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Foliar-Fed Nutrients and Pulsed Sound Revisited

BY CHRIS BIRD

Treatment of plants and seed with the Sonic Bloom process—a combination of foliar-fed nutrients and pulsed sound—have appeared in previous issues of this paper. The purpose of the present article is to review some of the impressive results obtained by Dan Carlson's clients over the 1985 growing season in various parts of the American midwest, Florida, Arizona and, particularly, in northern New Mexico, San Juan Pueblo, an Indian community not far from Santa Fe. In the last instance master gardener Gabriel Howearth conducted meticulous field tests on five crops: peppers, tomatoes, melons, corn and amaranth.

ALFALFA

Harold Aungst, a McVeytown, Pennsylvania dairy farmer, had a chance to win the state-wide contest for alfalfa tonnage per acre. Aungst showed me photographs of his alfalfa field with plants measuring five feet tall.

The official report of the 1985 Pennsylvania Alfalfa Growers' Program, sponsored by the state's Grassland Council and the State University at College Station, became available in February 1986. With 7.61 tons of alfalfa per acre, produced with only three cuttings, Aungst won his regional five acre contest hands down over 93 other participants and with plants four years old, as against those only two years of age for many other participants. He came in third for "Total Digestible Nutrients (TDN)" as determined on a dry matter basis.

While many of Aungst's competitors achieved their yields ranging from 6.03 to 6.85 tons/acre only through the use of copious, and expensive, amounts of chemical fertilizers, Aungst's total costs for Carlson's nutrients were $50 per acre, which allowed him to realize an officially recorded *net profit* of $446.75 per acre. Furthermore, Aungst reported that, fed on the Carlsonized alfalfa, his cows used one-third less feed than previously while upping average milk production from 6800 to 7300 pounds per hundred weight per cow.

He has also noticed that his alfalfa plants were favorably stooling out, *i.e.*, sprouting heavy branch growth on the lower part of their stems, which in his eyes augured so well for the 1986 growing season that he confidently expects to achieve a yield this year of 10 to 12 tons per acre, or more.

Also successful with Carlson's method was Pennsylvania farmer Aaron Zimmerman, of Morrison's Cove (see *Acres U.,S.A.*, January, 1986) who produced bales of alfalfa each weighing 37½ pounds. On acreage treated with Sonic Bloom, Zimmerman realized 93 bales per acre as against only 37 bales on untreated land, or 3,487 pounds versus 1,387 pounds per acre. No less successful was Chip Struckmeyer, in hot Yuba City,California, who increased his previous alfalfa production by over 60% by spraying the last three of six cuttings, then, for the first time in his career adding a seventh cutting, the only one in the country. Struckmeyer grew up with chemical agriculture, and he knows its successes and its failures, and its legacy. His march to a different drummer was a reasoned reaction.

CORN

Corn growers also have come up with impressive results. After treating a hybrid field variety with Sonic Bloom during a growing season that included six weeks without a drop of rain, Jim Blake in Dorchester, Iowa, achieved from 97 to 130 bushels per acre, whereas his neighbors for miles around were averaging only 85 bushels per acre. In a hand-written testimonial, Blake reported: "49 acres were planted on May 7 and 8 in freshly plowed alfalfa sod ground. All acres were sprayed on May 21 with one gallon of liquid calcium, one pint of spray adjuvant, and 1½ pounds of "Bladex 80-w" per acre in 20 gallons of water. The spraying was put on with a drag. No starter or added nitrogen was used."

"The Sonic Bloom treated plot was sprayed on May 28, June 4 and July 10 with 10 ounces of nutrient in 10 gallons of water per acre, each application being made between 7:30 and 9:00 a.m. with clear skies and temperatures in the 50s. Control strips were sprayed on June 13 with liquid fish and seaweed and 10-8-8 fertilizer at one quart per acre, with a little spray adjuvant.

"My harvest data, taken during the second week of November showed: 96.8 bushels per acre (bpa) on the control land. Treated varieties produced as follows: Dairyland D/S 1006, 97.7 bpa; Dairyland D/S 1008, 111 bpa; Dairyland D/S 1001, 120.5 bpa; Riverside RS 40, 123.8 bpa; Henry's 12A, 123.8 bpa; Henry's 21A, 130.3 bpa. (The Henry's 12 A produced 90 to 95% double ears, the other varieties between 40 to 60% double ears)."

Blake's fellow-Iowan, Doradean Kahl of Cherokee, grew a newly-developed field corn high in *lysine*, with some of his plants putting out as many as five ears per stalk. At the same time, Kahl also used Carlson's method to make $1,000 on a small garden of cantaloupe melons that weighed an average 5 to 6 pounds each compared to 1 to 3 pounds for untreated fruits.

In Deer Grove, Illinois, H.W. Hosteller tried Sonic Bloom on seed corn, a crop with normally low yields per ear and requiring intensive labor input. He was elated with the results which earned him a net profit of $416 per acre, or an 18% increase (at $54 bushel) over untreated controls.

VEGETABLES

Three growers of sweet corn and other vegetables were equally pleased with their Sonic Bloom derived results. Don Jansen of Fort Meyers, Florida, grower of "Seaponic" vegetables increased his cucumber count by 400%. In ten rows, each 100 feet long, his vines turned out 17,000 pounds, or 8½ tons, of fruit so appealing he received 50 cents for each "cuke."

On the left bank of the Mississippi River not far from its source, Will Krahn, of River Falls, Wisconsin, tripled his sweet corn yield in his truck garden, attaining three ears on 65% of his cornstalks, and chalked up an estimated 50% plus increase across the board with such table vegetables as onions, tomatoes, peppers, baked beans, sweet peas and cucumbers and even second-year asparagus. Some 225 miles to the east, Jim Percy, of Sturgeon Bay, also grew multiple-eared sweet corn; "Big Boy" tomatoes with clusters of 12 to 14 fruits instead of the normal 3 to 4; and the "best-tasting cucumbers I ever grew," for all of which he received premium prices at seven different small stores supplying "organic" produce.

SOYBEANS

Particularly impressive were tests of the sound and nutrient method run on soybeans by *Gerald Carlson*, a farmer and senior editor of *Professional Farmers of America*, in Cedar Falls, Iowa, whose long journalistic experience had made him highly skeptical of Carlson's claims. In a formal report of his field trials, he stated that average yields were the following:

	BPA
For untreated crops	37
For crops treated only with "Sonic Bloom" sound	44.2
For crops treated with "Sonic Bloom" sound and three sprayings of "Sonic Bloom" nutrients	51
For crops treated with "Sonic Bloom"*extra sound* and five sprayings of "Sonic Bloom" nutrients	75.2

Gerald Carlson adds: "These trials were done in strips in three adjacent plots. Pioneer early beans were planted on May 20. The plots treated with sound only out-yielded the same variety on similar soils one-half mile distant and exposed to neither sound nor spray. Additional sprays on the five-spray acreage were applied by hand. Other sprays were applied by ground boom and tractor. Soybeans were visibly larger in treated fields, with an increase in pods per plant, pods numbering from 60 to 100. Clusters of pods were typically 5 to 7 per bract, sometimes as high as 9 per bract. The untreated beans had a tendency to behave like climbing plants, twining themselves both around one another and around the buttonweeds that grew up above the canopy. Treated beans had few nodules on their roots as compared to untreated which had normal nodulation. The extra sound was played continuously during daylight hours for two weeks in June."

ORANGES

At LaBelle, Florida, in the heart of one of Florida's leading orange-growing centers, Roy McClurg, who will harvest in late March of this year, estimates at least a 30% increase in orange production on the 160 acres he treated. If last year's prices hold, this will mean a $500 per acre increase in revenue. More significantly, his trees affected, like those of most Florida orangemen, with "young tree decline (YDT)," a so far incurable disease which shrivels their root systems, were beginning, under the Carlson-devised ministration, to return to health as shown by the fact that they were producing 50 to 60 oranges in contrast to untreated YDT trees that were bearing only 5 to 6. McClurg hopes that another year's treatment of the recovering trees may bring them back to normal which may imply a revolutionary solution to a disease problem on which the state of Florida has thus far fruitlessly spent millions of dollars of research money.

In mid-Florida's community of Lake Wales, Rodney Dean, a nurseryman, treated Bitter, Hamlin and Valencia baby orange trees to find that they quickly doubled in size as compared with untreated stock. The key to the doubling seemed to be the fact that the little trees receiving treatment put out leaves more than twice the size of the half-dollar sized leaves of their untreated neighbors, allowing them to reach a stage for transplanting in the field in two-thirds the time normally required.

Many of the above growers have indicated they intend to increase the number of acres treated in 1986 and Marvin Koehn, a New Order Mennonite farmer in Leoti, Kansas, has signed up to treat 800 acres of corn and sunflowers—for a total cost of $50 per acre—cultivated by himself and his two brothers.

Carlson also has plans to make his process available to the Olive Garvey Center for the Improvement of Human Functioning in Wichita, Kansas, a holistic medical research institution which plans to start a garden of herbs to test their nutritional qualities. The center's laboratories will also do careful analyses of Sonic Bloom treated produce to determine increases in its amino acids and other nutritionally important contents.

In 1985, Carlson revealed the following inventory of information:

- Sonic Bloom has now been tested on over 100 species of plants with marked success.
- A *Purple Passion Vine*, a house plant which normally attains a length of no more than 18 inches, grew 1,300 feet back and forth on narrowly spaced wires strung across the ceiling in a living room. The feat is recorded in the *Guinness Book of Records*. Carlson told me: "I made about 400 cuttings from that vine and, when I sold them, I included my telephone number with each cutting, plus the message: *If the plant dies, call me for a replacement*. Over three to four months, I got many calls . . . not to say that any of the plants were dying, but to report that all the cuttings had grown from 75 to 100 feet long, out of pots only 4 inches tall."
- Carlsonized huge white cauliflower heads could be packed only four to a box in boxes that normally contain a dozen heads. The Minnesotan farmer who grew the outsized heads which were disease-resistant and of exceptional taste, netted $200,000 on 20 acres, or $10,000 per acre. His costs for the treatment came to only $1,000.
- Soybean plants produced up to 300 pods per plant (30 to 35 pods is normal), with more beans on each side shoot than on any untreated plant. The beans, treated in Wisconsin, contained 27% protein as against a normal 15%.
- Cucumber vines with up to six (instead of just one) cucumber per leaf segment. "I call this challenging the seed," Carlson said.
- Papaya trees on the Big Island of Hawaii with 135 large papayas (normal 30-35). "See where they've been trimmed and cut back at the bottom . . . a lot of them usually die after that, but the sprayed trees began to put papayas out all over again," Carlson commented.
- On root systems between treated and untreated winter wheat plants, the treated ones were longer and lusher.
- Eight enormous lettuce heads filled to the brim a box that normally contains 24 heads.
- An old macadamia nut tree in Hawaii considered "past the age of production" was putting out nuts in all stages of maturity plus flowers, virtually becoming an "ever-bearing" tree.
- A greenhouse in Hawaii fed over 500 people with vegetables on just half an acre of growing surface . . . 20 large

sacks per day of cucumbers were constantly harvested just 38 days after planting from seed . . . 70% increases *over normal* were recorded for squash growth and 50% for bush beans.

- An avocado tree in Hawaii produced fruit clusters of 18 to 20 avocados in place of the normal 1 or 2.
- A Florida orange tree was treated on one side only. The treated half revealed oranges in all stages of maturity, plus copious flower growth, making of it, like the above-mentioned macadamia nut, "ever-bearing." The untreated side was pedestrianly normal.
- Dill plants over four feet tall, calla lillies over six feet tall, bell pepper plants bearing 50 peppers and up, and African violets with 200 to 300 blooms (30 blooms being normal).

Perhaps the most amazing aspect of Dan Carlson's discovery is the fact that, not alone *plants*, but also their *seeds*, are affected by the simultaneous treatment of his nutrients and sound. In my Washington D.C. kitchen, I soaked open-pollinated corn seed in a bowl of the nutrient solution while leaving control seeds taken from the same corn plant in an empty bowl beside them. While soaking, the treated seeds were exposed for about an hour and a half to the pulsed sound buried in Hindu Indian "raga" music played on a cassette tape. By morning, most of the treated seeds had germinated. Put into the ground, along with the untreated seeds, they sprouted 8 to 9 days earlier than their untreated counterparts.

I also used the home kit on a dozen plants producing green bell peppers which I had been growing in good soil for several seasons. Whereas my peppers had never reached full size until the first or second week of August, the treated plants began bearing mature fruits in the first week of July.

The implications of Carlson's research and development are far-reaching, opening a horizon that promises to any person with even a small plot of ground the opportunity to feed himself, his family and his neighbors at very low cost for plant nutrients applied. This, in turn, heralds an emancipation of countless growers from their enthrallment to the monopolies of agribusiness and chemical companies.

As an example of what his methods can do for drought-oppressed "Third World" countries, Carlson has recently reported that in the fall of 1985, Sonic Bloom treated seeds were sent to Sudan, in Africa, through the good offices of Save the Children, a multi-million dollar charitable organization operating in over 40 of the earth's nations. Save the Children has reported that his seeds matured well and produced excellent crops in a region where day-time temperatures are often measured at 145 F. As I finish this account, another 300 pounds of treated seed were shipped to Sudan for planting.

SONIC BLOOM
FOR THE WORLD

An insane claim or do plants grow like crazy?

By Jan M. Brenny
Staff Editor

Imagine your customers being able to produce African Violets with over 200 blooms or 15-foot tomato plants bearing 800 tomatoes each or rose bushes with 70 blossoms.

Such results may be possible for home gardeners with an unusual new plant-growth stimulator called Sonic Bloom. Developed by Dan Carlson, a plant scientist and self-proclaimed "classical inventor" from Blaine, MN, the product is available for operations ranging in size from large farms to kits for home gardeners.

The home kit consists of a cassette tape of high-frequency sound imbedded in Indian sitar and lyre music; six ounces of an organic mixture containing trace minerals, chelated amino acids, and other "balanced nutrients;" and a spray bottle to dilute the mixture and mist the plants. The kits retail for around $30 and Carlson is currently negotiating with certain retail outlets to carry the kits.

"We've been waiting for the packaging," Carlson says. "It's a problem because of the truth in advertising rules – people don't believe me until I show them."

Carlson, a graduate of the University of Minnesota, admits his process leaves people skeptical.

"We're creating plants that people haven't seen before," Dan says. "At home we can't have too many plants around the house because they get too big." A Purple Passion plant of Carlson's that grew to 1300 feet is in the *Guiness Book of World Records*. Part of the plant was destroyed when it got caught in a ceiling fan but over 600 feet still hang overhead on hooks in the Carlsons' kitchen ceiling.

Sonic Bloom is a two-step process. Playing the cassette to the plant is first. The sound and music open the leaf stomata so they better absorb nutrients, according to Carlson. Spraying the plant with the nutrient mixture is second. The best time for this treatment is early morning, he says.

Dan Carlson grows record-setting plants with Sonic Bloom. His Purple Passion plant is listed in the *Guiness Book of World Records*.

Carlson began his work over 20 years ago. As an Army border guard in south Korea, he witnessed a woman trying to kill her own child rather than see it starve. At that moment Carlson dedicated his life to solving the world hunger problem. And, while working to achieve that goal, he developed Sonic Bloom.

After going commercial three years ago, Carlson began selling his product by mail order, advertising primarily in agricultural publications and through word-of-mouth. Sonic Bloom is patented in several countries and Carlson is awaiting a patent in the United States.

"We've had offers to sell out," he says. "But the hunger problem is my main concern and we're starting to see some real possibilities."

Bill Krahn, an organic gardener from River Falls, WI, sells vegetables and cut flowers and has used Sonic Bloom for three years.

"People constantly tal about the high quality of ou vegetables," he says. "We ge increased yields and we ge them earlier so we get to mar ket ahead of everyone else. Krahn says his cut flower last longer and he has notice "tremendous growth" in th house and blooming plan where Sonic Bloom has bee used.

"We've noticed the plan are healthier," he say "There aren't as many insec and the plants don't get sic I think their immune system are better."

Helping his "stressed out plants is the reason Bru Stone uses Sonic Bloo Stone operates Decorative Designs company that leases and mainta green plants for offices, hotels a condominiums.

"We have a lot of plants goi into low-light areas," he says. " find that if we treat them with Son Bloom they do much better. Es cially the ficus trees. They shipped up from Florida and lose lot of their leaves but if we tr them with Sonic Bloom they hold much better."

Stone added that he treats plant on site in the office or ho because the spray is non-toxic. also uses the process in his gre house.

Carlson says his communicat with plants is only the beginning what is possible.

"Someday we'll be able to plants exactly what we want fr them," he says.

Any tomato plant that bears tomatoes or houseplant that grow 1300 feet is getting at least par the message right. ■

EFFECT OF ELECTRIC AND MAGNETIC PHENOMENA ON THE VITAL ACTIVITY OF ORGANISMS

THE PROBLEM OF LIGHT-PULSE PROCESSING OF SEEDS AND PLANTS

A. A. Shakhov

Moscow

Translated from Élektronnaya Obrabotka Materialov, No. 2,
pp. 61-74, March-April, 1965

Since long ago, the low value of the coefficient of solar energy utilization by plants for the synthesis of organic matter has prompted phytophysiologists to explore the possibilities of improving the efficiency of utilization of radiant energy by the plant organism. However, although the photosynthesis mechanism is rather well understood at the present time, we are still very limited in our ability to increase considerably the absorption and utilization of the solar energy by plants and thus improve the yielding capacity.

One way of increasing the productivity of agricultural plants is the possibility of intensifying the photoenergetic processes in plants, a possibility which we have been studying for sometime. It is necessary to determine the dependence of these processes on the intensity and the spectral composition of sunlight in the range from the ultraviolet (UV) to the infrared (IR) radiation, inclusive. Thus, the photoenergetics of plants includes the study of the action not only of visible light rays (the biologically most important "octave" of the entire range of electromagwaves), but also of the bordering ultraviolet and infrared radiations. Besides the photosynthetic action of light, the photoenergetics of plants is also concerned with nonphotosynthetic light-induced reactions in seeds and plants. Nonphotosynthetic reactions are caused by visible light rays, mainly in the illumination of seeds and sprouts, as well as by the UV and IR radiations bordering on visible light. The reactions that develop in this case are often referred to as photobiological reactions.

The combined action of UV and IR radiations with rays of the visible portion of the electromagnetic spectrum is of special interest. An important subject of photoenergetic investigations is the action of concentrated pulsed sunlight (CPSL) on seeds and plants.

The photoenergetics of plants, as a new problem of general physiology, is closely connected with the related fields, in particular, biological radioelectronics, which also constitutes a new field that has developed on the meeting ground of biology and radio electronics. As will be shown below, the method of electron paramagnetic resonance (EPR) can be used very effectively in solving certain problems of photoenergetics.

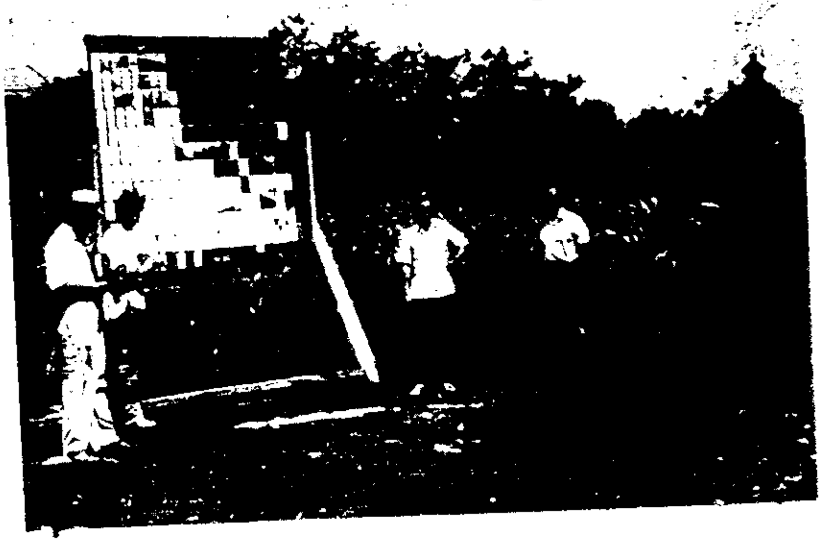

Fig. 1. Medical sunlight reflector. Experiment on the radiation of corn plants in Moldavia.

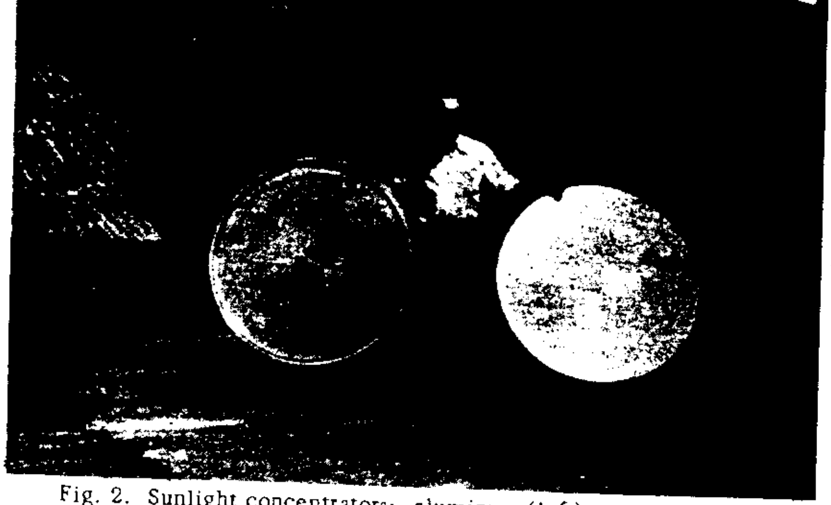

Fig. 2. Sunlight concentrators: aluminum (left); mirror (right).

Certain opinions expressed by the Novel prize winners N. N. Semenov [1] and A. Szent-Gyorgyi [2, 3] are of interest for the subsequent theoretical development of biological photoenergetics. In his article, entitled "The Twenty-First Century – The Century of Complete Electrification," N. N. Semenov noted that two fundamental problems are encountered in contemporary natural science: in the first place, the theory of elementary particles in physics or, in other words, the problem of primary particles of matter, and, in the second place, the structure and behavior of highly organized matter in biology and chemistry. N. N. Semenov expressed his conviction that work on elucidating the mechanism of the physicochemical processes in the vital activity of organisms will bring about a genuine revolution in chemistry. He considers that the problem of highly organized matter will constitute the chief scientific problem in the next decade.

A. Szent-Gyorgyi [2] introduced the concept of the energetic life cycle, which consists in the fact that electrons in living systems are first raised to higher energy levels by photons, after which they descend to their ground level, emitting portions of their excess energy, which actually drives the entire "machine of life." He says that "Life is actually controlled by electrons, i.e., by the energy which these electrons release in discrete amounts as they descend from the high level to which they were raised by photons. However, an electron that moves along a closed path constitutes a weak electric current. Consequently, life is actuated by weak electric currents, which are maintained by sunlight. All the complex processes of intermediate metabolism are only superimposed on this basic fact. The other postulate consists in the following: Electrons leave after themselves only ATF and DPN-N or TPN-N.* Thus, the latter constitute the true fuel of life. The third postulate states that electrons pass through this cycle individually. They are excited one after another, and they also pass one by one through a series of cytochromes, since the central iron atom in cytochromes can experience only monovalent transformations" (pages 30-31). The question concerning the manner in which energy controls the vital activity, which A. Szent-Gyorgyi posed in his monograph Bioenergetics [3], was reduced in a later work to the problem concerning the manner in which macroenergetic bonds can be transformed into electron energy [2].

The above approach to an understanding of the energetics of biological processes prompted us, in developing the theory of pulsed illumination, to resort to the magnetic resonance method in using the action of concentrated pulsed sunlight. However, we shall first examine the nature of concentrated pulsed sunlight (CPSL) and its biological effect.

The Light Pulse Effect and Improvement of the Productivity of Plants

CPSL constitutes an intermittent flux of radiant energy, reflected from a reflector and, consequently, intensified in comparison with natural sunlight by a certain given factor. Concentrated sunlight can be produced by using

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*ATP is adenosintriphosphate, DPN-N is diphosphopyridinenucleotide, and TPN-N is triphosphopyridinenucleotide – Editor's note.

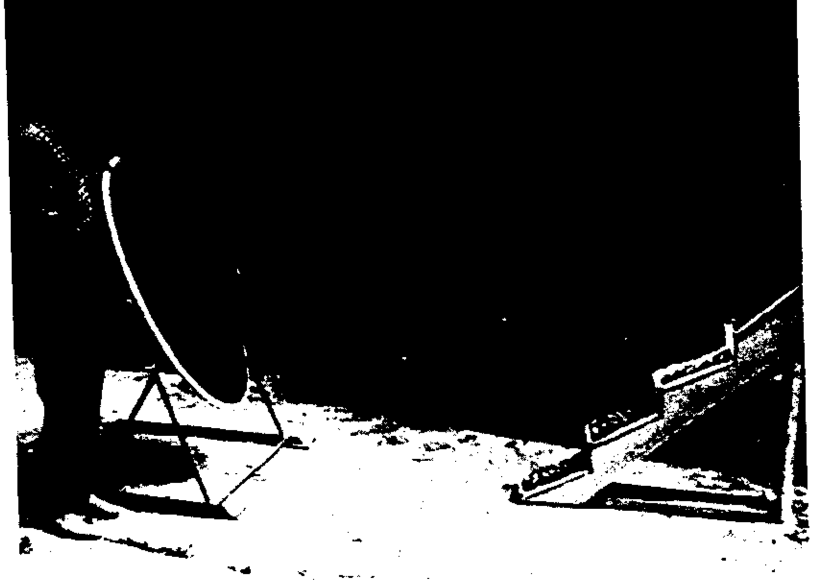

Fig. 3. Irradiation of potato tubers with concentrated sunlight.

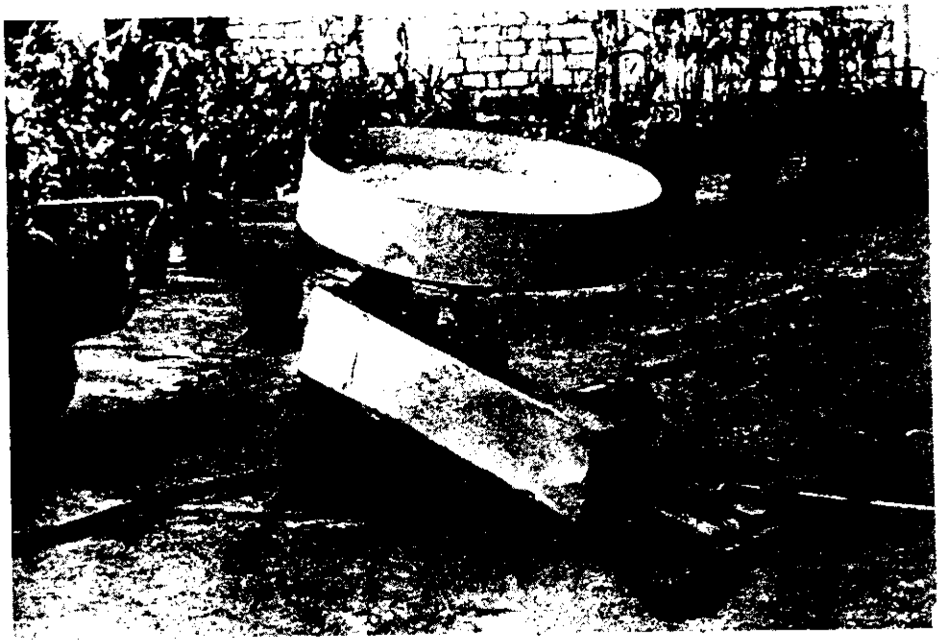

Fig. 4. Centrifugal device for the rotation of seeds while they are irradiated with a fixed flux of concentrated sunlight.

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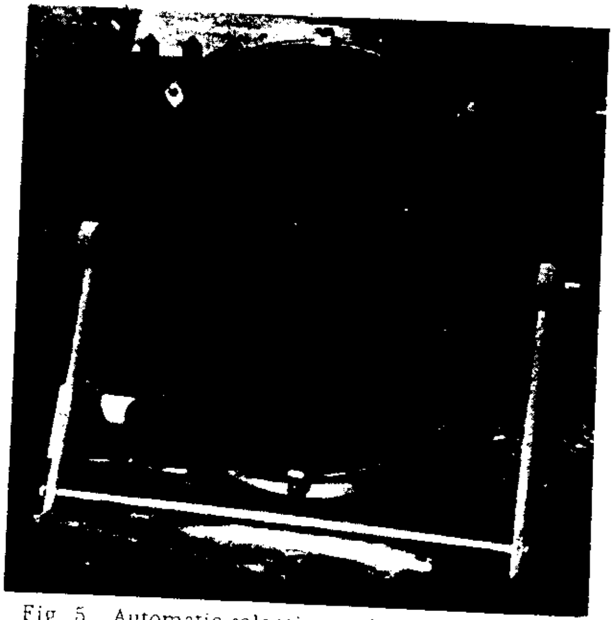

Fig. 5. Automatic selective sunlight concentrator.

various methods, including an ordinary medical reflector of the type designed by V. N. Bukhman (Fig. 1). This reflector consists of 200-300 mirrors, which are arranged according to a certain system on the frame shelves and are focused to a very small area. In dependence on the number of mirrors and the accuracy of their focusing, the light concentration can be increased by a factor of up to 80-100. However, the medical reflector under consideration increases the light concentration by a factor of 50-70, while the energy at the focal spot attains 60-80 cal/dm^2 · min. Pulsed irradiation of the specimen is secured by shaking the reflector lightly about the horizontal axis (Fig. 1). Another variant of the sunlight concentrator (designed by F. Kh. Nabiullin, VNIIT) is the spherical aluminum (left) or mirror (right) reflector (Fig. 2), which increases the sunlight concentration by a factor of up to 30. Intermittent irradiation of the specimen is secured by means of manual or automatic rotation of these mirrors about the horizontal axis (Fig. 3). Pulsed irradiation of seeds can be effected in an efficient manner in the centrifugal device designed by V. A. Miroshnichenko, which consists of a pan with a semiconical bottom (Fig. 4). As the pan is rotated by means of a motor at a speed of 100-130 rpm, the seeds arrange themselves in a single layer on the pan's wall, where they are irradiated intermittently as they pass through the fixed focal spot projected on the inside wall of the pan. The third reflector variant used in the experiments in our laboratory* is the VNIIT selective concentrator designed by F. Kh. Nabiullin (Fig. 5). It consists of a mirror fastened in an annular frame, a crank mechanism, and a motor, which drives the crank mechanism to which the annular frame (with the mirror) is linked. The shape of the mirror is close to that of a paraboloid. In order to produce the required wavelengths, the mirror is tinted with certain colors, whereby selective concentrated light is obtained [4].

Pulsed irradiation consists in the short-duration action of the reflected radiant flux on seeds or plants, which is repeated at certain given time intervals. Thus, the irradiation occurs in spurts, i.e., it has an intermittent character. The pulsed-light conditions created by means of the above light concentrators are generally characterized by light energy pulses whose duration is not very short: They last from 1 to 0.2 sec. In the case of high light concentrations (concentration intensifications by factors of 50-100) and a correspondingly high energy density, the pulses produce a considerable effect on biological specimens. The instantaneous power of concentrated light that is many times repeated under the described pulse conditions is a specific factor whose effect constitutes a new, important, and interesting biophysical problem. One or several thousands of pulses of concentrated sunlight (CSL) (the exposure time would be equivalent to 10-40 min) are sufficient for causing physicochemical changes and producing biological aftereffects in the irradiated plant specimen. It was found that seeds, tubers, and leaves have the ability to cumulate, i.e., to sum, the multiple concentrated light pulses in the [illegible] development of plants, which produces a definite effect in the phys[illegible] productivity of agricultural

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*The B. A. Keller Laboratory of Evo[illegible] Physiology, Academy of Sciences, USSR [illegible] Institute of Plant

TABLE 1. Effect of Presowing CPSL Irradiation of the Seed on the Yield and the Early Ripening of Ground-Sown Cucumbers (Alma-Ata)

Sort	Type of experiment	Early crop of July 20th			Over-all yield		
		centners/ha	% of control data	Difference reliability	centners/ha	% of control data	Difference reliability
Boston	Control (unirradiated seed)	8.1 ± 0.35	100.0	–	298.3 ± 4.3	100.0	–
	Seed heated over a period of 45 min	8.8 ± 0.36	108.6	1.39	316.0 ± 0.5	105.9	4.09
	Seed with CPSL irradiated over a period of 45 min	11.4 ± 1.1	140.7	2.85	381.1 ± 8.4	127.7	8.79
Nezhin 12	Control (unirradiated seed)	9.2 ± 0.5	100.0	–	361.7 ± 3.4	100.0	–
	Seed heated over a period of 45 min	9.5 ± 0.2	103.3	0.57	384.5 ± 2.6	106.3	5.35
	Seed with CPSL irradiated over a period of 45 min	12.4 ± 1.1	134.8	2.62	418.3 ± 5.2	115.6	9.2
Nerosimyi 40	Control (unirradiated seed)	97.1 ± 13.6	100.0	–	418.5 ± 6.2	100.0	–
	Seed with CPSL irradiated over a period of 45 min	114.2 ± 2.5	117.6	1.23	542.8 ± 32.7	129.7	3.73

TABLE 2. Effect of Presowing CPSL Irradiation of the Seed on the Yield of Kolkhoznyi 34 Tomatoes (Ground Planting)

Type of experiment	Over-all yield		Yield from the first three collections	
	centners/ha	Percentage of control data	centners/ha	Percentage of control data
Control (unirradiated seed)	246.6	100.0	121.2	100.0
Seed irradiated over a period of 10 min	264.4	107.2	121.2	100.0
Seed irradiated over a period of 20 min	264.0	107.0	130.6	107.7
Seed irradiated over a period of 30 min	297.6	120.7	135.0	111.3
Seed irradiated over a period of 40 min	325.8	132.1	164.4	135.6

TABLE 3. Effect of Presowing CPSL Irradiation of Tubers on the Yield of Berries and Tubers of Katagdin Potato in the Mountainous Zone (1800 m above sea level)

Type of experiment	Crop	1963		1964		
		centners/ha	% of control data	Difference reliability	centners/ha	% of control data
Control (without irradiation)	Berries	25.0 ± 0.4	100.0	–	3.68	100.0
	Tubers	297.0 ± 2.4	100.0	–	135.7	100.0
CPSL irradiation over period of 30 min	Berries	35.3 ± 1.7	141.2	5.8	4.9	133.3
	Tubers	368.0 ± 15.8	120.5	4.4	176.4	130.0

plants. The Commission for concentrated Sunlight of the State Committee of the Council of Ministers of the RSFSR on the Coordination of Scienfific Research Work has organized the testing and further experimental development of the CPSL method for its utilization in agriculture. As a result of field and vegetation experiments, which were performed under different soil and climatic conditions in our country (the Kola peninsula, Kazakhstan, Moldavia, and Ukraine), the existence of the light pulse effect was established in several agricultural crops [5-11].

As an example, we shall give certain data obtained in the experiments performed by the author together with G. T. Kaplina and M. Z. Yusupov on the effect of presowing (or preplanting) CPSL irradiation of seeds (or tubers).

It is seen from Table 1 that the increases in the early crop of the Boston, Nezhin, and Nerosimyi sorts were equal to 40, 34, and 17%, respectively; the increases in the over-all yield were equal to 27, 15, and 29%, respectively. At the same time, the heating of seeds in a dark thermostat over a period of 45 min at 40-45°C resulted in an increase in the early crop by 3-8% in the case of the first two sorts and an increase of almost 6% in the over-all yield. If one can rely on the fact that the increase in the over-all yield is due to the presowing heating of the cucumber seed, it is obvious that the CPSL effect is caused not by the thermal action of concentrated light, but most probably by the photophysical and photochemical pulse action of radiant energy. In the described experiments, the seed received 2000 pulses from a reflector whose design was similar to that shown in Fig. 1.

Presowing irradiation of the seed affected very favorably the yield of tomatoes (Table 2).

The increase in the over-all and the early crop of tomatoes became larger with an increase in irradiation; it amounted to 20-30% for an irradiation period of 30-40 min.

Potato tubers irradiated in the Alma-Ata region and transplanted at the Ushkonor landmark (1800 m above sea level) produced under mountainous conditions a 20-30% increase in the tuber yield and a 30-40% increase in the yield of berries (Table 3).

The geographic sowing of seed that has been irradiated by CPSL prior to sowing has shown that the seed or tubers seem to store a certain "photoenergy reserve," which, after their exposure to pulses of CPSL quanta, acts during the development of plants as a source of higher productivity. As a result of the CPSL effect, the reliably established yield increase amounted to 20-30% in the case of vegetable crops (tomatoes and cucumbers) and an increase of 5-10% in the case of grain crops (corn and wheat). Besides the increase in the yield, preplanting CPSL irradiation of tubers also increases the seed productivity of potatoes. This, however is of interest for the development of a method for increasing a certain crop by using seedlings grown from seed of sexual origin.

A great amount of experimental data showing the effectiveness of CPSL has been published in [4-11]. It should also be mentioned that, according to the data obtained by I. P. Kroitor and S. A. Stanko at the Moldavian Scientific Research Institute of Crop Selection, Seed Growing, and Agricultural Engineering and communicated by the department chiefs I. K. Lisunov, V. A. Gordienko, and N. M. Kalashnyuk, CPSL acts favorably on certain grain and bean crops. Thus, after irradiating the seed of hybrid corn VIR 42 over a period of 10 min by means of a mirror reflector (Fig. 1), the yield of cob grain increased by [illegible] centners/ha for an average yield of [illegible] centners/ha. As a result of the presowing irradiation over a period of [illegible] min of the Cuban Sorgo [illegible] sort, the grain yield increased by 5.9 centners/ha over the [illegible]-centners/ha yield of the control crop. As a result of irradiating the seed of [illegible] 12 soybean, the number of beans per plant increased from [illegible] to [illegible], the number of seeds increased from [illegible] to 57.5, and the seed weight increased from [illegible] to [illegible] g. One hundred twenty soybean plants were investigated.

Experiments on the irradiation of seeds, tubers, seedlings, and whole plants indicate that CPSL initiates very intimate metabolism processes; the physicochemical changes that are produced to a greater or smaller extent are preserved and are reflected in ontogenesis, thus leading to an increase in the productivity of plants. Therefore, at this stage, investigations of the mechanism of CPSL action constitute the main task in work on the problem of light-pulse irradiation of plants in the sense of the light-pulse effect.

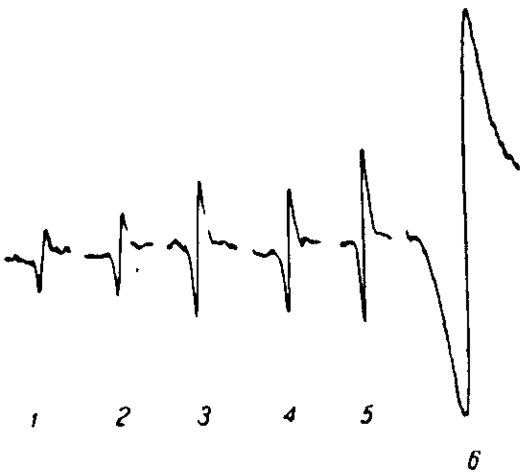

Fig. 6. EPR signals in CPSL-irradiated cucumber seed in dependence on the number of pulses. 1) 1000; 2) 1500; 3) 2250; 4) 3000; 5) 4500; 6) $CuCl_2 \cdot 2H_2O$ standard.

Formation of Photoinduced Unpaired Electrons

In order to investigate the mechanism of CPSL action of seeds and leaves, it is first necessary to determine the possibility of resonance absorption of electromagnetic energy by unpaired electrons in a magnetic field during the pulsed irradiation of seeds and plants. It is known that visible light quanta possess sufficient energy for the formation of unpaired electrons in pigments and photosynthetic systems [12]. All particles characterized by the presence of unpaired electrons (atoms or molecule fragments) are considered as free radicals (FR). Thus, the presence of an unpaired electron at the external orbits of the system is considered as the basic characteristic of FR. The presence of an unpaired electron endows the system with two characteristic properties [13]: a very high reaction ability in chemical transformations and the existence of the magnetic moment, which is due to the uncompensated spin of the unpaired electron.

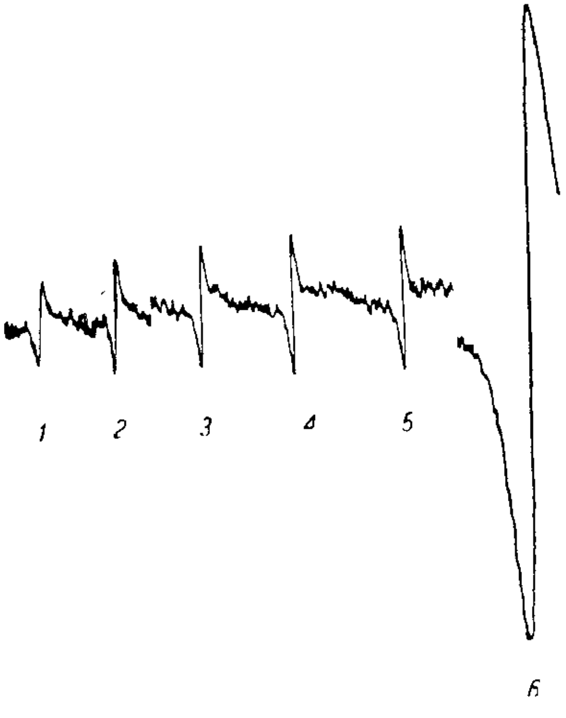

Fig. 7. EPR signals in CPSL-irradiated tomato seed in dependence on the number of pulses. 1) 1000; 2) 1500; 3) 2250; 4) 3000; 5) 4500; 6) $CuCl_2 \cdot 2H_2O$ standard.

TABLE 4. Concentration of Free Radicals in CPSL-Irradiated Seed

No. of pulses	Number of paramagnetic centers ($\times 10^6$) per 1 g of air-dry seed		
	Ruslan 95 cucumbers	Nerosimyi 40 cucumbers	Kolkhoznyi 34 tomatoes
Control (unirradiated seed)	86.2	68.7	151.3
1000	99.5	66.2	146.7
1500	95.4	71.0	171.3
2250	153.4	129.0	244.7
3000	143.3	122.9	261.3
4500	177.4	180.7	274.0

In the investigations of pulsed irradiation of seeds with concentrated light that were performed by the author in company with N. I Bidzilya, S. A. Stanko, and F. Kh. Nabiullin [4-15], it was found that photoinduced free radicals are formed in seeds. It was found that pulsed irradiation makes it possible to record EPR signals in seeds soon after they have been irradiated and even after a few days. The FR yield in dependence on the pulse load can be determined by using different irradiation doses.

The new data given below were obtained by M. Z. Yusupov on March 7th in the region of Alma-Ata by irradiating seeds by means of a reflector similar to that shown in Fig. 1. The measurements were performed by N. I. Bidzilya on April 23rd at the Institute of Plant Physiology, Academy of Sciences, Ukr. SSR (Kiev) by means of an RÉ-1301 microwave spectrometer, using a method described earlier [15]. A $CuCl_2 \cdot 2H_2O$ standard was used for determining the number of paramagnetic centers.*

The determination of FR in cucumber seed as late as one and a half months after they were irradiated with concentrated light showed well-defined EPR signals (Fig. 6). The previously detected trend was observed in seeds of several plants [4-15]: With an increase in the number of CSL pulses, the FR content increased until a state of saturation of paramagnetic centers was reached. This state set in after irradiation by means of the above-mentioned reflector amounting to a dose of 2000-3000 pulses. A similar trend was also observed in the case of tomato seed (Fig. 7).

Due to the fact that the seed was partially dried in a bright ventilated room during its preparation for sowing, a certain amount of FR developed in the control specimens. Subsequent CPSL irradiation considerably augmented the number of paramagnetic centers in the seed. The number of paramagnetic centers in the seed increased especially in irradiation over the period of time that was most effective for an increase in the yield (45 min), when the number of pulses was 2250 (Table 4).

It is obvious from Table 4 that, under the action of 2000-3000 pulses of concentrated light, the FR content in irradiated seed almost doubles in comparison with the control batch. With the above number of pulses, the number of paramagnetic centers in irradiated seed attains almost $150 \cdot 10^{16}$ and $250 \cdot 10^{16}$ per 1 g of air-dry seed for cucumbers and tomatoes, respectively.

At the present time, investigators have still far from a thorough understanding of the nature of free-radical processes, and they do not have a sufficient knowledge of the laws governing the formation and destruction of FR in biological matter. Nevertheless, it has been proved that a higher FR concentration is connected with high metabolic activity of living tissue and that it changes in dependence on the degree of this activity. The question arises in this case whether it is possible to influence by means of pulsed irradiation the metabolic activity of tissues in seeds through free-radical processes. An affirmative answer to this question suggests itself, but we still do not have direct reliable data on the relationship between the light-pulse effect and the intensity of the free-radical processes that characterize the magnitude of the biological aftereffect. However, on the basis of the experiments which I performed together with my collaborators, it can be considered that photoinduced unpaired electrons constitute one

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*The spectrum of cupric chloride was recorded at each determination of FR in seeds.

of the primary mechanisms of the aftereffect of the solar irradiation of seeds. Therefore, the investigation of photo-induced FR is of great interest not only for an understanding of the mechanism of light-pulse irradiation of plant tissue, but also in work on the general problems of light and electromagnetic radiation action on biological specimens.

Pigments may be among the basic acceptors of light energy in seeds. There is a large amount of literature, which we shall not dwell upon here, on the pigment content in seeds and the role of the photochrome pigment in the sprouting of seeds. We shall only mention the recent paper [16], where it was shown that even seeds without chlorophyll, which contain only small amounts of carotinoids in the germs, sprout only when exposed to light. Data on the formation of free radicals in plant pigments under the action of light are of the greatest interest to us [17]. It was found that the final steady-state FR concentration in dry crystalline pigments is proportional to the light intensity, while the rise time of EPR signals is approximately inversely proportional to this intensity. If a high-power pulse lamp is used, virtually all the pigment molecules are transformed into paramagnetic centers. Unpaired electrons are localized in molecules of various quinones, flavones, and other compounds present in leaf cells and in integumentary and internal seed tissues. It would be especially interesting to investigate the dependence of the structure and amplitude of EPR signals and of the number of paramagnetic centers (FR) on the wavelength of concentrated light. As was shown in [13], EPR signals arise in seeds when they are irradiated with blue or yellow-red light. For the identification of FR in seeds, it is necessary to investigate, in the first place, the pigmented integumentary tissues of seeds and tubers under the action of chromatic light.

As a result of pulsed irradiation with concentrated light, the seed becomes "charged" with radiant energy, as it were, and the molecules of many substances in the seed pass into the free-radical state, which is ordinarily not peculiar to unirradiated seed. Due to their high reaction capacity, free radicals produce changes in the metabolism processes in the sprouting and the subsequent growth of plants. Due to the gradual recombination of paramagnetic centers in seeds, the light-pulse effect, as a manifestation of the biological aftereffect produced by high-energy pulses of concentrated light, must diminish. With the onset of saturation of paramagnetic centers and, especially, with their recombination during the storage ("laying-up") of the seed, the recombination energy must influence the processes in seeds and sprouts. However, we do not have any general knowledge of the magnitude of this energy and of the importance of its role in biological processes. The solution of this problem depends on studies of the processes occurring during the pulse and the period between pulses. During the action of CPSL, the pause between pulses is much longer than the pulse duration. Do the processes in seeds or leaves that are caused by the preceding pulse end before the arrival of the next pulse? What is the nature and duration of the transient state between pulses, i.e., the physicochemical processes, including free-radical processes? In what way do these processes depend on the pulse energy? In what manner do the absorption of solar energy and chemiluminescence change in the plant material under different pulse conditions? This is, in short, the range of the fundamental questions to be answered in solving the problems under consideration.

Thus, a new field for the application of pulse spectroscopy, luminescent spectroscopy, and pulse photoanalysis has been created. These disciplines will undoubtedly help in a thorough investigation of nonphotosynthetic and photosynthetic reactions that occur when plants are irradiated with pulses of concentrated chromatic or white light. From the point of view of the photoenergetics of plants, the above processes are of interest mainly in investigating the effect of the spectral regions of visible light and of the bordering radiations on the processes in seeds and plants. In discussing the EPR method in biology, G. M. Endros, and M. Calvin [18] consider that, if the spin concentration is photoinduced, it would be of interest to determine the action spectrum of the equilibrium spin concentration as a function of the wavelength of incident light.

DISCUSSION OF THE RESULTS

New possibilities for a deep understanding of the physiochemical basis of the vital activity of organisms were revealed as investigators began to penetrate the subcellular and the molecular mechanisms of life processes. These possibilities arose as a result of the cooperation of representatives of the basic natural sciences and the utilization of physical, chemical, and technical means in the study of biological processes. The creative cooperation between biologists on the one hand, and physicists, chemists, cyberneticists, and technicians on the other, brought to light many important problems of mutual interest. Among such promising problems, biological photoenergetics deserves attention.

In work on problems of the photoenergetics of plants, it is undoubtedly very important to know the processes occurring in the living cell at the molecular and atomic levels. The method of electron paramagnetic resonance makes it possible to reveal the changes that arise in the biological material, in particular, seeds and plants, as a result of their irradiation with intermittent concentrated light. Although investigators encounter great difficulties in identifying or localizing unpaired electrons in the living tissue, there is a pressing need for further investigations of photoinduced processes in plants by means of the EPR and NMR (nuclear magnetic resonance) methods.

Niels Bohr has written that "The recognition of the great importance of atomicity features in the mechanism of living organisms is not sufficient in itself for a comprehensive explanation of biological phenomena." According to Bohr, "The initial problem is that of determining whether it will be necessary to add certain still missing fundamental ideas to our analysis of natural phenomena before we reach the ability to understand life on the basis of physical experiments" [19, page 22]. Furthermore, "... The peculiar properties of living organisms that have developed throughout the entire history of organic evolution indicate concealed possibilities of extremely complex material systems that do not have their counterparts in the relatively simple problems which we encounter in ordinary physics and chemistry. It is against this background that concepts pertaining to the behavior of an organism as a whole, which are opposite, as it were, to the methods of describing the properties of inanimate matter, found fruitful application in biology." [19 page 150].

Considering what has been said above, the problem of light-pulse processing of seeds and plants should be approached not only from the point of view of biological electronics, which is useful in investigating the mechanism of pulsed-light action, but also from the point of view of general biology. For this, it is necessary to analyze comprehensively from a biological point of view the action of pulsed concentrated light on the vital activity processes. In acting on an organism, one can perhaps find a fundamentally new approach which would be connected with the characteristic of the pulse process – its intermittent nature – where short-duration high-energy pulses are separated by longer pauses. Is it not possible that the action of concentrated pulsed sunlight is of such specific importance for the organism that it can cause fundamental organic changes that may involve heredity and produce stable, modified, and perhaps more productive forms? An analysis of the ecological and physiological reorganization of plants on a photoenergetic basis, performed in [20], substantiates the hope for an affirmative answer to this question. Repeated CPSL action, i.e., the irradiation of cucumber seed from plants grown from seed that has been irradiated before sowing, resulting in a higher yield. The yield characteristic and the chemical composition of daughter potato tubers grown from tubers that have been irradiated by white and monochromatic CSL indicate the possibility of fundamental changes [5].

The recent data on the effect of additional illumination by light flashes on the yield and the photoperiodic reaction of spinach [21] are of interest. The plants were irradiated in a hothouse with electric light flashes (120 flashes per minute), which produced an illumination of 70,000 lux. Considerable changes were observed in the plants as a result of this illumination, although its light energy was considerably lower than the energy of CPSL. The control (unirradiated) plants were in a vegetative state. In the case of the plants additionally illuminated over a period of 8 h, stalks began to grow already after 25 days, while flowers appeared after 40 days. Two months after the experiment was started, the additionally illuminated plants had thinner stalks, longer and narrower leaves, and shorter principal and longer lateral roots. They contained more nitrogen and chlorophyll and were characterized by greater moist and dry weight. Although these experiments could not be compared with CPSL action, they still indicated the effectiveness of additional intermittent illumination. In some other experiments [22], intermittent light did not materially effect the rate of duckweed growth. In investigating the effect of intermittent light with periods from 12 to 0.004 sec, the maximum additional growth of duckweed was observed for a 0.004-sec period.

CPSL irradiation of plants causes intensive formation of FR in leaves and basic changes in the metabolism. According to the data obtained by our collaborator S. A. Stanko in Moldavia, irradiation of soybean with white and, especially, red pulsed light for 30 min each day over a period of one week resulting in a considerable increase (by 6-8%) in the protein content of the seeds.

These and other factors connected with the action of CPSL on seeds and plants indicate that the CPSL method offers an unexplored field of activity for selectionists and geneticists. Changes which could be used as a useful basis for selection can be expected as a result of irradiation of plants at various stages of their development, irradiation during the fertilization and seed formation, and action of CPSL on young embryonic seed taken from plants and on germs cultivated in artificial media. It would be interesting to investigate the combined action of CPSL and ionizing radiation on plants. Presowing CPSL irradiation of seeds and tubers promises not only higher yields, but also better quality. Great attention should be paid to investigation of the quality of crops. It can be expected that important data on the effectiveness of CPSL action would thus be obtained.

The method of presowing CPSL-irradiation of grain is also promising for the control of blights and diseases of agricultural crops. Thus, curculionidae are destroyed when the grain is illuminated over a period of 15-20 sec. In seed growing, concentrated light can also be found useful for the drying of grain, intensifying the germination, preparation for storage, etc.

In summarizing the work on testing and developing the described method at the meetings of the State Committee of the Council of Ministers of the RSFSR on the Coordination of Scientific Research Work, resolutions concerning the subsequent development of the CPSL method in plant growing were adopted. In connection with this, it is necessary to investigate more thoroughly the theoretical basis of the action of CPSL on seeds and plants, to design and test lighter reflectors and devices for grain mixing during irradiation, and to test the method in production areas on farms.

CONCLUSIONS

The irradiation of seeds and plants with concentrated pulsed sunlight (CPSL) constitutes one of the methods for increasing the yield of many agricultural and, especially, vegetable crops. Multiple pulsed action of concentrated light on seeds, tubers, seedlings, and plants over periods of 20-45 min (depending on the number of pulses and the light concentration) results in the light-pulse effect, which, from the biological point of view, is manifested in more intensive growth, especially during the early stages, and an increase in the productivity of plants.

High-energy pulses of concentrated sunlight cause in seeds and leaves an intensive formation of photoinduced unpaired electrons, which can be efficiently recorded by using the method of electron paramagnetic resonance (EPR). The number of paramagnetic centers in seeds and leaves increases with an increase in the number of pulses until saturation sets in, after which the content of free radicals ceases to increase or even drops somewhat as a result of the recombination processes.

Free-radical processes in seeds and sprouts resulting from light-pulse irradiation constitute one of the primary physicochemical reactions of the biological specimen to intermittent high-density sunlight fluxes. The light-pulse action, rather than the temperature action of solar energy, initiates the free-radical processes.

Light-pulse irradiation of biological specimens constitutes a new trend in biology and plant-growing which is promising in its theoretical and practical aspects. This trend is expected to attract the interest of physicists, chemists, heliotechnicians, etc. CPSL could form the basis for an efficient method to be used in the selection and genetics of plants, control of plant diseases, improvement of the sowing qualities of seeds, preparation for their storage, etc.

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All abbreviations of periodicals in the above bibliography are letter-by-letter transliterations of the abbreviations as given in the original Russian journal. ***Some or all of this periodical literature may well be available in English translation.*** **A complete list of the cover-to-cover English translations appears at the back of this issue.**

PRESOWING ELECTRICAL TREATMENT OF SEEDS

A. P. Ivanov

Leningrad

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Among the measures directed towards the obtaining of high and stable crop yields methods of presowing treatment of seeds and plants occupy an important place.

It is known that the measures directed towards the development of advanced agricultural practice, including the use of fertilizers, irrigation, and soil improvement, not to mention correct soil cultivation and crop management, are inadequate or not very effective if low-quality seeds are used. Hence, science and practice have always ascribed primary significance to presowing treatment of seeds and planting material.

Such widely practiced methods of presowing treatment of seeds as grading and dressing have been supplemented by many other methods in the last ten years. Vernalization, warm-air heating, hardening, scarification, treatment of seeds with various growth stimulators, including microfertilizers, etc., have been employed in the agricultural industry.

However, many of the methods of presowing treatment which have been recommended at various times for use in agriculture have proved to be fairly complex and laborious, while some are not effective enough and have not been widely adopted in practice.

It is quite understandable that attempts should now be made to use electricity for presowing treatment of seeds with the aim of improving their germinating qualities.

As far back as the thirties work on the presowing treatment of seeds with high-frequency currents was begun by Comrade Gaman under the leadership of Academician N. I. Vavilov in the All-Union Research Institute of Plant Growing. This research, however, was not developed in due measure for a number of reasons. Just after the end of the Great Patriotic War this work was taken up again under the leadership of Corresponding Member of the Academy of Sciences, USSR V. P. Bologdin in the Institute of High-Frequency Currents in Leningrad. This method, however, was not recommended for adoption in agriculture.

Scientific research in the field of application of various sources of electrical energy for presowing treatment of seeds has continued.

Several methods of presowing treatment of seeds with various forms of electrical energy and other physical reagents – ultraviolet and infrared rays, ultrasound, etc. – are now used. Investigations in this direction are being conducted not only in the USSR, but also in many foreign countries – the USA, England, East Germany, West Germany, France, Italy, Japan, etc.

In our country a large amount of factual data has been collected by various research institutes, which have also carried out field experiments on collective and state farms. These data indicate that the use of various physical factors can improve the germinating qualities of seeds and thus have a significant effect on the subsequent growth and development of the plants.

For instance, the investigations of the Chelyabinsk Research Institute for Electrificiation and Mechanization of Agriculture in Collaboration with Chelyabinsk Pedagogical Institute, and the Ural and Siberian Agricultural Research Institutes showed that exposure to a powerful electric field has a beneficial effect on seeds. Treatment of the seeds not only improved germination and crop yield, but also improved the baking qualities of the marketable grain.

The All-Union Research Institute for the Electrification of Agriculture with the assistance of the All-Union Research Institute of Plant Growing, the Agricultural Research Institute of the Central Regions of the Nonchernozem Zone, the V. R. Vil'yams All-Union Fodder Research Institute, The K. A. Timiryazev Agricultural Academy, and other institutions conducted experiments over a number of years and showed that presowing treatment of seeds with alternating current was promising. Certain seed-treatment procedures had a beneficial effect on the germinating and cropping qualities. In particular, seed vigor and germinating power were increased, especially in seeds with low initial germinating power. It is of interest that the maximal effect was found some time after the treatment of the seeds. This indicates that in seeds treated by this method biochemical changes proceed for some time and build up. After some time the effect reaches its maximum and persists in the seeds for a relatively long time: from 2-3 to 6, or even 12 months, depending on the species of plant. This is extremely important, since the presowing treatment of seed by this method can be conducted well in advance, i.e., during the winter.

In the Azerbaijan Power Engineering Research Institute I. G. Es'man developed a method of presowing treatment of moistened seeds with high-voltage pulses. Treatment of cotton seeds in particular conditions increased their field germination rate and stimulated growth of the plants. This increased the number and weight of bolls on the plants and led ultimately to a higher crop yield. In the case of other crop plants ripening was accelerated and the quality of seeds in the obtained harvest was improved.

The Zaporozhe Branch of the All-Union Research Institute for Electrification of Agriculture conducted investigations on the effect of ultraviolet rays on seeds. The results obtained indicated a beneficial effect of presowing treatment of seeds by this method. The treated seeds had higher vigor and germination rate. This led to an increase in yield and an improvement in the quality of the grain.

The investigations of the Volgograd Agricultural Institute showed the effectiveness of presowing treatment of seeds with infrared rays. In seeds irradiated two or three weeks before sowing the seed vigor and viability was increased. A reduction or cessation of the activity of the harmful microflora and stimulation of enzymic activity were noted.

In several research institutes in our country, including the All-Union Research Institute of Plant Growing, and in some foreign countries research has been conducted on the effect of acoustic vibrations on seed germination and the subsequent development of plants. New data indicating that ultrasonic vibrations have a definite effect on plant growth and development have recently been obtained.

Thus, there is now a fairly large amount of experimental data, which has been obtained by many research and experimental institutes and some of which has been tested out on state and collective farms in several zones of our country.

It is extremely important to investigate the mechanism of action of various physical stimulants on seeds. In this respect biochemical investigations are of great significance, especially during germination, growth, and ripening of the seeds.

Preliminary investigations conducted in this direction indicate that methods of electrical treatment stimulate the activity of proteolytic, diastatic, oxidative, and other enzymes. Data indicating an increase in the protein content of wheat grains, peas, and corn due to the action of an electric field are of particular interest. In addition, a change in qualitative amino acid composition has been discovered. For instance, electrical treatment of beans increased the amount of lysine, cystine, glutamic acid, and arginine.

It can be prudently stated that these preliminary investigations indicate that electrical treatment can be used to alter the direction of protein synthesis and to obtain protein with a higher content of essential amino acids and, hence, a more complete protein for human nutrition and animal feeding.

Yet many questions still remain obscure and even the factual data which provide the basis for the claim that these methods of presowing treatment of seeds are effective are frequently contradictory. In addition to the predominant positive results there is a fair amount of information which indicates the absence of any effect and even a harmful effect of presowing treatment. For instance, it is essential to ascertain if a second electrical treatment actually leads to adverse results and if it does so in all cases.

As regards the use of ultrasonic vibrations it will be important to determine the role of the seed coats, the importance of the position of the embryo, the sensitivity of different types of seeds (proteinaceous, starchy, oily, etc.) to this form of treatment, the importance of the size of the seeds, varietal differences in the sensitivity of seeds to ultrasound, the physiological indices of seeds which have been exposed to ultrasonic vibrations, their enzymic activity, the change in the swelling capacity of the colloids of the coat and endosperm cells, and so on.

The question of the possibility of producing hereditary changes is a very important one. This is important because in this case it might be possible to use various methods of electrical treatment to obtain plant forms with high protein content and of high quality, which are transmitted to the progeny. Plant breeders would find such forms very valuable initial material for the production of new high-quality plant varieties.

It is particularly important in all research on presowing treatment of seeds by physical methods to determine the role of energy processes. Special attention will have to be paid to an elucidation of the role of the moisture content of the seeds and the activity of reducing enzymes in relation to temperature (in seeds, seedlings, and plants).

The existing sparse data on changes in the biochemical composition of seeds which have been subjected to presowing treatment by the above methods and on the changes in the technological qualities of the treated marketable grain indicate that far-reaching changes are produced in seeds by physical factors. There are grounds for postulating that the various sources of electrical energy which have been used for presowing treatment of seeds lead to changes in the electric fields existing in the seeds themselves, including various cell structures. There is no doubt that subjection to these physical factors improves the health of seed and planting material, etc.

Since the nature of the action of the physical factors used for presowing treatment of seeds has not yet been adequately clarified, it has become a serious obstacle to the further improvement of these methods and the wide and universal application of the considered presowing treatment of seeds cannot be recommended.

In our opinion, if these drawbacks are to be overcome, new investigations will have to be conducted simultaneously along three lines.

1. Pot experiments in the laboratory to determine the effect of a particular physical factors on the germinating qualities of seeds and to clarify the nature of the action of these factors.

2. Field experiments to determine the effect of the changes occurring in the seeds on cropping and other qualities. These investigations will have to be conducted by agronomical and biological research and experimental institutes so that the effect of presowing treatment of seeds on the nature of plant growth and development and ultimately on the crop yield and quality can be reliably determined.

3. Extensive field experiments on collective and state farms as an intermediate stage before recommendation of a particular method of presowing treatment of seeds for wide adoption in the agricultural industry.

Many years of research in the field of intensification of the vital activity of plants by electrical factors provide a sound basis for claiming that electrical presowing treatment of seeds will be a significant factor for the presowing treatment of seeds will be a significant factor for the production of high and stable crop yields.

SOME DATA ON BIOLOGICAL INTERACTION WITH THE VISIBLE AND INFRARED REGIONS OF THE ELECTROMAGNETIC SPECTRUM

I. A. Kondurushin and A. A. Shakhov

In the statement and formulation of the problem on plant photoenergetics the attention of the authors was focused not only on the energy (as such) of limiting regions with visible light. They were interested in the effects on plants of the energy of limiting regions (ultraviolet or infrared) in combination with spectral regions of visible light [1]. In this connection, they stressed the importance of regularities of spectral mutual complement, spectral incompatibility or reaction. Research carried out in the ultraviolet [2] and infrared [3] regions of the electromagnetic spectrum seemed promising and encouraged further work.

A. Szent-Györgyi [4] pointed out that the near infrared region is of direct interest to biologists and it is noteworthy in itself. Szent-Györgyi believes that it is just here that pure electron and vibrational excitation become equal in magnitude, and transitions between them become easiest. As other limiting regions, this spectral region, which lies beyond the region of visible spectroscopy and before the region of usual infrared spectroscopy, is still a "no man's land." This region has plenty of surprises even for physicists. The secrets of the region are guarded not only by technical difficulties, but also by water, which has several absorption bands in this region [4, p. 41].

The objective of this research, which was started in 1965, is to investigate the effect not only of thermal, but also of infrared radiation on the energy producing process of plants. In this work the effect of the near infrared radiation in itself and in combination with spectral regions of visible light on the respiration rate of plant leaves, is examined. From some of the previously presented photoenergetic preconditions it can be expected that the effect of infrared radiation in combination with other regions of the optical spectrum will differ from the effect of only infrared radiation.

The test procedure consisted in the following. Leaves were cut off under water and the cut stems were put into a test glass filled with water and placed in a specially constructed analytic chamber which was connected to an IRAS-1 infrared gas analyzer. In the upper, tilted part of the chamber (roof) there are grooves for two or three light filters measuring 80 × 80 mm or 40 × 40 mm. Inside the chamber there are two thermistors for continuous temperature measurement of the leaves and air. During the test the infrared gas analyzer was operating in a closed system which ensured an air stream of 60 liters/h.

Various reflecting and projecting filament cinelamps were used as radiation source. The angle of incidence of the rays onto the leaves was 45°. The required region of the spectrum was selected by using standard glass light filters [5]. For plant irradiation by visible light a water filter 35 mm thick was also used. The radiation was measured with Prof. B. P. Kozyrev type thermopiles [6].

The first test, carried out on Trabzon type tobacco, showed that the respiration in the dark in the budding phase of the third upper leaf was about 2.5 mg $CO_2/dm^2 \cdot h$. In such a leaf the approach to the compensation point of gas exchange is reached on its exposure to red light (KS-10 filter transmitting in the region of 600-800 nm) with an intensity of about 2000 $ergs/cm^2 \cdot sec$. In these conditions the respiration does not exceed 5-15% of the respiration in the dark. When the leaf was exposed for 5 min to near infrared radiation (IKS-3 filter transmitting in the region of 0.9-3.0 μm) with an intensity of 200,000 $ergs/cm^2 \cdot sec$, the respiration increased by 90-100%. Under the simultaneous effect of red and infrared light, the respiration did not exceed 10-20% of the respiration in the dark. The small increase in the respiration during the combined effect of the infrared and red regions of the spectrum, compared with the infrared only, was indicative of the distinctive effect of red light. Similar data were obtained on lilac, black currant, Indian corn, and pea.

Thus, infrared activation of the respiration and deactivation corresponding to it, which is produced by [illegible] the [illegible] infrared, was observed. The observed data on such regularities required

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[illegible] No. 7, pp. 13-[illegible], Septem[illegible] ber, 196[illegible].

TABLE 1. The Activating Effect of Infrared Radiation on the Respiration of Leaves and the Deactivating Effect of Red and Blue-Green Light (on Simultaneous Irradiation with Infrared Radiation)

Object	Conditions of irradiation (brand of filter)	The energy received by the leaf, ergs /cm^2·sec	The respiration rate	
			CO$_2$, mg/dm^2·h	% of respiration in the dark
Leaf of lilac	Darkness	–	2.7	100
	KS-10	2000	0	0
	IKS-3	200000	4.3	160
	KS-10+IKS-3	202000	0.3	11
Leaf of tobacco	Darkness	–	2.4	100
	KS-10	2000	0.36	15
	IKS-3	200000	4.8	200
	KS-10+IKS-3	202000	0.44	18
Leaf of black currant	Darkness	–	1.4	100
	SZS-14	2000	0.4	29
	IKS-3	150000	2.4	171
	SZS-14+IKS-3	152000	0.6	43

verification. This was done in ensuing experiments, the more typical of which gave the following results (see Table 1).

As can be seen from Table 1, during a 5-min irradiation of the leaf by red light, a cessation or a considerable decrease in respiration was observed. Such a drastic decrease in respiration also occurred during a 5-min irradiation (prior to that the leaf had been in darkness for 20 min) by blue-green rays. Under the effect of infrared light on such a predarkened leaf, its respiration increased by a factor of 1.5 or doubled. During the 5-min exposure to the infrared light, the temperature of the leaf increased by 10-12° C.

On irradiating simultaneously with infrared and red light, the respiration did not increase, but on the contrary, considerably decreased; at the same time a sharp increase in the leaf temperature would be observed. The respiration became not only several times lower than that on activation by infrared light only, but considerably lower than that of the respiration in the dark.

Thus, under infrared exposure and with the accompanying increase in the leaf temperature to 30-32° C, the red or blue-green light drastically reduces the respiratory activity of the leaf without reducing the temperature. The red or blue-green light together with the near infrared radiation becomes reactivating. Something similar to photoreactivation of respiration is observed. This was observed by Owen [7] on tobacco leaves for which the respiration increased by 20% after being exposed to ultraviolet light, and decreased to 7% of the initial value on exposure to visible light. In the latter case, opposing types of interaction can also be observed in the region of the electromagnetic spectrum, i.e., visible with ultraviolet light, which is known as photoreactivation.

In the authors' experiments, photoreaction, produced not only by white, but also by red, green, and blue-green light, can be observed. According to other data obtained by the authors, the red light produced the strongest effect, the reactivating ability of which without infrared increased with the increase in intensity in a range from 1000 to 18,000 ergs/cm^2·sec. A 3-min exposure to red light of an intensity of about 15,000 ergs/cm^2·sec was sufficient to normalize the respiration which had been activated by a 5-min infrared irradiation at an intensity of about 200,000 ergs/cm^2·sec, whereas in darkness the respiration was normalized within 25-30 min.

It is interesting to note that the reactivating effect of white light with respect to the effect of infrared radiation is also observed when the plant is exposed to visible light before the infrared. At the beginning of the investigations of the problem it was noticed that, if the leaf was left in darkness for 30-60 min before infrared irradiation, the normalization of respiration after infrared irradiation was somewhat different from the normalization of a leaf taken directly from the light. Most reliable data were obtained in experiments when the leaf was pre-exposed to red light. On exposure of a tobacco leaf to red light at an intensity

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The observed phenomena of photoreactivation of infrared radiation is connected with the low-energy region of the electromagnetic spectrum and therefore must have a mechanism differing from that due to the damaging effect of short-wave ultraviolet radiation. Therefore this particular effect should have a different name in order not to confuse it with the photoreactivation related to the ultraviolet region.

Is the protective effect of the red light on the respiration, activated by infrared light, connected with phytocrome ? A negative answer should be given to this question.

On a classical object for phytochrome studies, such as lettuce seeds, an increase in the respiration rate on exposure to red light with a maximum wavelength of 660 nm [8, 9] was observed. The red light stimulated the respiration of mustard shoots [10]; however, the respiration intensified only after 24 h after exposure to red light, apparently as a result of the change in metabolism. In all the tests connected with the presence of phytochrome in seeds and shoots, the far red light (λ = 735 nm) cancelled the effect of red light (λ = 660 nm). In the experiments, carried out by the authors, another (reverse) regularity was observed, i.e., the desactivating effect of the red light compared with near infrared with a maximum at about 2 μm. Besides, in the tests of the authors, the plants received a thousand times more energy from both the red and infrared light than would have been necessary for the saturation and reversible transition of both forms of photochrome [11]. During irradiation at the level of low-energy "phytochrome" reactions (of the order of tens of thousands of ergs/cm^2 in all), the authors have not observed any change in the respiration rate either during irradiation or at least an hour after irradiation. Finally, in the authors' tests, not only red, but also green and blue-green light, though to a lesser extent than the red, produced a reactivating effect relative to infrared light.

On the basis of the mentioned facts, the authors believe that the reactivating effect of the red light on the respiration activated by infrared light, as observed by the authors, is not connected with phytochrome.

Since, under the simultaneous effect of red or green light with infrared, the temperature of the leaf which has been raised by infrared light by 10-12° C does not drop, and the respiration nevertheless becomes normalized, it is believed that the infrared activation of the respiration and its reactivation is due not only to the thermal but also to the purely radiational effect of the infrared light. This being the case, the protective effect of the visible light and its separate regions (red, green, blue-green) against the infrared light, which makes up half of the sun's radiation, is of wider biological interest.

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PROGRESS IN AGRICULTURAL PRODUCTION

ELECTRICAL STRATIFICATION OF VINE GRAFTS

L. V. Kolesnik, G. M. Fedorishchenko, and N. E. Fedorenko

Kishinev

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One of the main problems of viticulture is the production of grafted vines resistant to Phylloxera. Hence, the stratification process is a very important period in the life of grafts. During this time callus tissue forms on the graft sections and subsequently becomes differentiated, thus leading to the fusion of the scion and stock. At the same time the eye of the scion is formed and the rudiments of the root system are laid down at the base of the stock. Thus, the successful growth of grafts in nurseries and the number of top-grade plants obtained depends greatly on the correct progress of the physiological processes in the stratification period.

Investigations in this field show quite definitely that the correct progress of the stratification process requires accurate temperature control and for certain varieties of vine the temperature has to be different in the upper and lower parts of the cutting.

It has been found [1, 2, 3, 4] that stratification of vine grafts with a lower temperature at the base of the stocks is more successful than in the case of uniform heating in hothouses.

Subsequent investigations [5] showed a better uptake of nutrient elements into grafts when the temperature was 18-25°C. The effect of different temperatures in the upper and lower parts of the grafts on callus formation and fusion of the scion and stock was also investigated.

The stages of differentiation of the conducting tissue of the scion and stock in the callus during fusion and hardening have been determined [6].

It is obvious that all these results of investigations could not have been obtained in nurseries, where the whole stratification building is usually heated. It would be impossible not only to regulate the temperature accurately in the region of union of scion and stock, but also in the stratification boxes.

A very simple solution to this problem was secured by local electrical heating of the region of junction of scion and stock. With the aid of the special ÉFI-14 electrical stratification apparatus designed by the Institute of Applied Physics, Academy of Sciences, Moldavian SSR and the M. V. Frunze Kishinev Agricultural Institute, electrical heating was effected by metal frames with a heating cable. The temperature was automatically maintained at within ± 2°C of a preset level throughout the stratification period.

With this system of regulation the temperature of the heating element itself changes abruptly and fairly considerably, but the very low heat conduction of the sawdust and its continuity smoothe out these variations very well and, as accurate temperature measurements in the region of callus formation have shown, they are of no practical significance. Moreover, since the heating element is situated at a distance of 4-5 cm above the grafts, the temperature field in the stratification box has the required configuration. With increase in depth below the heating element the temperature decreases owing to heat conduction and heat loss, and in the lower part of the box is equal to the temperature of the surrounding air. This temperature distribution ensures local heating of the zone of callus formation and an appropriate temperature distribution along the plant. The temperature in the upper part of the grafts is set and automatically maintained by a thermostat, whereas the temperature of the lower part is maintained by an appropriate change in the ambient temperature.

The first experiments on local electrical heating of the graft zone showed that callus formation was most rapid at 28-30°C. We noted in this case that large callus excrescences are formed in the first 12-14 days. However, the differentiation of the conducting vessels in the callus is retarded. This is because new cells are formed rapidly at elevated temperatures and the callus grows outwards without forming a conducting system (Fig. 2, a).

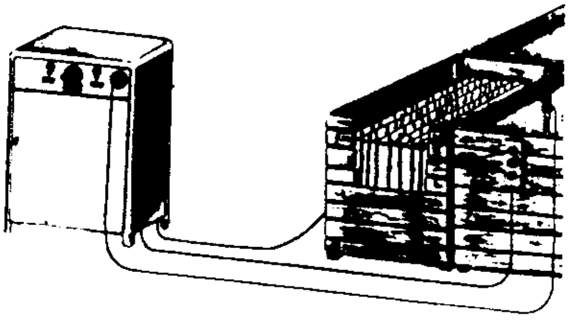

Fig. 1. Schematic illustration of arrangement for electrical stratification of vine grafts by means of the ÉFI-14 apparatus.

At a slightly lower temperature (23-24°C) the rate of callus formation is lower than in the previous case but the differentiation of the cells is better and more rapid. In this case anatomical sections obtained at the end of stratification (16-18th day) showed good formation of conducting xylem vessels at the site of union of the scion and stock (Fig. 2, b). This indicates good fusion and, ultimately an increase in yield of top-grade plants in the nursery.

We also found a very significant relationship between the good development of the plant, the variety of the stock, and the temperature conditions during stratification. For instance, for a Berlandieri × Riparia Kober 5BB*rootstock a more effective temperature was 25-26°C in the upper part and 22-23°C in the lower. For Rupestris dyu Lo rootstocks the most favorable temperature conditions were 24-25°C in the upper part and 22°C in the lower, while the best temperatures for Riparia Gluar and Riparia × Rupestris 101-14 stocks were 22-23°C in the upper part and 18-19° in the lower part of the grafts.

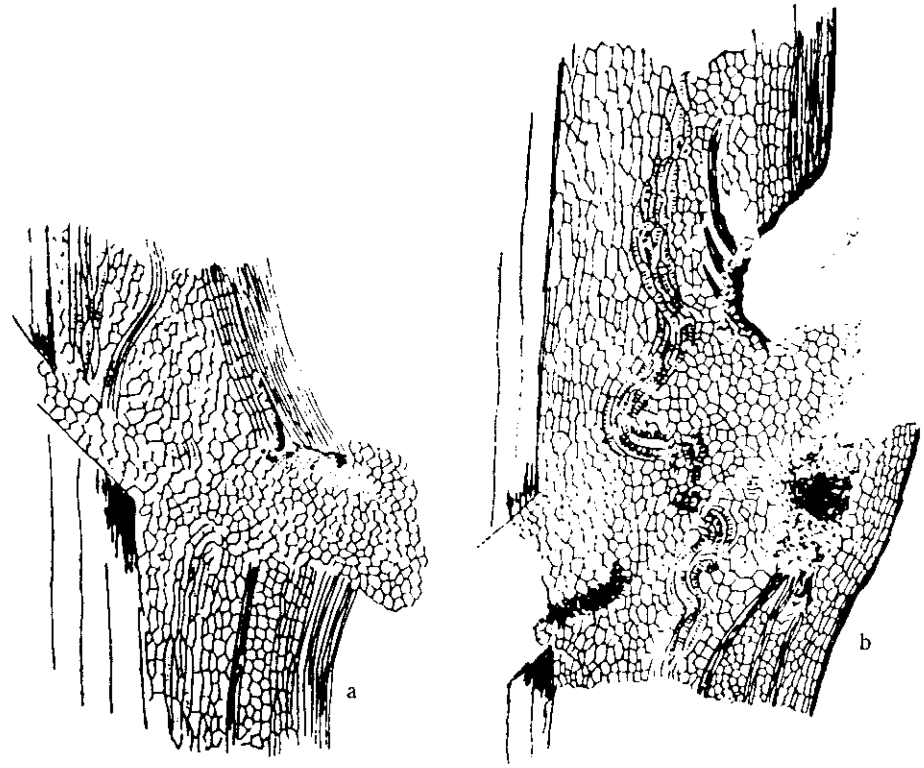

Fig. 2. Anatomical section of graft on side of acute angle of scion: a) Stratification at 28-30°C. A large callus excrescence is formed but its cells are not differentiated; b) stratification at 24°C. Xylem vessels can be seen on the section.

If the temperature at the base of the stocks was too low the yield of young plants was reduced. For instance, the yield of plants was 80.1% when the temperature in the lower part was 23°C, whereas the yield was reduced to 53% when the temperature was lowered to 17°C. In addition, of course, reduction of temperature increases the duration of the stratification process.

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* The plant names are transliterated from the Russian—Publisher's note.

Of no less importance for electrical stratification is the maintenance of the optimum moisture content in the sawdust to secure the normal progress of the physiological processes in the grafts. A low moisture content of the sawdust in the upper part of the box has an adverse effect on callus formation. The heating elements and the drying up of the sawdust at the open sides of the boxes tend to reduce the moisture content. We found that the most effective method of maintaining optimum moisture content of the sawdust was to damp it with warm water on the 6th, 9th, and 12th day of stratification.

The question of the nutrition of the grafts during stratification is very important. It is recommended that nutrient solutions should be placed in the immediate vicinity of the base of the stock at the bottom of the box.

When all the above-mentioned conditions (temperature conditions, moisture content, nutrition, etc.) are fulfilled, the yield of top-grade plants obtained by electrical stratification is much higher than that obtained by the previously employed hothouse stratification. For instance, according to the data of the Moldavian State Machine Testing Station, hothouse stratification of the variety Korna nyagra on Riparia Gluar in the case of a blind stock and the nutrient mixture "soil + PK + B" gave a yield of 42.1% top-grade plants, whereas electrical stratification with the ÉFI-14 apparatus for the same type of stock and nutrition increased the yield to 52.1%.

SUMMARY

1. Electrical stratification of vine grafts is an effective method of increasing the yield of top-grade plants from a nursery.

2. The best temperature conditions during stratification vary with the biological characteristics of the stock.

3. Electrical stratification is a very promising method as regards improvement of the quality of grafted plants, saving of power, and reduction in the relative amount of manual labor.

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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 vigorously 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).

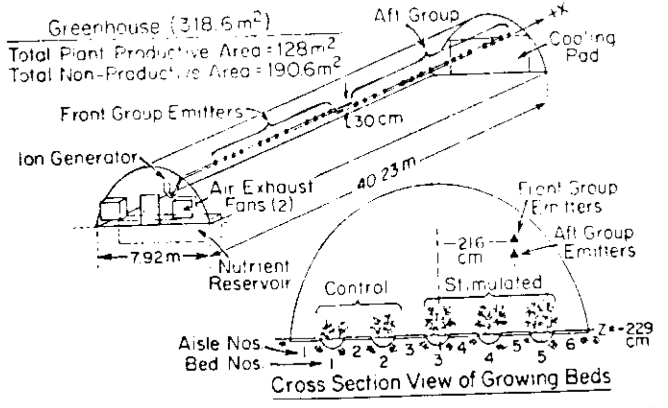

Fig. 1. Longitudinal and cross-section views of the greenhouse. The air-ion emitter installation and the location of the air-ion-treated and control plants are shown.

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 m^2. A covered below-ground level reservoir to contain the nutrient solution and pump/valve assembly is located just inside the entrance door

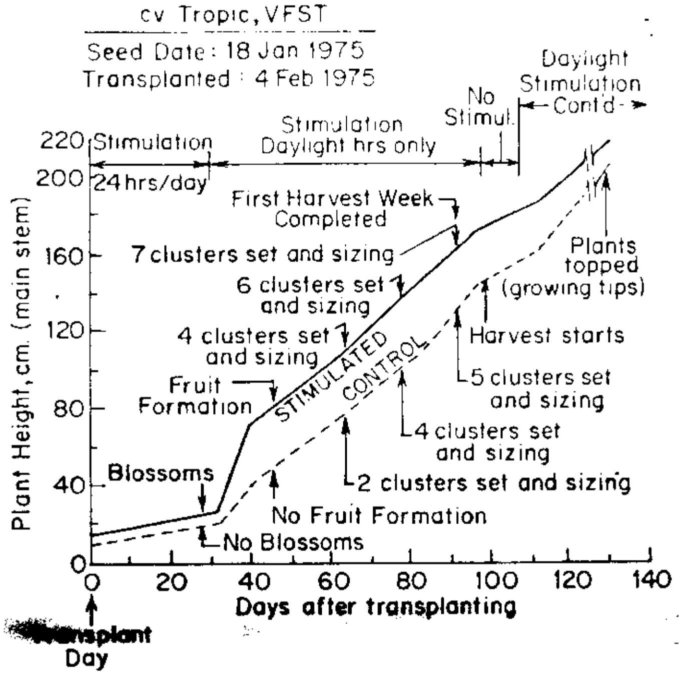

Fig. 2. Plant growth rate of control and air-ion-treated tomato plants. The ordinate indicates average main stem length in centimeters. The abscissa lists the days after transplanting. Major events characterizing the air-ion-treated plants and controls are entered.

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

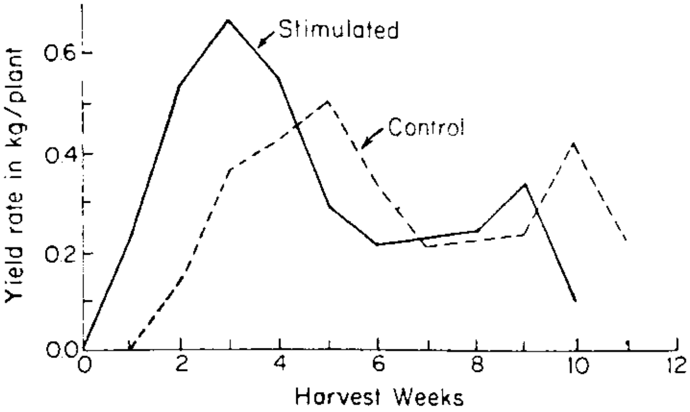

Fig. 3. Tomato plant yield for air-ion-treated and control plants plotted as yield rate against harvest weeks.

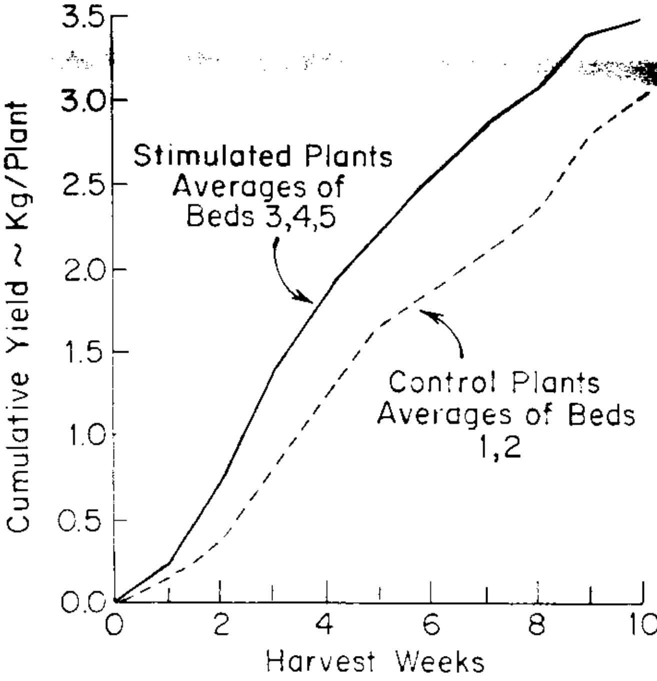

Fig. 4. Fruit yield as a function of greenhouse unit area.

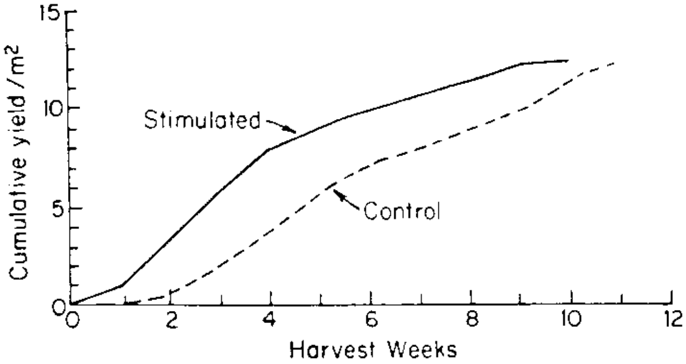

Fig. 5. Cumulative fruit yield per plant for controls and ion-treated plants plotted against harvest weeks.

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

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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.

THE USE OF ULTRAVIOLET RADIATION IN PLANT PROTECTION

M. I. Zhigal'tseva and S. M. Chernobrovina

Kishinev

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Crepuscular and nocturnal insects usually move around randomly in space. However, when there is a particular landmark, such as an artificial light source, their movement begins to show elements of regularity and, as a result, most insects approach the landmark until they come into direct contact with it.

This characteristic of insects has been known for a very long time and there are abundant, though very contradictory data, on the capture of insects by means of light. In the middle of the 19th century simple traps consisting of a lamp and a vessel containing a viscous liquid were used in the U.S.A. and Canada, but they did not justify the hopes placed in them. In the late thirties and early forties of the present century new light sources, including mercury and fluorescent lamps, were tested for the purpose of capturing insects. According to existing data, ultraviolet light sources attract more insects than incandescent lamps and baits. They are recommended for control of the cockchafer, pests of waters, the gypsy moth, and *Dendrolimus sibiricus* Tschtw.

Electric light traps are used abroad on rice and other plantations; it has been reported that their efficacy is increased if they are used in conjunction with odorous baits.

Electric light traps are also recommended for the Prediction and Warning Service. Yet they have not been widely used so far and it is questionable if the data on the number of insects attracted to light are sufficient to determine the times for chemical treatment of plants.

Thus, the available data on the efficacy of light traps are contradictory and lack an adequate experimental and theoretical basis. Moreover, the lack of information on the age composition of insects attracted to light sources gives ground for doubting the advisability of using this method at all.

The aim of the present investigation was to clarify some aspects of the biological action of ultraviolet rays on insects and to determine their applicability for the Prediction and Warning Service and for the control of crepuscular and nocturnal crop pests.

The action of ultraviolet rays on living tissues begins with the absorption of these rays by biological structures. A primary center of absorption in insects is the visual system. It has been found that after exposure to a particular dose of ultraviolet radiation the insect nervous system begins to cause movements of the musculature. Using a technique we have devised, we registered these movements automatically (Fig. 1). The nature of the curves of motion of the insect musculature clearly show that the response to irradiation is practically the same as the reaction of insects to poisoning by DDT (Fig. 2), i.e., in this case ultraviolet rays produce a toxic effect [1]. Of equal interest is the effect of ultraviolet rays on the reproductive system of females, since they secure the preservation of the species. In fact, up to 70 thousand insects, about half of which were females, were collected around one lamp during the mass flight period. More than 60-70% of the attracted insects were agricultural pests. For instance, during the mass flight period a PRK-4 lamp attracted up to 3500 specimens of *Hyponomeuta malinellus* Zell., of which 40-50% were females. It can be assumed that not all the attracted insects are caught in the collector, i.e., they are not all killed. Then we might have expected an increase in the numbers of *H. malinellus*, for instance, around the lamp in the next season. However, in the second year of operation of the traps not a single nest of *H. malinellus* was found within a radius of one kilometer from the lamp. In the following years only a few egg batches were found in the same region.

What has been said and the obtained experimental data on the characteristics of light perception of several insects induced us to analyze their response to light from the viewpoint of age-dependent functional characteristics, because light traps are useful and necessary only in the case where they trap young insects before or at the onset of egg-laying and are quite useless if they attract only old insects which have already laid a large number of eggs.

We found that electric light traps attracted young individuals which had not laid their eggs or had only started to do so. Only a few specimens out of 4000 insects which we examined were attracted after they had laid a large number of eggs.

To determine the practical value of electrical plant protection we had to determine the radius of action of the source and the best height at which to place it.

Any emitter of ultraviolet and visible light of different wavelength is surrounded by three zones which have different effects on the behavior of flying insects. In the immediate vicinity of the lamp there is a zone in which the insects are inhibited by light and lose their sense of direction ("shock reaction"). In this zone the positive phototaxis is obviously replaced by negative phototaxis. This is the first zone—the zone of inhibition. Outside it there is a second zone—the zone of attraction. This is the optimum zone of action of ultraviolet rays on insects. Insects flying into this zone change their direction of flight and move towards the source. Outside this zone there is a zone in which the lamp has no action.

The absolute sizes of these zones vary with the power and kind of lamp. This, in turn, determines the number and species of attracted insects. An increase in the power of the lamp does not always lead to an increase in the number of insects attracted. This is clearly borne out by the data shown in Table 1, which gives information on the number of tortricids (Tortricidae, Lepidoptera) attracted to various lamps (mean data for 15 days in August, 1963).

The limits of the zone of attraction of different lamps have to be determined experimentally. For instance, we found that <u>Tortrix viridana</u> L. is attracted to the lamps indicated in Table 1 from a distance of 0.5 km and species such as the European corn borer are attracted from a distance of more than one kilometer.

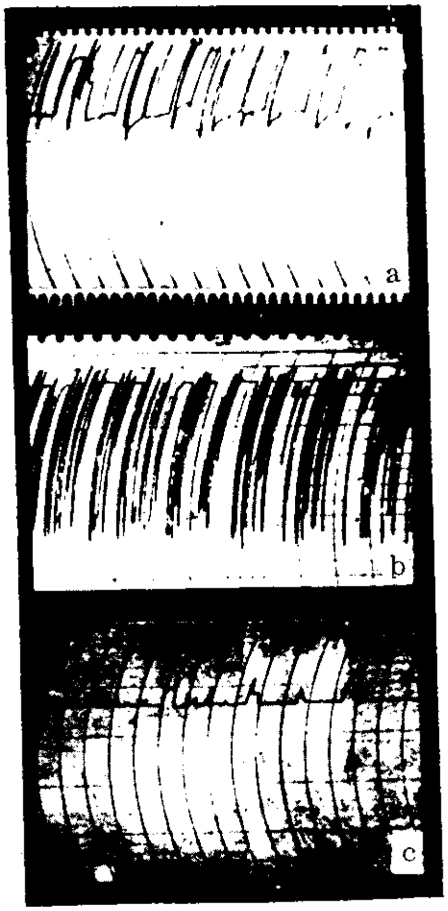

Fig. 1. Records of movements of imagines of the codling moth after ultraviolet irradiation: a) At start of "quivering" stage; b) a "convulsion" stage; c) weak response to stimulation.

Insects which have flown into the optimum zone do not leave it, although it sometimes appears that the insects move away from the radiation source. Insects during this time apparently need to receive a particular amount of light energy to complete their oriented flight. Such behavior of insects may be used to direct their flight to a concentration center, where they can subsequently be destroyed.

TABLE 1

Peak emission of lamp, nm	Power consumption, W	No. of insects per day		
		mean	maximum	minimum
300—325	30	73	180	0
365	220	150	317	14
365	375	148	293	35
577—600	100	41	79	0

In the optimum zone of action of the lamps each species of insect selects the optimum intensity and height of flight. For most insects this height of flight above the ground is 0.5 m. This is the height preferred by insects of the orders Lepidoptera, Diptera, Coleoptera, etc. The experimental data on which this conclusion is based are given in Table 2 which shows the number of species of noctuids attracted to a lamp of the PRK-4 type (mean data for 14 days).

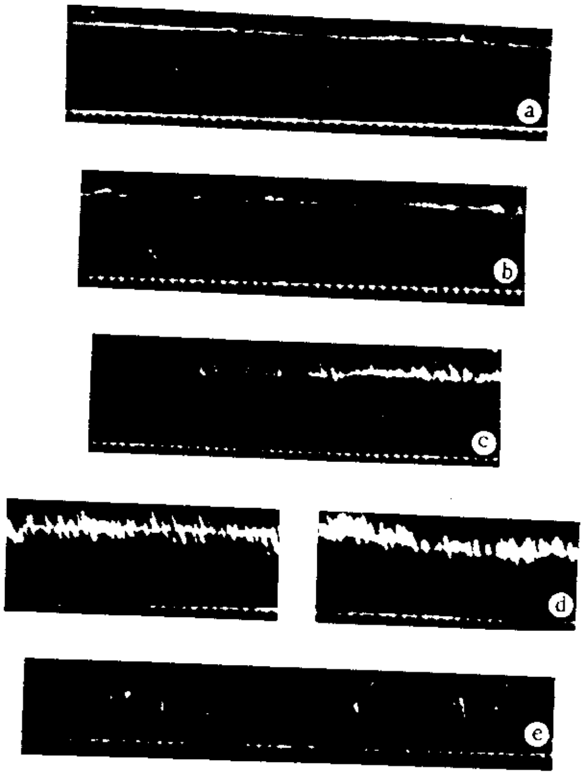

Fig. 2. Records of movements of limbs of a fly poisoned with DDT. Top line—30-sec time marks. a) Before poisoning; b) in "convulsion" stage; c) at start of "quivering" stage; d) at end of "quivering" stage; e) retention of only a weak response to mechanical stimulation (according to N. B. Il'inskaya [1961]).

TABLE 2

Pest	No. attracted per day	Percentages at different heights			
		0,5 m	2 m	1 m	6 m
Phytometra gamma L.	176	31,8	25,2	21,5	21,5
Chloridea dipsacea L.	95	60	9,5	20,0	10,5
Agrotis ypsilon Rott.	51	45,2	23,5	15,7	15,6
Euxoa segetum Schiff	39	54,0	—	30,4	15,6
Barathra brassicae L.	85	22,4	7,1	27,1	43,4

This gives rise to the need to create inexpensive effective and selective radiation sources for the attraction of insects. This is particularly important in the case of crepuscular agricultural pests, where the positive response to light increases with reduction of wavelength in the ultraviolet region of the spectrum.

The use of ultraviolet lamps in plant protection may become very extensive. Regular collections of insects will give reliable information for an estimate of the time of onset, peak, and end of flight period of insects. Warning of the flight of imagines so that times for aerosol application can be fixed is a particularly promising application. Ultraviolet lamps can provide the most rapid method of determining the harmful species present and of obtaining information on reproductive biology (dynamics of adult population, number of broods, ratio of sexes, potential fecundity, etc.). Such lamps can be effectively used for the control of flying insects with a crepuscular or nocturnal mode of life.

EQUIPMENT AND INSTRUMENTS

ÉFI-14 APPARATUS FOR ELECTRICAL STRATIFICATION OF GRAPE GRAFTS

S. P. Fursov, G. M. Fedorishchenko, A. I. Kornienko,
N. K. Naumov, and S. I. Gnilyuk

Kishinev

Translated from Élektronnaya Obrabotka Materialov, No. 2,
pp. 83-86, March-April, 1965

The ÉFI-14, which was developed by the Institute of Applied Physics, Academy of Sciences Moldavian SSR, is designed for stratification of grape grafts by means of local electric heating of the junction of the scion with the wilding.*

The apparatus consists of a power supply, 96 heating elements, and a control system, which are interconnected in a certain manner. A schematic diagram of the ÉFI-14 is shown in Fig. 1, and an external view of it is shown in Fig. 2.

To accomplish stratification, four groups of heating elements are connected to the power supply; the elements heat boxes with the grafts in them, automatically maintaining the assigned temperature.

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*See L. V. Kolesnik, G. M. Fedorishchenko, and N. E. Fedorenko, Élektronnaya obrabotka materialov, No. 1, p. 74 (1965), for a more detailed description of electrical stratification of grape grafts.

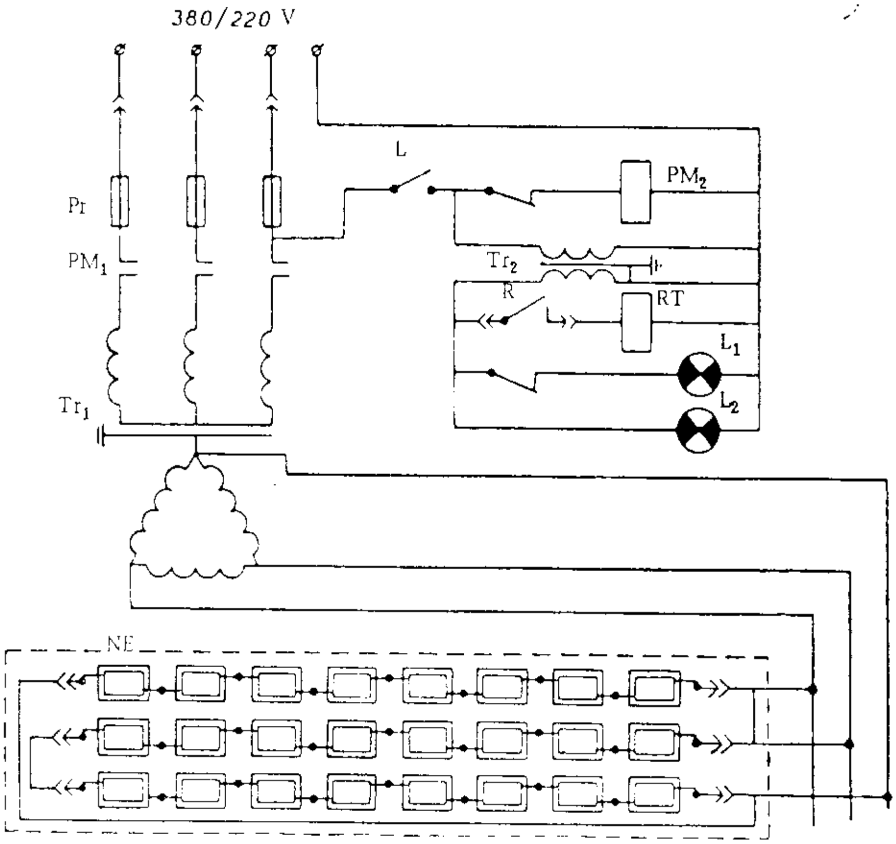

Fig. 1. Schematic diagram of ÉFI-14.

Technical Specifications

Productivity (number of grafts per season)	100,000-150,000
a) Power Supply	
Three-phase line voltage	380/220 V
Frequency	50 cps
Secondary voltage	38 V
Power consumption	2.5 kW
Over-all dimensions	520 x 320 x 760 mm
Weight of power supply	75.5 kg
b) Heating Element	
Working voltage	4.5 V
Current	5 A
Power	22.5 W
Over-all dimensions	360 x 570 x 10 mm
Temperature deviation in heating zone	± 2°C

The heating elements are connected in series (eight each), and then they are connected into a triangle in groups of 24 each.

The magnetic starter PM_1 is actuated by the rotary switch P (Fig. 1). The line voltage goes through fuses Pr to the primary winding of the power transformer Tr_1. The 38 V from the secondary winding of the transformer Tr_1 is fed through connecting leads to the heating elements NE, which are located in the stratification boxes. When the temperature in the heating zone exceeds the assigned value, the contacts of the temperature relay RT – which is located in one of the stratification boxes – are closed, which causes relay R to disconnect the pilot lamp L_2 and the magnetic starter PM_2. As a result, the power is removed from the heating elements. When the temperature falls, the heating elements are connected. Thus, the temperature conditions in the stratification zone are maintained automatically.

The required temperature conditions are created at the junction of the scion with the wilding as follows: the disk of the DZhK-2 relay is moved counter clockwise to the extreme position and connects the apparatus. When the assigned temperature is reached (checked during calibration with a mercury thermometer), the disk of the DZhK-2 relay slowly turns clockwise until the apparatus is disconnected.

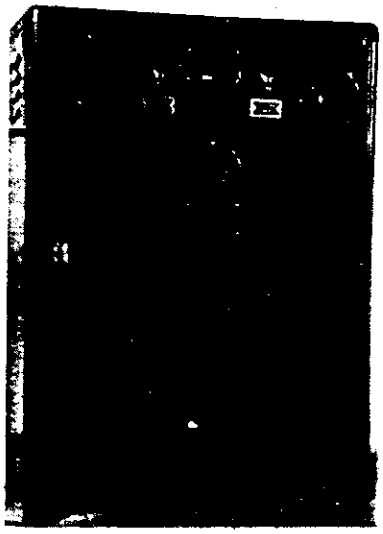

Fig. 2. External view of ÉFI-14 for electrostratification of grape cuttings.

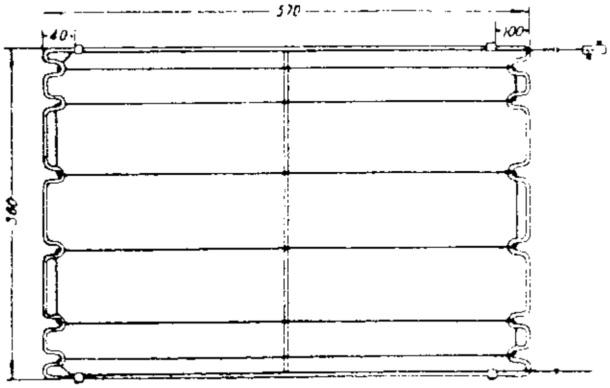

Fig. 3. Heating element of ÉFI-14.

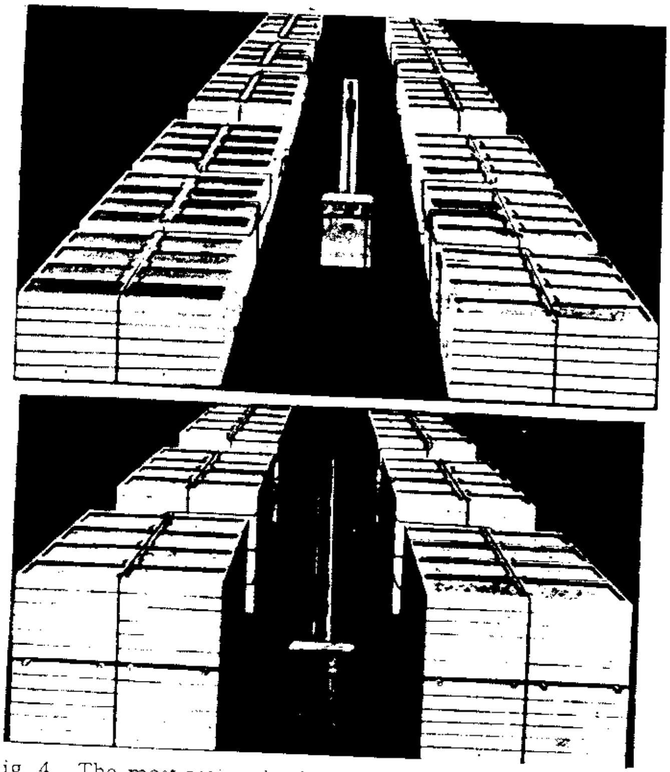

Fig. 4. The most rational schemes for connecting the ÉFI-14: a) in one level; b) in two levels.

The temperature can also be controlled manually with the apparatus.

The power supply of the apparatus is made in the form of a rectangular welded frame. The front of the unit has access to the fuses and the terminals of the 38 V transformer. An external view of the unit is shown in Fig. 2.

The heating elements of the ÉFI-14 are made in the form of metal frames (Fig. 3), to which a POSKhV steel conductor with a diameter of 1.1 mm is attached. Alternate spacing of the conductor ensures uniform heating of the sawdust and grafts over the entire cross section of the box. One end of the conductor ends in a terminal for connecting the free end of the next heating element.

The apparatus is designed for heating boxes of standard size (length 670 mm, width 480 mm, and height 600 mm).

In the place for stratification, the boxes are arranged in groups such that the heating elements in them can be connected by terminals without additional conductors. The most successful arrangements are shown in Fig. 4.

A gap is left between the levels so that the moisture content of the sawdust and the state of the grafts can be controlled.

This new, electrical method of stratification of grape grafts with the ÉFI-14 opens great possibilities for expanding the production of grafted planting material, increases the quality of grafts, and reduces the cost of grape seedlings.

In 1964 these devices successfully passed the state tests at the Moldavian and Georgian State Machine Testing Stations.

The experimental plant of the Institute of Applied Physics, Academy of Sciences, Moldavian SSR, manufactured a batch of ÉFI-14s for nurseries in Moldavia and the Ukraine.