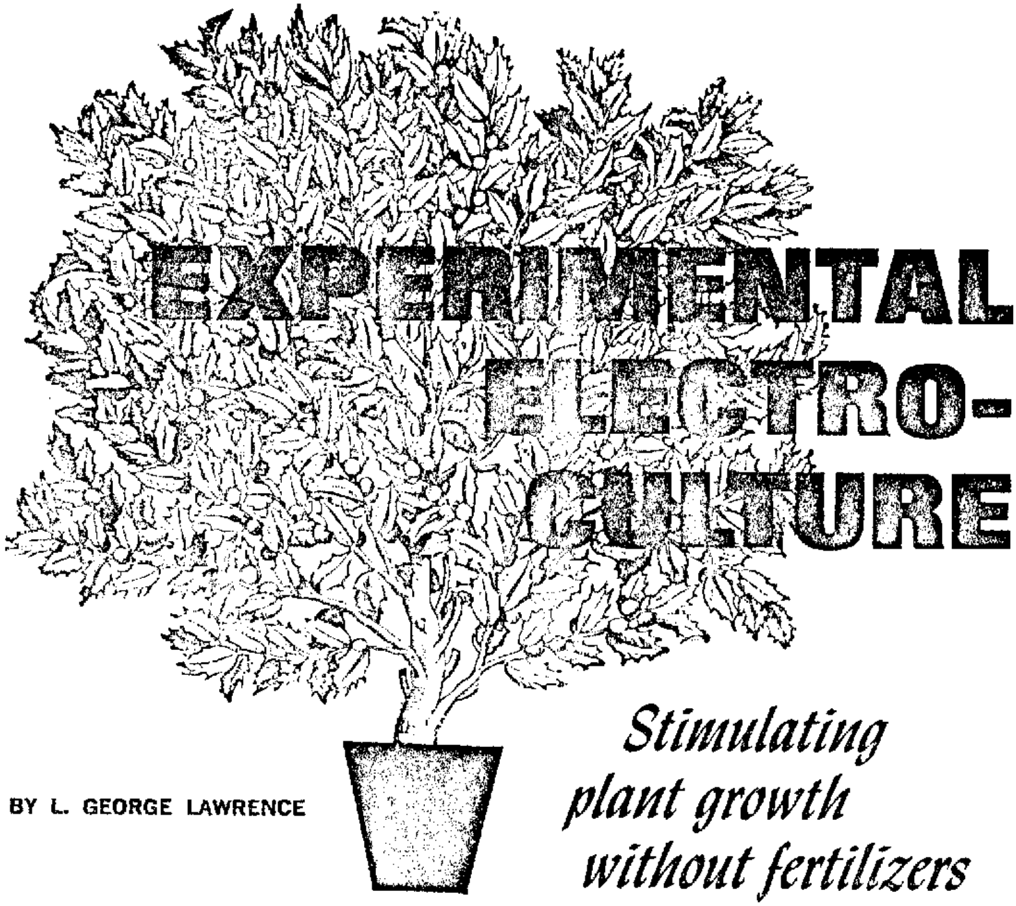
EXPERIMENTAL ELECTRO-CULTURE



Stimulating plant growth without fertilizers

BY L. GEORGE LAWRENCE

This is an experimental arrangement developed by the author to test certain theories relative to stimulating plant growth in a very high voltage electrostatic field. Details on the equipment built for the experiment are detailed and some of the background on the "why" of electro-culture is discussed.

HANGING your pet geranium upside down in the cellar all winter isn't necessarily all it takes to grow a beautiful plant next spring. Of course, amateur horticulturists—as well as professionals—have any number of theories about how you can automatically have a green thumb; but several historical and many more recent experiments have shown that successful gardening isn't just a matter of fertilizing, watering, and tender loving care.

Indeed, only a handful of people realize the role that natural electricity plays in the development of plant life. Yet, in 1902, physics professor S. Lemstroem, after a trip to the northern polar regions, decided that the rapid growth of vegetation during the short arctic summer was due to the unique electrical conditions of the atmosphere in those latitudes. Back in his laboratory, Professor Lemstroem reproduced the assumed arctic conditions by increasing the atmospheric current (which normally flows from the air to the plant) by placing a wire with a high static charge on it (generated by a Wimshurst machine) over a plant. An increase in plant yield was noticed.

Study of electro-culture (as the science is called) began with basic experiments by a Dr. Mambray in England in 1746. Later, in 1879, a French scientist, L. Grandeau, saw dramatic possibilities in the field which he described in a paper "Influence de l'Electricite Atmospherique sur la Nutrition des Vege-

Jaux." But the real break came in 1902 with the Lemstroem experiments.

In more recent times, other experimenters extended the work to treatment of viable seeds using radio-frequency and ultrasonic methods. The r-f techniques involved frequencies above 30 MHz applied for a few seconds to seed bags placed into r-f tank circuits. Ultrasonic schemes involved the brief dipping of bags into baths agitated at frequencies up to 1 MHz. Plants grown from seeds treated in this way had yield profiles ranging from fair to excellent.

Fertilizers Spoil Picture. It was the invention and use of cheap chemical fertilizers that effectively suppressed electro-cultural engineering. Today, however, we are in the position where nitrate pollution by these very fertilizers threatens not only our water supply but the entire ecological panorama as well. Thus it would appear that the revival of electro-culture is not only desirable but imminently necessary.

Experimenting with electro-culture is hardly the same as building a stereo amplifier or a digital voltmeter. For one thing, high, static voltages are involved and a good degree of professionalism is required to obtain good results. (Keep in mind that we are concerned with living plants, which have their own peculiarities and may not *always* respond as expected —only large-scale trends are important.)

Typical electro-culture systems frequently operate unattended for long periods of time in an open-air environment. This requires heavy-duty construction in both the electrical and mechanical aspects of the equipment.

MORE INFORMATION?

See:

"Electronics and the Living Plant," L. G. Lawrence, *Electronics World*, October 1969.

Plant Physiology, E. C. Miller, McGraw-Hill Book Co., New York, 1938.

However, expenditures can be kept low by using surplus-type materials. In the case of an experimental electro-culture system using high-voltage discharge, the cost of a typical exciter unit can be below $35.00.

Basic System. A schematic of a Lemstroem type of electro-culture system is shown in Fig. 1. Here, the positive terminal of the high-voltage power supply is connected to the overhead wire, with current return through a ground path. Potentials are as high as 20,000 volts—up to 60,000 volts for short periods of time. While natural atmospheric currents range between 10^{-16} and 10^{-15} amperes, the excitation provided by the high-voltage wire provides currents around 10^{-12} or 10^{-11} A, as measured by a sensitive electrometer. In open-air experimental fields, the height of the overhead discharge wires with respect to ground may be from 3 to 10 feet. The height above ground naturally affects the amount of atmospheric current. Remember that the high voltage essentially serves as a "current carrier"—appropriate current values cannot be generated under other than high-tension conditions.

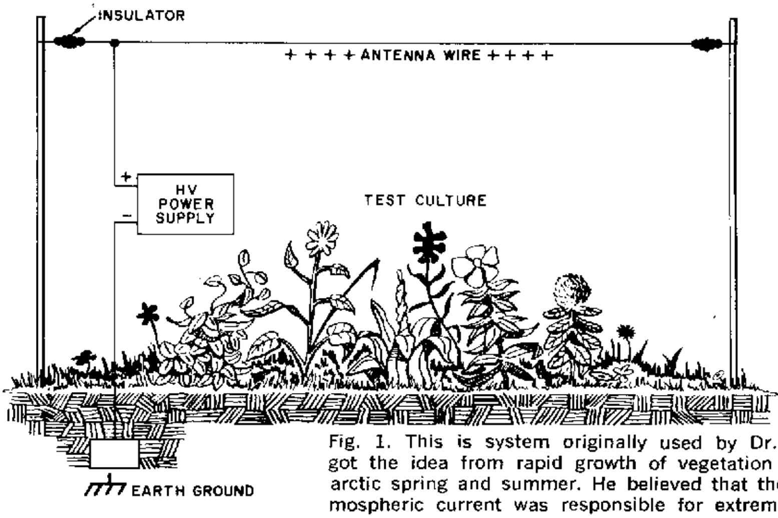


Fig. 1. This is system originally used by Dr. Lemstroem who got the idea from rapid growth of vegetation during the short arctic spring and summer. He believed that the natural high atmospheric current was responsible for extremely rapid growth.

Fig. 2. Provision must be made to prevent animals, children, or strangers from touching the high-voltage lead. A simple wooden barrier is sufficient.

High-voltage electro-culture systems may take the form shown in Fig. 2. The apparatus was designed to investigate the susceptibility of many different plants to stimulation. The equipment generates ozone (O_3) and must be used in well-ventilated areas only.

An electrical schematic of this system is shown in Fig. 3. Transformer *T1* has an output of 3000 volts rms. After rectification, the effective dc is approximately 4200 volts. A dropping resistor may be necessary on the filament winding to obtain the correct voltage for the rectifier. If leakage current in the reverse mode can be tolerated, a high-voltage rectifier diode may be used instead of the tube and filament winding.

The 3000 volts dc generated is highly dangerous to touch.

Resistor *R1* (made up of several resistors in series) serves as a current limiter and can be anywhere from 5 to 20 megohms, the latter value limiting the current to 210 μA in the event of an accidental short circuit. Resistor *R1* may be in series with either the positive or negative output terminal.

Resistor *R2* is connected to two pieces of high-voltage cable with the connections and resistor thoroughly wrapped with high-voltage insulation so that the resistor is actually imbedded in the cable. Put insulated alligator clips on each end of the cable. This resistor forms a safety discharge shunt and *must* be

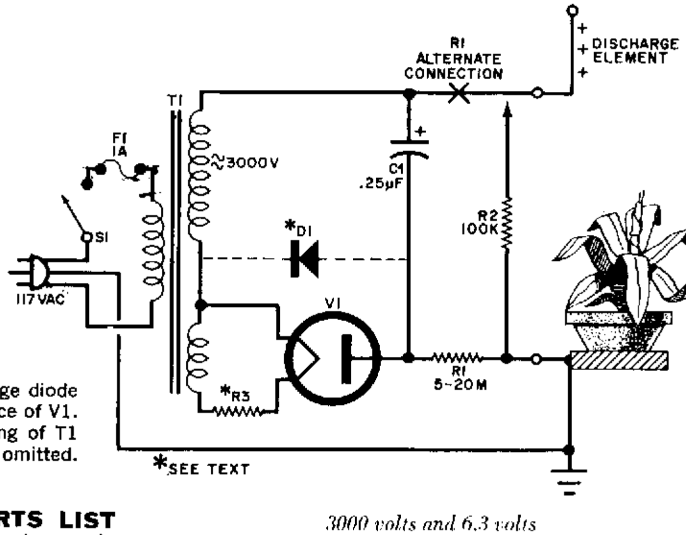


Fig. 3. A high-voltage diode may be used in place of V1. The filament winding of T1 and R3 can then be omitted.

PARTS LIST

C1—0.25-μF, 7500-volt capacitor
F1—1-ampere fuse with holder
R1—5-to-20-megohm resistor (see text, ½-watt each)
R2—100,000-ohm, 2-watt resistor
R3—See text
S1—Spst slide or toggle switch
T1—Oscilloscope transformer; secondaries: 3000 volts and 6.3 volts
V1—Half-wave, high-voltage rectifier tube
Note—Alternate rectifier diode D1 (IR 67 D-050H55FNN) can be used as shown by dotted line. See text.
Misc.—Large plastic container, 3-lead power line, mounting plate, insulators, high-voltage cable (10-kV test), hookup wire, hardware, ground plate for pot.


DANGER

connected across the output terminals when the apparatus is shut off to discharge capacitor *C1* and the antenna structure ("discharge element" in Fig. 3).

The power supply's physical layout is shown in Fig. 4. For safety's sake and good appearance, the entire power unit is mounted on the lid of a plastic camping chest. Ceramic insulators are fastened to the lid to provide connections for the discharge element and ground wires. A simple ground electrode is inserted into the moist dirt (earth mixed with moss is good) in the pot and the pot sits in a metallic basket which is connected to the negative terminal of the supply. The antenna or discharge element is connected to the positive terminal and consists of a simple metal rod.

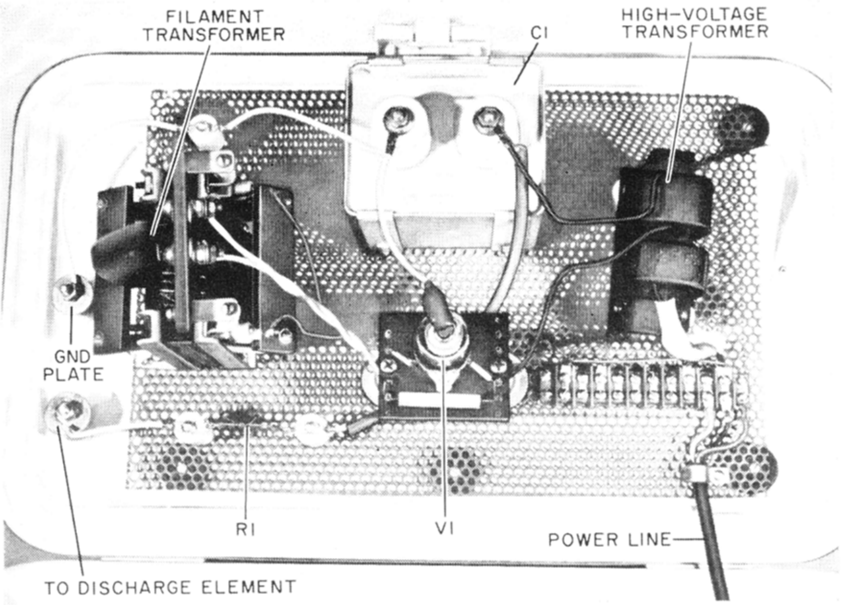
The 117-volt line cord is a grounded 3-wire type, with the green (ground) wire connected to the perforated-steel mounting plate on which the plant basket sits. The high-voltage transformer is mounted on insulators and the rectifier tube socket is mounted on insulators on a bakelite terminal board. The string of resistors comprising *R1* is fastened to standoff insulators of the ceramic type. In the model shown in Fig. 4, a separate transformer was used for the tube filament supply with dropping resistor *R3* mounted on the bakelite terminal board. The entire high-voltage section is wired with high-voltage cable tested to 10,000 volts dc.

R-F High-Voltage Supply. A schematic for a radio-frequency high-voltage unit is shown in Fig. 5. It is an inexpensive and slightly less dangerous alternate to the supply described above.

Effective dc output of this supply is 5000 volts at 200 microamperes maximum. Thus, should the supply's output electrodes be touched accidentally, an unpleasant, but nonlethal, shock will be experienced.

Electronically, the supply is comprised of a straightforward feedback oscillator. Optimum oscillator frequency is approximately 225 kHz. Tube *V2* is a half-wave rectifier. The supply may be constructed on a simple chassis and installed in a manner similar to the one shown in Fig. 2.

Note, however, that the transformer specified for *T1* does not have a filament winding for the rectifier. A filament loop may be added simply by placing one turn of No. 20 insulated high-voltage wire around *T1*'s ceramic base, being careful to maintain spacing from the tuned r-f circuit. (Follow the instructions packaged with the transformer.) A VTVM or similar high-impedance meter my be used to measure output voltages without excessive



Because the relatively weak plastic chest cover will not support much weight, a perforated metal base plate is used to mount the heavy components. Feedthroughs are used to couple to the "antenna" and the main ground plane that supports the flower pot.

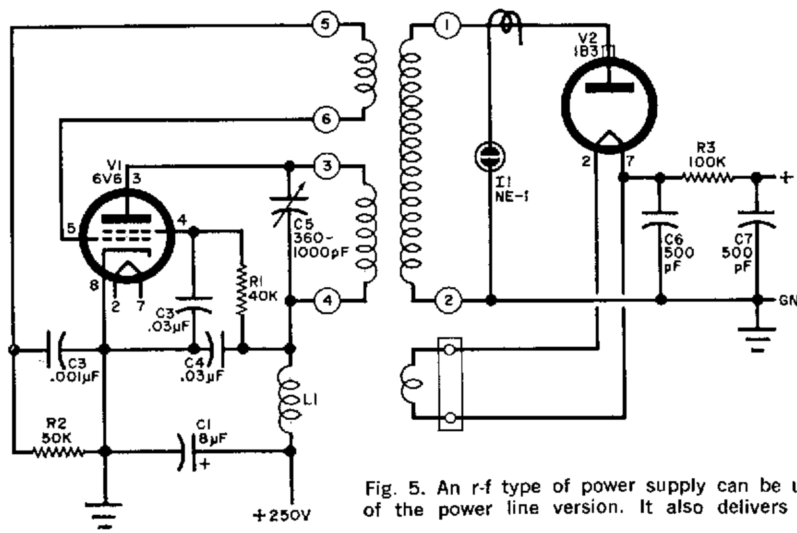


Fig. 5. An r-f type of power supply can be used instead of the power line version. It also delivers 5000 volts.

PARTS LIST

C1—8-μF, 350-volt electrolytic capacitor
C2,C4—0.03-μF, 600-volt capacitor
C3—0.001-μF, 600-volt capacitor
C5—360-1000-pF tuning capacitor (J.W. Miller 160-A or similar)
C6,C7—500-pF, 10-kV capacitors (TV type)
I1—NE-1 neon lamp
L1—2.5-mH r-f choke (J.W. Miller 4537 or similar)
R1—40,000-ohm, 1-watt resistor
R2—50,000-ohm, 1-watt resistor
R3—100-000-ohm, 1-watt resistor
T1—High-voltage, r-f transformer (J.W. Miller 4525 or similar)
V1—6V6 tube
V2—1B3 tube
Misc.—Suitable high-voltage and filament supply, insulated chassis, tube sockets, high-voltage wire for 1B3 filament winding (see text), cap for 1B3.

loading. After wiring is complete, remove rectifier tube *V2* and adjust the oscillator for maximum output power by tuning capacitor *C5* with an insulated alignment tool. Place a "gimmick" or single-turn coupling loop with a neon lamp on the output of *T1* as shown in Fig. 5 and tune the circuit until the lamp attains maximum brilliance. Remove the neon lamp and gimmick after tuning is complete. In operation, it is proper for the filament of the 1B3-GT to glow a dull red.

Safety Precautions. Due to the inherent shock hazards involved in either of the systems described here, they should be operated behind a simple wooden barrier marked to keep away "unauthorized personnel." The experiment may then be operated near a window or other well-lit area indoors.

The equipment may also be operated outdoors, preferably in a fenced-in private garden, provided it is protected from rain and moisture and the proper precautionary measures are employed. With component values shown, an "antenna" height of three feet is suggested—depending on local wind conditions and ambient aerobic moisture content.

When it is necessary to work on a plant or water it, turn off the power and connect safety shunt *R2* across the high-voltage terminals. When watering, avoid wetting the electronic equipment and the high-voltage discharge element. When you are through working on the plant, remove the safety shunt, get out of the way, and turn the power back on.

Always keep safety uppermost in your mind. Physically protect the electro-culture experiment from strangers, children and animals.

What Can You Expect? According to data advanced by Dr. K. Stern and others, a true increase in yield of 45 percent for a well-cultivated field can be expected. Yield differences are determined by comparing results against non-treated control cultures of the same type. Some plants give very low yield

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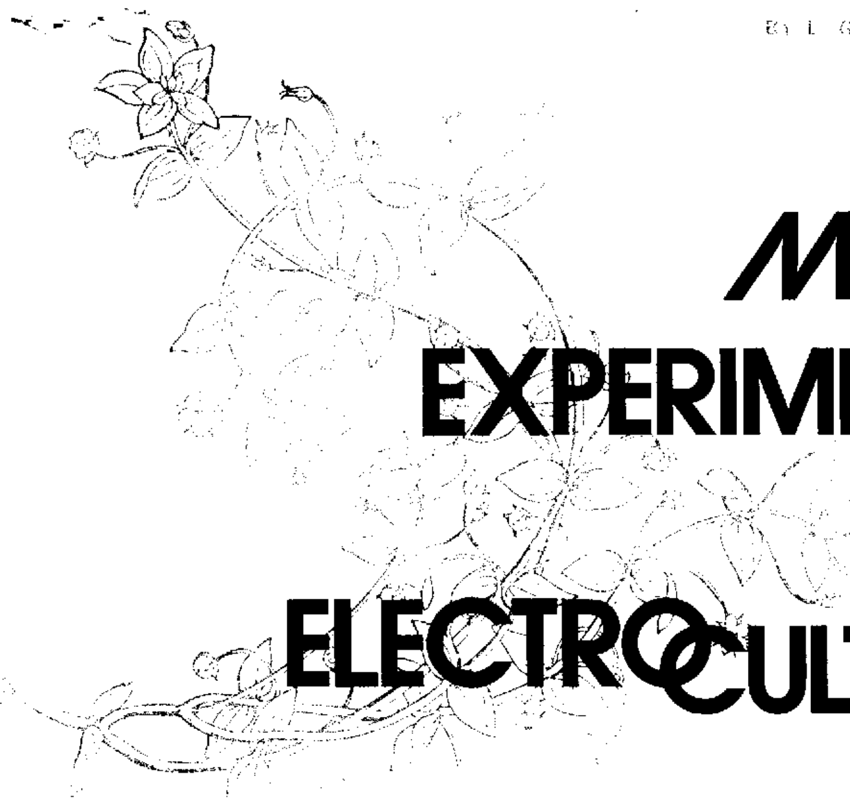
unless well-watered. Peas and carrots are in this group. Further, electric treatment must be stopped if days are hot and sunny. A simple photoelectric relay circuit, connected in series with the power line, provides adequate control for this purpose.

Note that plants are mavericks in many ways and do not necessarily show uniform yield patterns. Electronically speaking, being living organisms, species utilize the energy contained in the phosphate bonds of adenosine triphosphate (ATP) to drive reactions which lead to maintenance and growth of cells, tissues, etc. This ATP is produced from adenosine diphosphate (ADP) by processes involved in aerobic respiration, fermentation, and electromagnetic bionuclear constituents of photosynthesis. In many ways, plants are *organic* semiconductors and apparently feature electron transport systems which, in higher plant mitochondria, are exactly the same as those for animal mitochondria in ways of generating enzymes.

However, taken together, science has only a vague idea why plants react to applied electro-culture and related methods mentioned earlier. The field is wide open for experimentation and improvement, and it certainly has exceptional hopes for the future. —30—

BY L. GEORGE LAWRENCE



MORE EXPERIMENTS IN ELECTROCULTURE

EXPERIMENTING on living organisms is exciting and—as history shows—often rewarding. But there just aren't many people, dogs, birds, fish, etc., that you can (or would want to) subject to tests to determine such things as emotional reactions, nervous response, or sensorial perception. So, how about plants? They are after all, living things, and there are many indications that when stimulated, they have sensitive, sensible reactions which can be measured on ordinary electronic equipment. Before going into the details of the equipment (which you can build for yourself), let's get to know a little more about plants and how they tick.

Do They Just Sit? On first thought, plants appear to be quite remote from life as we know it. Their sedentary existence stands in strong contrast to energetic animals, which are endowed with a massive inventory of sensory capacities, fast reflex movements, and many active organs.

However, recent research has revealed that many of the same environmental factors and stimulations that affect animals also affect plants. Of course, here we find modified abilities to sense, feel, and react. Also, since a plant cannot run away from a threat to its existence, it would appear that special internal forces are set in motion to protect the organism from shock and possible death. These phenomena are akin to states of anxiety in animals and are evidenced by changes in the plant's psychogalvanic or electric states which occur in threatening situations. The recently discovered "Backster Effect," seems to provide evidence that plants have some ability to function in a mode of supersensory perception. This, of course, invites a host of exciting and unique investigations.

However, prior to engaging in plant-ori-

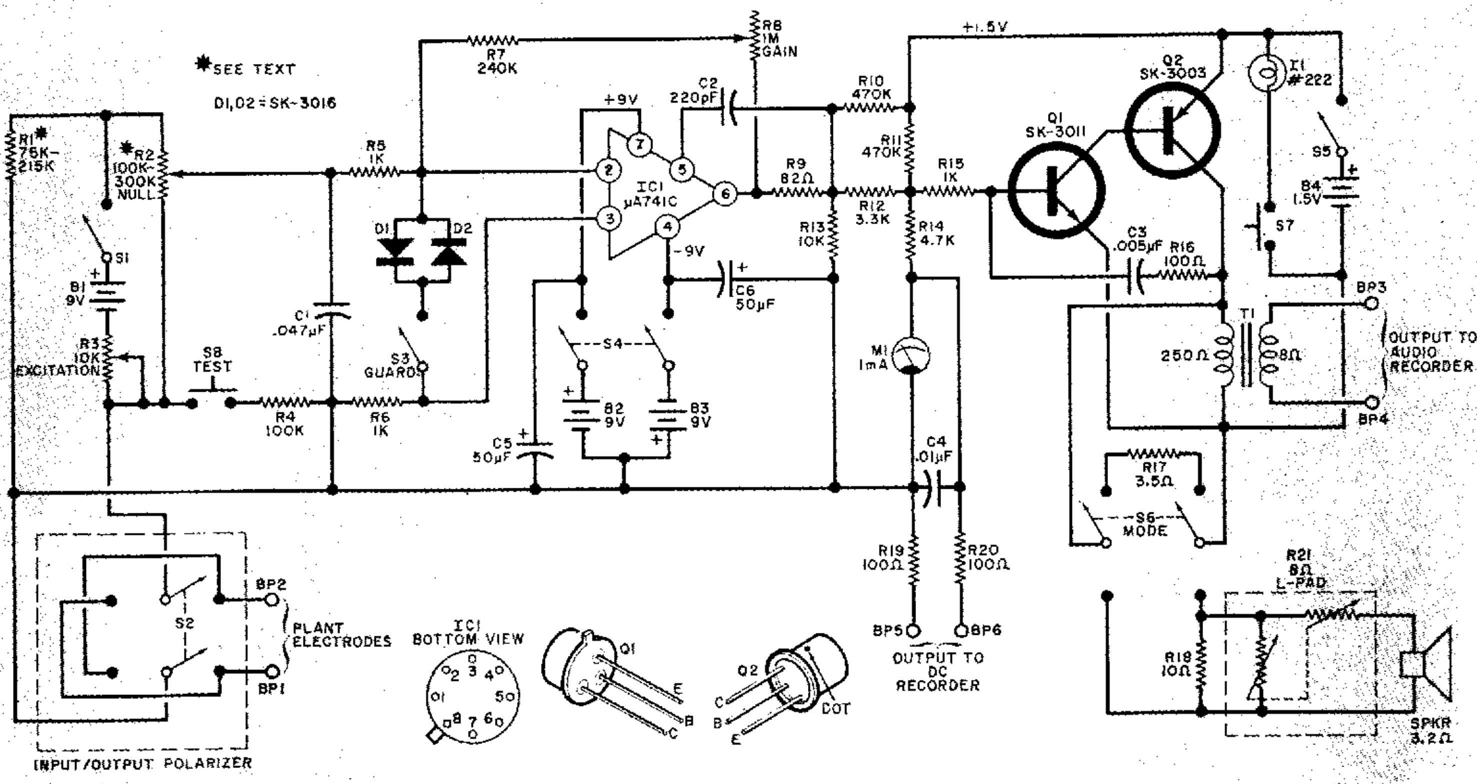


Fig. 1. If desired, the circuit can be terminated at meter M1 if you just want meter readout, or you can drive the audio oscillator with headphones connected to the 8-ohm output and the meter out of the circuit. However, for maximum versatility, the entire circuit can be built and both an audio and dc recorder used.

ented experiments, you should realize that living systems frequently produce maverick results. While a plant may be regarded as an organic semiconductor having variable resistance and self-generating properties, it also has elements of apparent cellular consciousness. Electronic and mechanical response profiles are not uniform.

Some plants (such as the *Mimosa Pudica*) react rapidly; others give no discernable reactions to stimuli and still others exhibit strangely delayed responses. Remember that typical electrical signals provided by plants are in the low millivolt/microampere range. The equipment described here for making experiments should give you a good start, but for some extremely sensitive tests, you should avail yourself of an ultra-high-gain electrometer with input impedances of 10^{10} ohms or higher.

Another factor to remember is the importance of repetition. If, for example, a plant specimen is stimulated continuously, badly injured by burns or cuts, infrequently watered, etc., it is bound to tire quickly, perhaps lapse into shock and die. Terminal conditions are indicated by wilting, and discoloration usually forecasts death. Depending on the plant's overall chemistry and the amount of moisture retained in leaves and stem structures, a dead specimen is little else than a simple conductor of the carbon type and no psychogalvanic response of any kind should be expected. In short, be gentle and allow plants to recuperate after they have served your purpose.

Some 350,000 plant species are known to science. At this time, we have no concise information as to which group is psychogalvanically superior to others. In general, however, it has been discovered (Lund, 1931) that the distribution of gradients of electrical potentials in large plants (such as trees) is more complex than in small plants. Apparently, each individual cell in a plant is electrically polarized and acts as a tiny, variable battery. The electrical potentials occurring in tissues are summation effects of the potentials of individual cells which may act either in series or in parallel (Rosene, 1935). Various mechanisms of correlation are involved here; but, as you are bound to discover, there is no complete uniformity from one specimen to the next, either in looks or reactions.

Plant Response Detector. The basic instrument for plant experimentation is a response detector whose schematic is shown in Fig. 1. The detector has both visual (meter) and acoustical (speaker) indications of plant reaction. The audio tone output can also be

TRANSMITTER EFFECT

The behavior of plants in strong r-f fields has been studied only superficially. Although excessive energy levels induce heating and death and although plants are (electrically speaking) dc-oriented organisms, they nevertheless incorporate mechanisms which allow them to survive in the immediate vicinity of high-power radio transmitters of all types. To our knowledge, no tests have been performed to detect psychogalvanic behavior in plants under these conditions.

PARTS LIST

B1-B3—9-volt battery
B4—1.5-volt D battery
BP1-BP6—Five-way binding post
C1—0.047-µF capacitor
C2—220-pF capacitor
C3—0.005-µF capacitor
C4—0.01-µF capacitor
C5,C6—50-µF, 10-volt electrolytic capacitor
D1,D2—Silicon diode (RCA SK-3016)
I1—2.2-volt lamp (222)
IC1—Op amp IC (Fairchild µA741C)
M1—1-mA dc meter (Calectro D1-912 or similar)
Q1—Transistor (RCA SK3011)
Q2—Transistor (RCA SK3003)
R1—75,000-ohm resistor (see text)
R2—100,000-ohm linear potentiometer (see text)
R3—10,000-ohm linear potentiometer
R4—100,000-ohm resistor
R5,R6,R15—1000-ohm resistor
R7—240,000-ohm resistor
R8—1-megohm linear potentiometer
R9—82-ohm resistor
R10,R11—470,000-ohm resistor
R12—3300-ohm resistor
R13—10,000-ohm resistor
R14—4700-ohm resistor
R16,R19,R20—100-ohm resistor
R17—3.5-ohm, 1-watt resistor
R18—10-ohm resistor
R21—8-ohm potentiometer L pad
S1,S3,S5—Spst switch
S2,S6—Dpdt switch
S4—Dpst switch
S7,S8—Normally open pushbutton switch
T1—Audio transformer; 250/8-ohm, 200-mW (Calectro D1-726 or similar)
Misc.—Suitable chassis and cabinet, battery holders, pilot-lamp mounting assembly, clamp support, machine clamp, clamp insulators, metal electrodes, twin shielded lead, rubber feet, plastic pot for plant, knobs, mounting hardware, etc.
Note—The µA741C op amp is available from PolyPaks, PO Box 942W, Lynnfield, MA 01940, for $2.98.

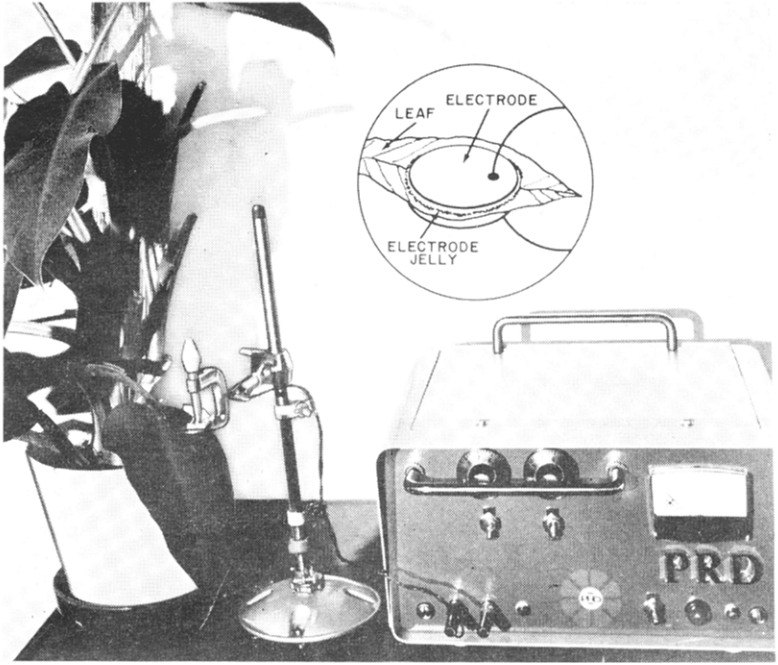


Fig. 2. Leaf contact is made through a highly conductive metal disc and electrode jelly of the same type used by physicians to make medical electronic tests. Take care not to crush the leaf when making the contact, and use a stable support system.

connected to a conventional audio tape recorder and a pen-type recorder can be connected to the dc amplifier output to make permanent records of results.

The schematic is divided into four operational sections: the Wheatstone bridge input with exciter and input-output polarizer; an op amp guard circuit having a disabling feature; a high-gain dc operational amplifier; and an audio tone generator whose frequency varies with the potential generated in the plant. The op amp used has a large-signal gain of 100,000 and has built-in short circuit protection.

The circuit can be assembled on perf board or a printed circuit board. Be careful to avoid heat damage when soldering the IC and other semiconductors. Observe the polarity of the electrolytic capacitor. Either a well-filtered dual 9-volt power supply or 9-volt batteries may be used for the power source. Use a suitable metal chassis to house the detector, with the meter and all controls on the front panel.

Connections to Plant. The pickup electrodes which are attached to the plant (see Fig. 2) can be of almost any shape and any metal that has good conductivity. Stainless steel or silver electrode pairs will work very well. Use of dissimilar metals can cause undesirable electrolysis. The effective size of the electrodes can be determined experimentally, but normally would be less than one inch in diameter. If it is found that the leaf resistance is very high, a larger diameter on the electrodes is required. If the plant has thin, moist, semi-opaque leaves, a smaller electrode is used. Leaf conductance can be enhanced by using electrocardiographic electrode contact cream, such as ECG KONTAX (Cat. No. 391, Birtcher Corp., Los Angeles, CA 90032). It is water soluble and should be wiped off plant leaves after the experiment is complete. Give the leaf a good rinse after that. Connections to the electrodes are made through a shielded pair cable. The electrodes are insulated from the metal clamp by pieces of plastic with the leaf gently compressed between the electrodes. Using the bridge resistor values shown in Fig. 1, the resistance between the electrodes should not exceed 250,000 ohms. Also keep in mind that the plant generates a small current of its own which, depending on the setting of switch *S2*, is superimposed on the excitation current flowing in the circuit.

Theory of Circuit Design. The resistance of the plant leaf, connected to *BP1* and *BP2*, forms part of a Wheatstone bridge with the other arms formed by *R1* and the two portions of *R2*. Power for the bridge is supplied by *B1* controlled by *R3*. The final values of *R1* and *R2* are determined by the type of plant leaf being used. The resistances must be increased when the leaf is thin and sensitive to avoid over-excitation and undesirable side effects.

The input/output polarizer switch *S2* permits reversal of the current applied to the plant leaf since living matter tends to saturate and gradually cease to function as an organic resistor.

The offset signal from the bridge is amplified in *IC1*, which is guarded by diodes *D1* and *D2*. When *S3* is closed, these diodes limit the input voltage to the op amp and protect it from large signals. However, once the circuit is operational and maximum sensitivity is required after *M1* has been nulled, *S3* can be opened. The output of the dc amplifier

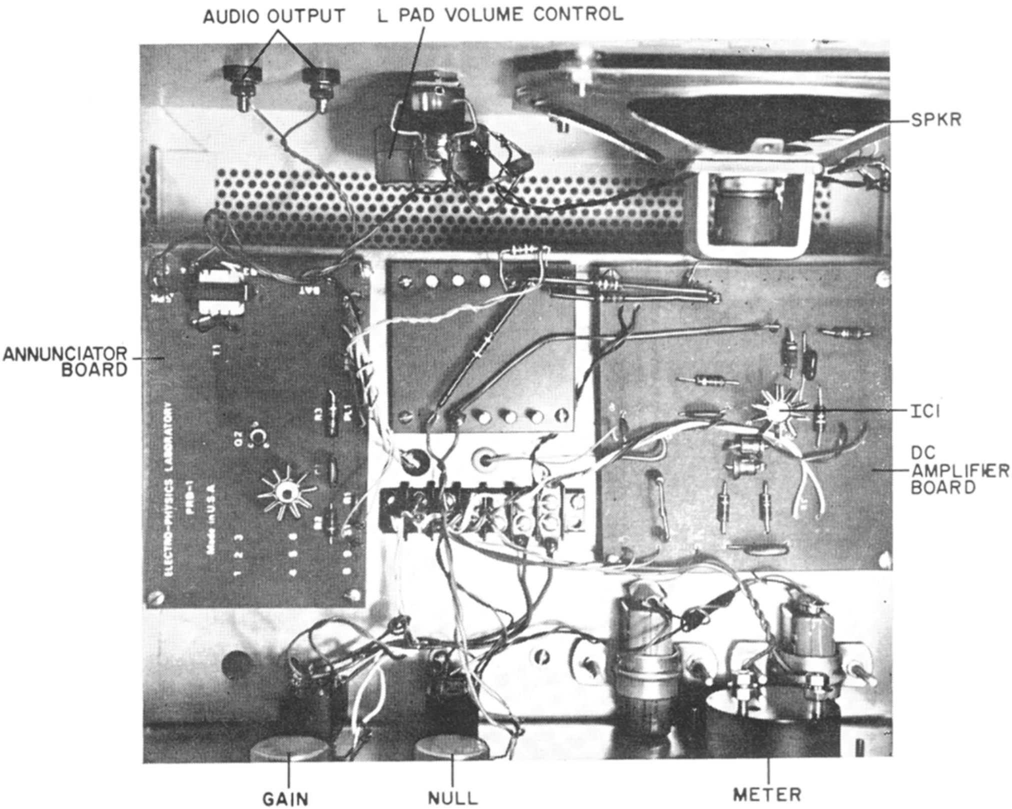
MAGNETO-TROPICISM

This phenomenon was discovered by Dr. L. J. Audus, of Bedford College, London, in 1959, and reported by him in "Nature" in 1960. This report clearly showed that plants are highly susceptible to electromagnetic fields.

In tests, a viable seed of any plant is inserted in a small plastic container which is then placed between the poles of a strong magnet (of the magnetron type). For control purposes, another similar seed and container are placed far away from the magnet but with all other conditions being the same.

The "magnetized" seedling should show some bending effects plus a more emphatic growth than the control specimen.

It is also possible to "quick-ripen" fruit with a 900-gauss magnet. For example, a number of tomatoes placed at various distances around the magnet poles (anywhere from 3 to 17 inches away) will show varying rates of ripening. Those closest to the magnet will be the first to turn red. Horticulturists at the University of Utah believe that the earth's magnetic field activates an enzyme system inside fruits and vegetables causing them to ripen and that a similar thing is caused artificially when the fruit is placed near a powerful magnet.



The prototype was constructed in sections on independent circuit boards, but any other physical arrangement may be used as well as any type of cabinet.

is indicated on a meter and can be used to drive a dc pen recorder if a permanent record is desired. The output also drives an audio oscillator (*Q1* and *Q2*) whose frequency is a function of the dc signal. Transformer *T1* couples the audio tone to an optional audio tape recorder and to an internal speaker. Capacitor *C3* and resistor *R16* provide feedback for the oscillator.

The circuit is sensitive to a few microamperes of input current, and when this current changes as a result of plant stimulation, the bias on *Q1* changes to alter the pitch of the oscillator. Indicator lamp *I1*, momentarily activated by pushbutton switch *S7*, permits intermittent tests of battery voltage and provides for the injection of cue markers on a tape recorder since the pitch increases when *S7* is activated. Power to the audio oscillator is controlled by switch *S5*.

Transformer *T1* provides an audio output for the tape recorder at all times regardless of the position of *S6*. In one position of *S6*, *R17* serves as a load; while in the other position, *R21*, an 8-ohm pad, is the load. Volume control is essential since the beep in the audio tone produced by *S7* is annoying to listen to and can produce an undesired stimulus to the plant.

While performing a particular experiment, the audio signal can be fed to one channel of a conventional stereo tape recorder, while the other channel is supplied with time markers (from WWV or CHU) or vocal announcements. This permits recording of vocal stimulus to the plant as well as the plant's response.

THE BACKSTER EFFECT

Cleve Backster, one of this country's leading authorities on the polygraph (lie detector) connected a pair of electrodes to a leaf of a *dracaena massangeana* while it was being watered. Surprisingly, the plant's psychogalvanic reaction pattern resembled that of a human subject exposed to emotional stimulation.

In further tests, Backster decided to ignite a match and burn the leaf to which the electrodes were attached. At the instant that the thought image occurred in his mind, a dramatic change appeared on the plant's polygraph readout. Tests were carried out on other living matter including paramecium, fresh fruits and vegetables, amoeba, mold cultures, scrapings from the roof of a human mouth, and yeast. All showed similar results. It would appear that there is an unknown communication between all living things, outside the orthodox electromagnetic spectrum. For example, placing plants in lead-lined, Faraday-screened cages, fails to suppress the phenomenon.

It also appears that plants form some sort of emotional attachment to their owners. Cleve Backster has reported that one plant responded to his emotional attitude at a distance of over 1000 miles. Obviously, much work remains to be done in this area.

Conducting Tests. In connecting the electrodes to the leaf, apply just enough pressure to make a good contact with the leaf without crushing it. Place the guard switch (*S3*) in the closed position to protect the IC from an excessive input signal.

When *S1* is turned on, power is applied to

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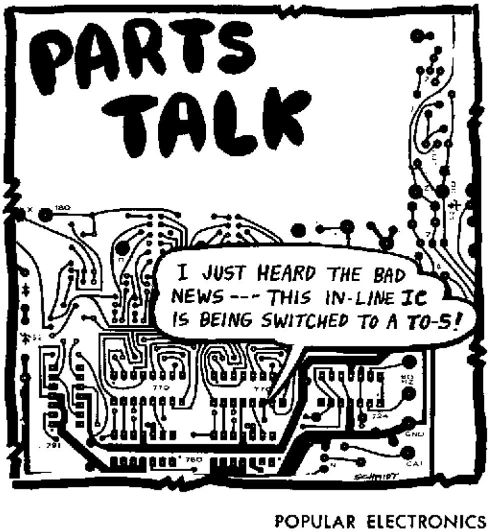
DC BOOSTER

In tests performed on a tree by the U. S. Department of Agriculture at the University of California in 1964, the application of about 58 volts dc (negative electrode high in the tree, positive attached to stainless steel nail driven in the base of the trunk) showed that leaf density on the electrified branches increased substantially after 28 days. Over a much longer period of time, the leaf growth was 300% over that on the non-electrified branches.

It was also noticed that when a sensitive dc voltmeter was connected between two conductors driven into a living branch (one at the center of a cut-off portion; the other in the layer just under the bark), cutting twigs or branches in any other part of the tree produced a sudden fluctuation on the meter. Even burning a leaf produced a noticeable effect. Not only did the natural voltage rise and fall; at times it even reversed polarity. There is no explanation for this effect.



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the bridge circuit at a level determined by *R3*. Then turn on *S4* to activate the op amp IC. Potentiometer *R2* is adjusted for a meter null indication. This null may have to be re-adjusted when the plant is in a non-stimulated condition. Note the pitch of the audio tone coming from the speaker when the plant is quiescent. A change in pitch, as well as in the meter indication, may result when the plant's well being is threatened.

The amount of excitation (via *R3*), and the state of the input/output polarizer switch *S2* must be determined by actual use. Obviously, the gain control (*R8*) can be adjusted to obtain more or less sensitivity, and *S3* can be opened to increase the gain of the dc amplifier.

There is very little more to be said about the use of the response detector. Patience and repetition are the key words. Obviously, also, controlled conditions are a must. The area in which the plant lives must be quiet so that stimuli can be applied. There should be a minimum of power-line noise to avoid fluctuations in the audio and meter indications. There should be no r-f transmitters in the vicinity to cause faulty indications. -30-

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