bernard Dubos, proposes to produce rain by lending Nature a hand; in other words, helping her to carry out her routine process of drawing heated, water-laden air from the surface of the earth, and cooling it (by expansion into thinner atmosphere) until the water comes down again.

His project, illustrated here, is to put up stupendous towers of concrete, hollow within, which will create drafts in the same manner as a factory chimney. The ascending air column will carry water up with it, as vapor; and whirling vanes will distribute it in all directions. By this means, M. Dubos believes, the natural moisture of the air can be readily increased. Such a tower, steel reenforced, and two-thirds higher than the Empire State Building, would cost about $10,000,000, it is estimated, and be of great scientific as well as climatic value.



An engineer's plan to utilize scientific principles, for regulating climate.

SCI. AMER Feb 15 1919
p 142-3

The Electrification of Seeds

A Revolution in Agriculture

By Charles A. Mercier, M.D., F.R.C.P., F.R.C.S.

FROM time to time, arts have been revolutionized by the efforts of individual men, often, men not brought up to the art, but practicing in a very different occupation. Arkwright, a barber, revolutionized the art of spinning; Cartwright, a clergyman, revolutionized the art of weaving; Watt, a maker of mathematical instruments, revolutionized every heavy industry; Rowland Hill, a schoolmaster, revolutionized our communications by devising the penny post; and Mr. Fry, an electrician, is revolutionizing the art of agriculture.

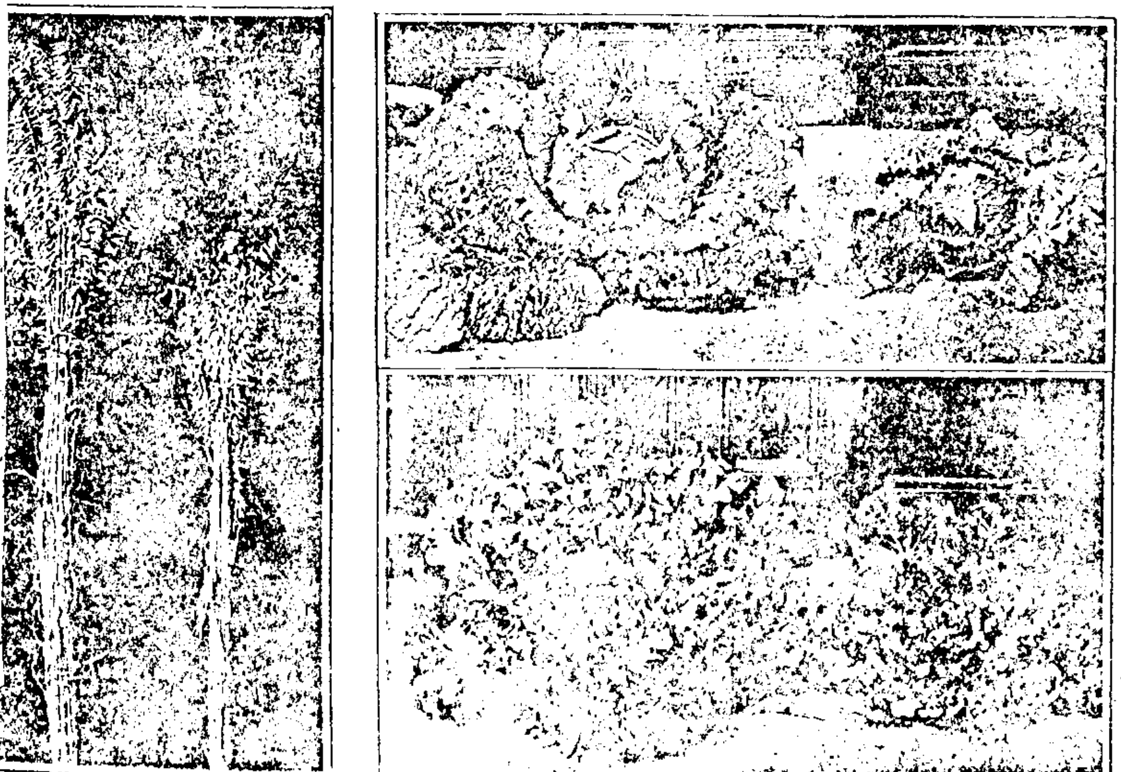
For to produce a large increase in the yield of corn and other crops, and at the same time a material improvement in quality, and to do this without any increase in the farmer's expense, without requiring any additional implement on the farm, or any new acquirement of skill, or any additional expenditure of time, on the part of the farmer—this is nothing short of a revolution in agriculture, and this is what Mr. Fry has done.

Electricity has long been applied to growing crops, and has had a decided effect upon them in producing more rapid and more luxuriant growth; but to subject a plant to electricity, either continuously or at intervals during the whole period of its growth, requires a considerable supply of electricity and more or less continuous attention; to apply it over large areas of many acres must necessarily be costly; and to apply it over hundreds and thousands of acres is scarcely practicable, especially as the installation of wires, etc., must necessarily interfere with the operations of agriculture. For horticulture it is no doubt practicable, and may be found useful and even profitable, but the difficulty of applying it on a large scale to agriculture is evidently considerable, and Mr. Fry turned his attention to the electrification of seeds, which is open to none of these drawbacks.

The process is novel. There was no previous experience whatever to go upon, and the inventor had to feel his way gradually to success by the tedious process of trial and error, making many mistakes on the way, suffering many disappointments, checked in every direction but the right one, and learning from every failure the way to success. Beginning first in a few pots, the experiments were soon extended to a patch of garden ground; then a neighboring farm-manager was persuaded to sow, very reluctantly and sorely against the grain, a few plots of agricultural land. Seeing the results, he was less reluctant the next season; and as year by year his crops from electrified seed continued to contrast favorably with those from untreated seed, he sowed a larger acreage with the former, until now he sows no unelectrified seed except a small patch in each field for comparison; and from being an utter sceptic, he is become an enthusiastic advocate of the process.

Farmers meet at market and talk about the weather and their crops, and thus news of the process spread in the neighborhood, and one farmer after another adopted it, first only as a trial, and on a few acres of ground, but when they had had experience of it, upon larger and larger acreages; until at the present harvest 150 farmers have reaped grain growing from electrified seed. Farmers are a cautious and conservative race, not eager to adopt new methods until these have been well tried at other people's risk, and have had their value proved beyond question; and those who tried the electrified seed for the first time tried it upon a few acres only, so that the total acreage thus sown last season was not much more than 2,000; but 2,000 acres is quite enough ground to yield a thorough and satisfactory test, especially when the trials are scattered over many different parts of the country, on many different soils, from the infertile sands and newly plowed heaths of Dorset to the chalk around Salisbury Plain and the stiff clays of Cheshire. No doubt a much larger acreage would have been sown with electrified seed if efforts had been made to spread a knowledge of its advantages, if the inventor had not waited with the intention of perfecting his process and discovering all its possibilities before taking any steps to make it known.

But it seems that the possibilities are almost unlimited. The more he investigates it, and the wider the scope of his experiments, the greater are the advantages they reveal. As it is, quite enough is known, first to prove that the process is one of very great value if properly conducted, and second to enable it to be conducted to the best advantage, eliminating with certainty all the errors that vitiated the results in some of the early experiments, and ensuring without fail a substantial increase in the crop. This is enough to justify, and indeed to demand, the use of the process. It would be unjustifiable to withhold the process longer on the ground that all the possibilities it contains are not yet become available in practice; and the inventor has at length been prevailed upon to place it on the market as it is.



Oats, cabbage and kale grown from treated (left, in each case) and untreated (right) seed, under identical conditions

In the first place, there is a notable increase in the yield of grain from the electrified seed. An average crop of whe[illegible] Great Britain is abo[illegible] bushels per acre, of oat[illegible] to 80, of barley 32 to 40 bushels. If electrified and unelectrified seed of any of these crops are sown separately in the same field on the same day and treated in every respect alike, it is found that, according to the nature of the crop and other circumstances as yet imperfectly known, the yield of the electrified seed exceeds that of the unelectrified by from four to 16 bushels. The average of the considerable number of trials whose results are at present known is between 25 and 30 per cent of increase.

The quality of the crop also, as indicated by the weight per bushel, is improved. The increase in weight has ranged from one pound to as much as four pounds per bushel. This does not seem a large proportion of the weight of an average bushel, which is about 63 pounds; but the normal variations from this average weight are not wide. A poor sample of wheat weighs 60 pounds to the bushel; a good sample 64 pounds; 66 pounds to the bushel is an exceptionally fine sample. It is evident that a gain of from one to four pounds to the bushel may make all the difference between poor and good, between good and excellent. It means better milling quality, less offal, and more flour per bushel. It may mean all the difference between grain that can be used only for milling and grain that can be used for seed.

Even this is not all the advantage to be gained by using electrified seed. Besides the increase in the bulk of the yield and the increase in the weight per bushel, there is an increase in the straw that may be very important. In the first place, the electrified seed throws up more straws from each seed than the unelectrified. In one field of oats the increase was characterized by a previously sceptical expert as "astounding," for whereas the bulk of the unelectrified seed had thrown up only two straws per seed, the electrified had thrown up five. In the second place, the straw growing from the electrified seed is longer than that which grows from the unelectrified. The straw is in some cases only one or two inches, in other cases as much as eight inches, longer; but in every case the length is increased. In the third place, and this is the most important, the stoutness and the strength of the straw are increased. From this it results that the crop is less liable to be laid by storms of wind and rain. In one case the visitors to a farm, who had gone for the purpose of inspecting the electrified and unelectrified crops growing side by side, asked the farmer to show them the dividing line between the two. "Go and look for yourselves," said he. "No one but a blind man could fail to see the difference." And truly it was so. On half the field nearly the whole of the barley was lying flat upon the ground, laid by the recent thunderstorms. On the other half not a straw was laid; the whole crop was standing upright waiting for the reaper.

Even those that have been mentioned are not all the advantages that may be gained from electrifying seed corn. It seems that corn growing from seed thus treated is less susceptible to the attacks of fungus diseases and wireworm than that growing from seed that has not been treated. Little can be said at present on this score, for the observations are as yet incomplete, and experiments are in progress that will test the matter up to the hilt. All that can be said at present is that there seems to be a great likelihood that the process is protective against smut, bunt, rust, and other fungus diseases.

So much for the advantages of the process; now what of its disadvantages? These are few, and can scarcely be considered serious. The first is that if the process is not properly carried out, the result will be disappointing. This can scarcely be considered a drawback to the process itself. It is a simple process, easily performed, occupying only a few hours, and no more difficult than the process of dyeing a parcel of yarn or sterilizing a surgical dressing; but, like these operations, it requires the use of a certain technique, and cannot safely be entrusted to inexperienced hands. Properly performed, it can neither damage the seed nor fail to enhance its value.

Secondly, the effect produced upon the seed is not permanent; it will retain its enhanced efficacy only for about a month after electrification, if kept in a dry place. It is therefore desirable that the seed be sown promptly after it has been electrified. The drawback is not a serious one, but if not known and allowed for, it may lead to disappointment and to undeserved discredit being thrown upon the process.

Thirdly, the advantage accruing from the process is not uniform. The process always results in an increase in the yield of the seed; but whether the increase will be mainly in the grain or mainly in the straw, and what percentage of increase it will effect, are unpredictable. The best results are often obtained on poor land, where the untreated corn gives but a small return, but this is by no means uniformly so. What the conditions are that go to secure the largest increases are at present unknown. Doubtless they will be ascertained in time, when more experience has been had, and the rationale of the process is better understood; but at present we cannot say beforehand whether the crop will be greatly benefitted or only moderately benefitted.

The process is very simple in principle, though it requires a good deal of care and of experience in carrying it out. A current of electricity cannot be passed through a heap of dry seed; the grain must be steeped in water that contains, in solution, some salt that will act as a conductor. Such a solution is placed in a tank, the seed is steeped in it, and a weak current of electricity is passed by means of electrodes of large surface attached to two opposite end walls of the tank. The seed is then taken out and dried.

This is the outline of the process, but the outline needs a good deal of filling in. The kind of salt employed to enable the water to conduct the electricity is not without importance. Seed that is to be sown on one kind of soil will yield better results with a calcium salt, and seed that is to be sown on another kind of soil will yield better results with a sodium or some other salt. One kind of seed will need treatment for so many hours, and another kind for many more or fewer. Barley, for instance, needs twice as long treatment as wheat or oats. The strength of the solution and the strength of the current must be appropriate, and are not necessarily the same in each case. The drying is very important. The seed must be dried at the right temperature, neither too rapidly nor too slowly; and it must be dried to the right degree, neither too much nor too little.

All these matters are important, and it is possible that variations in them are responsible for the variety in the results that are obtained. The proper treatment has to be ascertained by long and copious experiments with each kind of seed, and it is only by degrees that the proper treatment has emerged from these experiments, which have now been in progress for six or seven years.

It will take many years before all the benefit that can be obtained from the process is finally arrived at. At present, it has been worked out only for wheat, oats, and barley; but experiments have shown that its advantages extend to many other kinds of seeds. Turnips and other roots, maize, rice, cabbage, and many other plants grown from seed are known to benefit; but for these the process is not yet recommended, because the exact conditions have not been thoroughly ascertained. Some of the most remarkable results have been obtained from electrifying seed potatoes; but the results are not yet sufficiently uniform to justify its application on a large scale to potatoes.

Electrification of seeds will be adopted on a very large scale in England for next year's harvest. Every farmer who has tried it once upon a small acreage will use it freely; and though it has scarcely been advertised at all, farmers talk to one another, they see the articles written by experts who have inspected the crops; and the amount of seed that will be electrified for next year's harvest will be practically limited only by the pacity of the plant laid down for the purpose. In Great Britain the process is established.

So emphatically true is this that Dr. Wray, the United States Inspector in Charge in Great Britain, after an extended tour of inspection of farms, has advised his Government to have immediate trials made in every State of the Union. To my mind, the time for trials is past. Further trials are but waste of valuable time. We must face the fact that there is a shortage of food all over the world, and that this shortage will be most acutely felt next year. It is next year that the increased production will be required; and further trials, which could tell us no more than we know already, would only postpone the adoption of the process for another year. It is wanted now, and badly wanted.

UPI

J. Carmen Garcia holds an oversized bunch of collard greens in a 1978 photo.

Giant Vegetable Secret Safe

VALLE DE SANTIAGO, Mexico (UPI) — The case of J. Carmen Garcia's giant vegetables gets more curious and more curious.

Garcia, the marvel of the marketplace in his village in a produce-rich valley in Guanajuato state 260 miles northwest of Mexico City, perennially brings in 50-pound cabbages and 10-pound onions and 5-feet-long collard greens.

So how does he do it?

He says a man — claiming extra-terrestrial underground-dwelling humanoids who live on giant vegetables held him in a subterranean prison — gave him a scrap of paper containing a formula of symbols. Garcia said he gained inspiration for his own growing talents from contemplating the formula.

Whatever one thought of the extra-terrestrial connection, the existence of the vegetables is undeniable. Garcia produces them year in and year out. Photographs exist. And Bill Robinson, a San Diego Police Department information officer, keeps a 10-pound Garica onion in his freezer in San Diego.

In February, United Press International transmitted an illustrated dispatch about Garcia based on an article in San Diego Home and Garden Magazine by Robinson. Robinson had stumbled upon the giant vegetables, Garcia and his associate, Oscar Arredondo, while on a Mexican vacation.

After the UPI dispatch, Robinson received over 1,000 letters from would-be greenthumbs around the world, requesting more information, including two from U. S. Department of Agriculture plant pathologists in Florida and California.

Awed by the sudden interest, Robinson felt duty-bound to return to Mexico to seek more information from Garcia. UPI tagged along as interpreter.

Garcia was less than overjoyed to see Robinson again, and it wasn't because the visit interrupted irrigation chores on his 3-acre parcel.

"Last week on one day I had people here from New Zealand, Venezuela, France, the Dominican Republic, Canada, Germany and the United States," Garcia said. "I tell them 'Stay here six months and I'll teach you the method.' Finally they go away, but others come."

2,340,313

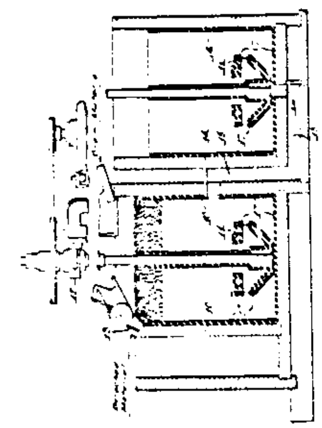
METHOD OF TREATING CEREAL GRAINS

Theodore Earle, Pacific Palisades, Calif., assignor to Continental Baking Company, Wilmington, Del., a corporation of Delaware

Application April 15, 1940, Serial No. 329,725

4 Claims. (Cl. 83—28)

1. The method of stripping non-nutritive, exterior bran coat laminations from cereal grains for the production of peeled grain berries retaining their nutritive bran coat laminations and germ elements in substantially undisturbed, natural relationship, which consists of agitating and freely circulating the grain berries in water to soften and initially loosen their exterior bran coats, sloughing the thus-loosened outer laminations from the berries through repetitious impingement of the berries against, along and into slightly indenting relation with resilient, adherescent surfaces as an incident and under the sole influence of agitation and circulation of said berries in water, and separating the consequently-detached material from the peeled berries.



2,143,306

METHOD FOR THE PURIFICATION AND CLEANSING OF SEED AND CEREAL GRAINS

Theodore Earle, Pacific Palisades, Calif. No Drawing. Application March 23, 1937, Serial No. 132,552

8 Claims. (Cl. 209—166)

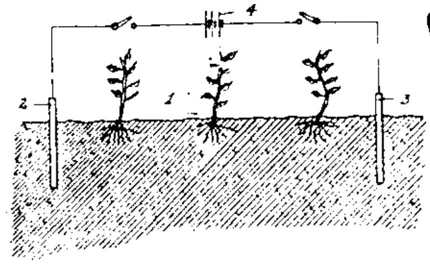
1. The method of treating seeds and cereal grains for the separation and removal therefrom of fungus growths, spores, spore cells, insects and their eggs, larvae, nits, and infested grains, which consists of agitating the material in a froth flotation cell in the presence of a reagent consisting of a relatively minute amount of a true frother, for physical detachment of infesting material from the seed and grain surfaces through rubbing contact between said surfaces, thorough exposure of the infesting material surfaces to contact with the frother, and development of a froth bed in the cell, and consequent selective elevation of the detached infesting agencies and infested grains as a froth-held concentrate separate from the cleansed material remaining as a tailings product in the cell.

Electricity as a Tree Pest Cure.—Patent papers were recently granted to Isadore Kitsee, a Philadelphia inventor, covering a process for the destruction of insect and germ life harmful to plants and trees, the electrical method taking the place, to a great extent, of the usual sprays and other applications. The process consists of making an application of a solution such as saline water where the ground is to be treated, and then causing a current of electricity to be passed through the soil, whereupon the gas generated will rid the soil of germs, larvae and insects without the least injury to the vegetation. Where a larger area is to be treated, it has been found desirable to dig shallow trenches at opposite sides of the area to be treated, and the electric terminals are placed in these. An application of a somewhat more powerful current will rid the entire area of pests. When the plant itself is to be treated, the solution carrying the element is made the electrolyte in an apparatus, and the plant sprayed with a solution after decomposition has taken place through the action of the electric current.

Sci. Amer. May 27 1916
p 549

1,172,367. DESTROYING INSECTS HARMFUL TO PLANT LIFE. ISIDOR KITSEE, Philadelphia, Pa. Filed Dec. 12, 1914. Serial No. 876,848. (Cl. 204—1.)

Feb 22
1916



1. In the purifying of the soil from insects harmful to vegetable life, the method which consists in providing the soil with a compound carrying in combination a germicide element, electrolyzing said compound while in said soil, thereby freeing said element and causing through said element the destruction of obnoxious insects.

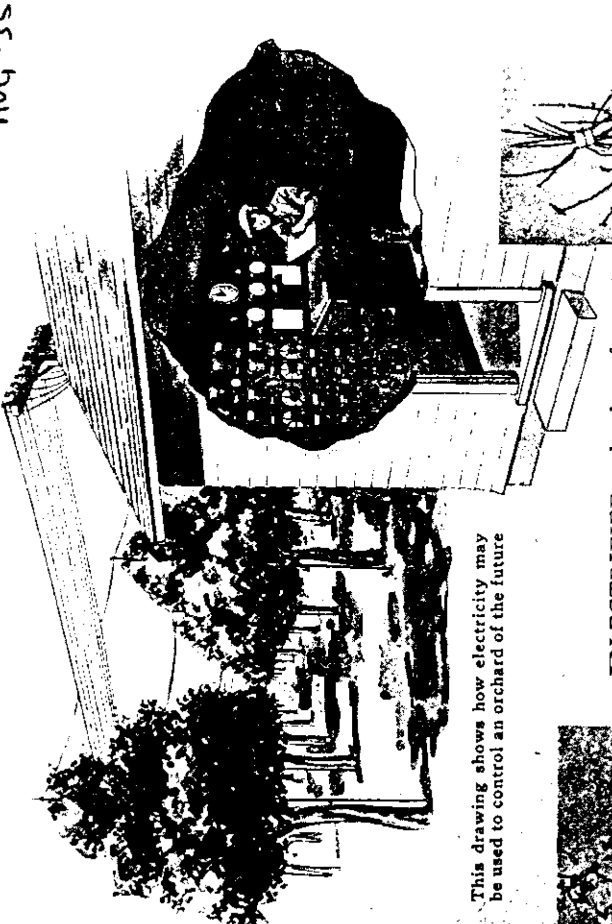
2. The method of destroying obnoxious insects their larvæ or eggs infecting the soil, which consists in impregnating the soil with a solution carrying an insecticide in a dormant state, electrolyzing the solution during the time that the same is in said soil thereby freeing the insecticide and making the same available for the destruction of said insects.

3. In the destruction of insects obnoxious to plant life, the improvement which consists in electrolyzing required compounds in the soil carrying the plants and causing, through the gases freed during the electrolytic action, the destruction of the insects infesting said soil.

4. The method of destroying the larvæ or eggs of obnoxious insects which consists in providing the area inhabited by said larvæ or eggs with a compound carrying in chemical combination an insecticide element and electrolyzing said compound, thereby freeing said insecticide element.

ELECTRICITY CONTROLS TREE GROWTH

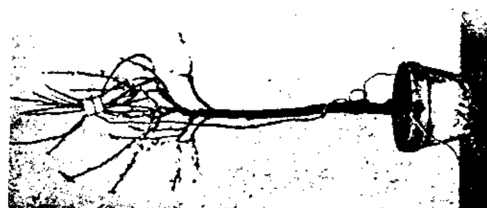
POP SCI.
AUG '35



This drawing shows how electricity may be used to control an orchard of the future

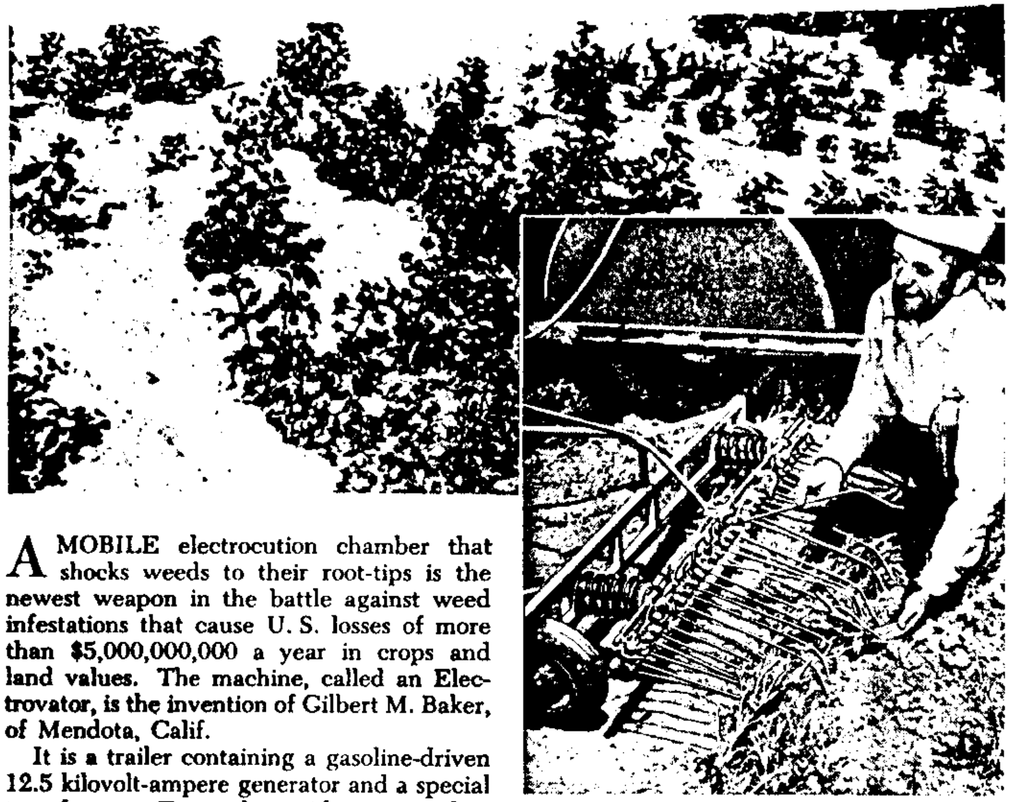
Tree at left shows result of stimulation by electric current

ELECTRIFIED orchards are forecast by Georges Truffaut, French experimenter. Attaching wires from a forty-volt battery to seedling trees, he found their growth markedly stimulated when the current passed upward through the stems and branches. Reversing the flow retarded their development. Similar results could be obtained, Truffaut suggests, by fitting full-sized fruit trees with metal collars, connected to a suitable source of direct-current electricity. Thus a grower could retard the development of fruit to protect it against unseasonal frost, or hasten its ripening when conditions were favorable. To explain his observations, Truffaut offers the theory that the electric current alters the rate at which sap rises.



Downward flow of current retarded flowering of upper branches

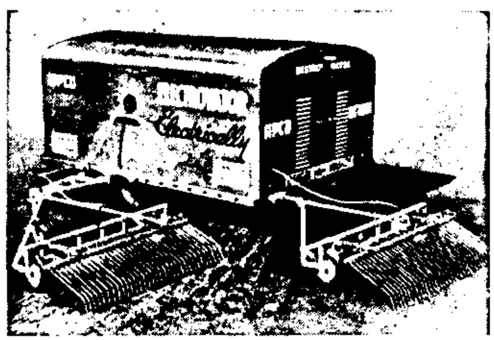
26



A MOBILE electrocution chamber that shocks weeds to their root-tips is the newest weapon in the battle against weed infestations that cause U. S. losses of more than $5,000,000,000 a year in crops and land values. The machine, called an Electrovator, is the invention of Gilbert M. Baker, of Mendota, Calif.

It is a trailer containing a gasoline-driven 12.5 kilovolt-ampere generator and a special transformer. Two rakes with copper electrodes for teeth transmit the high-voltage, low-amperage current to weeds as the machine is drawn at one mile an hour by a jeep or tractor. The weeds burn, from tops to root-tips, leaving the land ready for new crops. The treatment can be repeated for successive growths at a cost of $10 per acre per treatment. The Avco Corporation, of Los Angeles, distributes the machines.

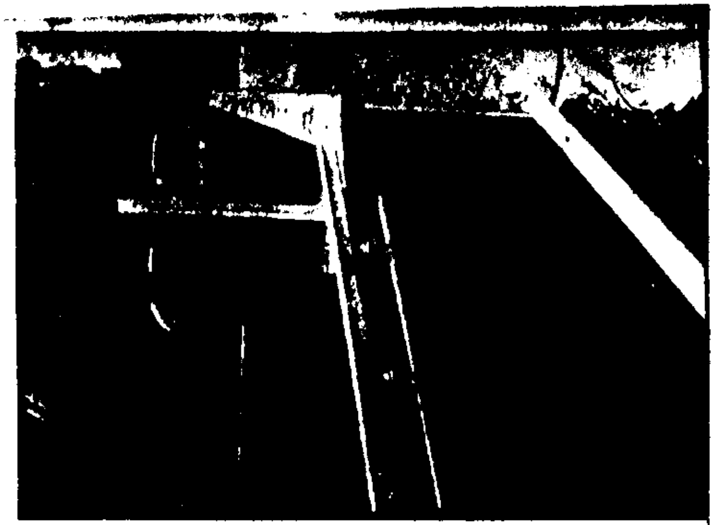
Shocking Weeds to Death



The bare patches of ground in a cotton field (top) show where the weed killer has been at work. In inset, Mr. Baker displays the "stingers" of his machine—flexible rods, connected to the transformer, that ride along the surface of the ground. A control panel in the towing vehicle varies the charge transmitted by the rods to suit different kinds of weeds and soil. Above is the Electrovator itself, showing the overlapping arrangement of the two rakes and their connections for towing and power.

Sep 46

Fence Shocks Fish



OUT in California, foolish fish who try to swim into irrigation ditches are going to get the shock of their lives. A marine version of the electric cattle fence keeps fish out—without hurting them—while passing water or debris. Shown at right, it consists of a free-swinging row of electrodes, connected to a generator. The electrodes slightly charge the water around them.

Invented by Henry T. Burkey, of Hollywood, Calif., the fish screen uses a generator he developed jointly with Westinghouse. Nettings in California have shown that at times as many as 25,000 salmon have been lost in a single irrigation ditch in a 24-hour period. Hydroelectric plants and industrial pumps are other hazards.

Oct '47

He Tells How You Can Blitz the Termites

You can assure J. H. T., Palo Alto, Calif., that it is possible to kill termites, or any other living organisms in wood, by subjecting them to high frequency on the order of 20 megacycles. This high frequency will heat the wood throughout to temperatures that will kill termites without injuring the material. The work can be done with a portable high-frequency machine brought to the premises. Radio Corporation of America, as well as others, manufacture such units.—I. C., Little Silver, N. J.

CONDUCTING CHLOROPHYL ENERGY OVER WIRES

Dr. T. G. Hieronymus

About 1930, I decided to try an experiment of conducting Chlorophyl Energy over wires. I had been conducting Eloptic Energy over long distance via wire.

A wood platform was installed on the south side of the house about six feet above ground. Later experiments indicate that the platform must be at least 6' above ground in order to get the desired potential of energy which increases with distance above ground.

Having some wooden cigar boxes available, I cut boxes apart and cut pieces and made eight boxes that were 2"x2"x4" although any size boxes will work.

Aluminum foil was placed on the bottom of seven boxes inside so as to be in contact with the soil. Similar pieces of foil were placed on the under side of the lid of each box. Wires were connected to each piece of foil, the wires from the lids were extended to the sun plates, the wires from the bottom foils were connected to the water pipe and thus grounded. See figure "2" for details of the box construction.

Refer to figure "1" which shows a "side" view of the installation. Figure "3" shows the system of connections.

Seven plates were placed on the platform so as to pick up energy from the sun and a wire was connected to each plate and extended down into the basement, each box, having the top foil plate connected via wire to a plate out on the platform in the sun light. The eighth box had no connection to the outside, it being the "control".

The plates on the platform were all different in size. The smallest was 2"x4", the next 4"x8", the largest was about 8"x10", and one plate was copper screen wire.

Some dirt was screened and ½" of dirt placed in each box. Oat seeds were selected, all of uniform size and planted in two rows of 5 seeds spaced in each row, then ½" of dirt was placed on top in the box. The same amount of water was added to each box as needed from day to day.

All of the seeds sprouted about the same time. Then we noticed that there was no chlorophyl in the 10 plants in the control box. All of the boxes connected to outside plates had plants with much chlorophyl.

We were quite surprised to note that the plants in boxes with large outside plates, seemed to look as if they had been subjected to heat. Apparently the large outside plates were bringing in an excess of energy compared with the effect of the small size outside plates.

Very soon, the plants grew too tall for the small amount of 'head room' in the boxes so each box was equipped with a spacer to raise the top of each lid up about 3/4".

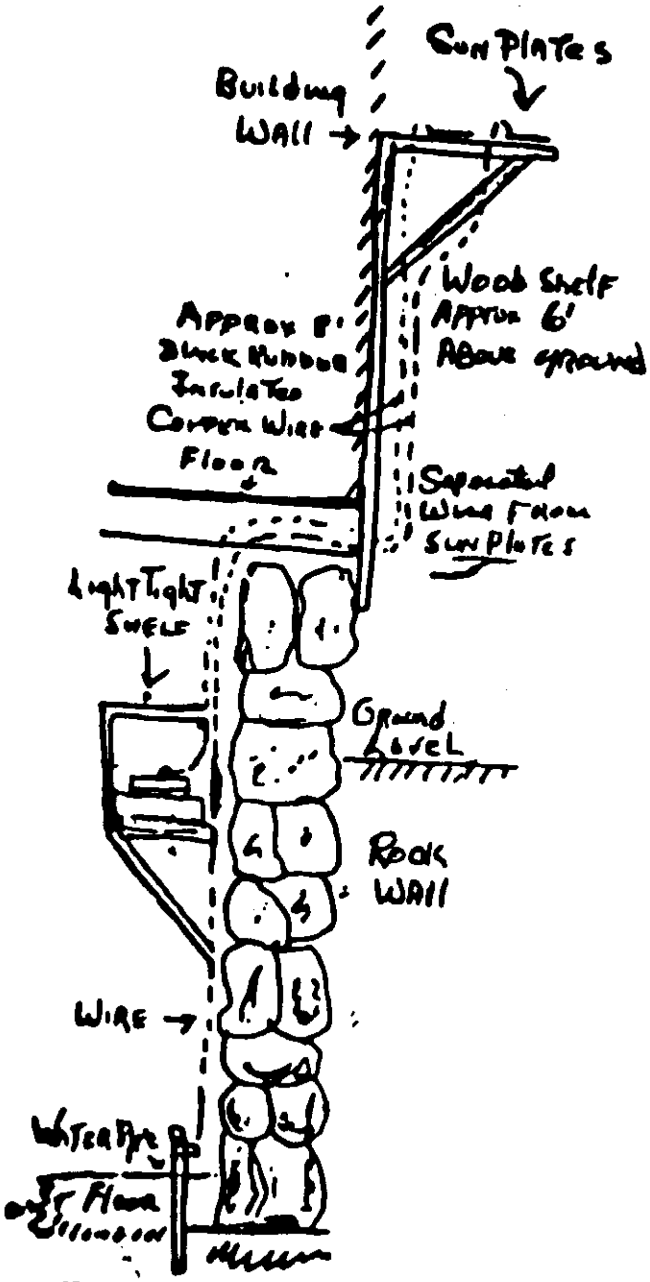
The boxes were placed on a shelf in the end of the basement where there was little light, with no windows at that end. Also, the shelf was kept dark by a board placed in front and another on top to exclude all light. The plants were dark all of the time except when they were examined by flashlight.

A friend tried to duplicate the experiment but did not follow all instructions. Their basement was only about 3 feet from basement floor to ground level outside. Instead of placing the outside plates above ground 6 feet, they laid the metal collector plates on a board that laid on the ground, thus they did not have the potential difference between outside collector and inside boxes and the experiment was a failure. Also, there was a window near that let much light into where the boxes were placed.

Anyone who expects to duplicate an experiment should be sure they know all the factors and that they follow the instructions exactly without any substitution or change. And as to changes, if you are trying to get a special result and are trying out several methods or ideas, one of the cardinal points to doing good work is to make just ONE change at a time. Then you know just what the results are. If you make two changes and the result is failure, you do not know but that one of the changes may have been all right. (see Figures #1,2,&3, next 2 pages).

By: DR. T. GALEN HIERONYMUS

* * * * *



Sun PlaTes
Building WAll
Wood Shelf Approx 6' Above ground
Approx 8' Black Rubber Insulated Copper Wire
Floor
Separated Wire From Sun Plates
Light Tight Shelf
Ground Level
Rock WAll
Wire
Water Pipe
Floor

FIGURE "1"

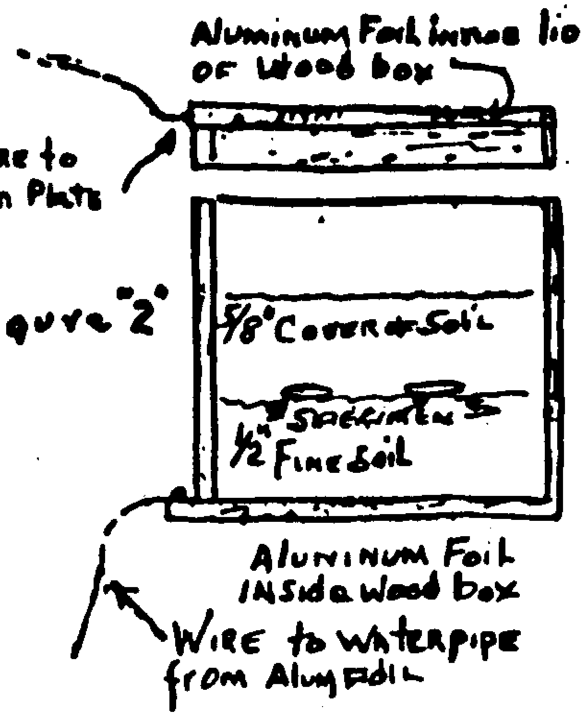


Figure "2"

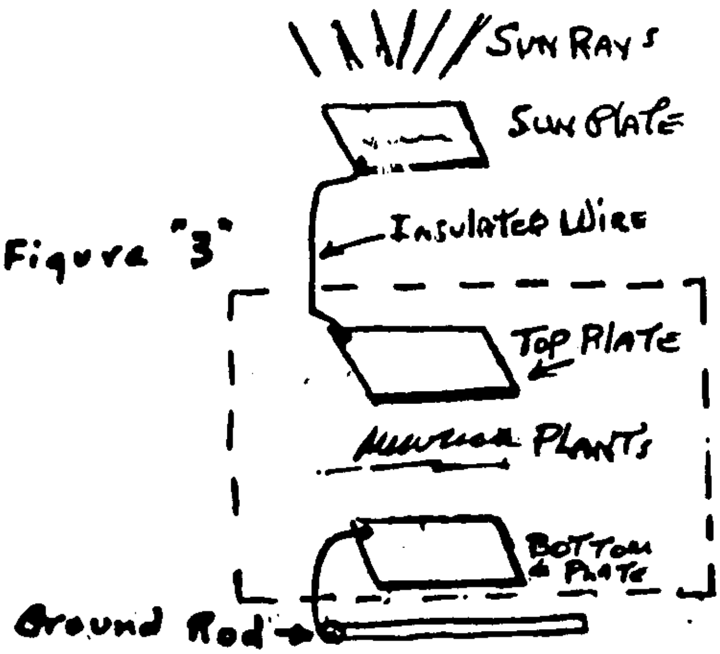


Figure "3"

ELECTRONIC FIRE-ANT KILLER

Benson Electronics
Route 1, Box 143 • Nixon, TX 78140

VSP # 4667436

INSTRUCTIONS FOR USE

For your convenience, the coil wire has already been connected to the negative and positive posts of the transformer by the wing nuts. At the other end of the coil wire, a small amount of insulation has been partially cut away to expose the wire inside. Continue to cut away the insulation in this manner until enough wire is exposed to reach around your post, tree, pipe or another wire at least twice. This forms a coil which no ant can cross. You may want to use some tape to hold down the loose end of the coil wire.

There are many more uses for the control box. For instance, it can be used as an electric fence. Just connect one post to a good ground, (either post - it doesn't matter), and the other post to your fence wire. This will electrify a fence wire from three to five miles distance. To be used as a cattle prod, connect one post to a good ground and the other to a wire running through a piece of one-half inch PVC pipe of whatever length is convenient for you. The end of that wire must be exposed and attached at the end of the pipe which will make contact with the animal. This will not harm the animal. This unit puts out approximately 1/100 of an Amp.

Always make sure the unit is unplugged before making any hook-ups. Should there be any questions concerning this unit or any application thereof, please feel free to write.

FOR MORE INFORMATION CONTACT:

BENSON ELECTRONICS
Route 1 Box 143
Nixon, Texas 78140

(512) 424-3373

Jim Benson demonstrates the Yaard-Vark, which uses an electrical charge to destroy ants.

BEAUMONT ENTERPRISE (TX). AUG. 26 1984.

Benson's Yaard-Vark invention rids farmers of annoying ants

By Suzanne Halliburton
Staff writer

BRYAN — About two years ago, Jim Benson noticed some fire ants hanging around the electrical switches on his farm's water well. The ants were killing each other.

Though Benson originally dismissed the episode from his mind, the Yaard-Vark, along with hopes of riches, resulted from his observation.

The Yaard-Vark is not an animal, but a conglomeration of insulation, metal and electrical wires.

A metal prong is inserted in the anthill; an electrode lightly rests on the mound's surface.

Electric currents shoot out, causing the ants to turn their vicious stings on each other.

Destroys ants

Within several hours, the anthill becomes its own cemetery.

Fire ants had so inundated Benson's farm in Central Texas, he says, that he eventually could not avoid the ants' earthen homes.

Seeking a better way to rid his acreage of the ants — they develop an immunity to pesticides — Benson remembered the episode at the water well and began to investigate the effects of electricity on the ants.

He told son Robert Benson, owner of Timebase Inc. in Bryan, of his findings, and Yaard-Vark Inc. emerged.

Possible patent

Robert Benson said the U.S. Patent Office will decide the invention's future. Because the creation is not yet officially registered with the office, Robert Benson has cautioned his father not to elaborate on the Yaard-Vark's workings.

If the Bensons get their patent, Robert Benson plans to market the machine in states bordering the Gulf of Mexico and in Central America and Mexico, all areas with a tremendous ant problems. The planned cost is $79.95.

"There's no question it's going to sell," Robert Benson said. "We've been inundated with calls."

Four species of fire ants harass farmers in this area, stinging livestock and clogging plows and tractors. The area is particularly susceptible to fire ants because of its mild winters. The typical ant colony averages between 100,000 and 500,000 ants.

Researchers curious

While Benson deals with his makeshift invention, researchers at the U.S. Department of Agriculture are growing interested in the ants' hormones.

Hidden among cornmeal pellets developed by scientists at the Agriculture Department are juvenile hormones that retard the development of the ants' offspring, the larvae.

Spokesman Steve Berberich said the hormone shuts down all activity in the colony, killing the remaining ants.

Berberich said research in the killing of insects through use of hormones is five to 10 years old.

Insect hormones

"Scientists are finding that hormones in insects are in some ways not unlike those in mammals," he said. "They are developing chemicals that can disrupt these signals."

Berberich said the scientists hope ants will not develop a tolerance to hormones, as they have with pesticides.

Meanwhile, Jim Benson is simply stretching extension cords across his yard to rid it of the pests.

"If I make some (money) that's fine," he said. "If I don't, we've still killed a lot of ants. There's not any here, at least nothing I can't reach with my extension cord."

Backyard inventor makes fire ant weapon

AP Laserphoto

By JEAN WALLACE
Bryan-College Station Eagle

BRYAN, Texas — Backyard tinkerer Jim Benson may have invented the ultimate lethal weapon in the war against fire ants.

It's an electrical zapper, a slim, three-foot-long device that rests on top an ant mound. Emitting a tiny electrical current, the device snaps, crackles and pops as the first ant victims meet their maker.

Then, a few minutes later, all heck really breaks loose in the ant colony. Out of the ground surge forth thousands of angry ants. Inexplicably, the electrical disturbance causes the pests to kill each other. As their frenzied fratricide proceeds, a thick, doughnut-like ring of dead ants forms around the electrode.

"I really enjoy killing them," says 60-year-old Benson, who lives on a farm in Seguin.

"Whenever they form a doughnut and begin to die, I am filled with enjoyment, because I've been fighting those sons of guns for years."

Benson made his discovery after noticing that fire ants were attracted to, then killed by, the sparks emitted by his water-well electrical pump. Following his intuition, he devised his first zapper from plastic plumbing pipe and odds and ends.

Once implanted, the device can annihilate an ant colony in several hours, depending on heat and humidity factors which affect how deeply the ants burrow. So far, the ants haven't recolonized the mounds, either, Benson says.

Benson's son, Robert, who lives in College Station, was called in for a demonstration two months ago.

"I was in awe," recalls Robert, 40, a doctoral student in physics at Texas A&M University and also an entrepreneur.

"It has all the qualities for anyone who wants revenge," Robert adds. "It feels like a real weapon."

The weapon has been renamed the Yaard-Vark, a name that now graces a company that Robert has formed to produce, market and sell the devices.

The company, which is gearing up for mass production, will refashion the devices to include a range of safeguards. Next spring, Yaard-Varks will probably be available at lawn and garden centers for between $59 to $79.

"The market will be huge," predicts Robert, who is applying for a patent to protect his dad's invention.

"We're going to produce as many as we can," he adds.

ELECTRO-CULTURE

Thomas L. HARRELSON

Bibliography- Books

Baker, Jerry: Talk to Your Plants- Put a Lightining Rod in Your Garden, pgs. 64&5, Nash Publ., 1973.

Callahan, Philip S.: Tuning into Nature- My Friend, the Nettle, pgs. 195-206, Devin-Adair, 1975.

Lemstrom, Selim: Electricity in Agriculture and Horticulture, Van Nostrand, 1904.

Lund, E.J.: Bioelectric Fields and Growth, University of Texas, 1947.

Miller, E.C.: Plant Physiology- Effects of Electricity on Crop Production, pgs, 1083-86, McGraw Hill, 1938.

Perenyi, Eleanor: Green Thoughts- Compost, pg. 45, Vintage Books, 1981.

Powell, Betty: The Avant Gardener- Current Experiments, pg. 174, Houghton Mifflin, 1975.

Sheppard, Asher R., and Eisenbud, Merril: Biological Effects of Electric and Magnetic Fields of Extremely Low Frequency- Electric Field Effects on Plant Life, pgs. 8-6&8-7, New York Univ. Press, 1977.

Smyser, Steve: The Encyclopedia of Organic Gardening-Electroculture, pgs. 342&43, Rodale Press, 1978.

Stone, G.E.: Cyclopedia of American Agriculture Vol. 2, L.H. Bailey- Effects of Electricity on Plants, pgs. 30-5, Macmillan, 1910.

Stone, G.H.: Standard Cyclopedia of Horticulture- Electroculture, pg. 1109, Macmillan, 1947.

Tompkins, Peter, and Bird, Christopher: The Secret Life of Plants- Plants and Electromagnetism, pgs. 163-77 and Force Fields, Humans, and Plants, pgs. 178-99, Harper&Row, 1973.

Uman, Martin A.: Understanding Lightining- Has Lightining Any Practical Use?, pgs. 145-49, Bek Technical Publ., 1971.

Electrical Plant Growth.

The qualities of electricity, though when in the form of lightning and strong direct currents readily take life, are such that in other forms as readily give life. Recently experiments have been made on seeds, and in one-half the time it takes Nature to turn out her work by ordinary processes, the application of electricity has brought out mature plants.

The first experiment was made on an egg that was being hatched. An electric current strong enough to kill a fowl did not destroy the germ of vitality, but the chicken when hatched was of most abnormal size and monstrous in shape. This proved, however, what might be done with this marvelous agent.

In plant stimulation the apparatus consists of two glass cylinders, a larger one about two inches in diameter for the larger seeds, and one about three-fourths of an inch for those of less size. Within these receptacles the seeds are placed, thoroughly moistened, and the openings closed with copper disks having wires attached. By these wires the disks are connected with the poles of an induction coil, and then the current is passed through the moist seeds, which are good conductors. After this treatment the seeds are placed in germinating pans. These consist of two plates one within the other, the inner being of porous clay. The seeds are sown between two sheets of filter paper, and water passing through the porous plate is absorbed by the paper, thus keeping the seeds moist at all times. The temperature is kept at about 48 degrees all the time by aid of electrical devices, and the growth of the plants is 30 per cent quicker by this method than otherwise, while, at the same time, many seeds not perfect enough to grow under ordinary climatic conditions are saved by this electrical treatment.

Electrical Treatment of Seeds

A PAPER was recently read before the British Association of Science by Mr. A. E. Blackburn, which elicited a long discussion. Some 10 to 20 packages of seeds were placed in tanks with electrodes at the extremities; an electrolyte consisting of sodium nitrate, or other fertilizer was used. It is considered especially useful with the cereals, wheat, barley or oats. Some 500 agriculturists have adopted this electric treatment of seeds, which is followed by a very careful drying in kilns, to be applied for a month or two, before they are put into the ground. During the discussion which followed, Mr. A. V. Baines said that the dried seeds sowed in the soil took up a charge in the electric field of the earth and atmosphere in the fashion of the Leyden jar. If electrodes were applied above and below the seed, the current would favor the development of roots, or the stalks according to its direction. Mr. M. L. Brenchley declared that the experiments conducted at Rothamstead had given doubtful results. Others feel that the nature of the ground was of great importance, and that the good effect was not durable. Still others stood up for the electrolyzed seeds. The question seems still confused, and the process needs further accurate experiment.

Practical Electrics Nov '21

He Tells How You Can Blitz the Termites

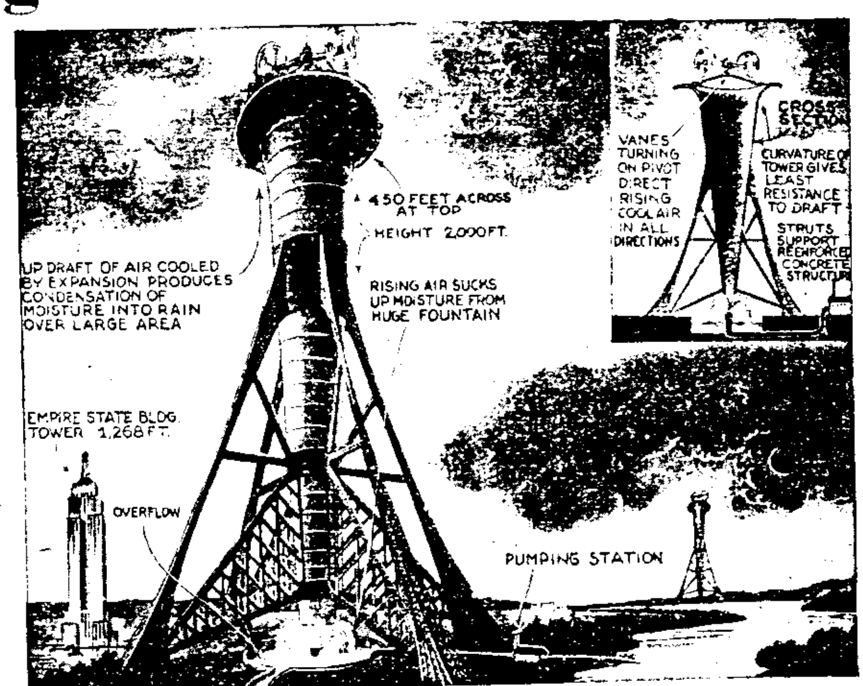
You can assure J. H. T., Palo Alto, Calif., that it is possible to kill termites, or any other living organisms in wood, by subjecting them to high frequency on the order of 20 megacycles. This high frequency will heat the wood throughout to temperatures that will kill termites without injuring the material. The work can be done with a portable high-frequency machine brought to the premises. Radio Corporation of America, as well as others, manufacture such units.—I. C., Little Silver, N. J.

Sky-Scraping Towers to Make Rain

● RAIN is caused, as everyone knows, by the upper air's becoming too cold to hold any longer the water it contains. Consequently, the idea that rain can be made by firing bombs into the sky, to shake loose the water, is impractical.

A French meteorologist, Bernard Dubos, proposes to produce rain by lending Nature a hand; in other words, helping her to carry out her routine process of drawing heated, water-laden air from the surface of the earth, and cooling it (by expansion into thinner atmosphere) until the water comes down again.

His project, illustrated here, is to put up stupendous towers of concrete, hollow within, which will create drafts in the same manner as a factory chimney. The ascending air column will carry water up with it, as vapor; and whirling vanes will distribute it in all directions. By this means, M. Dubos believes, the natural moisture of the air can be readily increased. Such a tower, steel reenforced, and two-thirds higher than the Empire State Building, would cost about $10,000,000, it is estimated, and be of great scientific as well as climatic value.



An engineer's plan to utilize scientific principles, for regulating climate.

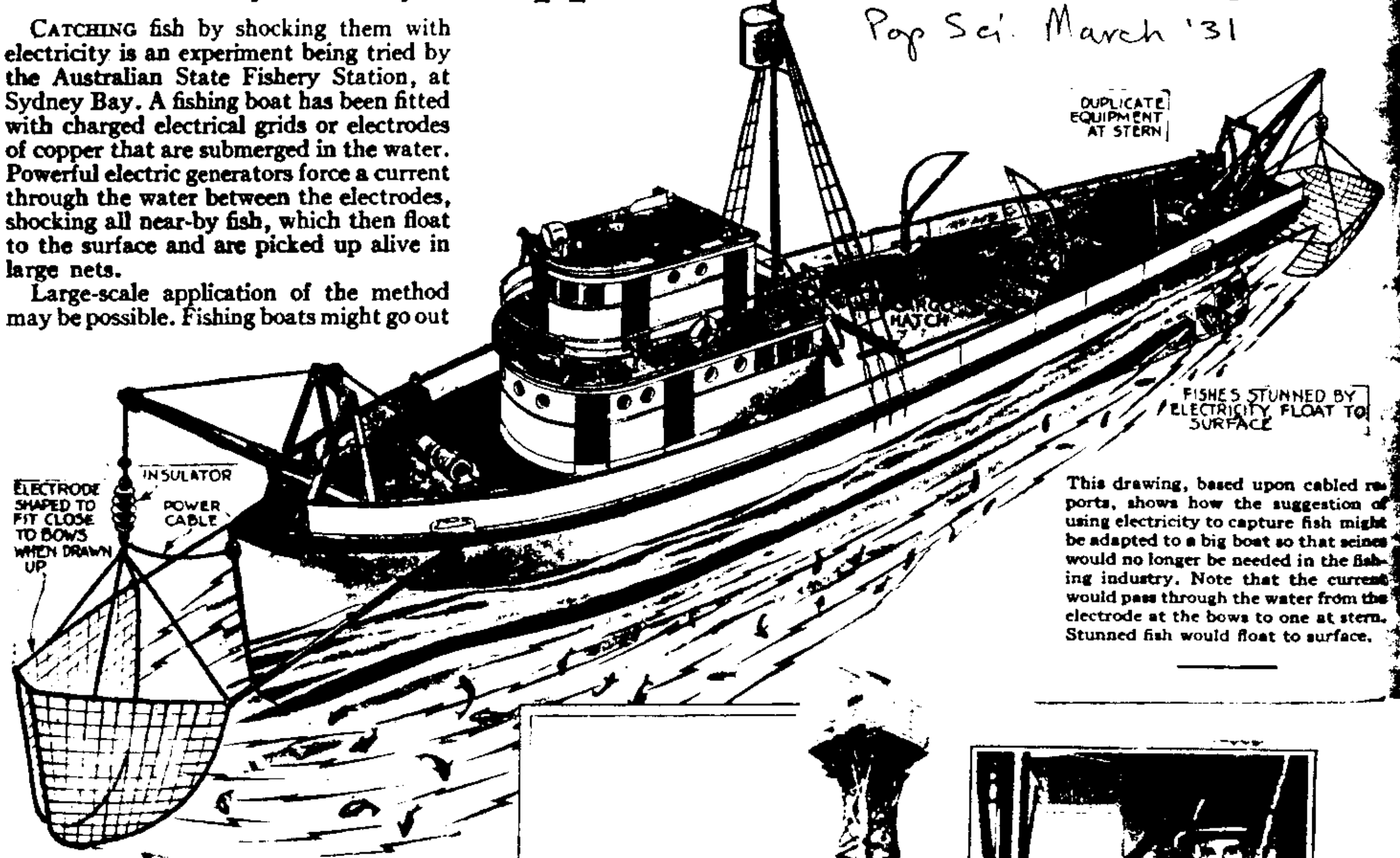
Electricity May Supplant Nets in Taking Fish

Pop Sci. March '31

CATCHING fish by shocking them with electricity is an experiment being tried by the Australian State Fishery Station, at Sydney Bay. A fishing boat has been fitted with charged electrical grids or electrodes of copper that are submerged in the water. Powerful electric generators force a current through the water between the electrodes, shocking all near-by fish, which then float to the surface and are picked up alive in large nets.

Large-scale application of the method may be possible. Fishing boats might go out singly or in pairs, to fish electrically. Single boats would have electrodes at bow and stern. If two boats operate together, each would use a single electrode and an electric cable would connect them.

A Swedish engineer named Möller devised this electric fishing, after making good hauls with an electrified rowboat. The drawing on this page, based on cabled reports of his system, shows how it might be applied on a large wooden-hulled fishing ship. A metal hull could not be used, as it would short-circuit the current.



This drawing, based upon cabled reports, shows how the suggestion of using electricity to capture fish might be adapted to a big boat so that seines would no longer be needed in the fishing industry. Note that the current would pass through the water from the electrode at the bows to one at stern. Stunned fish would float to surface.

Electrified Water Keeps Fish Out of Ditches

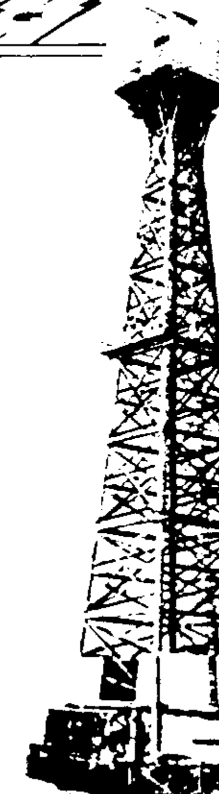
Pop Sci, April 1929

AMAZING screens formed by streaming particles of electrified water are being used in the Northwest to keep young trout and salmon out of irrigation ditches. When schools of these fish stray into the ditches, loss results to the fishing industry, so experts of the Federal Bureau of Fisheries have been investigating to find the best method of turning them back at the mouth of a ditch.

They discovered that fish are sensitive to electric shocks and dread to pass through electrified water. So "electrical screens" were suggested and tried, using several schemes to electrify the water.

The same idea was adopted by the engineer of a power company on the Pacific Coast to keep fish out of the turbine wheels of a hydroelectric plant. On wooden frames over the water he suspended two rows of parallel electrodes which set up an electric field reaching to the bottom of the stream. The strength of the field tapered off in direct proportion to the distance up or down stream.

Thus each fish approaching the turbine wheels entered the electrified area and received a shock. If it did not turn back at the first shock, but swam nearer, the severity of the shocks increased rapidly as it approached the whirling wheels.



"Rain-Making" Tower

William Haight, of Wilmington Park, Calif., claims he can make rain by the manipulation of what he calls negative electric ground waves and positive waves of the atmosphere's upper strata. His apparatus, mounted on a tower (at extreme left), is designed, he says, to reverse the natural order of electrical emanations, resulting in a pulsating current between the ground and upper strata, which in turn causes condensation of cloud moisture and brings on rain. Mr. Haight is pictured at the left

Pop Sci. Sept '25

British Patent # GB251689

Rex Research

MURR, L.E.: <u>Nature</u> 201 (4926):1305-6 (Mar. 28, 1964)

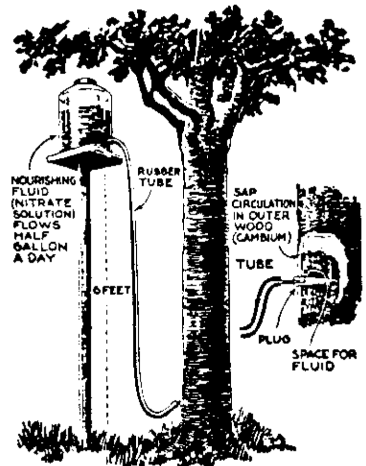
Mechanism of Plant-Cell Damage in an Electrostatic Field

Electrical stimulation of plant growth produces increased concentrations of minor elements (Fe, Zn, Al) in active leaf tips. Compared to controls, such increases are of the order of several hundred per cent. This is due to an increase in metabolic oligo-enzymes in the electrically-activated plants, which appear greener because ozone generated by electrical field oxidizes porphyrins, resulting in deep-green, open-ringed molecules of these or similar metallo-enzymes. Under the influence of an excessive ele trical field, the activity of these substances is accelerated to such an extent that cellular respiration is impeded, with resultant cell deterioration and tissue destruction.

Fruit Trees Fed From Bottle

● NITRATES are tonics to a tree; it absorbs them greedily from the fertilizer around its roots. But nitrates are so soluble that they wash readily out of the soil. A method of applying them, developed in France by Dr. Mokrzecki, gets 100% results; the solution, under pressure from the bottle, is fed into the sensitive layer of the tree between wood and bark, just as a physician makes a hypodermic injec-

(Continued on page 880)



How the nitrate is administered.

William Van Tassel

" THE STARS LOOK DOWN "

Mrs. De Land is the widow of Mr. John De Land. John was an amazing man who lived to perfect the "De Land Magnetic Control." This is a simple apparatus that prevents freezing in citrus and other fruit on sub-freezing nights. *It costs nothing to operate!*

Mrs. De Land told me how John received the details of the apparatus. John used the same means of thought reception 17 years ago that I use today. He heard a voice speaking inside his head, describing how to control frost and fruit freezing by a new method. John wrote the information down a little at a time, as it was given to him. Then he spent the next 15 years developing and proving true the information.

He has left a monumental contribution to humanity in his "Magnetic Control."

The drawing is made here of the principle of the device that John De Land gave to humanity, because he believed in progress. Mrs. De Land holds the patent papers on this apparatus. This drawing (fig. 3) is reproduced with her permission.

There are seven # 10 bare copper wires, running radially out underground from a 32 foot pipe mast. The pipe mast tapers up with reducers from 2 inch diameter, through 1½ inch diameter, to 1 inch in diameter at the top. Three plywood disks 12 inches in diameter rest on each of the reducers. Each plywood disk has seven equidistant holes for the wires to run through. At the top disk the seven wires are wrapped once around the edge at each hole, and extend outward 4 inches parallel to the ground. Each wire points parallel radially, back to its own other end underground. The mast, which is 32 feet above the ground level, sets in a 3 foot depth of concrete. The wires run through the concrete and loop back up outside the concrete to a depth below the surface that will permit a plow, or any cultivation equipment to pass over them.

Each of the seven wires extend radially underground to a distance not to exceed 144 feet from the mast. At this distance they are wrapped 10 turns around a 1 inch diameter by 5 inches long alnico 5 magnet.

The magnet sets inclined toward the mast at 45 degrees to the surface of the ground. It is also buried below cultivation equipment level.

These magnets are made up and coated with one-eighth inch of plastic to hold the windings in place and prevent rusting. The magnets are set polarized to the North magnetic pole parallel to the lines of magnetic force.

No smoke — no dirty laundry — no expense to operate — nothing but the expense of the original installation. This device is that simple!

This single unit will prevent freezing of fruit over an area of more than an acre of ground. ***This is free energy in operation.***

De Land FROST GUARD

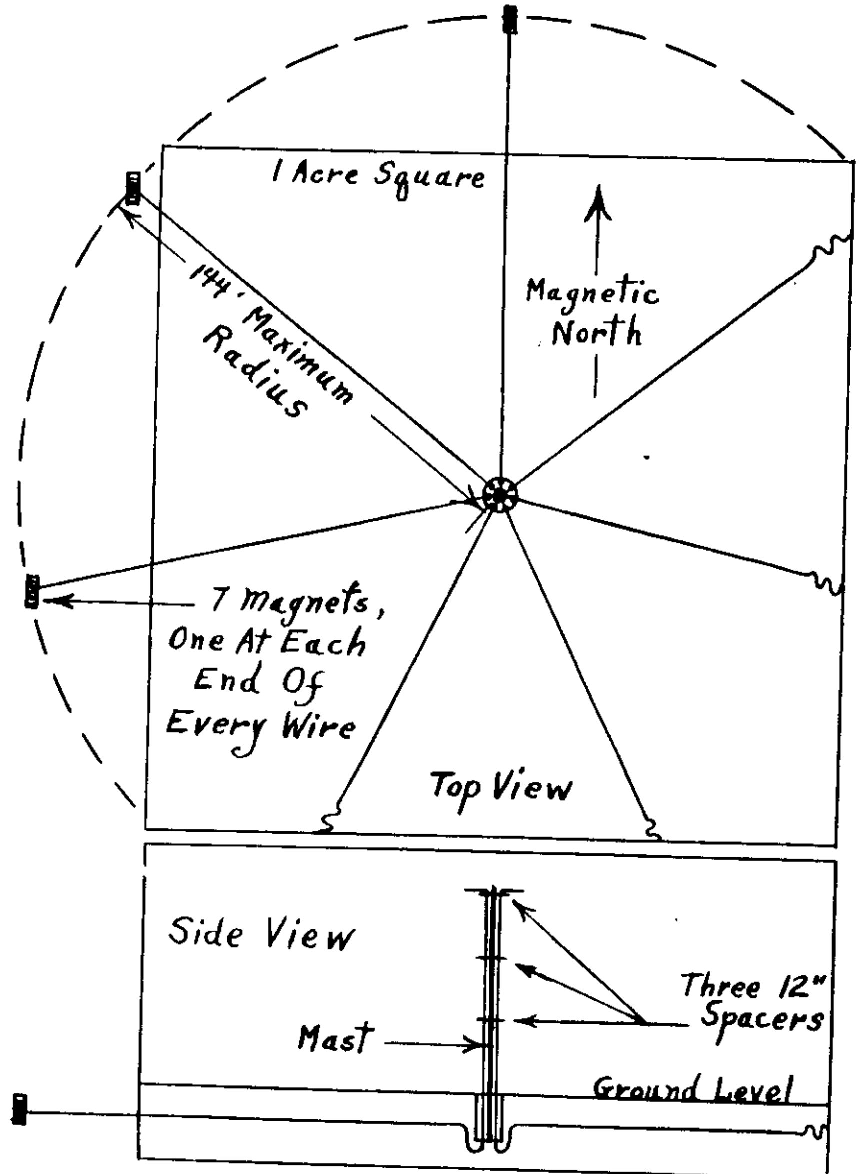


Figure 3

Anti Frost Control

UNITED STATES DEPARTMENT OF AGRICULTURE

DEPARTMENT BULLETIN NO. 1379

Washington, D. C. ▼ January, 1926

ELECTROCULTURE

By Lyman J. Briggs,[1] A. B. Campbell, R. H. Heald, and L. H. Flint, *Office of Biophysical Investigations, Bureau of Plant Industry*

CONTENTS

The term "electroculture" as used in this bulletin refers to practices designed to increase the growth and yield of crops through electrical treatment, such as the maintenance of an electric charge on a network over the plants or an electric current through the soil in which the plants are growing.

During the past 75 years many experiments in electroculture have been carried out with varying degrees of refinement. Some of these experiments indicate that the yield of crops can be materially increased by electrical treatment. Others, conducted along similar lines, fail to show any marked response to the treatment. In this latter class are included the experiments conducted by the Office of Biophysical Investigations of the Bureau of Plant Industry, which are reported in the following pages. This report is followed by a brief account of other investigations in this field. Investigations relating to the cultivation of plants under electric lights are not included in the review of the literature of electroculture, the response of the plants under such conditions being due primarily to the heat and light into which the electrical energy has been transformed.

NORMAL ELECTRICAL STATE OF THE ATMOSPHERE

Since the effect of using a charged network over growing plants is to change the electrical state of the atmosphere surrounding the plants it seems desirable to discuss briefly the normal electrical conditions in the atmosphere and the changes produced by the charged network. An examination of the electrical conditions in the atmosphere over an open field on a clear day shows that there is a force tending to move a positively charged body downward; in other words, the electrical field of force is identical with that which would exist if the earth were charged negatively.

[1] Physicist, Bureau of Standards, since 1920.

62149°—26†——1

The lack of uniformity in the yields of the control plats A and C in the 1907 experiments (Table 1) is such that no great dependence can be placed in these results. It is significant, however, that in only one of the 10 trials recorded did the treated plat show any evidence of a substantial increase in yield when compared with the mean of the control plats.

Experiments in 1908.—In the 1908 trials the wires were run directly over the treated rows and kept at a height of 6 to 18 inches above the plants by means of adjustable brackets on which the insulators were mounted. The control rows ran parallel to the treated ones at a distance of 6½ feet and were separated from them by intermediate guard rows.

In one part of the plat the wires over the plants were charged positively to about 50,000 volts from 4 p. m. to 7 a. m. each day, 955 hours in all. In the other part of the plat the wires were charged and discharged rapidly by connecting them to one terminal of the secondary of an induction coil, the other terminal being grounded. In this case the potential rose to about 20,000 volts and then discharged suddenly through a small spark gap between the wires and the ground.

The treatment first described is similar to that employed by Lemström and believed by him to result in increased yields. In these experiments, however, neither treatment gave any evidence of increased growth. The detailed yields consequently are not of special interest.

ELECTROCULTURAL FIELD EXPERIMENTS WITH GRAINS

In selecting a location for the electrocultural field experiments near Washington, three conditions were sought: (1) A uniform soil, (2) available electric power, and (3) accessibility from the laboratory in Washington, since the equipment had to be visited daily during the experimental season. Soil uniformity is particularly difficult to find in the environs of Washington, and the Arlington Experiment Farm forms no exception in this respect. It seemed to be the best available location, however, and portions of sections A, B, and E were made available for the experiments, which were carried on from 1911 to 1918. Sections A and B proved very disappointing with regard to their uniformity, and the most reliable results were obtained in section E. These experiments will be first described.

The Lodge-Newman apparatus used in the experiments from 1912 to 1915, inclusive, was designed in England primarily for electrocultural work and consists essentially of a 110-volt induction coil, operated by a mercury interrupter, and a rectifier. Five Lodge valves[4] designed to rectify the high-tension alternating current were placed in series with the network, thus allowing only the positive impulses from the secondary of the coil to reach the network (*33*). The negative pole was grounded. Two balls 25 millimeters in diameter, one of which was grounded and the other connected to the network, were used to determine the potential, assuming a breakdown gradient of 3,000 volts per millimeter.

Systematic measurements of the current from the network were not made, but the current could be determined approximately from the potential of the network and the known power characteristics of the machine used. The current from the network over the experimental plat in section E was of the order of 0.1 to 1 milliampere per acre, depending on the voltage and network used. This is of the order of 10,000 to 100,000 times the intensity of the normal air-earth current.

[4] For a description of the valves, see Lodge, O. (*34*).

EXPERIMENTS IN SECTION E

It has been shown by Jørgensen and Priestley (*26*) that the ionization from the highly charged network is by no means limited to the area beneath the network, but may be carried by the wind to a considerable distance, depending on the weather conditions. It was consequently deemed advisable to separate the treated and control plats so far as practicable. Accordingly, two plats of half an acre each (132 by 165 feet) were selected in section E which were separated by a distance of 350 feet, one plat being directly north of the other.

FIG. 1.—General view of the experimental field at Arlington Experiment Farm, showing the system of double insulators used in suspending the wire network from poles and the power lines leading to the motor in the apparatus house (foreground). Poles supporting the grounded network along the side of the control plat may be seen in the distance. (Photographed May 8, 1918.)

The rye which was growing on the plats of section E when they were selected in 1913 was cut and weighed. The results show that the productiveness of the two plats was about the same, being as follows: Yield of south plat, 2,438 pounds; of north plat, 2,499 pounds; ratio of south plat to north plat 0.98.

Experiments in 1914.—A network 16 feet high was erected over the south plat, having cross wires at intervals of 15 feet. (Fig. 1.) Winter wheat was sown on both plats the following October, and the treatment was given by means of the Lodge-Newman apparatus, which furnished a positive charge to the network at a potential ranging from 30,000 to 60,000 volts. The treatment was given in the fall and spring from 3 to 7 p. m., a total of 336 hours. The grain was harvested in June, 1914, giving yields which were substantially the same for both plats, as shown in Table 2.

TABLE 2.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section E, Arlington Experiment Farm, in 1914*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Treated	2,332	644.8	1.02	0.97
Control	2,281	656.5		

Experiments in 1915.—Wheat was again sown in the autumn of 1914. The fall treatment was omitted, owing to bad weather. In 1915 the network was charged positively by the Lodge-Newman apparatus twice a day from 4 to 7 a. m. and from 5 to 8.30 p. m., a total of 345 hours. The distance between the cross wires of the network this year was 6 feet. The plats were divided at harvest into east and west halves. The yields are shown in Table 3.

In both plats two bad spots developed on the western halves, in which the grain was much poorer than the average.

TABLE 3.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section E, Arlington Experiment Farm, in 1915*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Eastern half:				
Treated	832	321.5	1.01	0.92
Control	822	350		
Western half:				
Treated	716	303	1.32	1.19
Control	540	254.5		
Total:				
Treated	1,548	624.5	1.14	1.03
Control	1,362	604.5		

Experiments in 1916.—In the fall of 1915 winter wheat was again sown, as it was desired to get a test with the network charged negatively, about 45,000 volts, instead of positively as heretofore. A powerful static machine was used to supply the current, and it was run from 4 p. m. to 8 a. m. daily (totaling 800 hours) during the spring, the fall treatment being omitted.

The plats were divided into eastern and western halves at the time of harvest and again showed considerable variation. The yields are given in Table 4.

TABLE 4.—*Yields of winter wheat on plats following electrocultural (negative) treatment, section E, Arlington Experiment Farm, in 1916*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Eastern half:				
Treated	1,324	347.5	0.98	0.85
Control	1,352	411.0		
Western half:				
Treated	1,204	324.5	1.10	.95
Control	1,092	343.0		
Total:				
Treated	2,528	672.0	1.03	.89
Control	2,444	754.0		

Experiments in 1917.—Wheat was again sown in section E in October, 1916, and allowed to mature the following summer without treatment, as an additional check on the soil conditions. At time of harvest in 1917 the plats were again cut into eastern and western halves, the south plat being the one which had received the electrical treatment in previous years. The yields are shown in Table 5.

Comparison with the rye yields of 1913 shows that the south (treated) plat apparently gained slightly in its relative productivity during the five years, but the change is well within the errors of field trials.

TABLE 5.—*Yields of winter wheat on plats without electrocultural treatments, section E, Arlington Experiment Farm, in 1917*

Plat	Yields (pounds)		Ratio of south to north plats	
	Shock	Grain	Shock	Grain
Eastern half:				
South plat	1,628.0	580.5	1.00	0.92
North plat	1,625.0	631.0		
Western half:				
South plat	1,562.5	557.0	1.08	.98
North plat	1,439.5	567.5		
Total:				
South plat	3,190.5	1,137.5	1.04	.95
North plat	3,064.5	1,198.5		

Experiments in 1918.—In the fall of 1917 winter wheat (Currell) was sown on the plats in section E, and in the spring a ½-inch mesh galvanized-iron screen 132 feet long by 15 feet high was erected 20 feet south of the check plat. It was thought that the grounded screen might protect the north plat from the drifting charge, but later measurements show that it is of doubtful value.

The static machine was again used, with the positive pole connected to the network. The number of cross wires was increased to one every 3 feet. This increased the current and reduced the potential of the network to about 30,000 volts.

Although the winter was exceptionally cold the stand in the spring was excellent. Treatment was started April 15 and continued for 46 days from 4 p. m. to 8 a. m. each day, a total of 736 hours.

At harvest the eastern and western halves of each plat were kept separate and weighed. The yields are shown in Table 6.

TABLE 6.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section E, Arlington Experiment Farm, in 1918*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Eastern half:				
Treated	1,531	569	1.16	1.10
Control	1,332	518		
Western half:				
Treated	1,289	481	.99	.95
Control	1,307	507		
Total:				
Treated	2,820	1,050	1.07	1.02
Control	2,639	1,025		

A general view of the experimental field as it appeared on May 8, 1918, is shown in Figure 1.

After the 1918 crop was harvested, measurements of the charge carried by the wind were undertaken. A flame collector was used, which was connected to the gold leaf of an electroscope, the case being grounded. A full-scale deflection of 25 divisions represented a potential of about 1,000 volts. In all the measurements the collector was held at a height of 1 meter above the ground.

A light south wind was blowing the day the measurements were made. With no charge on the network, a very slight deflection of the gold leaf could be noticed. With the network charged, however, the full-scale deflection occurred very rapidly at any point under and within 20 feet outside the network on all sides, even to the south, the direction from which the wind was coming. At 50 feet south, only about 1 division deflection was obtained. North from the network the deflection to full scale was slower and more irregular the greater the distance from the network, and when only 2 feet south of the screen along the south side of the north plat the maximum deflection obtainable was about 20 divisions. Just north of the grounded screen the maximum deflection obtained was about 9 divisions. As the collector was moved farther north from the screen and into the control plat, the deflection again increased, until at the center of the control plat it was off the scale again. The grounded screen along the south side of the control plat thus afforded little protection from the drifting charge. At a point 1,000 feet from the network, the last point observed, a full-scale deflection was obtained. At all points beyond 100 feet from the network over the south plat the deflection was very irregular and unsteady.

The Weather Bureau records show that during the 46 days of treatment in 1918 the wind was due south only 3 days. Owing to the distance of 350 feet between the treated and control plats, the wind would have to be nearly due south to carry any appreciable charge over the control plat.

SUMMARY OF EXPERIMENTS IN SECTION E

The relative yields of the south (treated) and north plats in section E are summarized in Table 7.

TABLE 7.—*Summary of yields of rye and winter wheat on the south (treated) and north (untreated) plats, section E, Arlington Experiment Farm, in six stated years*

Year	Crop	Treatment of south plat	Ratio of yields of south to north plats		Year	Crop	Treatment of south plat	Ratio of yields of south to north plats	
			Total	Grain				Total	Grain
1913	Rye	None	0.98		1916	Wheat	Negative	1.03	0.89
1914	Wheat	Positive	1.02	0.97	1917	do	None	1.04	.95
1915	do	do	1.14	1.03	1918	do	Positive	1.07	1.02

It is evident from the summary that the electrical treatment did not produce any sensible increase in yield. An examination of the detailed results for 1915 shows that the somewhat higher ratios obtained during this unfavorable year are due to a marked decrease in yield in half of the control plat. Aside from this, there appears to be a gradual increase in the total yield of the south plat relative to the north one, irrespective of whether a positive charge, a negative charge, or no charge at all was used. It is of interest to note that the grain ratios with a positive charge on the network are all slightly higher than the ratio in 1917, when no treatment was given; with the negative charge the reverse is true. This seems consistent, for if increasing the positive gradient of the electrostatic field tends to stimulate growth, then to reverse the sign of the field may perhaps tend to inhibit growth. Opposed to this speculation is the fact that the negative field apparently had no effect on the ratio of the total yields of the two plats. In brief, while there is some evidence of a slight increase in grain yield when wheat is grown under a network which is positively charged to a high potential, the observed effect is so small that it is well within the experimental errors of field trials.

EXPERIMENTS IN SECTION B

Experiments in 1911.—The first electrocultural field experiments at Arlington Experiment Farm were made in 1911 with grains in section B, employing a plat which had been seeded in strips to wheat the previous fall. In the spring of 1911 a network of small wire was installed over the eastern half of the plat, covering half of each variety. The network was 7 feet high with wires at intervals of 3 feet, connected to the positive pole of a static machine operating at a potential of about 40 to 50 kilovolts. The machine was in operation six days a week from 3 p. m. to 7 a. m. except during rainy weather from early spring to harvest.

Table 8 shows the relative yields of the treated and control halves.

TABLE 8.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section B, Arlington Experiment Farm, in 1911*

Variety	Yields per acre (pounds)				Ratio of grain, treated to control
	Treated half		Control half		
	Grain	Straw	Grain	Straw	
G. I. 1942	820	1,740	780	1,360	1.05
Fultz	1,320	1,920	1,450	2,070	.91
G. I. 1974	1,240	2,520	1,300		.95

Experiments in 1912.—In the fall of 1911 one variety of wheat, Currell (*Currell's Prolific*), was sown on section B, and the network was again erected at the height of 7 feet with cross wires 3 feet apart, as before. The treated and control plats each had an area of three-fourths of an acre. This year the network was charged with a Snook-Roentgen set, which consisted of an inverted rotary converter supplying a 160-volt current to a 1-kilowatt 100,000-volt transformer. A mechanical rectifier was used on the high-tension side to obtain a positive charge on the network, the other terminal of the transformer being grounded. Even with this set it was not possible to charge the network much above 50,000 volts. The treatment was given daily from 3 to 7 p. m., except Sundays and during bad weather.

At harvest the weights shown in Table 9 were recorded.

TABLE 9.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section B, Arlington Experiment Farm, in 1912*

Plat	Yields (pounds)			Ratio of treated to control		
	Shock	Grain	Straw	Shock	Grain	Straw
Treated	3,465	1,154	2,311	1.05	1.04	1.06
Control	3,300	1,114	2,186			

Experiments in 1913.—In the fall of 1912 the same plat in section B was again sown to wheat. The 7-foot network of the previous year was replaced by a permanent one 16 feet high, with cross wires 10 yards apart. The new network was erected over the northern half of the plat instead of the eastern half as in preceding years. The network was charged positively with the Lodge-Newman apparatus, and the treatment was given daily from 4 p. m. to 8 a. m.

The treated and control portions each had an area of three-fourths of an acre. At harvest the weights shown in Table 10 were recorded.

After the wheat was cut, cowpeas were sown on the B plat on July 29, 1913.

The static machine was connected to the network (16 feet high), giving about 40 to 50 kilovolts. The machine (positive charge) was run four hours a day from 3 to 7 p. m. for 32 days. On account of the lateness of the season, the cowpeas were cut for hay. After being stacked and cured, the crop was weighed in the field by means of a tripod and spring balance, showing the following yields: Treated portion, 1,807 pounds; control portion, 1,847 pounds; ratio of treated to control, 0.98.

TABLE 10.—*Yields of winter wheat on plats following electrocultural treatment (positive charge), section B, Arlington Experiment Farm, in 1913*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Treated	3,254	808	1.04	1.03
Control	3,139	782		

Experiments in 1914.—Corn was planted in the B plat on May 24, 1914, and the network (16 feet high) was connected directly to one wire of a 6,600-volt 3-phase 25-cycle alternating-current power line running past the farm. The voltage was on continuously day and night for 110 days, when the corn was cut and the total weights recorded in the field. It was then shocked and given time to dry. Husking was done in the field on October 9, 1914, and the grain and fodder brought to a platform balance in the barn and weighed. The superintendent of the farm expressed the opinion that the treated plat had had some advantage over the check plat as regards soil-moisture conditions. The yields shown in Table 11 were recorded.

TABLE 11.—*Yields of corn on plats following electrocultural treatment (alternating charge), section B, Arlington Experiment Farm, in 1914*

Plat	Yields (pounds)			Ratio of treated to control		
	Green shocks	Dry shocks	Grain (on cob)	Green shocks	Dry shocks	Grain (on cob)
Treated	16,031.5	4,060	2,892	1.16	1.03	1.28
Control	13,775.5	3,952	2,260			

Experiments in 1915.—The corn was followed by rye which was sown in section B on October 22, 1914. The 6,600-volt treatment alternating charge was started November 5 and maintained continuously till June 24, 1915. This year at time of harvest each plat (treated and control) was divided into eastern and western halves, and each section was weighed separately to show any inequalities in soil conditions.

The yields recorded at harvest showed a lack of uniformity in the plats, but gave no evidence of a sensible increase in yield due to the electrical treatment. The results are shown in Table 12.

TABLE 12.—*Yields of rye on plats following electrocultural treatment (alternating charge), section B, Arlington Experiment Farm, in 1915*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Eastern half:				
Treated	1,532	565	1.13	1.08
Control	1,350	525		
Western half:				
Treated	1,304	481	.93	.93
Control	1,408	515		
Total:				
Treated	2,836	1,046	1.03	1.01
Control	2,758	1,040		

Experiments in 1916.—In order to measure the relative yielding power of the two plats (treated and control) under normal conditions wheat was again sown in the fall of 1915 and allowed to mature the following summer without electrical treatment of either plat. Table 13 shows the figures recorded at harvest, the north plat being the treated plat of the three preceding years.

TABLE 13.—*Yields of winter wheat on plats without electrocultural treatments, section B, Arlington Experiment Farm, in 1916*

Plat	Yields (pounds)		Ratio of north to south plats	
	Shock	Grain	Shock	Grain
Eastern half:				
North plat	1,568	456.5	0.95	0.84
South plat	1,660	542.0		
Western half:				
North plat	1,448	403.5	.83	.86
South plat	1,752	467.0		
Total:				
North plat	3,016	861.0	.88	.85
South plat	3,412	1,009.0		

SUMMARY OF EXPERIMENTS IN SECTION B

The 1916 results show about 15 per cent difference in the yield of the plats when no electrical treatment was used, the control plat giving the higher yield. During the preceding three years the yields of the two plats were approximately equal. If the 1916 results are accepted as indicating the relative productivity of the two plats under normal conditions, the conclusion follows that during the preceding three years the electrocultural treatment increased the yield 15 per cent or more and that an alternating charge on the network was equally as effective as a high positive charge. During the time the network was connected to the alternating-current power line the charge was changing sign 50 times per second, the maximum gradient was about 1,500 volts per meter, and there was no appreciable ionization at the network. The conditions were so different from those prevailing when the network was charged to a steady high positive potential that it seems highly improbable that the effect on the growing crop would be the same unless the effect is nil under both conditions, the 1916 results not being representative. The latter conclusion seems the more probable, and this is supported by the experiments in section A which follow.

EXPERIMENTS IN SECTION A

A plat in section A of the same dimensions as the one in B was also used for electrocultural tests. The north half of this plat was equipped with a 16-foot network similar to the B network except that it had twice as many cross wires (5 yards apart). The two networks were connected electrically, so that both received the same charge.

Experiments in 1914.—Soybeans were planted in section A in June, 1914, and subjected to a 6,600-volt 25-cycle treatment (alternating charge) continuously from July 15 to October 19, when the crop was harvested. The total weight of the crop from each plat was determined just after cutting, again after drying in the field, and finally after threshing. The weights recorded are shown in Table 14.

TABLE 14.—*Yields of soybeans on plats following electrocultural treatments (alternating charge), section A, Arlington Experiment Farm, in 1914*

Plat	Yields (pounds)			Ratio of treated to control		
	After cutting	After drying	Beans only	After cutting	After drying	Beans only
Treated	4,093	2,776	811.3	0.97	1.13	1.04
Control	4,242	2,446	782.5			

Experiments in 1915.—After the plat had been plowed and put in good shape, rye was seeded on October 22, 1914, and the 6,600-volt treatment (alternating charge) was started November 5 and maintained continuously until harvest. The field was divided into four equal parts when the rye was cut, to get some idea of the soil variation in the eastern and western halves of the plats. At harvest time the crop under the network showed a much better growth than the control plat, but this was probably owing to soil conditions rather than to the electrical treatment, as indicated by the comparative test the following year. The yields obtained are shown in Table 15.

TABLE 15.—*Yields of rye on plats following electrocultural treatments (alternating charge), section A, Arlington Experiment Farm, in 1915*

Plat	Yields (pounds)		Ratio of treated to control	
	Shock	Grain	Shock	Grain
Eastern half:				
Treated	1,270	469	1.46	1.29
Control	868	363		
Western half:				
Treated	1,392	512	1.56	1.52
Control	890	337		
Total:				
Treated	2,662	981	1.51	1.40
Control	1,758	700		

Experiments in 1916.—Rye was again sown in section A in the fall of 1915 and allowed to mature without electric treatment. This crop was cut in June, 1916, giving the yields shown in Table 16, the north plat being the plat treated during the two preceding years.

TABLE 16.—*Yields of rye on plats without electrocultural treatments, section A, Arlington Experiment Farm, in 1916*

Plat	Yields (pounds)		Ratio of north to south	
	Shock	Grain	Shock	Grain
Eastern half:				
North	1,802	557	1.36	1.36
South	1,328	409.5		
Western half:				
North	1,892	590.5	1.54	1.50
South	1,230	393.5		
Total:				
North	3,694	1,147.5	1.44	1.43
South	2,558	803.0		

SUMMARY OF EXPERIMENTS IN SECTION A

A comparison of the yields obtained in the field trials in section A gives no evidence of an increased yield accompanying the use of an alternating charge on the network.

ELECTROCULTURAL EXPERIMENTS IN THE PLANT HOUSE

TRANSPIRATION

The effect of a very high potential gradient on the transpiration rate was investigated in plant-house experiments in Washington in 1913. Large galvanized-iron buckets were filled with moist soil and fitted with special covers to prevent evaporation from the soil. Six rooted geranium cuttings were planted in each pot through holes in the cover, the opening around the stem of the plant being sealed with wax.

The initial weights were taken on February 15, 1913, and the plants were allowed to grow until February 20 without treatment, to determine the relative transpiration of two sets of six pots each. One set was then placed under an insulated frame covered with galvanized-wire screen of ½-inch mesh, while the control set was protected from the discharge by being placed inside a Faraday cage of ½-inch mesh. The frame was connected to the positive pole of the static machine, the other pole being grounded. The frame was charged four hours a day, from 3 to 7 p. m., from February 21 to March 24. The plants were again allowed to grow without treatment from March 25 to April 7. During each period weighings were made to determine the loss due to transpiration, and water was added when necessary to maintain approximately the initial moisture content of the soil.

Table 17 shows the rate of transpiration for each pot during the three periods and the ratio of the treated to the control set. It will be noted that during the period of treatment no sensible change occurred in the transpiration ratio.

TABLE 17.—*Transpiration rate of geranium plants in pots under electrocultural treatment in the plant house at Washington, D. C., in 1918*

Pot designation	Transpiration rate per hour (grams)								
	No treatment		Treatment period					No treatment	
	Feb. 15 to 17	Feb. 17 to 20	Feb. 20 to 25	Feb. 25 to Mar. 1	Mar. 1 to 5	Mar. 5 to 13	Mar. 13 to 24	Mar. 24 to Apr. 1	Apr. 1 to 7
Treated set:									
No. 175	3.6	5.1	5.1	2.9	8.3	8.0	8.8	7.7	10.5
No. 176	3.3	4.7	5.1	3.4	8.4	8.0	9.5	8.2	10.9
No. 177	2.9	5.3	4.8	2.9	8.1	7.6	9.0	7.7	10.9
No. 178	2.6	4.7	4.4	2.9	7.7	7.4	9.4	8.9	11.4
No. 179	4.3	6.1	6.4	3.3	9.7	7.9	7.7	6.8	10.4
No. 180	2.1	5.0	4.9	3.2	7.9	6.8	8.7	8.6	11.4
Mean	3.13	5.15	5.11	3.10	8.35	7.61	8.85	7.98	10.91
Control set:									
No. 181	3.1	4.2	4.3	2.8	7.0	6.5	8.4	9.1	11.1
No. 182	3.3	5.7	6.0	3.7	8.6	8.0	8.6	7.8	10.7
No. 183	3.3	4.6	5.2	3.4	8.1	7.6	8.9	8.2	10.6
No. 184	3.6	5.0	4.9	3.2	8.0	7.6	8.9	8.4	10.9
No. 185	4.3	5.7	5.9	4.0	9.0	8.2	8.1	7.1	10.3
No. 186	3.6	5.3	5.5	3.5	8.7	8.4	8.6	7.4	10.6
Mean	3.53	5.08	5.30	3.43	8.23	7.71	8.58	7.91	10.70
Ratio of treated to control	.89	1.01	.97	.91	1.01	.99	1.03	1.01	1.02

The total transpiration from the treated and control sets of potted geranium plants for the three experimental periods is given in Table 18.

TABLE 18.—*Total transpiration of geranium plants in pots during the three experimental periods in the plant house at Washington, D. C., in 1918*

Designation	Total transpiration (kilograms)		
	No treatment, Feb. 15 to 20	Treatment period, Feb. 21 to Mar. 24	No treatment, Mar. 25 to Apr. 7
Treated set	3.00	33.42	20.01
Control set	3.08	33.42	19.62
Ratio of treated to control	.98	1.00	1.02

WATER REQUIREMENT

An investigation of the effect of a high potential gradient on the water requirement of cowpeas was undertaken in a plant house during the winter of 1918. Eighteen large galvanized-iron cans, each holding about 125 kilograms, were filled with well-mixed soil and fitted with special covers to prevent evaporation. The cowpeas were planted through holes in the covers, the openings being sealed with wax. The pots were weighed at the beginning and at the end of the experiment, and a record was kept of the water added to each pot, from which the total quantity of water transpired by the plants in each pot could be determined. In brief, the procedure was that followed by Briggs and Shantz (*10, 11*) in their water-requirement measurements.

These pots were divided into three sets of six each. Set No. 1 was placed on an insulated stand, with each pot connected to the positive pole of a static machine; set No. 2 was grounded and placed under a positively charged iron-wire screen suspended about 2 feet above the plants; and set No. 3 was used as a control and was protected from the influence of the charged sets by a well-grounded wire screen. The potential supplied by the static machine was above 50,000 volts.

As soon as the treatment started trouble was experienced with the set beneath the charged network, soot and dust (large ions) being deposited on the leaves and stems of the plants, and in fact all over the house. A coating would collect on the leaves over night during the course of a 16-hour treatment. The plants were washed several times, but they did not thrive, owing in part at least to the great reduction in photosynthesis resulting from the coating on the leaves. This set was finally discarded.

The other two sets, however, grew well throughout the experiment, although they were not so vigorous as plants grown out of doors in the summer. The positions of the pots in a given set were interchanged weekly, so as to provide average light conditions for each pot.

The plants were cut May 2, after 54 days of treatment for 16 hours each day (from 4 p. m. to 8 a. m.), and they were dried at 100° C. and weighed. The water requirement of the plants in each pot was computed by dividing the total weight of water transpired by the dry weight of the crop. The mean water requirement for each set of six pots with its probable error was as follows: For the treated set, 449±4; for the control set, 429±5. A slightly higher water requirement is thus shown for the treated set, the observed increase being 4±1.2 per cent. If some of the water molecules escaping through the stomata of the leaves carried a positive charge, they would move away from the leaf more rapidly than under normal conditions, owing to the strong electric field. This would be equivalent to a virtual increase in the vapor pressure gradient near the leaf and would tend to increase the evaporation rate. Although the above suggestion is highly speculative, it would be of interest to repeat the experiment, applying the electric charge during the daylight hours when the transpiration rate is highest.

SUMMARY OF EXPERIMENTS AT ARLINGTON EXPERIMENT FARM

Electrocultural experiments extending over a period of eight years have been conducted at the Arlington Experiment Farm, Rosslyn, Va., for the purpose of determining whether a highly charged network will increase the yield of crops growing under it. The electrical treatment was usually given during the early-morning and late-afternoon hours. The general experimental procedure was similar to that employed in experiments in England in which the electrical treatment is reported to have given increased yields.

These experiments do not show any well-defined increase in yield due to electrical treatment. There is an indication of a slight increase in the yield of wheat when grown under a positively charged network, but the observed increase is well within the experimental error of field trials.

The results of these field experiments are summarized in Table 19. The relative productivity of the plats when not subjected to the electrical field was determined in order to provide additional information in interpreting the results, a precaution which has not been generally observed by other investigators. A discussion of the yields from each section will be found in the text embodying the description of the experiments.

TABLE 19.—*Summary of the results of the electrocultural experiments in sections A, B, and E, Arlington Experiment Farm, in stated years*

[The treated and control plats in sections A and B were each three-fourths of an acre in area; those in section E half an acre each, separated by an interval of 350 feet. *Abbreviations and symbols.*—Column 2: C=Cowpeas (crop cut for hay); R=Winter rye; S=Soybeans; W=Winter wheat. Column 3: Numbers refer to preceding tables. Column 4: A=25-cycle alternating current; N=No treatment; −=Negative direct current; +=Positive direct current. Column 12: *=Yield of plats treated in previous years]

Section and date	Crop	Table reference	Network treatment: Character of current: Charge	Network treatment: Character of current: Voltage	Description of network: Height (feet)	Description of network: Spacing (yards)	Time of treatment (hours): Per diem	Time of treatment (hours): Total duration	Yields (pounds): Dry shock: Treated	Yields (pounds): Dry shock: Control	Yields (pounds): Grain: Treated	Yields (pounds): Grain: Control	Ratio of treated to control: Dry shock	Ratio of treated to control: Grain
1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
Section A:														
1914	S	14	A	6,600	16	5			2,776	2,446	811.3	782.5	1.13	1.04
1915	R	15	A	6,600	16	5			2,662	1,758	981	700	1.51	1.40
1916	R	16	N		16	5			2,700	2,558	*1,147.5	803	1.44	1.43
Section B:														
1912	W	9	+	45,000	7	1	[1] 16		3,465	3,300	1,154	1,114	1.05	1.04
1913	W	10	+	40,000 to 50,000	16	10	[1] 16		3,254	3,139	808	782	1.04	1.03
1913	C		+	45,000	16	10	[2] 4	128	1,807	1,847			.98	
1914	Corn	11	A		16	10			6,952	6,212	2,892	2,260	1.12	1.28
1915	R	12	A		16	10			2,836	2,758	1,046	1,040	1.03	1.01
1916	W	13	N						3,016	3,412	*861	1,009	.88	.85
Section E:														
1913	R	7	N						2,438	2,499			.98	
1914	W	2	+	30,000 to 60,000	16	5	[2] 4	336	2,332	2,281	644.8	656.5	1.02	.97
1915	W	3	+	30,000 to 60,000	16	2	[3] 6½	345	1,548	1,362	624.5	604.5	1.14	1.03
1916	W	4	−	45,000	16	2	[1] 16	800	2,528	2,444	672	754	1.03	.89
1917	W	5	N						3,190.5	3,064.5	1,137.5	1,198.5	1.04	.95
1918	W [4]	6	+	30,000	16	1	[1] 16	736	2,820	2,639	*1,050	1,025	1.07	1.02

[1] From 4 p. m. to 8 a. m.
[2] From 3 to 7 p. m.
[3] From 4 to 7 a. m. and from 5 to 8.30 p. m.
[4] Plats separated by grounded wire screen.

Plant-house experiments were also made on the effect of an electric charge on the transpiration rate and the water requirement of plants. The effect observed was well within the errors of experiment.

The use of electrocultural methods in their present state of development as a practical means of increasing the yield of crops in this country is not recommended.

REVIEW OF OTHER INVESTIGATIONS IN ELECTROCULTURE

Electrocultural experiments may be divided into two main classes: (1) Those in which the soil is the medium of conduction and (2) those in which the air is the medium of conduction. Experiments of the first class cover the use of soil currents resulting (1) from an externally applied electromotive force, (2) from the galvanic action of the soil moisture on zinc and copper plates buried in the ground, and (3) from the use of metallic uprights designed to collect and carry atmospheric electricity to the soil. Experiments of the second class are those in which the normal air-earth current is increased by means of a highly charged network over the plants or decreased by inclosing the plants in a grounded cage made of metal screen.

EXPERIMENTS WITH SOIL CURRENTS

Among the first experiments with soil currents on a large scale were those by Ross, prior to 1844, (*44*) in New York. He buried a copper plate 5 feet by 14 inches perpendicularly in the earth with the 5-foot edge horizontal, and at a distance of 200 feet a zinc plate of the same dimensions was similarly buried. The two plates were connected above the ground, forming a galvanic cell. Potatoes were drilled in rows between the plates and also in a similar plat without plates. At the end of the experiment some of the potatoes from both plats were measured, those from the treated plat averaging 2½ inches in diameter, while those from the control averaged only half an inch. The total weights at harvest are not given, and conclusive assurance that the two areas were of equal fertility at the outset is lacking. The supposed beneficial effect is rendered doubtful through the subsequent discontinuance of so simple a treatment.

About this time Solly (*46*) conducted in England 70 small tests similar in principle to those of Ross, the plates being 4 by 5 inches and spaced only 6 inches apart. Grains, vegetables, and flowers were planted between the electrodes. On comparing the appearance of the treated and untreated plants a beneficial effect was recorded in 19 cases, a harmful effect in 16 cases, and no effect in 35 cases. Solly concluded that electricity has practically no effect on plant growth.

Fitchner (*16*) has recorded large increases from treatment with galvanic currents. From his figures alone the experiments would indicate increases of 16 to 127 per cent due to treatment. The statement was made, however, that the treated plats were provided with drains but that the control plats were not. Such conditions do not constitute good experimental practice and leave the results open to question. This same objection holds for accompanying experiments on the decomposing action of the galvanic current on soil.

In 1881, F. Elfving *(15)* undertook an interesting series of experiments with different seedlings growing in culture solutions through which he passed battery currents of different strengths. After germination the seedlings were mounted on corks which were floated in the solution between electrodes 6 by 4 centimeters in size. He found that in nearly every case the root would turn and grow in a direction against that of the electric current. Plates of carbon, zinc, and platinum were used, and all gave the same effect. Elfving attributes this phenomenon of orientation to the slowing up of the growth on the side of the root toward the positive pole. This same phenomenon was noticed by Plowman *(40, 41)* in 1902–03.

Holdefleiss *(23)* in 1884 selected several rows of sugar beets in a field which showed a good stand and uniform conditions. In this field copper plates 50 centimeters square were sunk perpendicularly in the ground 50 centimeters deep, so that the plates included two rows of beets. At the other end of the rows, 56 meters distant, other plates were sunk, and between the two a 14-cell Meidinger battery was connected. This same arrangement was used on a potato field. Further experiments were conducted with copper and zinc plates 33 meters apart connected by a solid copper wire. The report of the experiments stated, in substance:

(1) That an electric current was present on all treated plats throughout the season, its presence being determined by a sensitive electrometer; (2) that the rows of beets and potatoes between plates which were connected to the battery showed no difference in growth at any stage of their development; (3) that the beets and potatoes in rows between the zinc-copper combinations assumed a somewhat fresher and stronger appearance about 10 days after the beginning of the experiment, and the harvest showed an increased yield ranging from 15 to 24 per cent.

It should be remembered, however, that in experiments with soil currents the path of the current is not wholly by the most direct route from one electrode to the other, but that the lines of flow spread out through the soil in a way similar to the spreading of the lines of force between the poles of a bar magnet.

Experiments conducted by Wollny *(48)* included five plats 4 by 1 meter each in size separated by a path 1.2 meters wide and by boards sunk 25 centimeters in the ground. On plats 1 to 3 a zinc plate was sunk at both of the narrow sides, and these were connected as follows: Plat 1, induction coil operated by three Meidinger elements; plat 2, a battery of six Meidinger elements; plat 3, a battery of three Meidinger elements. On plat 4 a zinc plate was sunk on one end and a copper plate at the other, the two being connected above ground by a copper wire. Plat 5 constituted a check or control plat. Each plat was divided into four equal parts 1 square meter each in area and seeded. Numbers of plants up on different dates showed practically no effect for any of the different treatments. The yields recorded at harvest time, based on an equal number of plants per square meter, are shown in Table 20.

TABLE 20.—*Yields of rye, rape, bean, and potato plants after electrocultural treatments in 1883, according to Wollny*

Plat	Treatment	Yields per square meter (grams)			
		Rye, 42 plants	Rape, 42 plants	Beans, 42 plants	Potatoes, 5 plants
No. 1	Induction	182.0	114.8	517.5	372.1
No. 2	6 cells	219.8	94.5	514.5	310.5
No. 3	3 cells	197.8	103.0	420.0	315.3
No. 4	Cu-Zn	201.6	114.7	600.0	397.8
No. 5	Control	228.7	118.7	631.0	377.6

These records show that in nearly all cases the control plat gave the best yields, but further experiments were conducted in 1886 and 1887. The ground was well worked over, and four plats 16 by 2 meters were selected, separated from each other by paths 1.2 meters wide and bordered by wooden lath walls. Each plat was divided into eight smaller plats 2 meters square and all were given equal applications of manure. On the small ends of the four large plats zinc plates 2 meters by 30 centimeters in area were sunk perpendicularly and connected above ground through an induction coil operated by 4 or 5 cells for plat 1 and through a 4 or 5 cell battery for plat 2. Plat 3 served as a control, and plat 4 had a copper plate at one end directly connected by a copper wire with a zinc plate at the other end. Diagonally lying plats were planted with the same crops, the grains being drilled to give a uniform planting. The presence of a current on all treated plats was noted by the use of a galvanometer. Throughout the season there was no perceptible difference in growth between treated and control plats during either year. The comparative-yield weights are shown in Table 21.

TABLE 21.—*Yields of vegetable crops after electrocultural treatments in 1886 and 1887, according to Wollny*

Plat	Treatment	Yields per plat 2 meters square (grams)							
		Rye	Rape	Peas	Beans	Corn	Potatoes	Beets	Turnips
In 1886:									
No. 1	Induction	113.3	339.0	1,420.0	2,040.0		6,400	23,400	22,250
No. 2	5 cells	108.6	300.5	1,570.0	2,410.0		4,650	24,420	18,080
No. 3	Control	107.8	405.8	1,380.0	2,220.0		6,620	28,100	21,520
No. 4	Cu-Zn	100.9	418.0	1,490.0	2,190.0		6,670	29,400	20,800
In 1887:									
No. 1	Induction	933.0	775.0	548.0	696.5	1,962.8	8,350	19,640	17,850
No. 2	4 cells	879.0	755.0	588.0	6[illegible]7.0	1,923.6	8,190	17,650	18,270
No. 3	Control	948.4	773.0	592.0	584.2	1,913.6	8,410	18,900	18,460
No. 4	Cu-Zn	838.5	761.6	571.0	465.0	2,072.9	8,920	16,320	19,660

From these experiments Wollny concluded that an electrical current conducted through soil in which plants were growing had in general no influence or possibly a harmful effect on the productiveness of the plants.

Leicester *(29, 30)* used boxes of soil 2½ by 3 feet in area, with copper and zinc plates connected above ground. Control boxes without plates were included. After several trials with different kinds of seeds, it was found that in every case the seeds grew much quicker in the boxes containing the plate. Hemp seed was fully an inch above the surface before controls showed any plants. The observation was made also that plants in the zones nearest the plates were the first to come up. Watering with dilute acetic acid was found to cause quicker growth for treated plants—possibly because of increased current resulting from the acid-metal reaction. Upon repeating these experiments, Leicester decided that the only action of the current was to stimulate the plant until the initial store of food was used up. No data were recorded in either of his reports.

Berthelot (*3*) conducted some tests with soil currents to determine whether electricity aided in the fixation of nitrogen by plants. Suitable control plats were provided. He reported that the treated plants grew much more rapidly, being nearly twice the weight of the control plants at the end of four to six weeks. Although not complete or definite, the experiments were abandoned for various reasons.

Kinney (*27*) made an extensive series of experiments to determine the influence of electrical currents on germination. Seeds were subjected to different current strengths for different periods of time and then put in suitable germination apparatus and the subsequent growth noted. An intermittent treatment of 30 seconds per hour was given in some cases, arranged by clock contacts. Two different arrangements were used for the treatments. In one a glass cylinder containing the seeds was equipped at each end with electrodes. These were pressed against the seeds through which the current was thus directly passed. In the other, the seeds were placed in wet sand held between perforated metal disks, which were used for the electrodes. The entire layer was held in a glass funnel in which the growth of the radicle could be measured without removal. Eight sets of 25 seeds each were used in each test, one set being the control and the other seven receiving different strengths of current. Experiments with barley showed that the growth of treated seeds increased as the current strength increased up to a certain optimum value, above which the growth decreased with increase in current strength. With white mustard, rape, and red clover the optimum treatment for both roots and stems was identical.

Plowman (*40*, *41*) has recorded the results of experiments conducted at the Harvard Botanical Gardens on the influence of soil-conducted currents on plant life. Platinum or carbon electrodes were used, with potentials ranging from 5 to 500 volts. The regulation of temperature was a serious difficulty—a fact mentioned for the first time in connection with such experiments and one that may have been ignored in earlier reports. Plowman found that seeds near the anode were always killed by a current of 0.003 ampere or more if continued for 20 hours. Seeds at the cathode were little affected by currents less than 0.08 ampere.

Gerlach and Erlwein (*19*, *20*), at Bromberg, investigated the effect of weak soil currents on germination and growth. The field was made up of seven plats of 200 square meters each. Current was taken from a car line and led to the three treated plats, which were provided with iron plates 20 meters long by 30 centimeters wide and 2 millimeters thick sunk into the soil at both ends. Each of the seven plats was seeded half with barley and half with potatoes.

The treatment continued 24 hours a day for 86 days for barley and 139 days for potatoes, beginning in April. Both barley and potatoes showed excellent growth, but no differences between the treated and control plats were discernible at any time. Other experiments were conducted with plants grown in boxes provided with copper and zinc plates connected overhead by wires. Trials with rye, wheat, and lupine gave no difference between treated and untreated crops.

Homberger (*24*) reported that the passage of high-frequency currents through the soil was beneficial to plant growth. His experiments were conducted on a small scale, using flowerpots with only a few plants, the treatment consisting of three applications daily until the temperature of the soil reached 35° C., when the current was cut off. The leaves and stems of the treated plants showed more chlorophyll than the controls. A photograph shows one pot each of treated and control plants, the treated plants being about five times as high as the others. In order to determine whether the heating was the main cause of increased growth another pot was subjected to test currents for five minutes daily. These plants were about four times the height of the controls when photographed. From these comparisons Homberger concluded that the oscillating field and not the temperature was the main cause of the stimulation, and he believed his results to be due to chemical changes taking place under the influence of the oscillating electromagnetic field, analogous to the catalytic action of light.

In 1907 (*17*) and 1909 (*18*) Gassner reported upon experiments with charged soil which indicated a general unfavorable action upon plant growth.

Kövessi (*28*) obtained unfavorable results in researches involving some 1,100 experiments.

Considerable publicity has been given to an apparatus called a "geomagnetifier," a sort of lightning rod designed to gather in atmospheric electrical energy and supply it to the crops. Among those who have reported favorable results through the use of such apparatus are Maccagno (*35*), Basty (*2*), and Paulin (*39*).

At the present time methods of electroculture employing soil-conducted currents have few proponents.

EXPERIMENTS WITH MODIFIED POTENTIAL GRADIENTS

Grandeau (*21*), in 1878, reported studies on the effect of the electrical condition of the atmosphere upon the growth of vegetation He grew plants in a Faraday cage consisting of four iron rods 1. centimeter in diameter by 1.5 meters high, holding fine iron wires forming 15 by 10 centimeter meshes. The cage was grounded in order to destroy the normal electrical field. Experiments were made with tobacco, corn, and wheat. The plants under the cage were reported weak and slender. Six stalks of wheat grown in free air weighed 6.57 grams, as compared with 4.95 grams for six stalks grown under the cage.

Grandeau was led by these experiments to the belief that high trees act as a grounded network, in that they shield the vegetation beneath their foliage from the action of the normal electrical field, thereby causing a decreased rate of growth. With a sensitive Thompson electrometer, he compared the strength of the field in the open with that under vegetation. The results indicated that under trees and shrubs the potential gradient was greatly reduced. The experiments of Grandeau were confirmed by Mascart (*36*).

As opposed to the conclusion of Grandeau, the modern greenhouse of steel construction constitutes in itself an approximation to a Faraday cage about the plants growing within it, and yet the development of the plants is surely not seriously impaired in consequence. Likewise, Briggs and Shantz (*10, 11*), in their investigation of the water requirements of plants, carried hundreds of pots of plants to full maturity under a grounded metal framework, covered above and on the sides with metal screen of ½-inch mesh, which must have annulled the normal electrostatic field; yet the plants grown within the inclosure were almost without exception superior in development and luxuriance of foilage to those grown in similar pots outside.

Lemström (*32*) conducted in Finland a long series of experiments to determine, if possible, the influence of static electricity on plant growth. The presence of strong electric charges in the atmosphere of northern regions, as indicated by the northern lights, linked with the astonishing development of vegetation in such regions, led him to regard atmospheric electricity as an important factor in plant growth. Garden vegetables, fruits, and small grains were subjected to several different treatments in these investigations both in greenhouses and in open fields. Lemström summarized the results of his experiments as follows:

(1) The real increase due to electrical treatment has not yet been exactly determined for the different plants, but we are approaching its smallest value by fixing it at 45 per cent.

(2) The better and more scientifically a field is cultivated and manured, the greater is the increase percentage. On poor soil it is so small as to be scarcely perceptible.

(3) Some vegetables can not endure the electric treatment if they are not watered, but then they will give very high percentage increases. Among these are peas, carrots, and cabbage.

(4) Electric treatment when accompanied by hot sunshine is damaging to most vegetables, probably to all; wherefore if favorable results are to be arrived at the treatment must be interrupted in the middle of hot and sunny days.

Experiments similar to those conducted in Finland were conducted in England, Germany, and Sweden with like results. A detailed description of all of these experiments may be found in "Electricity in Agriculture and Horticulture," by Lemström (*32*).

Priestley (*42, 43*) reported on the experiments of Newman (*37*) at Golden Valley Nurseries at Bitton. A small Wimshurst machine was used, one terminal of which was grounded and the other connected to wires suspended over outside plats and also to wires in seven glasshouses. The wires were hung 16 inches above the tops of the plants and were provided with discharge points hung at short intervals. The machine was operated 9.3 hours a day for 108 days between March 27 and July 26, the first half of the period in daytime and the latter half at night. Control plats were provided in all cases similar to the treated plats except without wires. The results recorded are given in Table 22.

TABLE 22.—*Results of electrochemical treatment of garden crops at Bitton, as reported by Newman*

Crop	Treated plants	Notes
	Per cent	
Cucumbers, increase	17	Less subject to bacterial disease.
Strawberries:		
5-year plants, increase	36	
1-year plants, increase	80	More runners produced.
Broad beans, decrease	15	5 days earlier.
Cabbage		
Celery, increase	2	10 days earlier.
Tomatoes (no difference)		

During the same year an installation was working at Gloucester with higher voltage and wires 5 feet from the ground. The following results with treated plants were reported: Beets, 33 per cent increase and higher total sugar content; carrots, 50 per cent increase; turnips showed an increase, but the percentage was not recorded owing to slugs.

In 1906 Newman (*37*) and Lodge (*33*), at Evesham, began some electroculture experiments using about 40 acres, 20 of which were electrified with a network 15 feet above ground. The Lodge apparatus was used, 22 poles carrying the wire over the area, with small wires 12 yards apart. These experiments were continued several years. The results are summarized in Table 23.

TABLE 23.—*Results of electrochemical treatment of crops at Evesham in stated years, as reported by Newman*

Year and crop	Electrified crops	Notes
1906:		
Wheat (electrified area 12 acres)—	*Per cent*	
Canadian, increase	39	Sold for 7½ per cent higher price when bakers found it produced a better baking flour. The somewhat poor yield from the control plat was probably due to deficiency in lime, afterwards rectified.
English, increase	29	
1907:		
Wheat (electrified area 11 acres), increase.	29 18	Estimated by cartloads.
Strawberries, increase	25	
1908:		
Wheat (electrified area 7.68 acres), increase.	24.3	
Strawberries, decrease	9	Dry season.
Tomatoes, increase	30	By weight per plant (average).
Cucumbers, increase	8.4	By number (average).

Newman reported later (*38*) that during seven successive years (1905 to 1911) wheat gave an average increase of 21 per cent in weight of grain and an increase of straw which it was not possible to measure.

Potato variety experiments conducted at Dumfries, Scotland, by Dudgeon in 1911 and 1912 (*14*) gave the yields shown in Table 24.

TABLE 24.—*Results of electrocultural treatment of potato varieties at Dumfries, Scotland, by Dudgeon in 1911 and 1912*

Variety	Yield (tons)		Variety	Yield (tons)	
	Treated	Control		Treated	Control
Ringleader	8.06	5.85	Golden Wonder	8.74	8.12
Windsor Castle	11.72	9.88	Great Scot	11.79	10.31

In 1912 further experiments at Dumfries were carried on in another field, exposed to wind from any quarter. Two corners of the 4 acres were treated, the others left as controls. No difference in yield was recorded, and it is explained that probably all plats are to be regarded as treated plats.

In 1915 Dudgeon conducted an experiment with oats. The crop was grown on ground that had been used for similar experiments on potatoes for three years. Two adjacent plats of 1½ acres each were separated by a well-grounded wire screen 3 feet higher than the charged network. A sensitive electrometer showed that the screen reduced the leakage over the control plat but did not altogether prevent it. The season was dry and the crop was not heavy. From early stages the treated plat showed a marked superiority in comparison with the control, and did not suffer from the prevailing drought to the same extent. The electrical discharge was applied about five hours each day for 108 days. The weights (pounds) recorded at harvest were as follows: Treated—grain, 1,309, straw 2,476; control—grain 1,008, straw 1,572.

These figures indicate an increase of about 30 per cent in grain and about 58 per cent in straw. Analyses of the grain from the two plats showed practically no difference in quality.

Blackman and Jørgensen (*6*) have also reported experiments by Dudgeon at Dumfries, Scotland, with oats. In a 9-acre field 1 acre was selected for treatment and two half-acre plats for controls. The distance between the silicon-bronze wires of the network was 4.5 yards. Current of 3 amperes at 50 volts was supplied to the primary circuit, giving a greater intensity of discharge than that obtained in the experiments of the previous years. The discharge was started just as soon as the crop appeared above ground, and within a month a marked difference was noted. The treated plants had deeper color and were higher than the control plants. Throughout the season the treated crop was 5 to 10 inches higher than the control. Plants around the network also showed the effect of the discharge. The total application from April 14 to August 17, daytime only, was 848 hours. Heavy rains did a good deal of damage. The comparative yields were as shown in Table 25.

TABLE 25.—*Results of electrochemical treatment of oats at Dumfries, Scotland, by Dudgeon, as reported by Blackman and Jørgensen*

Field	Yields (pounds)				
	Grain		Straw		
	Quality 1	Quality 2	Bunches	Total	Per bunch
Control 1 (half acre)	630	210	99	1,218	12.3
Treated (acre)	1,942	695	316	4,924	15.6
Control 2 (half acre)	714	210	103	1,401	13.6

These results indicate a 49 per cent increase in grain and an 88 per cent increase in straw for the electrical treatment.

The Liverpool City and Electrical Engineers reported on experiments conducted near Liverpool, England, in 1917. Two plats in newly plowed pasture land separated by about 375 feet were used, an analysis indicating that the surface and subsoil were of the same character. Various plant crops were grown, and in general the electrified area gave substantial increases in yield over the control area. A copy of this report is on file in the Office of Biophysical Investigations, Bureau of Plant Industry.

Honcamp (*25*) has summarized the results of several previous investigations and pointed out serious objections to the methods used.

TABLE 26.—*Results of electrochemical treatments of oat crops at Mocheln, Germany, according to Gerlach and Erlwein*

Electrical and soil treatment	Relative yields		Composition (per cent)			
			Grain		Straw	
	Grain	Straw	Dry matter	Nitrogen	Dry matter	Nitrogen
No electricity:						
Fertilizer, irrigation	28.60	34.40	91.4	1.94	77.4	0.32
Do	28.80	32.20	92.4	1.70	76.2	.27
Fertilizer, no irrigation	20.60	24.40	87.9	2.13	73.5	.46
Do	20.90	22.10	89.9	2.04	74.3	.38
No fertilizer, no irrigation	19.60	19.40	90.4	1.85	78.8	.32
Do	19.60	17.40	90.1	1.67	79.8	.32
Direct current:						
Positive, fertilizer, irrigation	27.80	36.20	90.4	1.94	71.6	.27
Negative, fertilizer, irrigation	27.80	37.20	91.7	1.74	72.9	.24
Positive, fertilizer, no irrigation	21.60	24.40	90.5	2.16	74.5	.36
Negative, fertilizer, no irrigation	20.50	22.50	91.2	2.07	73.7	.30
Positive, no fertilizer, no irrigation	21.00	23.00	84.4	1.68	76.6	.28
Negative, no fertilizer, no irrigation	17.80	18.20	90.4	1.72	78.4	.28
Alternating current:						
Fertilizer, irrigation	26.20	31.80	91.7	1.81	78.4	.28
Do	26.00	32.00	90.6	1.78	77.9	.23
Fertilizer, no irrigation	19.50	21.50	91.3	2.16	73.2	.33
Do	19.90	21.10	89.8	2.11	75.9	.30
No fertilizer, no irrigation	18.00	18.00	91.1	1.84	82.2	.28
Do	18.00	18.00	91.4	1.83	85.0	.26

SUMMARY OF RELATIVE YIELDS OF GRAIN AND STRAW

Soil treatment	No electricity	High-tension current		
		Direct		Alternating
		Positive	Negative	
Grain:				
No fertilizer, no irrigation	19.60	21.00	17.80	18.00
Fertilizer, no irrigation	20.75	21.60	20.50	19.70
Fertilizer, irrigation	27.70	27.80	27.80	26.10
Straw:				
No fertilizer, no irrigation	18.40	23.00	18.20	18.00
Fertilizer, no irrigation	23.25	24.40	22.50	21.30
Fertilizer, irrigation	33.30	36.20	37.20	31.90

On the Continent during this period many electrocultural experiments were carried out, using networks charged to high potentials. Reports by Höstermann (*22*), Gerlach and Erlwein (*19, 20*), Clausen (*13*), Breslauer (*9*), and others indicate that no benefit may be expected from the use of the network. The German experiments made use of an extensive and variable complex of conditions, designed to include the study of positive and negative potential in relation to fertilizers and irrigation and the relation of these factors to the composition of grain and straw. The results shown by Gerlach and Erlwein reporting experiments with oat crops at Mocheln are selected as representative. (Table 26.)

It may be well worth while to consider Table 26 in some detail, since it seems to represent a thoroughly impartial study of the methods which have given success elsewhere.

The instances in which duplicate trials were run and the agreements to be noted for these cases show rather conclusively that lack of uniformity in soil conditions was not a disturbing factor in these experiments. The six plats giving notably higher yields are those with fertilizer and irrigation. These are in good agreement and show no appreciable advantage for the three types of electrical treatment represented, the averages for relative yields only being as shown in the summary of Table 26.

The plats in these experiments were about one-fourth acre each, the control plats being separated from the electrified plats by about 325 feet. The potential of the direct-current network was about 30,000 volts, whereas that of the alternating current was about 20,000 volts. The statement of Lemström that the better the condition of the field the more favorable the influence of the high-tension discharge is not substantiated by these trials. In brief, the German experiments give little evidence of any definite crop increase attributable to the electrical treatment.

In 1913 Dorsey conducted greenhouse experiments in Ohio with radishes and lettuce, using a high-frequency current. In a letter to Doctor Briggs dated August 18, 1913, he reported the relative weights of 10 plants selected at random from each area. These are shown in Table 27.

TABLE 27.—*Results of electrocultural treatments of greenhouse radishes and lettuce in 1913, according to Dorsey*

10 plants	Relative weights (grams)			
	Radishes		Lettuce	
	Treated	Control	Treated	Control
Total	265.7	180.0	67.0	46.1
Edible portion	139.5	79.4	60.7	41.8
Tops	120.5	95.0		
Roots	9.3	5.6	6.3	4.3

Dorsey also conducted field trials with a high-frequency current. The plants used were beets, lettuce, cabbage, beans, melons, cucumbers, and tobacco. They were planted in long rows, one-half of each row being under the charged network. The treated plat covered about half an acre. The network was 9 feet above ground with wires 15 feet apart and carried a voltage of about 50,000 at an estimated frequency of about 30,000 cycles. The power was taken from a 7½ kilowatt 220-volt transformer supplying 11,000 volts at 60 cycles and exciting an oscillating circuit containing the network as capacity. Treatment was given daily, three hours in the forenoon and three hours in the afternoon. A generally favorable influence for the discharge treatment was reported. Unfortunately total weights were not included. The results for the second year were generally unfavorable for the discharge treatment, and Dorsey concluded that perhaps slight differences in the slope of the two plats may have been responsible for the favorable results of the first year.[5]

At the present time perhaps the best evidence of plant response to electrical discharge is that obtained by Blackman (*4, 5, 6, 7, 8*) of the electroculture committee of the British Ministry of Agriculture and Fisheries. His experiments extend over a period of years and comprise field trials, pot cultures, and laboratory tests, all of which he interprets as affording converging evidence for a favorable growth response to the application of electricity. On account of the practical possibilities associated with a treatment assuring increased growth it seems desirable to examine in some detail the data which have given rise to this assurance.

The field trials carried on in England by Blackman and his associates have given the results which are summarized in Table 28.

TABLE 28.—*Results of electrocultural treatments of grain crops in England, as reported in field experiments by Blackman*

Crop and year	Location	Acreage		Duration of treatment (hours)	Yield per acre (bushels)		Ratio of treated to control
		Treated	Control		Treated	Control	
Oat:							
1915	Lincluden	1.5	1.5	557	20.7	16.0	1.29
1916	do	1.0	1.0	848	62.8	42.0	1.49
1917	do	.33	.33	1,060	54.8	48.9	1.12
1917	do	.33	.33	1,060	42.2	44.9	.93
1917	do	.33	.33	1,060	36.9	38.1	.96
1918	do	.25	.06	704	75.5	56.1	1.34
1918	do	.25	.06	704	84.9	58.4	1.45
1918	do	.25	.06	704	80.4	46.3	1.73
1919	do	.11	.11	710	36.6	45.2	.80
1919	do	.11	.11	710	45.1	43.8	1.02
1919	do	.11	.11	710	53.3	28.9	1.84
1919	Harper Adams Agricultural College.	.50	.33	456	47.0	53.6	.87
1919	do	.25	.33	456	63.8	48.2	1.32
1919	do	.25		456	50.8	48.2	1.05
1919	do	.50	.33	456	60.2	59.6	1.01
1920	Lincluden	.11	.11	911	36.2	44.8	.80
1920	do	.11	.11	911	43.5	46.1	.94
1920	do	.11	.11	911	51.8	33.0	1.56
1920	Harper Adams Agricultural College.	.33	.33 ?	793	50.0	56.0	.89
1920	do	.33		793	52.5	56.0	.93
Barley:							
1917	Rothamsted	.0125	.0125	1,500	17.8	13.1	1.35
1918	do	.66	.10	643	44.7	36.4	1.22
1918	do	.66	.10	643	47.4	52.7	.89
1918	do	.66	.10	643	40.4	36.3	1.11
1920	do	.50	.50	786	31.7	29.5	1.07
1920	do	.50	.50	786	33.0	25.17	1.31
Winter wheat:							
1919	do	.50	.50	854	21.4	14.3	1.49
1919	do	.50	.50	854	22.3	17.4	1.28
1920	do	.25	.25	727	18.84	20.4	.92
1920	do	.25	.25	727	18.35	18.24	1.006
Spring wheat:							
1919	do	.50	.33	940	7.6	10.0	.76
1919	do		.33	940	7.3	7.9	.92
1919	do	.50	.33	940		6.3	1.15
Average							1.14

[5] Correspondence with the Office of Biophysical Investigations, Bureau of Plant Industry, September 2, 1924.

These tabulated values are in many ways not subject to biometrical analysis; they represent the results of experiments carried out with varied complexes of soil, season, acreage, crop, and electrical treatment. Nevertheless, in the absence of any definite knowledge concerning the conditions under which an electrical treatment may be presumed to be most effective there is perhaps no better index than a comparison.

Of 33 trials shown in Table 28, 21 indicate an increase for treated areas, whereas 12 indicate a decrease. The treated areas return a yield represented by the range 76 to 184 when the untreated areas return a yield represented by 100 and give an average increase of 14 per cent. This increase is based upon yields reported for experiments regardless of crop or seasonal normality, and Blackman estimates the more reliable experiments as indicative of an average increase in yield of about 22 per cent. In either case, such an increase would seem sufficient to be of promise from an agricultural standpoint. If an attempt is made to determine from these tabulated values the conditions under which the increases were obtained, serious difficulties are immediately encountered.

Unfortunately the normal productivity of the electrified and control areas is in most cases unknown, and a serious lack of soil uniformity is evident from the yields of different portions of control areas. For example, in the 1919 and 1920 plats with oats at Lincluden, which occupied the same areas for the two years, the control yields were as shown in Table 29, in which the relative yields of the corresponding treated areas for the same years, the controls being taken as 100, are also shown for comparison:

TABLE 29.—*Comparison of the results of electrocultural experiments with oat crops at Lincluden, England, in 1919 and 1920*

Area	Acre yields of control plats (bushels)		Relative yields of electrified areas, the controls being taken as 100	
	1919	1920	1919	1920
Section I	45.2	44.8	80	80
II	43.8	46.1	102	94
III	28.9	33.0	184	156

It is obvious that the yields of the third section of the control area were uniformly low compared with the yields of the other control sections and that this fact is almost certainly involved in the high percentage increases arising for the third section of the treated area. It would therefore appear that these particular increases may be attributed to a lack of soil uniformity, and the importance of this unknown factor is indicated.

The most consistent series indicating favorable response to electrical treatment appears to be the 1918 oat trials at Lincluden. The plats in oats at Lincluden gave the average annual yields shown in Table 30.

The yields from the electrified areas in 1918 seem to have been so exceptional compared with the electrified areas for the three other years that one may question whether it is justifiable to attribute the increase solely to the electrical treatment.

TABLE 30.—*Analysis of the average results of electrical treatments of oat plats at Lincluden, England, in the years 1917 to 1920, inclusive*

Year	Average acre yields (bushels)		Ratio of treated to control	Year	Average acre yields (bushels)		Ratio of treated to control
	Treated	Control			Treated	Control	
1917	44.6	44.0	1.01	1919	45.0	39.[illegible]	1.1[illegible]
1918	80.2	53.6	1.49	1920	43.8	41.[illegible]	1.[illegible]

The instances specifically considered in Tables 29 and 30 comprise the most notable of the percentage increases reported by Blackman, as shown in Table 28, and they are therefore in a large measure the basis of the 22 per cent average increase reported. One is thus left without definite assurance that the field experiments demonstrate a favorable response to the electrical treatment.

The pot-culture experiments in England by Blackman and his associates gave results which are summarized in Table 31.

TABLE 31.—*Results of electrical pot-culture experiments with grain crops in England, according to Blackman*

Year and crop	Yields (grams)		Ratio of treated to control
	Treated	Control	
1918:			
Wheat	0.72	0.73	0.98
	.71		.97
Maize	1.43	1.39	1.02
	1.21		.87
	1.24		.89
Barley	2.26	2.30	.98
	2.12		.92
	1.98		.86
	.97	1.29	.75
	1.17		.90
	1.12		.86
Maize	8.12	7.78	1.04
	8.37		1.07
	7.41		.95
	10.84	8.54	1.26
	10.36		1.21
	10.85		1.27
1919:			
Maize	5.70	5.62	1.01
	6.81	5.67	1.20
	2.52	2.32	1.08
	16.73	17.28	.96
	16.03		.92
	15.01		.86
Barley	13.72	18.69	.73
	15.84		.84
	11.75	16.89	.69

Year and crop	Yields (grams)		Ratio of treated to control
	Treated	Control	
1920:			
Maize	15.66	14.5[illegible]	1.07
	15.39		1.05
Barley	23.84	23.8[illegible]	.99
	23.28		.97
	26.33		1.10
Wheat	17.66	16.2[illegible]	1.08
	17.11		1.05
	18.76		1.15
1921:			
Barley	10.60	10.2[illegible]	1.03
	11.79		1.14
	34.0	31.5	1.07
	37.2		1.18
	49.2	46.5	1.05
	53.0		1.13
	48.5		1.04
	51.9		1.11
	22.8	21.2	1.07
Maize	15.5	15.6	.99
	14.27		.91
	18.20	16.6	1.09
	18.95		1.14
Average			1.01

As with the tabulated values for field experiments, so here also the results of the pot-culture trials represent more than the electric discharge variable; soil and seasonal factors vary as well as the crop and the duration, nature, and strength of the electrical treatment. Making a comparison, 26 trials out of 47 give positive results, while 21 give negative results. The treated plants return yields represented by the range 73 to 127; when the untreated plants return a yield represented by 100 and give an average increase of 1 per cent. This increase is well within the experimental error, and the pot-culture trials in their entirety thus furnish no definite evidence of a response to the electrical treatment.

In contrast to the field experiments, however, the pot-culture trials afford results from several similarly treated pots and plants, so that an estimate of individual experiments may be made by comparing the differences between treated and untreated plants with the probable errors involved in the measurements.

When the pot-culture records are examined in this way, it becomes evident that the treated and untreated plants present substantial differences. With uniform soil and seasonal factors for electrified and control plants the association of these differences with the treatment becomes intimate. The fact that these differences favor the control plants about as often as the treated plants emphasizes the complexities involved and makes one less certain that these differences are definitely attributable to the electric discharge.

The laboratory experiments of Blackman and his associates have been on the effect of a direct current of very low intensity on the rate of growth of the coleoptile of barley. Differences in the growth rate of treated and control plants were noted over short periods. The small differences attributable to the direction of the current and the pronounced after effects obtained make the interpretation of the data difficult and uncertain.

In general, then, one finds in Blackman's experiments many significant differences between the electrified and control plants. In some instances the relation of the discharge to these differences may well be questioned. In others the relation appears to be an intimate one, and the significance of such differences is the immediate concern of further research in electroculture.

TABLE 32.—*Summary of electrocultural trials*

Method	Definite influence reported		No definite influence reported	
	Year	Observer	Year	Observer
Soil-conducted currents:				
Germination	1889	Warren	1893	Bruttini.
	1892	Leicester	1899	Ahlfvengren.
	1897	Kinney	1902	Flammarion.
	1902	Plowman	1905	Löwenberg.
Pot cultures	1892	Warner	1846	Solly.
	1903	Stone		
	1914	Homberger		
Field trials	1860	Fitchner	1883–87	Wollny.
	1884	Holdefleiss	1907	Gassner.
	1844	Ross	1909	Gerlach and Erlwein.
Soluble plant food	1916	Yegoron		
Modified atmospheric potential gradient:				
Increased potential	1904	Lemström		
	1905–1911	Lodge, Newman	1907	Gassner.
	1913	Dorsey	1909	Gerlach and Erlwein.
	1914	Jørgensen, Priestley, Dudgeon.	1909–1910	Breslauer.
			1910	Höstermann.
			1911	Clausen.
	1917	Blackman, Liverpool engineers.	1918–1924	Briggs, Campbell, Heald, Flint.
Decreased potential	1876	Mascart	1880	Laikewicz.
	1878	Grandeau	1914	Briggs and Shantz.
	1910	Höstermann		

A review of the literature of electrocultural experimentation up to the present time does not lend assurance of great progress. (Table 32.) In 1800 Senebier (*45*) wrote substantially as follows:

The researches of Maimbray, Nollet, Bose, Menon, and Jalabert would indicate that electricity accelerated the development of plants, both in their germination and in their subsequent development. Nuneberg, many years afterward, repeated the same experiments with the same results. Linné and Kostling observed the same effects. Achard confirmed these results. Berthelon, in a treatise on the electricity of plants, has summarized the information on the subject and substantiated it by further research of his own. Gardini, from work carried on at Lyon, affirmed the influence of electricity on vegetation. Carmoy, d'Ornoy, and Rosieres have defended this opinion in the Journal de Physique. These doctors base their conclusions on the identity of natural and artificial electricity, on the continual electrified condition of the atmosphere, and on the meteorological phenomena which indicate in a more or less sensitive manner the presence of electricity; the different elevated parts of plants, which are in themselves excellent conductors of electricity, offer in their leaves, as De Saussure has observed, the proper points to receive the electric fluid. . . . All these experiences led to the opinion stated when Ingenhousz published experiments which proved that electricity would not produce the effects upon plants which had been attributed to it; that electrified seeds [6] would not germinate quicker than others. These experiments, reported in the Journal de Physique for December, 1785, were confirmed in the same journal for December, 1786, were given further support in May, 1788, and were finally summarized in "Expériences sur les végétaux." Various other workers later confirmed these researches. It seems to me at present [1800] that the opinion of those who believe that electricity does not favor vegetation is more logical than the contrary opinion.

At the present time (1924), there is still a diversity of opinion concerning the influence of electricity in plant development. The electroculture committee of the British Ministry of Agriculture and Fisheries recommends (1923) the continuation of experiments with high potential discharge,[7] Newman (*38*) in England considers electroculture by the same method as offering practical assurance of increased returns. Baines (*1*) points out a wonderland of electrobiological relationships. On the other hand the experiments of Gerlach and Erlwein (*19, 20*) in Germany and the experiments reported in the first part of this bulletin show no increased growth definitely attributable to electrical treatment.

[6] Leighty and Taylor (*31*) report experiments with electrified seed which indicate no advantage gained by treatment.

[7] Typewritten report on file in the Office of Biophysical Investigations, Bureau of Plant Industry.

LITERATURE CITED

(1) Baines, A. E.
1921. Germination in its electrical aspects. 185 pp., illus. London and New York.

(2) Basty, F.
1908. Essais d'électroculture tentés à Angers en 1908. (Extrait.) *In* Bul. Soc. Études Sci. Angers, ann. 37 (1907), pp. 87–92.

(3) Berthelot, M.
1889. Recherches nouvelles sur la fixation de l'Azote par la terre végétale. Influence de l'électricité. *In* Compt. Rend. Acad. Sci. [Paris], tome 109, pp. 281–287.

(4) Blackman, V. H.
1918–1924. [Electrical treatment of fields.] Gt. Brit. Min. Agr. and Fisheries Interim Rpts. 1–6 (1917–23). [Mimeographed.]

(5) 1924. Field experiments in electro-culture. *In* Jour. Agr. Sci., vol. 14 (1923), pp. 240–267.

(6) ——— and Jørgensen, I.
1917. The overhead electric discharge and crop production. *In* Jour. Bd. Agr. [London], vol. 24, pp. 45–49, illus.

(7) ——— and Legg, A. T.
1924. Pot-culture experiments with an electric discharge. *In* Jour. Agr. Sci., vol. 14, pp. 268–286, illus.

(8) ——— ——— and Gregory, F. C.
1923. The effect of a direct electric current of very low intensity on the rate of growth of the coleoptile of barley. *In* Proc. Roy. Soc., London, ser. B, vol. 95, pp. 214–228, illus.

(9) Breslauer, M.
1912. Amount of energy needed for electro-culture. *In* Electrician, vol. 69, pp. 889–890.

(10) Briggs, L. J., and Shantz, H. L.
1913. The water requirement of plants. I. U. S. Dept. Agr., Bur. Plant Indus. Bul. 284, 49 pp., illus.

(11) 1914. Relative water requirements of plants. *In* Jour. Agr. Research, vol. 3, pp. 1–63, illus.

(12) Chree, C.
1910. Atmospheric electricity. *In* Enc. Brit., vol. 6, pp. 860–870, illus.

(13) Clausen.
1911. Die Erfolge der Elektrokultur in Hedewigenkoog. *In* Landw. Wchnbl. Schles.-Holst., Jahrg. 61, pp. 83–86.

(14) Dudgeon, E. C.
[1912]. Growing crops and plants by electricity. 36 pp., illus. London.

(15) Elfving, F.
1882. Ueber eine Wirkung des galvanischen Stromes auf wachsende Wurzeln. *In* Bot. Ztg., Jahrg. 40 (1881), pp. 257–264, 273–278.

(16) Fitchner, E.
1861. Agronomische Zeitung, 1861, p. 550. [Not seen. Reference from Bruttini, A., L' influenza dell' elettricità sulla vegetazione, p. 148, Milano, 1912.]

(17) Gassner, G.
1907. Zur Frage der Elektrokultur. *In* Ber. Deut. Bot. Gesell., Bd. 25, pp. 26–38, illus.

(18) 1909. Pflanzenphysiologische Fragen der Elektrokultur. *In* Mitt. Deut. Landw. Gesell., Jahrg. 24, pp. 5–7.

(19) Gerlach, M., and Erlwein, G.
1910. Versuche ueber Elektrokultur. *In* Elektrochem. Ztschr., Jahrg. 17, pp. 31–36, 66–68, illus.

(20) 1910. Versuche über die Einwirkung der Elektrizität auf das Pflanzenwachstum. *In* Mitt. K. Wilhelms Inst. Landw. Bromberg, Bd. 2, pp. 424–453, illus.

(21) Grandeau, L.
1878. De l'influence de l'électricité atmosphérique sur la nutrition des plantes. (Extrait.) *In* Compt. Rend. Acad. Sci. [Paris], tome 87, pp. 60–62, 265–267, 939–940.

(22) Höstermann.
1910. Geschichte und Bedeutung der Elektrokultur unter Berücksichtigung der neueren Versuche. *In* Arch. Deut. Landw., Jahrg. 34, pp. 535–570.

(23) Holdefleiss.
1885. Elektrische Kulturversuche. *In* Centbl. Agr. Chem., Jahrg. 14, pp. 392–393.

(24) Homberger, E.
1914. Behandlung von Pflanzen mit Hochfrequenzströmen. *In* Umschau, Jahrg. 18, pp. 733–735, illus.

(25) Honcamp, F.
1907. Die Anwendung der Elektrizität in der Pflanzenkultur. *In* Fühling's Landw. Ztg., Jahrg. 56, pp. 490–499.

(26) Jørgensen, I., and Priestley, J. H.
1914. The distribution of the overhead electrical discharge employed in recent agricultural experiments. *In* Jour. Agr. Sci., vol. 6, pp. 337–348, illus.

(27) Kinney, A. S.
1897. Electro-germination. Mass. Hatch Agr. Exp. Sta. Bul. 43, 32 pp., illus.

(28) Kövessi, F.
1912. Influence de l'électricité à courant continu sur le développement des plantes. *In* Compt. Rend. Acad. Sci. [Paris], tome 154, pp. 289–291.

(29) Leicester, J.
1892. The action of electric currents upon the growth of seeds and plants. *In* Chem. News (London), vol. 65, p. 63, illus.

(30) 1892. Action of an electric current upon the growth of seeds. *In* Chem. News (London), vol. 66, p. 199.

(31) Leighty, C. E., and Taylor, J. W.
1924. Electrochemical treatment of seed wheat. U. S. Dept. Agr. Circ. 305, 7 pp., illus.

(32) Lemström, S.
1904. Electricity in agriculture and horticulture. 72 pp., illus. London and New York.

(33) Lodge, O.
1908. Electricity in agriculture. *In* Nature, vol. 78, pp. 331–332, illus.

(34) 1911. The mode of conduction in gases illustrated by the behaviour of electric vacuum valves. *In* Phil. Mag. and Jour. Sci., ser. 6, vol. 22, pp. 1–7, illus.

(35) Maccagno, J.
1880. Influenza dell' elettricità atmosferica sulla vegetazione della vite. *In* Staz. Sper. Agr. Ital., vol. 9, pp. 83–89.

(36) Mascart, E. E.
1876. Traité d' électricité statique. 2 vol., illus. Paris.

(37) Newman, J. E.
1911. Electricity as applied to agriculture. *In* Electrician, vol. 66, pp. 915–916, illus.

(38) 1922. Electricity and plant growth. *In* Standard handbook for electrical engineers, Ed. 5, pp. 1810–1811. New York.

(39) PAULIN.
1892. De l' influence de l'électricité sur la végétation. Montbrison. [Not seen. Reference from Bruttini, A., L'influenza dell'elettricità sulla vegetazione, p. 216. Milano. 1912.]

(40) PLOWMAN, A. B.
1902. Certain relations of plant growth to ionization of the soil. *In* Amer. Jour. Sci., ser. 4, vol. 14, pp. 129–132, illus.

(41) 1903. Electromotive force in plants. *In* Amer. Jour. Sci., ser. 4, vol. 15, pp. 94–104, illus.

(42) PRIESTLEY, J. H.
1907. The effect of electricity upon plants. *In* Proc. Bristol Nat. Soc., ser. 4, vol. 1 (1906), pp. 192–203.

(43) 1910. Overhead electrical discharges and plant growth. *In* Jour. Bd. Agr. [London], vol. 17, pp. 16–28.

(44) ROSS, W.
1844. Galvanic experiments on vegetation. U. S. Comr. Patents Rpt., vol. 27, pp. 370–373, illus.

(45) SENEBIER, J.
[1800.] Physiologie végétale. 5 vols. Genève.

(46) SOLLY, E.
1846. The influence of electricity on vegetation. *In* Jour. Hort. Soc. London, vol. 1 (1845), pp. 81–109.

(47) WILSON, C. T. R.
1923. Atmospheric electricity. *In* Glazebrook, R., A dictionary of applied physics, vol. 3, pp. 84–107, illus.

(48) WOLLNY, E.
1888–1893. Elektrische Kulturversuche. *In* Forsch. Agr. Phys., Bd. 11, pp. 88–112, 1888; 16, pp. 243–267, 1893.

Seci
Ass
Dir
Dir
Dire
Dire
Dire
tr
Solic
Wea
Bure
Bure
Bure
Fore
Bure
Bure
Bure
Burec
Burec
Burec
Burea
Fixed
Office
Office
Librai
Federc
Insect
Packe
Grain

Bureau
Of

CONCERNING THE BIOLOGICAL EFFECTS OF EXTREMELY LOW FREQUENCY ELECTRICAL PHENOMENA IN THE ATMOSPHERE

Kronig, H. L.,

W. O. Schumann developed theoretical predictions of electromagnetic resonance phenomena in the cavity which is formed by the earth and the ionosphere. Measurements have been carried out for several years in the frequency range near 10 cps. It was possible, for example, to record simultaneously in the U. S. and in Germany electromagnetic oscillations caused by strong lightning. Signals were observed in the frequency range between 0.5 cps. and 20 cps. which are due to field variations of local character. The signals were simulated and their effects observed. Positive results were obtained by measurements employing galvanic skin response records. The moulting of the Aphid changed under the influence of artificial electric fields. It was possible to affect the growth rate of lactic-acid bacteria and of yeast cultures. The yeast cultures under the effect of these fields reached the same growth stage after nine days as control cultures, not subjected to fields, after 15 days. A last test was concerned with the investigation of the growth of germinating wheat seeds. It appeared that after one week of development the seeds subjected to electric fields grew, on the average, to a length 23 percent greater than that of seeds which were not subjected to electric fields.

STUDIES ON THE BIOLOCIAL EFFECTS OF GASEOUS IONS. A REVIEW

Krueger, A. P., Kotaka, S. and Andriese, P. C.
Special Monograph Series, 1966. 1, Biometerorological Centre, Leiden

The experimental program on biological effects of gaseous ions conducted at the University of California during the past ten years is reviewed and related to similar work done in other laboratories. Acceptable evidence exists that: (1) (+) and (-) ions accelerate the death rate of micrococci, E. COLI, S. MARCENCENS and fungi. (2) (+) ions raise the blood level of 5-hydroxytryptamine (5HT) in mice and produced generally inimical effects on the respiratory tract. (-) ions lower the blood level of 5HT and reverse the changes evoked by (+) ions. (3) (+) and (-) ions accelerate the growth rate of higher plants. They also hasten the on set of iron chlorosis in plants grown in an Fe-free medium. When Fe is present, they speed the uptake of exogenous Fe, increase the O_2 consumption of seedlings, increase the content of cytochromes and other Fe-containing enzymes, decrease the active Fe fraction, and increase the residual Fe fraction of the plant tissue. This experimental evidence has been utilized in developing an hypothesis of air ion action on the plant sites responsible for Fe distribution. (4) When larvae of the silkworm are exposed to high concentrations of either (+) or (-) ions the rate of growth is accelerated, there is a marked increase in the production of cytochrome oxidase, peroxidase, and to a lesser degree, catalase, and the spinning of silk begins earlier. (5) The effects produced by air ions vary with the biological substrate and in some cases with the charge and chemical nature of the ion. The physiological changes can at times merge into pathological states. (6) Experiments with air ions are difficult to perform and to be significant, demand close attention to preclude interference by factors such as air pollutants and stray electrical fields.

96: 49235b **Effect of the magnetic field treatment of corn seeds on the physiological-biochemical state of seeds and seedlings.** Maslobrod, S. N.; Komarova, G. E.; Vrabii, T. N.; Shkolenko, V. V.; Krasnobaev, E. N.; Lysikov, V. N. (USSR). *Izv. Akad. Nauk Mold. SSR, Ser. Biol. Khim. Nauk* 1981, (5), 5–14 (Russ). Dissym. (with regard to the embryo shift to the left (L) or right (D)) and sym. (S) seeds of corn responded differently to treatment by const. magnetic field (7 KE) for 15 min. Most responsive were L-seeds in which the rate of H_2O uptake and the K and free amino acid contents 24 h after the treatment highly increased. The effect of the magnetic field on swollen L-seeds was generally highest when the embryo was oriented towards the northern magnetic pole. The magnetic-field treatment had a pos. aftereffect on seedlings grown from L- and D-seeds. The magnetic-field treatment decreased the activity of Mg^{2+}- and (Mg^{2+} + K^+)-stimulated ATPase, but in rootlets of seedlings from L- and S-seeds, some increase in K^+-stimulated ATPase activity was obsd.

96: 67828b **Effects of magnetized water and low-frequency current on activation of soil potassium and phosphorus.** Lu, Kaichun (Inst. Fruit Trees, Fujian Agric. Acad., Peop. Rep. China). *Fujian Nongye Keji* 1981, (1), 37–8 (Ch). Treatment of soils with magnetized water and(or) low-frequency current (0.5 or 5 A) resulted in an activation of soil P and K. As a result, the bioavailability of P and K was increased.

SCI. AMER. MAY 17, 1919

The Theory of Electro Culture

By Robert D. McCreery

If we believe in the ionic theory of "Electrolytic Dissociation" we are convinced of the fact that when an electric current is driven through an electrolyte there is produced a movement of the "ions" that carry charges of electricity.

In the use of direct current the negative ions move to the positive electrode and the positively charged ions move to the negative electrode. When alternating current is used this is not the case; the ions move rapidly first in one direction towards one electrode, then in the opposite direction towards the other. They are as it were in a state of intense vibration of an oscillating nature, caused by, and in unison with, the waves of the alternating current.

What then happens if we discharge high frequency electricity through an acre of soil to metallically coated seed, from electrodes (parallel to each other), embedded in the earth?

The earth is in this case the electrolyte, in which, by the action of water, there have been gaseous ions set free. When the electricity is applied, these ions set up an active bombardment on the seeds and the roots of the plantlet and since the seeds and roots are porous it must be evident from a mechanical standpoint that some absorption, by the plant, of the gaseous ions takes place. After being absorbed by the plant roots these ions are still subject to the influence of the high frequency electricity which, during application, will set up vibrations within the cells of the plant. Such an action will mechanically enlarge the cells in the tissues of the plant and allow it to grow more freely.

The discharge of high frequency electricity through soil is also equivalent to aeration since it causes air to be drawn into the soil with it. This is in a great measure the principal benefit derived from cultivation and is, therefore, an important factor in agriculture because of its stimulation of bacterial action.

Moreover the discharge of high frequency electricity through the air combines with the moisture in the soil to produce nitric acid, which contains nitrogen in a form readily available as plant food.

On the other hand the electronic collisions of the ions with alkalies in the earth produce nitrites. The earth in a sense becomes a storage of nitrogen that must be changed by the soil bacteria before it becomes available as plant food. This makes work for the soil-building bacteria.

In 1909, Prof. G. E. Stone of the Massachusetts State Agricultural College, proved in a series of tests that by discharging each day a few sparks of static electricity through soil containing bacteria, these organisms in 17 days increased 600 per cent.

There is another influence of electricity on the bacteria which might be termed bacterial stimulation. Bacteria are sluggish micro-organisms and the galvanic action of the current on their bodies increases their activity.

With the above proven facts in mind, is it at all surprising that enormous increases in production have been reported where electricity has been properly applied to this new art of promoting the growth of vegetation?

SCIENT. AMERICAN
AUG. 19, 1911

Electrified Artificial Rain for Agriculture

A New System of Irrigation

We have had occasion in these columns to refer repeatedly to experiments carried on by Sir Oliver Lodge and others on the influence of electricity on the growth of plants. Mr. Emilio Olsson of Buenos Aires, Argentine Republic, at present in the United States, has, of late years, been giving his attention to the practical development of a process in which it is proposed to make use of electrified water for sprinkling fields. The inventor claims that his experiments demonstrate the practical utility of such a procedure. The benefits which are said to be secured are two-fold. First, there is a direct advantage to the plants, and secondly, Mr. Olsson states that according to his observations various harmful insects and other organisms are destroyed because of his process.

The need of artificial irrigation is severely felt in many places where, owing to the nature of the climate, long terms of drought have to be contended with. It is particularly in such districts as these that Mr. Olsson proposes to introduce his system, by the aid of which he expects to increase the crop and to combat effectually drought, insects and other troubles. The cost of the Olsson system is estimated at a figure which is quite moderate as compared with the benefits to be derived. The cost of installation for the sprinkling apparatus is figured at $50 to $100 per acre, according to local conditions.

The system is very simple. The water is raised to a suitable height by a motor or traction engine. The supply may be drawn from a river, stream, artesian well, or any other suitable source. Two high towers may be installed, from which pipes are suspended by means of suitable supporting cables. The pipes supply circular spray nozzles which revolve automatically, and five to ten acres of land can readily be thus supplied with an evenly distributed shower of water.

When it is desired to use electrified water, a reservoir is used, into which the water is pumped, to be subsequently distributed in the manner indicated above. The reservoir consists of an iron tank placed on an insulated support and charged from a dynamo supplying 0.5 ampere at 110 volts. The iron wall of the tank serves as positive pole; the negative pole consists of a copper wire insulated all except the tip. It is claimed that certain chemical reactions take place in the water, with production of oxygen, ozone, and hydrogen peroxide at the anode, and that certain of the products formed are beneficial to the plants. Mr. Olsson further suggests that this electrification of the water would tend to purify it and render it better adapted for drinking purposes.

Mr. Olsson has installed his apparatus in a plantation near Buenos Aires and states that by the use of six sprinkling nozzles at a height of 5 meters above ground some six hundred acres of ground under cultivation were treated with very beneficial results. The apparatus has also been adopted by the municipality of Buenos Aires and is giving satisfaction in the public parks and gardens in that city. Mr. Olsson also states that during the long drought from which the republic suffered for over six months in 1910, he was able to produce a very fine crop of alfalfa and vegetables and to supply the owners of race horses with fresh fodder. By installing a system of artificial irrigation over some part of their crop, farmers should be able to insure themselves against drought, falling back upon artificial sprinkling in case natural rain fails.

Incidentally the interesting suggestion is made that the water line be used at the same time to carry the current for lighting and other purposes.

Mr. Olsson's invention has been protected by a number of patents, and the inventor has shown much perseverance in working out the details of his method.

SCI. AMER.

February 14, 1920

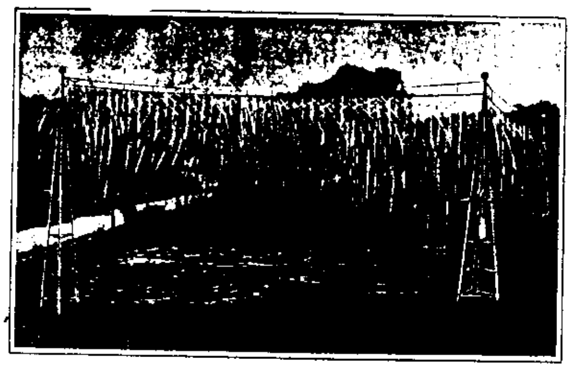
Electricity

Electrification of Seeds.—There appears to be much interest in the electrification of seeds and the application of electricity to growing plants. A recent account of work along these lines tells of a new method of aiding plant growth. The seeds, 10 or 20 sacks, are placed in tanks provided with iron electrodes at both ends; the electrolyte is a solution of sodium nitrate or some other fertilizer. Particularly with cereals—wheat, barley and oats—the yields of both grain and straw are said to be increased. Some 500 farmers have taken up the treatment of the seeds, which is followed by a very careful drying in a kiln. The treatment is applied about a month or two before sowing.

Colored Glass for Seed Germination

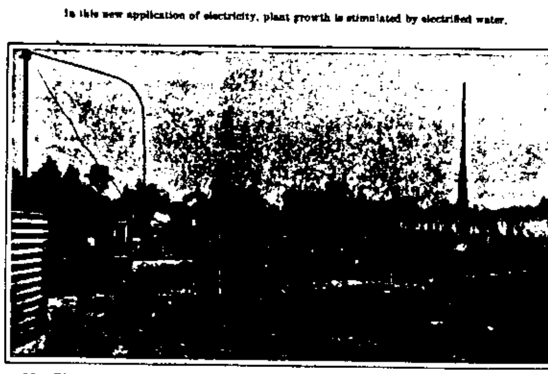
Some surprising results have been secured by growing seeds under sheets of colored glass. The plan is one which is easily followed by the gardner, for it simply consists of protecting the seeds with sheets of colored glass during germination, and for a few days after the little plants appear on the scene. Ordinary glass stained with the aniline varnishes, sold as hat dyes, answers the purpose very well indeed. Thus there is no need to go to the expense of getting real tinted glass.

Sheets of glass in the desired color are placed over the seed bed or the boxes and no other special treatment is required. It was found in an elaborate series of experiments that the seeds germinated better and grew into stronger plants sooner when they were under blue glass. The little plants shown in the photograph were given exactly the same treatment and just the same number of seeds were allotted in each case.—*S. Leonard Bastin.*



Irrigation by means of electrified artificial rain.

In this new application of electricity, plant growth is stimulated by electrified water.



Mr. Olsson's experiments with well water as a conductor for illumination.

The pipes are insulated and buried in the ground. Inasmuch as there has been no evidence of electrolysis, Mr. Olsson believes that the electrolytic destruction of water pipes may thus be prevented.

Electroculture of Tomato Plants in a Commercial Hydroponics Greenhouse

FRANK M. YAMAGUCHI (deceased), *Vice President, Research & Development, General Agriponics, Inc., 12727 Saratoga Creek Drive, Saratoga, California 95070*
and
ALBERT P. KRUEGER, *Emeritus Professor, Department of Biomedical & Environmental Health Sciences, School of Public Health, Emeritus Lecturer in Medicine & Research Biometeorologist, University of California, Berkeley, California 94720*

ABSTRACT: An experiment was conducted to evaluate the effects of air ion treatment on tomato plants (Lycopersicon esculentum P. Miller) in terms of: (1) growth and health; (2) fruit yield and quality; and (3) economic factors. The plants were grown by a commercial greenhouse (G.H.) grower employing soilless culture techniques. An air ion generator and emitters were installed in such fashion that 864 plants were exposed to a high negative air ion density flux, while 576 plants grew in an area which received relatively few ions. Normal operational procedures, with certain modifications, were employed for plant culture, feed/irrigation, and environmental control.

Plants responded vigouously to air ion stimulation, which equated to shortening of the seeding-to-harvest time period by two weeks as measured by vine growth, main stem height, time to blossoming, fruit set, and fruit yield. Throughout the first four-month growth period plant growth was good and no serious physiological disorders nor insect damage were observed. During the sixth harvest week a virus infection appeared in both control and ion-treated plants, but was not of sufficient severity to ruin the experimnent. Foliage and fruit samples were subjected to laboratory analyses. In general, the stimulated plants contained higher percentages of mineral elements than those of the controls. Fruit from ion-treated plants has more ascorbic and citric acid than that from control plants. Although there were no wide differences in fruit texture or flavor, a taste panel verdict indicated that fruit from the stimulated plants tasted better. An unexpected benefit was marked decrease in white fly infestation. All these factors combined with the low cost of air-ion treatment suggest that this modality offers potential for greenhouse cultivation of garden crops.

INTRODUCTION

THE OBSERVATION THAT atmospheric electricity occurs not only during stormy weather, but in fine weather as well (Lemmonier, 1752) very quickly led natural philosophers to speculate that this constantly prevailing source of energy might influence plant growth. Father Giambatista Beccaria of the University of Turin (1775) stated that, "It appears manifest that nature makes extensive use of atmospheric electricity for promoting vegetation". This putative relationship was independently conceived and explored by Bertholon (1783), Gardini (1782), and Ingenhousz (1788).

The discovery of air ions by Elster and Geitel (1899) and by Thomson (1898) made experiments on the biological effects of atmospheric electricity more comprehensible and ultimately led to the development of suitable methods for their production and quantitation. In 1904 Lemström reported that an electrical discharge from metallic points placed above seedlings produced a measurable stimulation of growth, and this observation was confirmed three years later by Gassner (1907). Blackman and Legg (1924) conducted a long series of experiments on single plants in the laboratory, on plants in pot culture, and on field crops exposed to ion-producing high-voltage, low-amperage electrical discharges. They obtained significant increases in growth and dry weight at harvest. Sidaway (1975) has reviewed the full history of what came to be called "electroculture." His own work has been concerned with the influence of electrostatic fields on seed germination (1967) and the influence of electrostatic fields on plant respiration (1968).

Recently, Winton *et al.* (unpublished data) at Oklahoma State University experimented by exposing green bush beans to a relatively constant DC current of 12 kV delivered 80 cm above the plant tops and providing a relatively constant DC current density of 7-20 picoamperes/plant, and observed a 61% increase in crop weight. A similar application of AC current produced an 85% increase in crop weight. In 1977 Pohl reviewed past work in electroculture and summarized all the recent research. He concluded, "Electroculture, the practice of applying strong electric fields or other sources of small air ions to growing plants, has potential to markedly increase crop production and to speed crop growth". Subsequently, Pohl and Todd (1981) applied these conclusions under greenhouse conditions, They found that a mild current of air ions (4 pA/cm^2) is capable of stimulating bean crop growth and the earlier blossoming and increased growth of the Persion violet and the geranium. Since the period of growth required for the plants to reach marketable maturity was shortened by some two weeks, the authors consider that electroculture may well have practical application.

Murr (1964, 1965a, 1965b, 1966a, 1966b, 1966c) has studied intensively the biophysics of plant growth in electrostatic fields under conditions producing either physiological stimulation or plant damage. During his work with the yellow bush bean and sweet corn he found that increased rates of growth occurred with applied electric fields below 60 kV/m and 100 kV/m, respectively. Above these levels growth rates were decreased. When orchard grass seedlings were exposed to relatively high electric field strength, the plants displayed tip damage and biochemical analyses indicated that the metalloenzyme content of the tissue was altered.

In the course of studies of small air ion action on net blotch disease of barley, Elkiey *et al.* (1977) noted that barley plants exposed to positive ions exhibited significant increases in height and dry weight. Earlier, Maw (1967) had observed growth stimulation of garden cress treated with positive or negative ions.

Bachman *et al.* (1971) experimented with electirc field effects on some 30 varieties of plants. With field strengths of 50<100 kV/m, a sizzling noise developed and the odor of ozone was detected. The wax bean proved to be exquisitely sensitive to electric field conditions and grew faster than controls (and all other plants tested) under fields of 100-300 kV/m. Subsequently, extensive experiments were conducted with barley plants, with monitoring of air ion production, corona current, and the presence of O_3. Electric field strengths of (200 kV/m stimulated growth. In a range of electric fields that included those occurring in nature, they found that sufficient corona current developed to produce O_3 and ions. Bachman and Reichmanis (1973) continued experiments with barley plants and concluded that growth is retarded by electric fields > 200 kV/m, while below this level it is enhanced. Growth stimulation is greater at 50 kV/m than at 150 kV/m. Further, the air surrounding the stimulated plants when vented into another chamber enhanced the growth of plants contained therein. They deduced that the growth-enhancing factor is a byproduct of corona and that it develops at relatively low field strength. Growth retardation occuring at higher field strength is associated with current flow from apex to base of the plant--a phenomenon reported earlier by Cholodny and Sankewitsch (1937) and by Lund *et al.* (1947). The mechanisms of electrostatic field actions suggested by Bachman and Reichmanis support the hypotheses espoused by the 18th century philosophers that atmospheric electricity, even in fine weather, acts to promote the growth of plants.

Zhurbitskii (1958) and Zhurbitskii and Shidlovskaya (1967) studied the influence of electrical conditions on the uptake of ions in solution by plants and found that potential gradients equivalent to those prevailing in nature can affect the absorption and incorporation of heavy metal ions. Exposure to artificially increased densities of small air ions enhanced these reactions. Similar results have been reported by Murr (1963, 1964, 1966), by Kotaka *et al.* (1965a) and by Krueger *et al.* (1964). It is significant that an environment in which plants are protected from atmospheric electricity inhibits some of their essential physiological processes and interferes with growth and development (Zhurbitskii 1969; Krueger *et al.* 1965).

Our own experience in this field began in 1960 at the University of California, where we developed facilities permitting exposure of plants to small air ions in a controlled microenvironment (Krueger *et al.*, 1962). For the most part, our subjects were seedlings of oats (*Avena sativa*) and barley (*Hordeum vulgaris*) grown in chemically defined media. We found that seedlings treated with unipolar ionized atmospheres of either charge produced statistically significant stimulation of growth as measured by mean stem length, integral elongation, and dry weight. The extent of growth increase was roughly proportional to the atmospheric ion density and this in turn determined the magnitude of current flow to ground. The minimal current measured in a ground circuit and capable of producing a measurable difference in growth was $4.3\text{-}4.6 \times 10^{-13}$ A/plant (Krueger *et. al.*, 1962). Reduction in the air ion content of the air resulted in retardation of growth and loss of turgor (Krueger *et al.*, 1965). The major biochemical changes accompanying the action of air ions on plants were found to be: (1) increase in rate of growth and dry weight; (2) increase in production of cytochrome C and other Fe-containing enzymes; (3) increase in Fe uptake; (4) shift in the distribution of Fe between chloroplasts and the rest of the cell; (5) shift in the rate of dark-light shrinking and swelling of isolated chloroplasts; (6) stimulation of ATP metabolism of isolated chloroplasts; (7) increase in oxygen consumption; (8) increase in RNAase activity of leaves (Krueger *et al.*, 1963; Kotaka *et al.*, 1965; Krueger *et al.* 1964; Kotaka *et al.*, 1968, Kotaka *et al.*, 1965, Kotaka and Krueger, 1972).

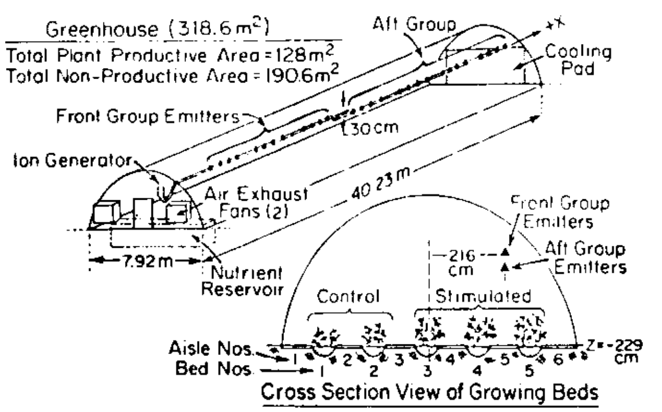


Fig. 1. Longitudinal and cross-section views of the greenhouse. The air-ion emitter installation and the location of the air-ion-treated and control plants are shown.

With this background, we undertook to determine whether the growth stimulation observed under laboratory conditions could be duplicated with a market crop grown in a hydroponics (soilless culture) greenhouse. This experiment was conducted during the period December 1974-July 1975.

MATERIALS AND METHODS

Seedling House (SH)

This structure, 9.6m by 3.4 m and 2.2m high, consisted of ribs and purlins covered with corrugated plastic panels. Exhaust fans at one end provided air circulation, and an automatic heating and cooling unit kept the maximum daytime temperature at ca 27°C and the minimum nighttime temperature above ca 21°C. The air ionization system utilized a high-voltage power supply connected to four emitters (needles) spaced 61 cm apart in a square pattern and suspended 56 cm above the trays which were to be exposed to air ions. It was operational 24 hr. a day. These trays and the emitters above them were located 2 m downstream from the trays holding control seeds and seedlings.

Experimental Plants

Seeds of the indeterminate variety of tomato (*Lycopersicon esculentum* P. Miller), cv tropic VFST, were seeded in moistened pellets and set in shallow plastic trays to germinate. Sixty percent of the pellets were placed beneath the air ion emitters in the seedling house and 49% in the control section. All irrigation, feedings, and environmental control procedures were performed according to the grower's normal operational standards. Treated and control seeds germinated 5 to 6 days after seeding. All the seedlings were left in the seedling house for 16 days before transplanting into the greenhouse, where they were divided randomly into two groups: 864 plants in beds 3, 4 and 5, and 576 in beds 1 and 2. Ion flux density was greatest in the area of beds 3, 4 and 5 (treated plants) and least in that of beds 1 and 2 (control plants). This point is considered in "Discussion".

Structural Design of the Greenhouse

The GH in which the stimulated and control tomato seedlings were transplanted is shown in Fig. 1. Essentially, the GH configuration shown is commonly described as a quonset (kamaboko) house. The primary structure consists of a series of ribs (bulkheads made from assembled plastic pipes with metal pipes as intercostals[purlins]) and roof truss members. The entire structure is covered with fiberglass-reinforced plastic panels. Cutouts are provided at the gable ends for exhaust cooling fans, doors, and cooling pad panels. Secondary structures of steel pipes are installed internally to support the natural gas heater/fan unit and the overhead air distribution duct and also for the necessary wire cables to support the tomato vine/fruit loads. The GH is 40.23 m long and 7.92 m wide, and provides a total productive area of 125 m². A covered below-ground level reservoir to contain the nutrient solution and pump/valve assembly is located just inside the entrance door of the GH. Its capacity is 4160 liters. The remaining floor area consists of concrete perimeter walkways, working aisleways, and five double-row planting beds, which accommodate a total of 1440 tomato plants. The beds are sunk below the aisleways and are protected from the earth with plastic liners or barriers. Inert gravel is used to fill the beds and functions as plant root support medium. The beds are periodically flooded and drained during the day with nutrient solution to provide the plant food needs and plant root aeration, The minimal night-time temperature during the experiment was 15°C and the maximal daytime temperature was 25°C.

Air Ion Generators

Negative air ions in this experiment were produced by a Klykon model 130/E109 generator with emitters positioned as indicated in Figure 1. The line of 28 emitters was located directly above aisle 5 between beds 4 and 5. Since the plants in the aft section were 30 cm closer to the emitters than those in the front section, they received a somewhat higher dosage of ions. It should be noted that the placement of emitters relative to the growing beds did not provide an ideal test of air ion effects. As is evident in Figure 1, the control beds 1 and 2 were not completely protected against ion drift from the emitters located above beds 4 and 5. The longitudinal flow of air minimized lateral dispersion, but did not entirely prevent it. At either end of the greenhouse the longitudinal flow averaged 175 ft/min. In the central area the flow from inlet to exhaust was ca. 90 ft/min.

Air ion flux density at various levels of the greenhouse was measured with a target probe and a Keithley electrometer, model 610B. The air ion flux density 20 cm above the growing beds ranged from 8-20 x 10^3 negative ions cm^{-2} in the aft ion-treated area and 6-9 x 10^3 negative ions cm^{-2} in the forward ion-treated area. Corresponding values in both the aft and forward control zones were 5 - 7 x 10^2 negative ion cm^{-2}.

The ion generating system went into operation 24 hrs a day three days after the seedlings were transplanted. Thirty days after transplant, operation was limited to daylight hours. As noted later, there was a brief period of deactivation 100 days after transplanting.

Since as little as 40 ppHM of 0_3 is harmful to tomato plants (Reinert *et al.*, 1972) and corona discharge type ion generators are liable to produce 0_3, we wanted to be sure that the injury threshold was not exceeded. The certified, exceedingly small output of 0_3 by the generator-emitter system employed and the enormous dilution factor imposed by the air exhaust system combined to exclude 0_3 as an element in the present experiment.

Plant Culture and Maintenance

The grower's standard operational and environmental control procedures were followed except for nutrient adjustment and changes in leaf pruning and pollination necessitated by air-ion-induced effects to be described under "Results." For this winter/spring crop during the plant maturing phase and through the immature green phase of the first fruit cluster, the nutrient formulation shown in Table 1 was followed.

Table 1. The elemental content of the basic nutrient formula. This solution was monitored every two days with a conductivity meter and a pH meter.

Element	N	P	K	Ca	Mg	S	Fe	Mn	B	Zn	Cu
ppm	124	99	266	64	17	87	1.32	0.64	0.3	0.38	0.08

During the course of fruit maturation from immature green through mature green and color blush, nutrient concentration imbalance became a frequent occurrence. Accordingly, except for trace elements, a two-step increase (20% per step) in major elements was effected at each nutrient change period, i.e. every three weeks. Visual observation of possible adverse effects stemming from nutrient imbalance was made three times per week. No other serious deficiency or toxic signs were noted except for phosphorus deficiency seen in plants located near the cooling pads. This, coupled with chill, caused some 50 plants to be discolored and stunted at the growing portion. Appropriate changes in temperature and nutrient formula brought about normal new growth within a few weeks. Fruit and petiole samples for analysis were obtained shortly after the early nutrient changes.

Location and Weather

The hydroponics installation used in this experiment is located a few miles northeast of Gilroy, California. The weather pattern for the period involved is summarized in Table 2.

Table 2. Summary of weather data for period of experiment.

Month	Temperature (C) Averages High	Low	Max	Min	Rainfall No. of Days	Total (cm)	Overcast Days 80% Cover during daylight hrs	Remarks
Jan	16.3	1.0	21.7	-5.0	2	0.86	9	Note 3
Feb	16.4	4.7	23.9	-1.7	10	13.31	15	Note 3
Mar	17.2	5.4	25.0	0.0	9	15.40	17	Note 4
Apr	18.9	4.6	26.1	1.1	5	4.50	10	Note 3
May	26.5	17.8	37.8	3.3	0	0.0	2	Note 3
Jun	28.0	19.5	36.1	6.7	0	0.0	1	Note 3

Note: 1) Barometric pressure ranged from a high of 772.2 mm Hg to a low of 750.1 mm.
2) Data source: National Climatic Center, U.S. Dept. of Commerce.
3) No unusual storms.
4) Gusty winds: 25 knots during latter part of month, occurring between 1000 and 1400 hours P.S.T.

RESULTS

After 18 days in the seedling house the air-ion stimulated tomato seedlings were 50-75% taller than the controls and had 1-2 more sets of true leaves.

During the first 30 days after transplanting into the greenhouse, the seedlings in the treated area were stimulated 24 hr. per day. No height or growth differences were noted between the stimulated and control plants, except that microbuds formed on the 20th day in the stimulated plants and on the 28th day in the controls. Blossoms appeared on the 29th day in the ion-treated plants. On the 30th day in the greenhouse we decided to stimulate only during the daylight hours (0700-1900) to allow for a rest period during the night. Several days later a marked elongation of the stems was noted in both treated and control plants. However, the stimulated plants exhibited a stem growth rate substantially greater than that of the controls by the end of the 41st day (Fig. 2). This was equivalent to "plant earliness" growth of 20 days over that of controls. Forty-one days after transplant the growth rates for the stimulated and control plants levelled off and remained constant with respect to each other. However, the residual "earliness" difference in growth rate remained about the same until 120 days after transplanting. Since the tomato plants were grown as single-vine plants, integral elongation measurement

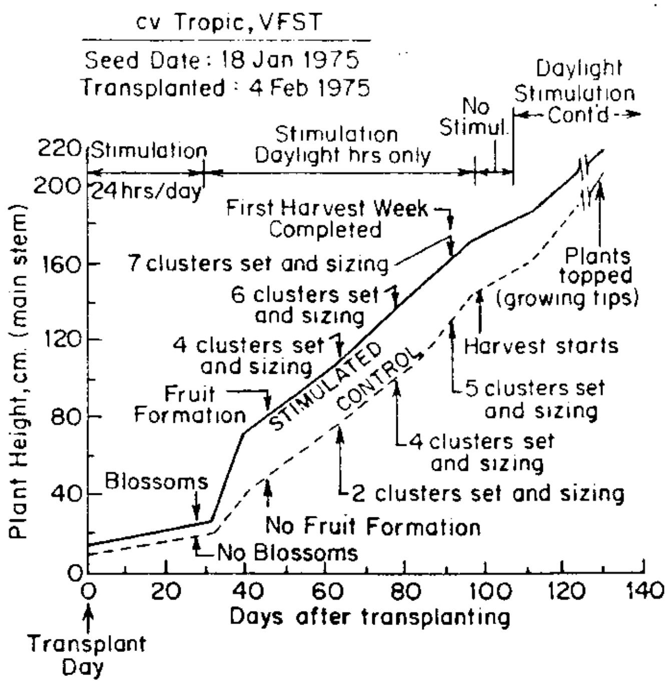


Fig. 2. Plant growth rate of control and air-ion-treated tomato plants. The ordinate indicates average main stem length in centimeters. The abscissa lists the days after transplanting. Major events characterizing the air-ion-treated plants and controls are entered.

was not possible. Consequently, in Fig. 2 only the main stem average rate of growth is shown as a function of days from transplanting. Notes have been entered in Fig. 2 to key certain growth events.

Visual inspection was on a continuing basis for plant responses and physical appearance. The stimulated plants in general had thinner stems, smaller leaves, less dense overall foliage cover and had two or three more flower-fruit clusters than the controls for equal stem height. The labor required for plant leaf pruning was much less for the ion-treated plants than for the controls because of the denser foliage in the latter. On the other hand, less effort was expended on pollination of the controls because the ion-stimulated plants had more flower clusters per plant. These differences balanced one another. Harvesting, sizing, grading, and packaging of mature fruit took place three times per week.

Ninety-seven days after transplanting the growth rate decreased for the stimulated plants and was only slightly reduced for the controls. This phase coincided approximately with the brief period when air-ion treatment was interrupted, as noted below, and produced no ill effect on flowers, fruit growth, or on maturation of tomatoes. Virus desease was detected in control and stimulated plants during the sixth week of harvest and caused a reduction of fruit yield. Diseased plants were removed at a rate of 3% per week of the total plant population, producing a total loss of 25% in the treated group and 10% in the controls. The collecting of data for plant performance in terms of fruit yield and quality was terminated 152 days after transplanting because of the excessive plant deterioration and losses to virus infection.

Harvest of fruit from air-ion treated plants began 104 days after seeding (86 days after transplanting) and proceeded more rapidly than did harvest among the controls. Figure 3 depicts the yield rate per plant as a function of harvest weeks for stimulated and control plants. Figure 4 displays the cumulative fruit yield per unit of greenhouse area. Because of the higher incidence of virus infection in the ion-treated group the yield curves begin to converge at the ninth week. Figure 5 is a plot

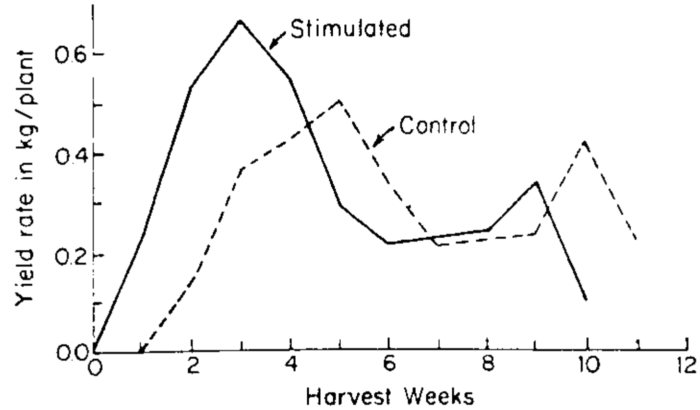


Fig. 3. Tomato plant yield for air-ion-treated and control plants plotted as yield rate against harvest weeks.

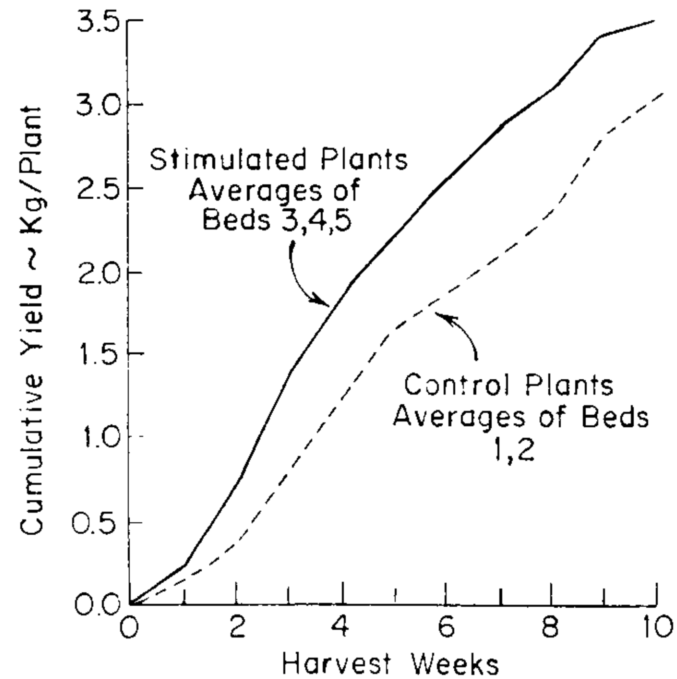


Fig. 4. Fruit yield as a function of greenhouse unit area.

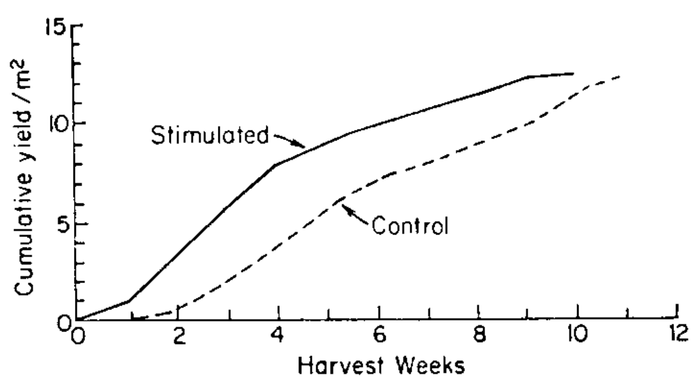


Fig. 5. Cumulative fruit yield per plant for controls and ion-treated plants plotted against harvest weeks.

TABLE 3. Analyses of fruit composition and petiole composition. The fruit composition data represent averages of analyses conducted by the University of California, Davis, and Goldsmith Seeds, Inc. The petiole composition figures refer to dry weight basis as reported by OARDC (Ohio State University), Wooster, Ohio.

Analyses - Fruit Composition (Averages)						
Ripe Fruit from	pH	EC (ppm)	Brix (°)	Citric acid (%)	Ascorbic acid (mg/100g)	Flavor
Control	4.42	2300	5.00	0.34	7.5	Good
Stimulated	4.40	1725	5.18	0.36	11.1	Better

Analyses - Petiole Composition (dry wt basis)																
	%							ppm								
Petiole	N	P	K	Ca	Mg	Na	Si	Mn	Fe	Cu	B	Zn	Mo	Sr	Ba	Al
Control	1.75	0.93	6.36	1.30	0.38	0.11	0.10	69	99	8	26	26	1.11	64	21	59
Stimulated	1.80	1.11	6.02	1.58	0.55	0.11	0.10	86	110	11	27	36	2.97	65	26	53

of the average cumulative yield/plant for controls and treated plants against harvest weeks.

Independent analyses of fruit and plant (petiole) were conducted on samples taken during the fourth harvest week and the results are displayed in Table 3. These data indicate the air-ion treatment improved the quality of the mature fruit. General observations of differences between ion-stimulated and control plants are summarized in Table 4.

DISCUSSION

During the past three decades through the impact of technological and horticultural breeding advances, the greenhouse production of vegetables, flowers, and bedding plants has become a dynamic and viable industry in the United States. Although the United States lagged behind Europe in terms of greenhouse acreage, the steady growth of the industry is beginning to close this gap, primarily because of increasing demands for high-quality fresh vegetables and flowers at reasonable cost. In general, the greatest concentration of greenhouses in the U.S. is located in the Eastern zone, notably in the state of Ohio. However, other states in the South and mid-Southwest are expanding their facilities. During the last few years the industry in the Pacific states has begun to show remarkable growth, especially in the production of greenhouse tomatoes and European-type cucumbers.

Although the industry has been on an up-trend, the impact of recent crises in availability of energy, escalating prices for fuel, material and supplies, and for labor have imposed a sereve constraint upon plant expansion and facilities. These factors have moved commercial growers in the United States to look for the implementation of technological and horticultural advances that would provide them with increased production and profits within the existing facilities. One potential element in the area of technological advances may well be the application of air-ion treatment.

Despite the fact that as long as 200 years ago atmospheric electricity was suspected of influencing plant growth, the requirements for critical investigation could not be met until 1899 when air ions were discovered. Since then, wide-ranging interest has developed in a whole spectrum of air-ion effects on living forms. The literature contains many accounts of experiments in which air-ion enriched environments have been used to treat diseases, e.g. asthma and weather-induced syndromes such as the sharav illness of Isreal. This phase of air-ion research has not been implemented in conventional medical practice, largely because of failure to meet the requirements of satisfactory experimental design and neglect of the placebo effect. Studies of general biological effects using bacteria, protozoa, higher plants, insects, and higher animals have been more productive, to the point where it now is possible to state that air ions *are* biologically active. As noted in the introduction of this paper, there even exists a fair amount of information regarding the mechanism of air-ion stimulation of plant growth.

Our goal in the present study was to determine whether the air-ion enhancement of plant growth, so readily demonstrable in the laboratory, occurs on a large scale under "practical" conditions, The experiments were conducted with tomato plants in a California hydroponic greenhouse facility where tomatoes and cucumbers are the primary vegetable crops. Hydroponics (soilless culture) was chosen as a first-choice test bed program because of it flexibility in the control of such variables as nutrient formulation and concentration, extent of irrigation, and environmental factors.

Our experimental design included observations for air-ion induction of (a) growth stimulation, (b) acceleration of fruit

TABLE 4. Observations comparing the results of negative-air-ion treatment of the spring tomato plant crop with a control (untreated) crop.

1. PLANT CHARACTERISTICS	REMARKS
a. Stem height growth	Earlier by two weeks
b. Stem diameter, averages (mature plants)	Smaller; 1.6 cm vs 2.1 cm for control
c. Leaf size (area), averages (mature plants)	Smaller by 60% to 75%
d. Cluster internode averages	Closer; 18 cm vs 25 cm for control
e. Number of flowers per cluster, averages	No significant differences
f. Petiole analysis	See Table 3
2. BUD, BLOSSOM & FRUIT FORMATION	
a. Buds and blossoming	Earlier by about two weeks
b. Fruit set	Earlier by about two weeks
c. Fruit ripening	Earlier by about 10 days
d. Fruit conformation and quality	Better by 10% to 15% for Grade 1
e. Fruit size	More of larger sizes (4x5s & 5x5s)
f. Fruit composition and flavor	See Table 1
3. FRUIT YIELD RATE PER PLANT	
a. Yield rate per week	Greater by 50% in first 3 weeks
b. Cumulative yield rate	Greater by 27% at end of 6 weeks
c. Spring crop yield	Equalled the previous good summer crop (untreated)

4. NUTRIENTS
   a. More adjustments required for N, P, K and Ca since a closed loop (nutrient recycling) method was employed for this experiment.

5. UNCERTAINTIES
   a. Optimum air-ion dosage level requirement for other cultivars or at different stages of plant maturity.
   b. Optimum air-ion dosage duration and/or frequency of application.
   c. Effects of air ions, of either polarity, on plant disorders due to viruses and fungi, and on flying or crawling insects.
   d. Apparent premature senescence of plants. Possibly due to bioelectrical effects described in introduction.

maturation/ripening, (c) increased crop yield and (d) improvement of fruit composition, We recognized that in such a preliminary experiment it would not be feasible to conduct a definitive test employing the control conditions one would impose in the laboratory. Ideally, an experiment of this sort should utilize two sections of the same greenhouse, one housing the treated plants, and the other the controls, completely isolated from the artificially ion-enhanced atmosphere. For practical reasons, we were not able to install a Faraday cage to pervent ions from reaching controls. As a compromise, we made use of the fact that air-ion density falls off rapidly with distance from the ion source. The emitters were so positioned along the length of the greenhouse that beds 3, 4 and 5 were closest to them and could be considered to present an ion-treated area (Fig. 1). Beds 1 and 2 were far enough away to serve as controls although they undoubtedly received a low dosage of ions. Consequently, in the absence of a completely untreated set of controls, any differences in biological effects observed during this experiment could be ascribed to differences in air-ion dosage. On the basis of the averages of the ion flux densities (number of ions/cm^2/sec) at plant level in the three different areas of the experiment, ion-treated plants in the aft section received ca 17 times the dosage of plants in the control areas, while ion-treated plants in the forward section were exposed to ca 13 times as many ion as the control plants.

It can be argued that the plant responses observed on our experiments depend on differences in the imposed electrical fields. Clearly, the control plants were exposed to lower electrostatic fields than the two groups on ion-treated plants. However, the work of Bachman and Reichmanis (1971) and our own experiments (Krueger *et al.*, 1978) demonstrate that air ions are the primary element in conveying the small electrical currents to plants that result in increased rate of growth. In our experiments, conducted in very low electrostatic fields, no growth enhancement occurred until air ions were added to the ambient air. Bachman and Reichmanis found that increases in plant growth, in the absence of added air ions, depended upon the intensification of relatively low electrical fields at the pointed ends and fine hairs of plants to such a degree that corona developed and air ions were produced. The electrical currents required to stimulate growth are quite small: 6-10 pA/plant in our early studies (Krueger, *et. al.*, 1962), 10 pA/plant in more recent ones, and 10 pA in Blackman and Legg's (1924) series. Pohl and Todd (1981) reported a current of 4 pA/cm^2 at plant level to be effective in expediting the growth and blossoming of geraniums and Persian violets.

The goal of the experiment recorded here was to evaluate the application of electroculture in the production of tomatoes in a hydroponics greenhouse. The generally favorable effects observed lead to the conclusion that the air ion enriched environment was responsible for:

1. Earlier appearance of buds and fruit by two weeks.
2. Earlier fruit ripening by 10 days.
3. Cumulative fruit yield rate per plant greater by 27% at the end of six weeks.
4. Superior fruit conformation and quality by 10%-15% for Grade 1.
5. Improved fruit size.
6. Improved fruit flavor and compostion.

Since the costs of installing air ion generators are modest, their energy requirements are minimal, and no detrimental effects of negative air ions on the personnel have been observed, this procedure appears to be a useful addition to greenhouse technology.

ACKNOWLEDGMENT

We express our sincere thanks to Mr. Richard Finger and Thomas Michel of Klykon Inc. of Florida for their interest and help in making it possible to carry out this study.

REFERENCES

Bachman, C.H.; Hademonos, B.G.; Underwood, L.W. *J. Atmospher. Terrestr. Phys. 33*, 497-505.

Bachman, C.H.; Reichmanis, M. 1973. *Int. J. Biometeor. 17*, 253-262.

Beccaria, G.B. 1775. *Dell' Elettricita Terrestre Atmosferica a Cielo Sereno.* Torino.

Bertholon de Saint-Lazare; 1783. *De l'electricite des vegetaux*, Paris.

Blackman, V.H.; Legg, A.T. 1924. *J. Agric. Sci. 14*, 268.

Cholodny, N.G.; Sankewitsch, E. Ch. 1937. *Plant Physiol. 12*, 385-408.

Elkiey, T. M.; Pelletier, R.L.; Bhartendu; Barthakur, N. 1977. *Int. J. Biometeor. 21*, 1-6.

Elster, J.; Geitel, H. 1899. *Terrestr. Magazin, 4*, 213-34.

Gardini, C. *De influxu electricitatis atmosphericae in vegetantia*, Turin, 1784. (Dissertation).

Gassner, G. 1907. *Ber. Bot. Ges. 25*, 26.

Ingenhousz, J. 1788. *1' influence de l' electricité atmospherique sur les végétaux. J. phys. 32.*

Kotaka, S.; Krueger, A.P.; Nishizawa, K.; Obuchi, T.; Kogure, Y.; Takenobu, M. 1965. *Proc. Bot. Soc., Jpn. C21*, 43.

Kotaka, S.; Krueger, A.P.; Nishizawa, K.; Obuchi, T.; Takenobu, M.; Kogure, Y.; Andriese, P.C. 1965. *Nature 208*, 1112-1113.

Krueger, A.P.; Kotaka, S.; Andriese, P.C. 1962. *J. Gen. Physiol. 45*, 879-895.

Krueger, A.P.; Kotaka, S.; Andriese, P.C. 1963. *Nature 200*, 707-708.

Krueger, A.P.; Kotaka, S.; Andriese, P.C. 1964. *Int. J. Biometeor. 8*, 5-16.

Krueger, A.P.; Kotaka, S.; Andriese, P.C. 1965. *Int. J. Biometeor. 9*. 201-209.

Krueger, A. P.; Strubbe, A. E.; Yost, M. G.; Reed, E. J. 1978. *Int. J. Biometeor. 22*, 202-212.

Lemstrom. S. 1904. *Electricity in Agriculture and Horticulture.* London.

Lund, E.J., et al. 1947. *Bioelectric Fields and Growth*, University of Austin Press, Austin, Texas. 391 pp.

Maw, G.M. 1967. *Can. J. Plant Sci. 47*, 499-504.

Murr, L.E. 1963. *Nature 200*, 490.

Murr, L. E. 1964 *Nature 201*, 1305-1306.

Murr, L.E. 1965a. *Nature 206*, 467-470.

Murr, L.E. 1965b. *Nature 207*, 1177-1178.

Murr, L.E. 1966a. *Int. J. Biometeor. 10*, 147-153.

Murr, L.E. 1966b. *Adv. Frontiers Plant Sci. 16*, 97-120.

Murr, L.E. 1966c. *Int. J. Biometeor. 10*, 135-146.

Pohl, H.A. 1977. *J. Biol. Phys. 5*, 3-23.

Pohl, H.A.; Todd, G.W. 1981. *Int J. Biometeor. 25*, 309-321.

Reinert, R.A.; Tingly, D.T.; Carter, H.B. 1972. *J. Am. Soc. Hort. Sci. 97*, 149-151.

Sidaway, G.H. 1967. *Spectrum, 211*, 303.

Sidaway, G.H. 1975. *J. Electrostatics. 00*, 389-393.

Sidaway, G.H.; Aspray, G.H. 1968. *Int. J. Biometeor, 12*, 321-329.

Thomson, J.J. 1898. *Phil. Mag. 46*, 528-545.

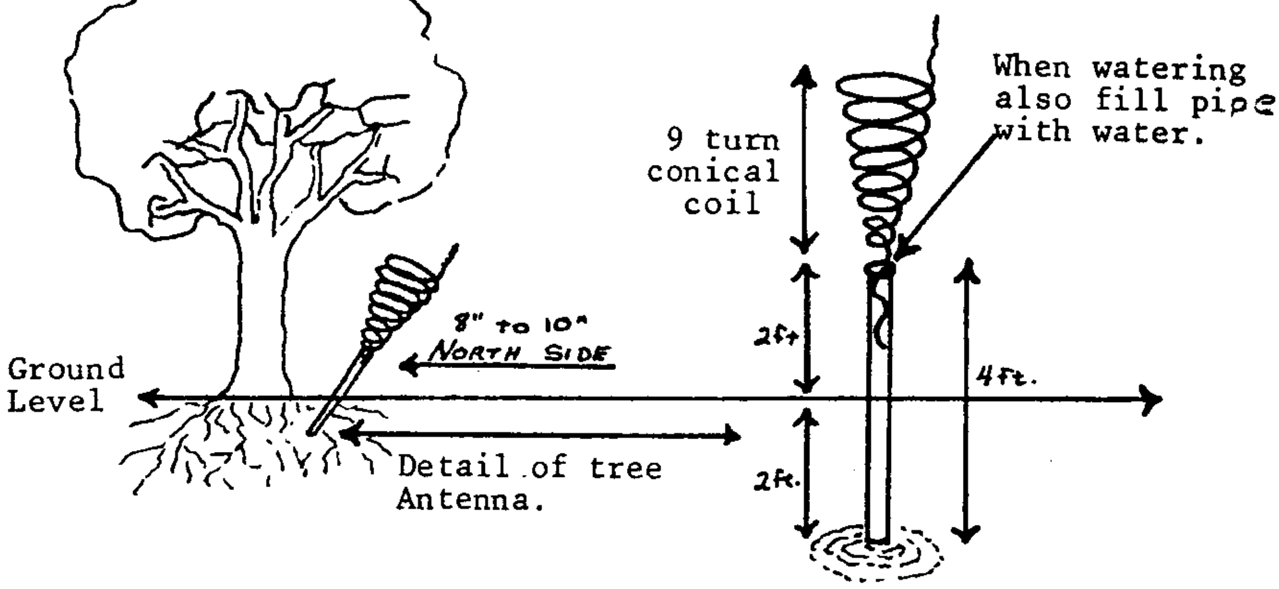
Winton, R., *et al.* Unpublished data.

Zhurbitskii, Z.I. 1969. Proc USSR Acad. Sci., Biol, Series #1, Jan.-Feb., 100-112.

Zhurbitskii, Z.I.; Shidlovskaya, I.L. 1967. *Elektron. Obrad. Mater. 6*, 70-73.

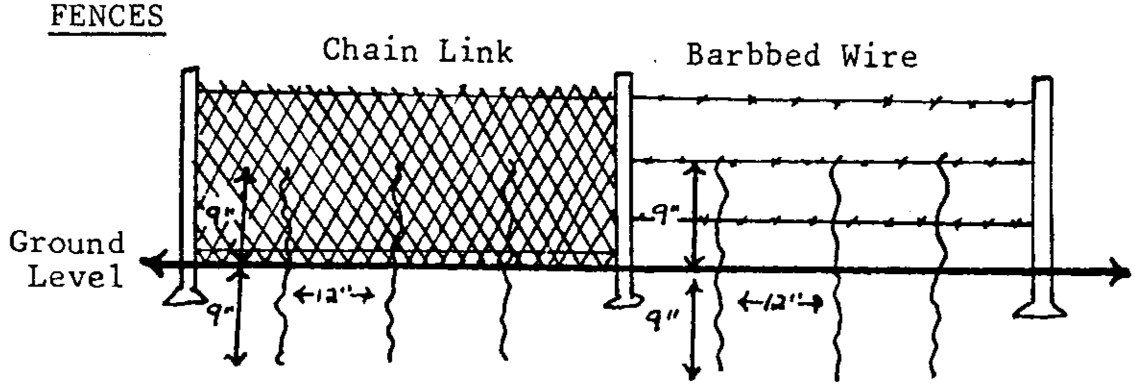
Editor's Note: Dr. Albert P. Krueger died on December 8, 1982. Please refer reprint requests or correspondance in care of the Air Ion Laboratory, Department of Biomedical and Environmental Health Sciences, University of California, Berkeley, California 94720.

FRUIT TREES



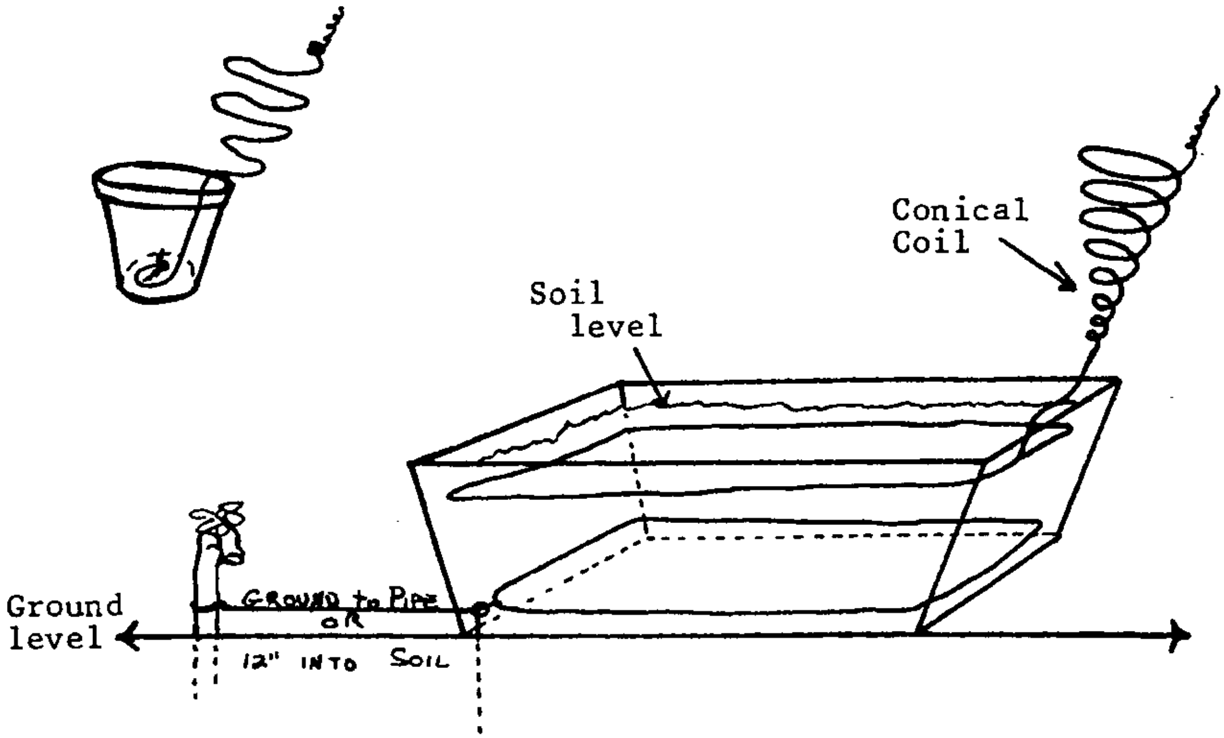
Always be careful not to allow the antenna wires to touch the leaves of the plants or burning could result.

FENCES

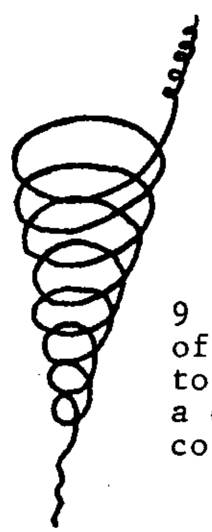


FENCES BECOME ANTENNA

POTTED PLANTS OR PLANTER BOXES



Planter box may be any size convienent for area available. Trellises can be attached for climbing plants - Peas, beans, tomatoes, etc. They may also be used indoors with Grow Lights.



9 turns of wire to form a conical coil.

Coils should be cleaned twice yearly. To do this imerse in a pail of hot water in which ½ box of soda has been disolved.

North of the Equator the coils should be COUNTER CLOCKWISE.
South of the Equator CLOCKWISE.

BIOLOGY

Influence of Electrostatic Fields on Seed Germination

RECENT investigations have stimulated wider interest in the possible biological significance of naturally occurring electric fields and related phenomena. Murr[1-3] has shown that high intensity electric fields appear to inhibit development in grass seedlings; he points out, however, that earlier workers, notably Jorgensen and Priestley[4], and Shibusawa and Shibata[5], observed increases in plant growth under electric field conditions, although the frequent occurrence of contradictory results in much of the early work on this subject has been emphasized by Lund[6]. The physiological effects of air ionization have been studied by a number of workers[7]. Krueger *et al.*[8] report that exposure to positively or negatively ionized air produced more rapid germination in *Avena sativa* seeds with subsequent increases in growth and dry weight; slight increases in growth were also noted with seedlings placed in positive or negative electric fields of 955 V over 30 cm; in these experiments, however, the seed containers were grounded to prevent the accumulation of surface charge. The present communication directs attention to an apparent dependence on polarity of the response of germinating seeds to induced electrostatic charges.

Four batches of 100 seeds of lettuce (*Lactuca sativa*), variety 'Clusoed Borough Wonder', were sown on filter paper laid on each of four 6 cm square sections of aluminium foil attached by a thin film of 'Vaseline' to the upper surface of a sheet of glass 45 cm × 7·5 cm. Foil sections were similarly attached to the under-surface of a second sheet of glass resting on spacers so arranged as to separate the two sets of 'field plates' by a vertical distance of 4·5 cm. Two pairs of plates were connected to 90 V batteries arranged in series to give a potential difference of 180 V, one pair positive over negative and the other pair negative over positive; the remaining pairs were left uncharged as controls; the relative positions of charged and uncharged plates were changed after each replication. After sowing, each batch of seeds was moistened with 1·5 c.c. of water, the apparatus being then enclosed in a polythene container and placed in a constant-temperature room for 24 h. Most of the experiments were conducted either in total darkness or with 12/12 photoperiod, but no attempt has been made to discriminate between the two conditions in the results given in Table 1. A comparison is given in Table 2 between twenty paired replications carried out in light and dark rooms simultaneously.

The criterion of germination in these experiments was taken as the emergence of the radicle when viewed under a × 15 lens. The margin of error inherent in purely visual determinations of this type must obviously be so great as to preclude the possibility of obtaining any precise estimate of the magnitude of the electrostatic response. Sufficient results have, however, been obtained to provide some indication of the general pattern of response, although it must be emphasized that considerable variation occurs in the germination level within any one treatment.

The results of 150 replications (Table 1) are in agreement with the work of Murr[1], in that a positive field appears to inhibit plant development, but from the present work it is further apparent that the nature of the plant response is dictated by the sign of the electrostatic field, and not merely by the presence of the field *per se*. The possible influence of light in reducing the magnitude of this polarity effect may be significant (Table 2). A comparison with the work of Krueger *et al.*[8] is not possible in the absence of ion-density and current measurements, but Edwards[9] found that a positive field slowed down the rate of development of *Nepytia* pupae; he also suggested that contact-induced electrostatic charges might influence insect behaviour[10,11].

The present experiments were initiated in an attempt to provide a possible basis for correlation between geoelectric phenomena and the manifestation of psychiatric disturbance symptoms, assuming such a relationship to be mediated through variations in neuro-hormone activity resulting from electrostatically induced changes in tissue respiration levels. Preliminary gas-analysis studies appear to indicate a possible polarity-dependent electrostatic influence on the rate of production of carbon dioxide in germinating seeds. Further work along these lines is in progress.

I thank D. G. Heathcote for carrying out the statistical analysis; I also thank Prof. G. F. Asprey, Dr. J. R. Etherington and Dr. A. G. Lyon for their advice and encouragement.

G. H. SIDAWAY

Department of Botany,
University College,
Cardiff.

1 Murr, L. E., *Nature*, **200**, 490 (1963).
2 Murr, L. E., *Proc. Penn. Acad. Sci.*, **37**, 109 (1963).
3 Murr, L. E., *Nature*, **201**, 1305 (1964).
4 Jorgensen, I., and Priestley, J. J., *J. Agric. Sci.*, **6**, 337 (1914).
5 Shibusawa, M., and Shibata, K., *J. Elect. Eng. (Japan)*, **473**, 1 (1927).
6 Lund, E. J., *Bio-Electric Fields and Growth* (Austin, Texas, 1947).
7 Griffin, J. E., and Kornblueh, I. H., *Intern. J. Biometeorol.*, **6**, 29 (1962).
8 Krueger, A. P., Kotaka, S., and Andriese, P. C., *J. Gen. Physiol.*, **45**, 879 (1962).
9 Edwards, D. K., *Nature*, **191**, 976 (1961).
10 Edwards, D. K., *Canad. J. Zool.*, **38**, 899 (1960).
11 Edwards, D. K., *Canad. J. Zool.*, **40**, 579 (1962).

Table 1. DIFFERENCE IN PERCENTAGE GERMINATION AVERAGED OVER 150 REPLICATIONS

Difference from control: + over −	Difference from control: − over +	Difference between polarities
−4·9468	+0·9863	5·9331

Variance-ratio = 3·95 (5 per cent significance point = 3·00).

Table 2. COMPARISON OF GERMINATION BETWEEN TWENTY REPLICATIONS EACH IN LIGHT AND DARK

	Difference from control: + over −	Difference from control: − over +	Difference between polarities
Dark	−12·2	+4·65	16·85
Light	+0·85	+6·4	5·55

Some Re...

cellular components. In a system such as dry seeds, where repair mechanisms are probably inoperative, this damage could accumulate to such an extent that cell death and consequent loss of embryo viability occur. In hydrated systems, where membrane turnover (*1*), and thus presumably repair, does occur, membrane damage by free radical peroxidation probably does not accumulate (*14*). However, accumulation of this type of damage might well be important in the terminal deteriorative senescence changes in such systems if repair mechanisms fail with age.

N. W. PAMMENTER
J. H. ADAMSON, PATRICIA BERJAK
Department of Biological Sciences, University of Natal, Durban, South Africa

References

1. L. Packer, D. W. Deamer, R. L. Heath, *Adv. Gerontol. Res.* **2**, 77 (1967).
2. H. van Zutphen and D. G. Cornwell, *Membr. Biol.* **17**, 79 (1973).
3. F. E. Hunter, A. Scott, P. E. Hoffsten, J. M. Gerecki, J. Weinstein, A. Schneider, *J. Biol. Chem.* **239**, 614 (1964).
4. J. D. Robinson, *Arch. Biochem. Biophys.* **112**, 170 (1965).
5. I. D. Desai, P. L. Sawant, A. L. Tappel, *Biochim. Biophys. Acta* **86**, 277 (1964).
6. B. L. Strehler, *Adv. Gerontol. Res.* **1**, 343 (1964).
7. D. Harman, *Radiat. Res.* **16**, 753 (1962).
8. R. S. Sohal and V. F. Allison, *Exp. Gerontol.* **6**, 167 (1971).
9. R. Hochschild, *ibid.*, p. 133.
10. D. Harman, *J. Gerontol.* **23**, 476 (1968).
11. A. Tappel, B. Fletcher, D. Deamer, *ibid.* **28**, 415 (1973).
12. K. Molnár, *Mech. Age. Dev.* **1**, 319 (1972/73).
13. P. Berjak and T. A. Villiers, *New Phytol.* **71**, 135 (1972).
14. T. A. Villiers, in *Seed Ecology*, W. Heydecker, Ed. (Butterworth, London, 1973), p. 265.
15. F. H. Abdalla and E. H. Roberts, *Ann. Bot. (Lond.)* **32**, 119 (1968).

9 July 1974; revised 28 August 1974

MAGNETOTROPIC RESPONSES IN ROOTS OF WILD OATS

Magnetotropic responses occur in the roots of some plant species (1, 3, 4, 5, 6). This note describes a magnetotropic response in the roots of wild oats (*Avena fatua* L.) grown in the laboratory and at random in fields across central North America.

In the laboratory, wild oat seedlings were grown in stationary and horizontally rotated cages (4) and in cages on a magneto-klinostat (5) for 10 to 14 days. The electromagnet in the klinostat was oriented horizontally at right angles to magnetic north, and the field strength at the seedlings was about 10 oersteds. The polarity of the magnet was reversed after 48 hr, and treatment was continued. There were 10 hr of daylight at 22 C and 14 hr of darkness at 15 C. All tests were replicated four to six times. When treatment was terminated, the growing medium (vermiculite) was washed from the cages, and the lateral roots of all plants were evaluated for direction of growth using the formula:

$$D = 100 - 5\,\frac{(dn - ds)}{9}$$

where D = direction of root growth and $dn - ds$ = declination in degrees from true north and true south.

In the field experiments from 1962 to 1967, the horizontal orientation of the main lateral roots was noted on approximately 175 wild oat seedlings grown at random at each of 27 locations in four geographical regions of North America. A D value was calculated for each of the 4239 seedlings, and fiducial limits were calculated for the groups of plants from each geographical region. D values were also calculated for hypothetical plants with lateral roots oriented in a magnetic north-south plane at each location.

Results from the laboratory showed that the lateral roots of seedlings that remained stationary after planting were oriented approximately north and south, and the average D value of these plants was 75.7 [a plant with lateral roots oriented in a magnetic north-south direction at Lethbridge, Alberta, where compass declination was 20 00′E in 1966 (2), would have a D value of 78]. The average D value of plants that were rotated 90° daily was 57.2 (a D value of 50 indicates perfect random orientation of roots).

Seedlings grown on the klinostat while the electromagnet was inactive had roots oriented in a north-south direction; their average D value was 81.9. In contrast, those grown while the magnet was activated had roots oriented approximately parallel to the horizontal magnetic flux midway between the poles and had D values of only −38.1.

Reversing the polarity of the magnet during treatment did not alter the growth pattern of the roots.

Generally, the lateral roots of wild oat seedlings from fields across North America were oriented in a north-south direction. Their D values were relatively high (Table 1). Seedlings grown west of the agonic line had D values that closely resembled those calculated for hypothetical plants, and thereby provided a fair index of magnetic declination if geographical directions were known. Seedlings grown east of the agonic line provided a less reliable index of magnetic declination

Table 1. Root growth pattern of hypothetical and actual wild oats growing at random in various regions of North America

Geographical region	Magnetic compass declination	Av. D values: Hypothetical plants	Av. D values: Actual plants
Pacific	<25°E>20°E	76	73.3±0.7*
Midwestern	<20°E>5°E	86	84.7±1.1
Great Lakes	<5°E>0	97	91.5±2.2
Eastern	>0<15°W	107	95.6±1.6

*95% fiducial limits.

but did provide a good indication of polar direction. Local anomalies in the industrial area east of the agonic line may have altered the full expression of the magnetotropic response to the geomagnetic field in this area.

1. AUDUS, L. J. 1960. Magnetotropism: A new plant-growth response. Nature **185**: 132.
2. DEPARTMENT OF MINES AND TECHNICAL SURVEYS. 1966. Canada air pilot. Ottawa, Ont. November 6, 1966.
3. KRYLOV, A. V. and TARAKANOVA, G. A. 1960. Magnetotropism of plants and its nature. Plant Physiol. **7**: 156–160. (Transl. from Fiziol. Rast.).
4. PITTMAN, U. J. 1962. Growth reaction and magnetotropism in roots of winter wheat (Kharkov 22 M.C.). Can. J. Plant Sci. **42**: 430–436.
5. PITTMAN, U. J. 1964. Magnetism and plant growth. II. Effect on root growth of cereals. Can. J. Plant Sci. **44**: 283–287.
6. WOOLLEY, D. G. and PITTMAN, U. J. 1966. P_{32} detection of geomagnetotropism in winter wheat roots. Agron. J. **58**: 561–562.

U. J. Pittman

Research Station, Canada Department of Agriculture, Lethbridge, Alberta. Received December 15, 1969.

14. O. J. David, J. Clark, K. Voeller, *Lancet* 1972-II, 900 (1972).
15. S. M. Pueschel, *Environ. Health Perspect.* 7, 13 (1974); A. M. Seppalainen and S. Hernberg, *Br. J. Ind. Med.* 29, 443 (1972).
16. R. G. Lansdown, B. E. Clayton, P. J. Graham, J. Shepherd, H. T. Delves, W. C. Turner, *Lancet* 1974-III, 538 (1974); P. J. Landrigan, R. H. Whitworth, R. W. Baloh, N. W. Staehling, W. F. Barthel, B. F. Rosenblum, paper presented at the Conference of Childhood Lead Poisoning Control Projects, Center for Disease Control, Atlanta, May 1974.
17. Supported by Canadian National Research Council research grant A4644. We thank the staff of the Toronto Board of Health, Public Health Department, the Hospital for Sick Children, and the Ontario Ministry of the Environment for their cooperation. Community screening programs were organized by local ratepayers associations; Drs. B. A. Britt and S. M. MacLeod collected blood and hair samples. Neurological tests were carried out by Dr. G. Murphy. The ALA and coproporphyrin analyses were carried out by Dr. K. Menon. We thank W. Gizya, A. Vaughan-Williams, and F. Huhn for technical assistance, and the Canadian Environmental Law Association for advice.
* Present address: Department of Botany, University of Liverpool, Liverpool, England.
† Present address: Trace Analysis Research Center, Dalhousie University, Halifax, Nova Scotia.
8 August 1974

Viability of Stored Seed: Extension by Cathodic Protection

Abstract. *Placing seeds on a negatively charged conductor extended their viability during artificial aging. Such cathodic protection may reduce free radical attack by providing a source of electrons. The results support the hypothesis of free radical damage to cellular components and are consistent with such damage being important in deteriorative senescence changes.*

It is well known that free radicals initiate peroxidative degradation of unsaturated tissue lipids, and it has been suggested that this could give rise to damage to cellular membranes (*1*). Lipid peroxidation in monomolecular and bimolecular films leads initially to an increase in membrane permeability and then to a decrease in membrane stability (*2*). Damage to biological membranes associated with lipid peroxidation has been shown in mitochondria (*3*), microsomes (*4*), and lysosomes (*5*). Lipofuscin granules accumulate with chronological age in some animal tissues and these granules appear to contain protein and peroxidized lipid (*6*), indicating that lipid peroxidation occurs throughout the life span of an organism. It has been suggested that this free radical peroxidation of unsaturated lipids is a basic deteriorative mechanism in cellular aging (*7*). There is as yet little direct evidence for the accumulation of membrane damage during senescence. However, extremely swollen mitochondria, with disorientated and fragmented cristae, indicative of membrane damage, have been observed in the flight muscle of old (25 to 30 days) male houseflies (*8*).

Attempts have been made to prolong the life span of organisms, and promising results have been obtained by supplying membrane-stabilizing drugs to *Drosophila* (*9*) and by including various antioxidants in the diet of mice (*7, 10*). However, these results are far from unequivocal: not all treatments are effective (*7, 9*), different results are obtained with the same antioxidant on different strains of mice (*7*), and in some experiments lipid peroxidation appeared to be reduced without any effect on life span (*11*).

Molnár (*12*) attempted to reduce free radical attack, not by supplying antioxidants in the diet, but by maintaining mice in a cage with an applied negative potential in a manner analogous to the technique of cathodic protection of metals against corrosion. The average and maximum life spans of mice exposed to a negative charge were, respectively, 25 and 32 percent greater than those of mice exposed to a positive charge.

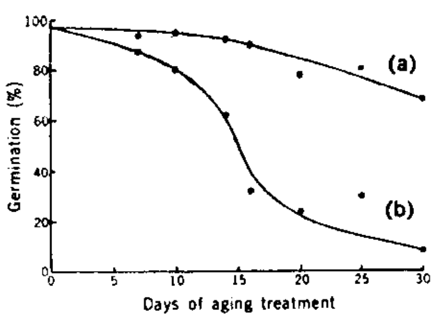


Fig. 1. Viability of stored seeds of *Zea mays* as a function of the duration of the aging treatment. Seeds with a moisture content of 13.6 percent were placed, embryo side down, on aluminum foil in a small enclosed chamber (to maintain the moisture content) and kept at 40°C to accelerate their aging (reduce their storage life). The entire contents of a single chamber were taken for each sample. The seeds were soaked in tap water overnight and then placed on moist paper toweling. Germination was recorded 84 hours after the start of soaking. (a) Seeds provided with cathodic protection by applying a negative potential of 300 volts to the aluminum foil; (b) control seeds.

Air-dry seeds can be rapidly aged artificially by maintaining them at a relatively high moisture content (13 to 15 percent) and an elevated temperature (40°C) (*13*). Air-dry seeds probably do not have sufficient moisture to permit aqueous-phase enzyme reactions to occur, and repair mechanisms are unlikely to be operative in such a system. Thus, damage induced by free radicals would accumulate in dry seeds, whereas in hydrated tissue such damage could be repaired (*14*). Seeds of *Zea mays* (Indian corn) that have been artificially aged show aberrations of mitochondrial membranes as an early sign of aging, before the viability of the seeds declines (*13*).

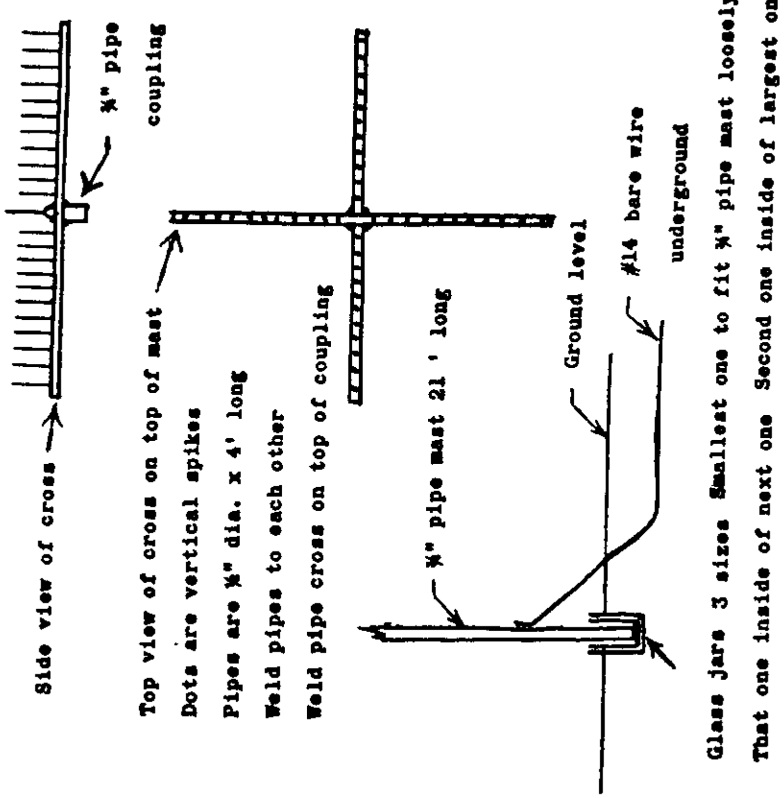
Seeds of *Zea mays* were subjected to artificial aging treatment by maintaining them in a small enclosed chamber at 40°C. The seeds were provided with cathodic protection by placing them, embryo side down, on aluminum foil within the chamber and applying a negative potential of 300 volts to the foil. Control seeds were maintained under similar conditions without the applied charge. The effect of storage time on the viability of the seeds is shown in Fig. 1.

Considerable decreases in viability loss were achieved with cathodic protection. In addition, the conductivity of the water in which the seeds were soaked before germination was consistently greater for the control seeds than for the seeds which had been exposed to the negative charge. This indicates that more material was leached from the control seeds during soaking, which suggests that greater membrane damage had occurred in them than in the seeds provided with cathodic protection. Chromosome aberrations are known to accumulate in nondividing cells of seeds under conditions of accelerated aging (*15*). Free radical peroxidation may affect macromolecules other than lipids; thus, our observation that after 10 days of the aging treatment the percentage of chromosome aberrations was 12.6 in the control seeds and 4.3 in the protected seeds may be of significance. The reductions in mortality rate for dry seeds, which are relatively nonhydrated systems, were far greater than any achieved for animals, which are hydrated systems.

Cathodic protection should reduce free radical attack on biological macromolecules by providing a source of electrons to react with the free radicals (*12*). Thus, these results provide strong evidence for free radical damage to

ELECTRO-CULTURE

This device employs natural electric and magnetic principles and costs nothing to operate. It will stimulate growth over an acre of ground.



Tests conducted with vegetables growing in a garden, show remarkable results when they are grown under electro-magnetic stimuli. They've found that up to 30% more seeds will germinate after they have been in the ground for 24 hours. Growth of the crop to the time of harvest, is accelerated by several weeks. In some growing areas this makes it possible to plant the second crop sooner, thereby avoiding early freezes; as about 6 weeks can be gained on both the plantings to the time of the second harvesting.

Leaf vegetables and above-the-ground vegetables will be nearly twice the size of normal vegetables that are grown in uncharged soil. Root vegetables, like carrots, parsnips, etc., will not only be larger, but will have more flavor. Ball-shaped vegetables will not react *as well* as pointed root and pointed leaf vegetables. This includes head lettuce, cabbage, turnips and potatoes, among others. This is because their spherical shape accumulates the charge instead of permitting flow of the current to keep passing through them.

A device to perform this activity can be made as follows. Get a straight length (21 feet) of ¾" diameter galvanized water pipe. Take a ¾" standard coupling and weld a four-foot cross of ½" pipe on one end of it. The cross is to be horizontal to the ground when the coupling is screwed on to the top of the pipe mast. Solder eleven spikes onto each arm of the cross – from center. These will be spaced 2 inches apart from the ends coming in, and each 9 inches long. These spikes are made from #10 copper wire and all point straight up. The top ends should be sharpened to a point by hammering, or grinding, before they are soldered on to the cross arms.

Solder 12 wires around the base of the mast, 18 inches up from the bottom end. This can be #14 bare copper wire, each equal in length to your garden radius. Screw the spiked cross onto the top of the mast. Connect four guy wires to the top of the mast at the center of the cross. Put an insulator on each guy wire six feet down from their connection at the top of the mast. Add ten more feet of guy wire to each of these insulators, and put another insulator on each of *these* wires. Drive four pipe stakes, at an angle to the ground, 15 feet from the mast and equally spaced about it. Fasten four guy wires to the stakes, each long enough to connect to the bottom insulators.

Dig a small hole for the mast. This hole should be big enough for a wide mouth large glass peanut butter jar. Be sure the *top* of this jar is above the ground level. Put a smaller glass jar in the peanut butter jar, and another smaller one in it; until the jar inside is just big enough to fit around the pipe mast. Slide the jars on the pipe mast lower end, set the mast up and attach the stake guy wires to the four lower insulators. Adjust the guy wires so the mast is vertical, but not tight enough to bend the pipe mast.

Now dig twelve, equally spaced, radial ditches out from the mast to the size of your garden. They are *not* to exceed 200 feet from the mast. These ditches should be deeper than the working depth of hoe or cultivator. Extend the twelve wires out and down these ditches and cover them up, after placing a stake at the outer end of each wire; so you can always tell where the wires are.

Now plant your rows radially from the mast in your round garden. Do not plant directly over the wires, as roots may entangle them. Rows should never be closer than four feet to each other on the inner end. Plant what you like best parallel to the wires.

This device works by activating the natural electric charge in the atmosphere and the earth. These charges being in unbalance (between the solid earth and the gaseous air) try to balance, thereby creating an electric flux in the mast and wires. The current in the wires produces a magnetic field around them, and brings about a gentle magnetic vortex perpendicular to the ground. This in turn creates accelerated ion and electric activity in the plants, and roots, which are in the vertical line of electric flux. Each vegetable then becomes a miniature atomic accelerator, and thus increases its own growth and current flow.

From: 'When The Stars Look Down'
by Van Tassel

Now for the proof of the successful operation of this control. This is where Mrs. Hibbs comes into the story.

Mrs. Hibbs had the foresight to permit the De Land apparatus to be installed on her land. Mrs. Hibbs came from Iowa and bought an orange grove. She didn't know until after she bought the property that the trees were considered "grown out," or beyond their age of producing an average crop.

Her caution only permitted the installation of five units of the "De Land Control" on five acres of her ground. After the first winter proved through freezing temperatures that the control worked, she had her entire 10 acres protected.

She proudly showed us around and compared her oranges with others for color, sweetness, and size. The "grown out" grove has increased its production every year. The crop had just been estimated by the packers before we visited Mrs. Hibbs. This year's crop will go nearly four times the average production per acre.

Mrs. Hibbs was forced to buy $400.00 worth of 2" x 2" props to support the limbs on her trees.

Not only has Mrs. Hibbs increased her profit each year from the crop, but she has saved $3000 worth of smudge oil in 5 years.

The saving in oil alone has payed for the installation of the free energy equipment. So over a period of time free energy pays for its own installation and cost.

Mrs. De Land said her husband John never did find out what makes the installation work. So I went back to our friends the spacepeople, through thought transference, and asked them to explain the principle. This is their explanation.

Trees manifest life but they do not manifest motion. Temperature is a result of molecular motion. The only motion manifested in a tree, or its fruit, is by the electrons in the atoms of its composition.

On a planet that rotates there are four periods each day. These are the positive quarter from 6 A.M. to 12 noon; the active quarter from 12 noon to 6 P.M.; the negative quarter from 6 P.M. to midnight; and the rest quarter from midnight to 6 A.M.

Atoms in free space are charged continuously. Atoms on a rotating planet are only charged according to their opposite polarity period.

As a negative electron rotates faster in the positive and active quarter of the earth's daily rotation, it manifests more heat due to the resistance of polarity opposition.

As an atom on the planet moves into the negative quarter, its electrons have no polarity opposition and they begin to discharge. As the electrons move into the rest quarter they discharge part of their energy and this in turn causes a slowing up in their orbits around the proton. An electron can be stopped in its orbit by extremely low temperatures, which removes its charge. The magnetic canopy of the "De Land Control" helps the electrons to hold their charge by keeping them in motion.

This is definitely proven in the "De Land Control" on Mrs. Hibbs' property. An orange on the tree does not freeze despite the fact that a fruit thermometer inserted into the orange shows the temperature is as much as 7 degrees below freezing. As long as the orange is on the tree it is part of the life process of that tree. Any orange that falls to the ground inside the control area will freeze. This is because it grounds out with earth and its electrons therefore slow up in their orbits.

The temperature inside of the control area reads just as low on a thermometer as the temperature outside of the control area, yet the fruit on the tree does not freeze.

Mrs. Hibbs has recorded temperatures as low as 19 degrees inside and outside the control area at the same time.

ELECTRICITY AS A STIMULANT TO PLANT GROWTH.

The flora of the north polar region is remarkable for rapid growth, fertility, and brilliancy of coloring, phenomena which seem incompatible with the climate. For the Arctic summer, though nightless, is very short, the sun is low, and its rays are often intercepted by fog and clouds, so that it cannot furnish an amount of light and heat favorable to very rapid growth.

The investigations of Prof. Lemstrom, of Helsingfors, and others, tend to show that electricity exerts a great influence on the growth of plants, and this view is confirmed by the luxuriant vegetation of the zone of action of that violent electrical manifestation, the aurora borealis. Furthermore, a close connection has been found, in Finland, between fruitfulness and frequency of auroras. Finally, Lemstrom was led to attribute to the sharp points of plants, such as the beard of grains, the function of "lightning rods," which collect atmospheric electricity and facilitate the exchange of the charges of the air and the ground.

Thereupon he proceeded to submit the suspected effect of electricity upon vegetable growth to the test of experiment, beginning in 1885 with a number of flower pots containing similar soil and seed. Some of the pots were subjected to the action of an influence or inductive statical electric machine, one pole of which was connected with the soil in the pot, and the other with a wire netting stretched over it. The other pots were left to nature. The electric machine was driven several hours daily. Within a week the electrified plants showed a more vigorous growth than the others, and in eight weeks the disparity in weight, of grain and straw alike, amounted to forty per cent. This favorable result suggested a field experiment with barley, in which an increase of 37 per cent was obtained by electrification. In the following year the experiments were extended to various plants. The results were contradictory in some respects, and showed that the advantage derivable from electroculture depends also upon other factors, such as temperature, moisture of air and soil, and the natural fertility and the manuring of the latter. The supply of water proved to be of especial importance. Extensive experiments with potatoes, carrots, and celery showed increases in crop of from 30 to 70 per cent. Potted strawberry plants, in the greenhouse, produced ripe fruit, under electrical influence, in half the usual time. Small differences, possibly due to extraneous causes, appeared when the direction of the current was reversed. Other field experiments gave increases of 45, 55, occasionally 85 per cent for grain, and 95 per cent for raspberries, while cabbage, tobacco, flax, turnips, and peas grew better without electrification than with it.

Then Lemstrom, in order to test the effect of climate on electro-culture, transferred his experiments from Finland to Burgundy, where he found his earlier observations confirmed, particularly in regard to the great influence of irrigation. He concluded that the more vigorous growth induced by electricity must be sustained by a rapid ingestion of food, that is to say—a rich soil being presupposed—by an abundant supply of water. With copious watering peas, which in the earlier experiments had reacted unfavorably to electrification, now showed a difference of 75 per cent in favor of the electrified plants, carrots gave an increase of 125 per cent, and sugar beets augmented their percentage of sugar by 15 per cent. The experiments in Burgundy also confirmed the importance of the character of the soil. The richer the soil, the greater is the advantage of electrical culture, which is quite useless in very poor ground. Hence, the Sahara cannot be converted into a garden by electro-culture.

In 1888 Lemstrom's experiments ceased for a time, but other investigators attacked the problem from a different side, endeavoring to affect by electrification, not the growing plant, but the seed. The Russian botanist, Spechniew, submitted grain to electrical action, and thought that it sprouted earlier and more vigorously than grain not so treated. Pautens, who in 1894 repeated Spechniew's experiments on a larger scale, came to the conclusion that electricity had no effect on dry seeds, but that it promised excellent results when applied in connection with moisture—which in itself promotes germination. The same conclusion was reached by Kermey, who in 1897 electrified grain strewn on moist sand in a glass cylinder through which it could be observed. The metal top and bottom of the cylinder were connected to the poles of a galvanic battery.

But while electrical treatment of dry grain is comparatively simple and cheap, electrification during germination is even more difficult and costly than the application of electroculture to the growing plant. Grandeau and Leclerq, therefore, returned to the latter method, but, instead of using an artificial source, they studied the effect of atmospheric electricity by covering part of a field with wire netting. The uncovered plants showed an increase of 50 or 60 per cent in growth and fruitfulness over the plants which were shielded by the netting from natural electrical action.

In 1898 Lemstrom resumed his experiments with the aid of an improved electrical machine and distributing apparatus. Again he observed remarkable increases of crop—with tobacco 40, potatoes 50, peas 56, sugar beets 40, carrots 37, grain 25 to 30 per cent. Spechniew and Bertholon obtained similar results.

As it is not practicable to cover fields with electrified nets, and as the influence of atmospheric electricity had been proved, Lagrange and Paulins have recently sought to increase the supply of the latter by setting among the plants galvanized iron rods to serve as conductors, and have thus obtained great increase in crops. This, as well as other methods of electroculture, is probably too expensive to be applied to ordinary field crops.

But in the cultivation of fruits and vegetables, particularly under glass, the economic conditions are very different. For, as electroculture promises not only greater, but also earlier crops, which command high prices, its introduction would secure to local gardeners large sums which now go to the South and would, at the same time, benefit consumers by reducing prices somewhat, though leaving them still remunerative. Floriculture offers another promising field for the application of electrical methods.

All this, however, belongs to the future. Much study and experiment and probably many failures must precede the general introduction of electroculture, though the results already obtained are certainly promising.

In what way is the growth of plants affected by electricity? Plants transform the energy of the sun's rays into chemical energy. Though the heat produced by the electric current may have some direct effect, especially in germination, the electrical energy supplied cannot, in general, replace or even greatly reinforce the energy of sunshine. It is rather to be regarded as a stimulus to metabolism and all the vital processes. One of these is the capillary elevation of water, which is promoted by a positive electric current flowing upward. This is one possible explanation of the promotion of growth by electricity, and though in some cases the best effect is obtained by directing the positive current downward, or in the opposite direction to the assumed principal flow of sap, these exceptions may mean that more food is supplied by the leaves than is commonly supposed. Another possibility is an increase in activity in both leaves and roots. The electrical influence on the flow of sap, however, appears to be proved by the fact that electroculture is beneficial only in connection with an abundant supply of water. According to Kermey, there is also an electrolysis of water within the plant, and further experiment may prove the existence of other electrical actions.

SCI. AMER. JUNE 10 1905

ELECTRO-CULTURE

8.5 ELECTRIC FIELD EFFECTS ON PLANT LIFE

Several studies illustrate the use of relatively str... electric fields to affect the viability of seeds during storage and seed germination, or to influence the growth of plants. Pammenter et al. (1974) reported that stored seeds subjected to an artificial aging process progressively lose the ability to germinate, so that after 30 days of treatment only 10% of the seeds are viable. However, by placing the seeds on an electrode at 300 volts the germination rate after the 30-day aging treatment was improved to about 70%. The data demonstrate that a substantial improvement in seed viability occurs for all degrees of aging and that the protected seeds also show a lower percentage of chromosomal abnormalities. These effects are attributed to a form of "cathodic protection" in that the electrode provides electrons to react with the free radicals and thus inhibit the normal course of lipid peroxidation by which, it is believed, the cell membrane is destroyed in both artificial and natural aging processes.

Sidaway (1968) examined the germination of seeds in an electrostatic field of 36 kV/m and came to the conclusion that a field with the positive pole above the seeds inhibits germination and, to a lesser extent, the negative pole above improves the rate of germination.

Murr (1964; 1965) studied the destructive effects which occur in plants grown in fields of 20 - 80 kV/m (DC) created by a plate located above the ground in which the plants were rooted. The leafy tips of grass plants were injured or killed by this strong electrostatic field, which was intensified to much higher surface field values at the leaf tip. From his studies, Murr finds a surface field of 110 - 130 kV/m is about the threshold for destructive effects in these plants. Murr (1964) speculates that the mechanism by which the plants are injured involves an acceleration of enzyme activity leading to impaired cell respiration and further destructive events.

M. W. Miller (1974) exposed the roots of the mung bean plant (Vicia faba) to electric or magnetic fields at 75 Hz wich no indication of an effect on either growth or mitotic index. No chromosomal anomalies were seen. The electric field exposure was made in a plastic tank filled with a plant nutrient solution in which there was a current of 0.1 A/m^2 and an electric field of 10 V/m. The control plants were in a similar tank for which the electrodes were not energized. The magnetic field experiments were conducted at 0.5, 5, and 17 G in plastic cylinders containing the plants in a liquid nutrient medium and wrapped with electrical wire. The authors cite other "well-documented" research (Beischer, 1965; Audus and Whish, 1964; Dunlop and Schmidt, 1969; Mericle et al., 1964) at higher field strengths (from several hundred to several thousand gauss) which did find effects on plant growth and the mitotic index, but in view of the

4:30 DYCUS, A. M., and ALICE J. SHULTZ. Arizona State University, Tempe. A survey of the effects of magnetic environments on seed germination and early growth. Plant Physiology 39:29

Seed of twenty different species of plants commonly used in laboratory courses were grown in magnetic environments ranging from a nulled region (magnetic quiet) of 0 to 25 milligauss to a permanent magnet of 6000 gauss strength. The majority of the seed germinated faster and produced larger tops and roots after two weeks in the magnetic quiet region. The cucumbers and radish plants maintained this increased rate of growth for the duration of the experiment.

Some seed showed a faster germination rate in the geomagnetic field and maintained the accelerated rate throughout the experiment. Two weeks after germination, corn, barley and vetch, while starting slower in the geomagnetic field, showed a marked increased rate of growth, as compared to plants in the nulled field.

Seeds placed in the strong magnetic fields generally were slower to germinate and did not maintain the rate of growth shown by the plants in the geomagnetic and nulled fields. Germination in the strong magnetic fields was influenced by the position of the axis of the seed relative to the lines of force of the field. When the long axis of some of the seed was placed at right angles to the lines of force the rate of growth was much slower than the rate for the seed placed with the long axis parallel to the lines of force. However, Coleus cuttings showed a marked increase in root growth in magnetic field of 2000 gauss strength. The number of roots and the length of the roots were both greater in the magnetic field than on similar cuttings in the nulled field or the geomagnetic field. There was no apparent effect on the top growth of the Coleus cuttings.

MURR, L.E.: Nature 201 (4926):1305-6 (Mar. 28, 1964)

Mechanism of Plant-Cell Damage in an Electrostatic Field

Electrical stimulation of plant growth produces increased concentrations of minor elements (Fe, Zn, Al) in active leaf tips. Compared to controls, such increases are of the order of several hundred per cent. This is due to an increase in metabolic oligo-enzymes in the electrically-activated plants, which appear greener because ozone generated by electrical field oxidizes porphyrins, resulting in deep-green, open-ringed molecules of these or similar metallo-enzymes. Under the influence of an excessive ele trical field, the activity of these substances is accelerated to such an extent that cellular respiration is impeded, with resultant cell deterioration and tissue destruction.