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Use of Radio-Frequency Heat in Seed Treatment

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The use of radio-frequency heat in research is a relatively new field which, until rather recently, has been but little explored. Radio-frequency heat or "dielectric" heat was probably first used by the medical profession where it was employed to induce "artificial" fever. (3) Radio-frequency induces internal heat rapidly and in a manner which can be fairly well controlled as to intensity and penetration. Radio-frequency heat is now being employed in the manufacture of plastics, in rapid cooking, and where rapid drying is essential. One large farmers' co-operative (1) makes use of radio-frequency heat for "sanitizing" feed bags for use in feed distribution. Soderholm (12) used radio-frequency heat to kill rice weevils and pink boll-worm larvae. Other workers (2, 8, 10, 15) have attempted, through its use, to control seed-borne diseases.

The principle of high-frequency heating is the generation of heat within the substance. This occurs because the charge on the condenser plates alternates millions of times per second. As a result, the electron orbits within the substance being treated are distorted, inducing heat. The amount of heat developed varies with the number of times per second the electron orbits are distorted, with the square of the applied voltage gradient, and with the type of material treated.

There is need for a practical and rapid method of heating contaminated seed and increasing germination of so-called "hard seed". Permeability and seed germination have been studied (6, 11, 14) in relation to moisture content, but these studies have not necessarily dealt with use of radio-frequency heat. The studies herein reported were designed to investigate the possibilities of radio-frequency heat as an adjunct to other seed treatments.

[1] Condensed from a thesis prepared by the senior author and presented to the Graduate School at the University of Idaho in partial fulfillment for the requirements of the Master of Science degree in Agriculture.

[2] Grateful acknowledgement is extended to Professor H. E. Hattrup of the Department of Electrical Engineering, University of Idaho for his aid in adaptation and operation of the instruments.

[3] Graduate fellow 1951-53 and Horticulturist, respectively.

Materials and Methods

A Westinghouse 1-kilowatt, 10-megacycle oscillator (Figure 1) was used as a source of the radio-frequency heat. The aluminum plates, 3 x 10 and 3 x 18 inches, spaced arbitrarily at 3/8-inches apart, served as electrodes between which seeds were passed on a belt system. The time of exposure was determined by various pulley sizes which regulated the speed of the belt. A time of 2 minutes, 37 seconds was used on most of the treatments. The treatments are expressed in terms of voltages across the condenser plates. These are read from the voltmeter toward the back of the generator (Figure 1). The meter in front of it is an ammeter which measures radio-frequency through the condenser plates. It serves as a check on the voltmeter to insure the same treatment each time the generator is used. Table 1 indicates the voltages used in these tests and also their corresponding amperages.

At times, the amperage did not check with its corresponding voltage. This was especially true when the higher voltages were

Figure 1. Apparatus used for treating seeds with radio frequency heat.

- **A. Condenser plates between which seeds were passed on a cloth belt.**
- **B. Pulleys which regulated the speed of the belt.**
- **C. Voltmeter used to measure voltage across the condenser plates.**
- **D. Ammeter used to measure the amperage of the treatments.**

used. However, every precaution was taken to get corresponding readings on both meters.

TABLE I

Voltages Used in The Treatments and Their Corresponding Amperages

Amperage	Voltage
1	1000
2	1250
3	1600
4	2000
5	2500
6	2800
7	3700
8	4500[4]

[4] Approximate capacity of the generator depending upon substances being treated.

Effects of Radio-Frequency Heat on Rate and Total Germination of Seed

Most of the experimental work has been done on peas *(Pisum sativum* L.*)*. However, as the work progressed other seeds were included in the tests. Onions *(Allium Cepa* L.*)*, beans *(Phaseolus vulgaris* L.*)* and peas were used in the preliminary determinations. These seeds were exposed to various periods and voltages to determine a narrow range that might be used for intensive testing.

All germinations were made in a Minnesota germinator.[5] The rag doll[6] method was found to be the best for germinating larger seeds such as peas and beans. Each rolled towel was wrapped in wax paper to prevent unequal drying out. They were placed upright in a beaker and the beaker placed in the germinator. For testing smaller seeds, germination blotters covered on the upper and lower surfaces with wax paper were used. These methods proved to be eminently satisfactory throughout the experiments. Most of the seeds were germinated at temperatures of 20 to 30 degrees Centigrade. The lower range of these temperatures gave best results.

The germinations were counted each day and recorded until approximately 7 days after placing the seeds in the germinator. Any seed whose radicle had pierced the seed coat was considered as germinated. The data were analyzed by the analysis-of-variance method to determine differences among treatments.

Preliminary tests revealed that different types of seed vary with respect to survival from heat treatment. Treatments to show effect of radio-frequency heat were determined for beans, peas and onions. From three to five treatments of 100 to 200 seeds were used for each crop. The voltages ranged from 1000 to 2800 volts. Time of exposure varied from 2 minutes, 37 seconds to 9 minutes, 54 seconds.

[5] Manufactured by the Specialty Mfg. Company, St. Paul, Minnesota.
[6] This method involves the use of moistened paper towels in which the seeds are rolled up.

Effect of Radio-Frequency Heat on Germination of Hard Seed

Seed lots which were known to have high percentages of seed with impermeable[7] seedcoats were used in these tests. Samples of alfalfa *(Medicago sativa* L.*)* and red clover *(Trifolium pratense* L.*)* were obtained from the state seed laboratory at Boise, Idaho, where germination tests had revealed hard seed contents as high as 72 percent. Germination tests on peas (var. Early Dwarf Sugar) showed 50 to 60 percent hard seed. Field bindweed *(Convolvulus arvensis* L.*)* was also included in these tests. Hard seed ran 85 to 95 percent. The original intent was to inactivate bindweed seed but results from preliminary tests revealed that treatments increased germination. Each treatment for alfalfa and red clover contained 400 seeds. For field bindweed and peas, 125 to 150 seeds were used per treatment. Treatments were 1600 to 2800 volts for peas and 3000 to 4500 volts for alfalfa, red clover and bindweed. All exposures were for a period of 2 minutes 37 seconds.One of the bindweed treatments consisted of seed scarified by hand. This was done in order to determine whether failure to germinate was due to causes other than a hard seedcoat. After the seeds were treated they were placed in the germinator. The number germinated each day was counted and recorded for the peas and bindweed. For alfalfa and red clover the total germination was recorded after 7 days.

Effect of Radio-Frequency Heat on Seed of Various Moisture Contents

Various moisture contents were obtained within the seeds by the use of humidity chambers consisting of inverted 800 ml. beakers within which were placed smaller beakers with various saturated salt solutions. Peas (var. Thomas Laxton) were used in the tests and were left in these chambers at a constant temperature for a period of 2 weeks. It was assumed that an equilibrium would be established between the seeds and the atmosphere in which they were placed. Groups of seeds were weighed before placing them in the humidity chambers and reweighed after being taken out to check moisture changes. In Table 2 are

TABLE 2

Salts Used, Gain or Loss in Moisture and the Total Percentages of Moisture Obtained in Seeds of Thomas Laxton Peas

Salt	Gain in Moisture (Gms.)	Total Percentage Within Seed
Check	0.000	12
$ZnCl_2$	-0.125	11
* CH_3COOK	0.273	13
KNO_2	1.052	15
$NaClO_3$	3.096	21

* Moisture contents were determined by oven drying for 24 hours at 105 degrees C.

[7] The term "impermeable" is used relatively throughout this paper. In other words, most "hard" seeds are not wholly impermeable, but may be considered so as far as germinability is concerned.

shown the salts used, gain or loss in moisture and total percentages of moisture within the seeds.

The seeds were treated as soon as possible after removal from the humidity chambers. The same treatment was given to all of the seeds of various moisture contents. Three treatments, 1000 volts at 2 minutes 37 seconds, 1300 volts at 4 minutes 57 seconds and 1600 volts at 2 minutes 37 seconds, were used. Each moisture level was represented by 100 seeds replicated four times.

Effect of Radio-Frequency Heat on Weevil Control in Infested Peas

For the studies on the control of weevils, two groups of infested peas were treated on different dates. These peas (var. Early Alaska), grown near Moscow were badly infested with pea weevil *(Bruchus pisorum* L.*)*. All of the weevils were in the adult stage.

The first group to be treated had been kept in cold storage for a period of 1 month. Since the period of cold storage might have weakened the weevils, thereby affecting the results, another lot of infested peas was obtained which had been stored in a cellar.

Approximately 125 to 150 peas were used in the first group treated and 150 to 200 peas in the second group. Treatments consisted of 1000 to 1600 volts for a period of 2 minutes 37 seconds. Two days after treatment, the number of dead and live weevils was counted. The "closed and open windows"[8] on the peas were separated as to the number of weevils killed to determine in which type of window the weevils were more readily affected. Approximately 60 to 75 weevils that had been removed from the peas were placed in each of four envelopes. They were given treatments of 1200, 1300, 1400 and 1500 volts for a period of 2 minutes 37 seconds.

Use of Radio-Frequency Heat in Inactivation of Weed Seeds

In seed-production areas, particularly when peas are grown, large quantities of "screenings" accrue from the processing operation. These screenings, consisting of weed seed, damaged crop seed and other plant refuse are valuable for feed. Idaho state laws prohibit removal of these screenings from the seed plant to the farm, unless the seed is inactivated by grinding or otherwise. This phase of the work was set up to investigate possibilities for killing seed with radio-frequency heat.

Screenings obtained from cleaning operations of small grain in northern Idaho were treated at 4500 volts for 2 minutes 37 seconds. Much difficulty was experienced from the generator cutting off as a result of burning of some of the larger seeds

[8] Open and closed windows refer to the openings through which the weevils may pass out of the peas and which are sometimes closed.

which heated much faster than smaller seeds. For this reason, longer periods of exposure were not used. After treatment, the screenings were placed between germination blotters and tested for germination. If all the seeds was killed the treatment could be considered a success.

Individual species of seeds were also tested. Only those that would germinate within a reasonable length of time could feasibly be used in this study. These seeds included field bindweed *(Convolvulus arvensis* L.*)*, Russian thistle *(Salsola Kali* L.*)*, rough pigweed *(Amaranthus retroflexus* L.*)*, and sheep sorrel *(Rumex Acetosella* L.*)*. They were treated at 4500 volts for 2 minutes 37 seconds. After placing them for 7 days in the germinator the results were recorded.

Experimental Results

As outlined under MATERIALS AND METHODS there are five phases of this study; namely, the influence of high-frequency radiation on rate of germination, on germination of impermeable (hard) seed, on germination in relation to moisture content of seed, on weevil control in infested seed and on killing of weed seed. Results from these experiments will be taken up in this order.

Influence of Radio-Frequency Treatment on Rate and Total Germination of Seed

These results are shown in Table 3. Although 100 seeds were used for each treatment on the beans, less than 50 percent germinated because of hard seeds. The exposures used were not effective in increasing total germination. One hundred seeds were used for each treatment of Thomas Laxton and 175 seeds for treatments on Early Perfection peas. Analysis of data shows no significant differences among the treatments and the check as to early germination and total germination. Although an exposure of 1600 volts for 2 minutes 37 seconds reduced slightly the total germination of Early Perfection peas, it was not significant. In onions, an exposure of 2800 volts for 4 minutes 57 seconds significantly reduced total germination. Where total germination was reduced the number that germinated early was also reduced. None of the treatments were significantly better than the check for either total or early germination. At 1000 volts, all types of seed showed some increase in total germination.

From these results it can be concluded that radio-frequency heat was not significantly effective in increasing either early or total germination. Germination was increased slightly in all of the seeds tested at lower voltages. Higher voltages were sufficient to cause a decrease of total germination of Early Perfection peas and of onions.

TABLE 3

Germination of Vegetable Seed Variously Treated With Radio-Frequency Heat

Type of Seed	Treatments Volts	Time	Percent Germinated on First Count	Percent Total Germination
Beans (var. Golden Wax	Check		17.0	42.0
	1000	2 min. 37 sec.	11.0	48.0
	1250	" " " "	13.0	39.0
	1600	" " " "	8.0	37.0
Peas (var. Thomas Laxton)	Check		11.0	90.0
	1000	2 min. 37 sec.	10.0	97.0
	1000	4 " 57 "	11.0	94.0
	1000	9 " 54 "	13.0	92.0
	1250	2 " 37 "	9.0	93.0
	1250	4 " 57 "	3.0	93.0
Peas (var. Early Perfection)	Check		9.7	91.4
	1000	4 min. 57 sec.	16.6	95.4
	1000	9 " 54 "	10.8	97.7
	1250	2 " 37 "	13.1	90.3
	1600	" " " "	9.4	72.5
Onions (var. Early Yellow Globe)	Check		8.0	92.0
	1000	9 min. 54 sec.	7.5	97.5
	1250	4 " 57 "	8.0	93.0
	1600	" " " "	8.5	93.5
	2000	" " " "	6.0	92.5
	2800	" " " "	2.5	62.5*

* Significant at 1 percent level.

Influence of Radio-Frequency Treatment on Germination of Hard Seed

A review of literature indicates that heat is effective in increasing germination of seeds with hard seedcoats (7, 9, 13, 14). This fact was further verified in this study. Alfalfa, red clover, field bindweed and peas were tested. As stated previously, the hard seed contents were 72 percent for red clover and 68 percent for alfalfa. In Figure 2 are shown the percentage germinations at the various voltages used. The increase in number germinated was not gradual but there seemed to be a rather sudden increase at 4000 to 4500 volts. This was true for both alfalfa and red clover. Figure 3 illustrates the relative differences obtained among the treatments and the check for germinated and non-germinated seeds from one replicate. Group 1 in the picture is the check which germinated 41 percent. Group 2 received a treatment of 1600 volts for 2 minutes 37 seconds. It was not different from the check in germination. Group 3, treated at 2000 volts for 2 minutes 37 seconds showed an increase in germination to 78.6 percent. Group 4 received a treatment of 2500 volts for 2 minutes 37 seconds. Most of the seeds were killed at this exposure. Dead seeds can be identified by their slightly larger size as compared to those which failed to germinate because of impermeable seedcoats. The peas that germinated produced normal seedlings even though some of the treatments were very severe. This is evident by the appearance of the seedlings in Figure 3.

The original intent with field bindweed was to inactivate it or kill it. However, a treatment of 3700 volts increased the germination to 56 percent as compared to 27.2 percent for the check. Longer exposures, or greater voltages might possibly increase germination still further.

Since seeds might, for several reasons, fail to grow, the aspect of seedcoat permeability was investigated specifically. Some bindweed seeds were scarified by hand by chipping the seedcoats. Obviously, if germination were influenced by factors other than permeability, such a treatment would probably be of little value. Conversely, if such a treatment measurably increased germination, one might deduce that the permeability factor was important. As a matter of fact, such a treatment increased germination from 27.2 percent to 89 percent. Radio-heat treatment was not as effective as scarification, but results were in the same direction.

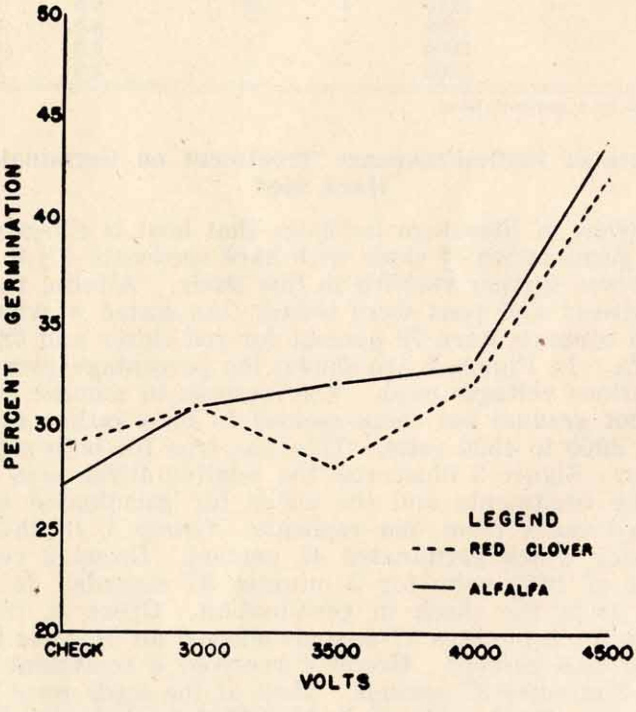

Figure 2. The influence of radio-frequency heat on germination of alfalfa and red clover with high hard seed contents.

Influence of Radio-Frequency Heat on Seed of Various Moisture Contents

An exposure of pea seeds to 1000 volts for 2 minutes 37 seconds was not sufficient to cause a significant decrease in germination at any of the moisture levels (Figure 4). However, a treatment of 1300 volts for 4 minutes 57 seconds reduced significantly the percentage of germinated peas at 21.7 percent moisture as compared to the check with 91 percent germination. No significant differences were obtained between seeds of other moisture contents and the check. A treatment of 1600 volts for 2 minutes 37 seconds was sufficient to kill practically all of the seeds at 15.8 percent and 21.7 percent moistures. The increase

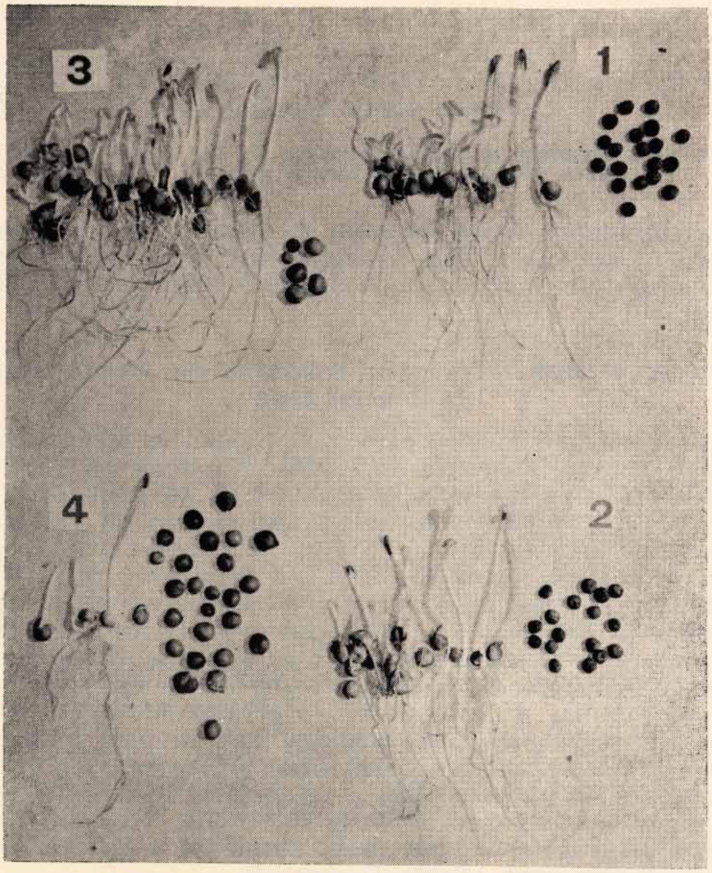

Figure 3. The influence of radio-frequency heat on germination of peas (var. Early Dwarf Sugar) with a high hard seed content.

1. **Check**
2. **1600 volts 2 minutes 37 seconds**
3. **2000 volts 2 minutes 37 seconds**
4. **2500 volts 2 minutes 37 seconds**

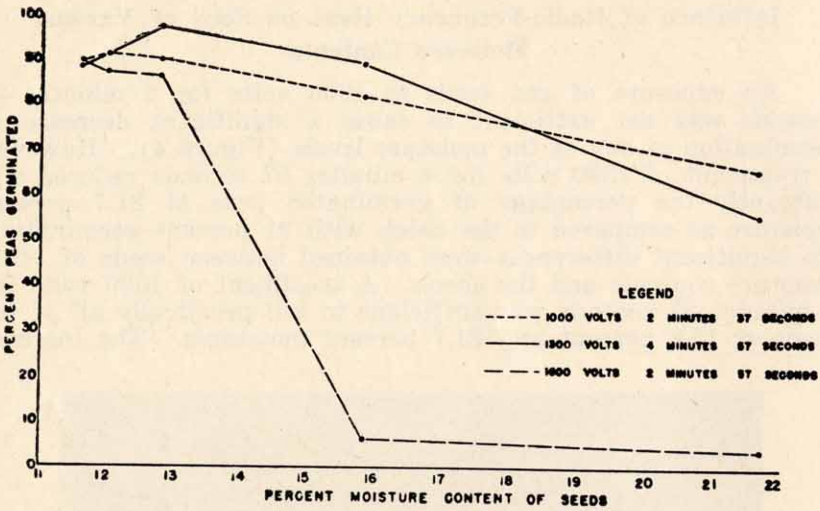

Figure 4. The influence of moisture content on the germination of radio-frequency treated Thomas Laxton peas.

in kill was rather abrupt between 13 percent and 15.8 percent moisture (Figure 4.) This indicates that high voltages and/or long exposures are much more damaging to seeds of high moisture content.

Influence of Radio-Frequency Treatment on Weevil Control In Infested Seed

Two groups of infested peas were treated on different dates, February 17 and February 19, 1953. Exposure to 1000 volts had little effect on the weevils (Table 4.) An increase in voltage from 1000 to 1250 volts killed 96.9 percent of the weevils in peas with open windows. In peas with closed windows, 78.5 percent of the weevils were killed. A treatment of 1250 volts on February 19 killed fewer weevils in both open and closed windows than on February 17. This can probably be attributed to slight variations of the generator from one time of treatment to another or to differences in the physiological condition of the two groups of weevils. In both groups, a greater mortality rate was obtained in peas with open windows than in peas with closed windows and a treatment of 1600 killed all the weevils. The results (Figure 5) indicated that it is possible to get 100-percent kill of the weevils between 1400 and 1500 volts. The voltages are less than those which caused slight reduction in germination of Early Perfection peas (Table 3), page 9.

Influence of Radio-Frequency Heat on Killing of Weed Seed

The screenings consisted predominantly of green foxtail *(Setaria viridis* Beauv.*)* and wild mustard *(Brassica juncea* L.*)*.

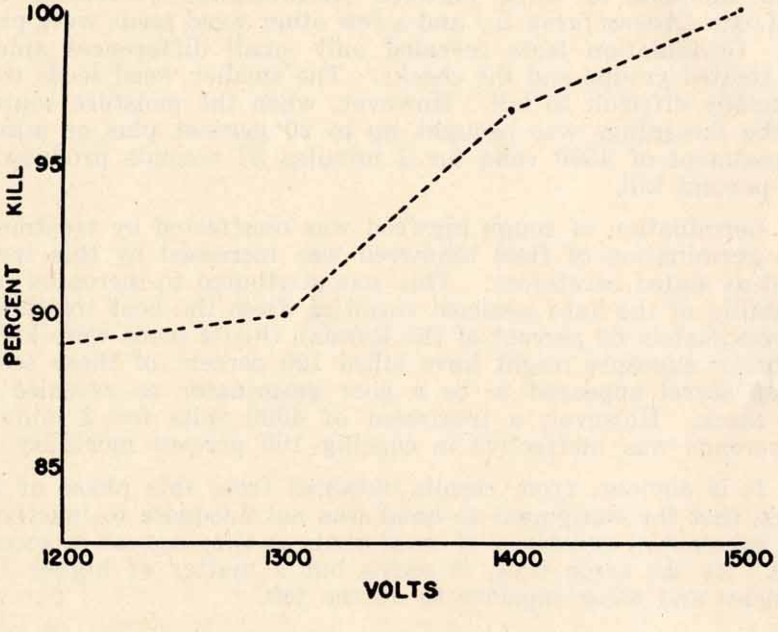

Figure 5. Percentage kill obtained by radio-frequency heat of weevils that are outside of the peas.

TABLE 4

Results of the Use of Radio-Frequency Heat in the Disinfestation of Weevil-Infested Peas

Date of Treatment	Treatment - Volts Time - 2 min. 37 sec.	Type of Window	Total No. Weevils	No. Alive	No. Killed	Percent Killed
February 17	Check	Closed	37	37		
		Open	68	63[1]		
	1000	Closed	35	31	4	11.0
		Open	67	56	9	13.0
	1250	Closed	56	12	44	78.5
		Open	65	2	63	96.9
	1600		106*	0	106	100.0
February 19	Check	Closed	60	60		
		Open	104	97[1]		
	1250	Closed	62	25	37	59.6
		Open	108	21	87	80.5
	1600	———	154*	0	154	100.0

* Peas were not separated for closed and open windows because 100-percent kill was obtained.

[1] Difference from the total due to death from natural causes between the time the peas were treated and the time of counting of the weevils.

Small amounts of white pigweed *(Amaranthus graecizans* L.*)*, wild oats *(Avena fatua* L.*)* and a few other weed seeds were present. Germination tests revealed only small differences among the treated groups and the checks. The smaller weed seeds were especially difficult to kill. However, when the moisture content of the screenings was brought up to 20 percent plus or minus, a treatment of 4500 volts for 2 minutes 37 seconds produced a 100-percent kill.

Germination of rough pigweed was unaffected by treatment. The germination of field bindweed was increased by this treatment as stated heretofore. This was attributed to increased permeability of the hard seedcoat resulting from the heat treatment. Approximately 60 percent of the Russian thistle seeds were killed. A longer exposure might have killed 100 percent of these seeds. Sheep sorrel appeared to be a poor germinator as revealed by the check. However, a treatment of 4500 volts for 2 minutes 37 seconds was ineffective in causing 100 percent mortality.

It is obvious, from results obtained from this phase of the work, that the equipment at hand was not adequate to inactivate any substantial quantities of weed seeds as they appear in screenings. At the same time, it seems but a matter of higher frequencies and more capacity to do the job.

Discussion

The data presented corroborate those of other investigators and indicate that internally induced heat is the main consideration in a study of radio-frequency treatment of seeds. Heat so induced, being of internal origin, is superior to many types of external heat applications. These studies have been carried out on the basis of such a concept. Limited work only has been conducted on radio-frequency heat treatment of seeds, and this work must be considered mostly exploratory.

It has been shown that viability of seeds varies considerably with duration and intensity of exposures to which they were subjected. In these experiments larger seeds seem to be affected more readily than smaller seeds. This has been demonstrated by treatments of 1700 to 2800 volts which caused injury to peas, beans and corn. Alfalfa, red clover, and bindweed were not injured by these exposures. Rough pigweed appeared to be even more resistant than the legumes tested. It is approximately one-third the size and tested 8 percent moisture as compared to 5 to 7 percent moisture content of the legumes.

It follows then that moisture alone is not the only determining factor with respect to susceptibility of seeds to radio-frequency heat. It seems reasonable to suspect that other factors may enter in such as: structure of seedcoat, amount of protein, and other organic and inorganic substances present which may determine the electrical or "dielectric" properties of seed treated. The dielectric properties may vary greatly even within species, depending upon the presence of the aforementioned substances.

If it is true that small seeds are less susceptible to injury from radio-induced heat, then such resistance might be attributed to the fact that they have a larger surface area per unit volume than larger seeds and lose heat much more rapidly. Thus, heat is not able to build up so rapidly as in larger seeds.

Such a statement is only an assumption, and perhaps has little basis of fact in this paper. Admittedly, the only way by which such a postulation could be proved would be to grade seeds of the same species and lot into various sizes and subject them to similar treatments. As stated above, the dielectric qualities of seeds are almost certain to vary from one species of seeds to another. The amount of heat developed is important in that high temperatures cause coagulation of the proteins and resulting death of the cells. This reaction can be expressed in terms of temperature coefficients or Q_{10}. That is: for every 10 degrees Centigrade rise in temperature, the rate of the reaction is doubled, tripled, or even may vary from 10 to several hundred times as is the case for protein coagulation. Such wide variations in Q_{10} for protein coagulation are influenced largely by the amount of moisture present (4). Groves (5) found the Q_{10} for 9-percent-moisture wheat to be 9.23. For wheat of 17.5-percent moisture content the Q_{10} was 16.45. This would indicate a direct relationship of rate of coagulation of proteins, or death of cells, to the amount of moisture present. This same relationship was found to be true by the authors for seeds treated with radio-frequency heat.

Watson (15) found indications of an increase in rate and of total germination of peas as a result of radio-frequency treatment. The results obtained in this study show almost no indication of an increase in rate of germination. This was determined by the number of peas that germinated early (Table 3). If the rate were increased the seedlings resulting from treated seeds would be expected to be taller than the check seedlings because of an earlier start in growth. From visual observations of the hundreds of seedlings germinated the authors were unable to detect any difference in the relative heights of the seedlings.

The effects that radio-frequency heat has on seeds of low permeability has been demonstrated on alfalfa, red clover, peas, and field bindweed. The germination of alfalfa and red clover was increased from less than 30 percent to approximately 45 percent after an exposure of 4500 volts for a period of 2 minutes 37 seconds. Though this increase was definite, it leaves much to be desired. A longer period of exposure may possibly increase the germination still more. These high voltages created undue strain on the available equipment; therefore, longer periods were not used. The use of higher frequencies is also a possibility. Soderholm (12) reports work on weevil-infested rice with 30 and 40 m. dielectric fields (10 m. dielectric field was used in this study) in which the time was reduced to exposures of seconds rather than of minutes, as was the case in these experiments. Higher frequencies are advantageous in that greater heat can be induced within the seeds in a much shorter time and the tendency to burn them is reduced.

Peas and field bindweed responded more to treatment than alfalfa and clover. Germination of peas was increased from less than 60 percent to 78.6 percent after an exposure of 2000 volts. Field bindweed was increased in germination from 27 percent to 56 percent which is much greater than the increase from 30 to 45 percent obtained on the legumes. This difference is not easily explained. Size difference could be important, but other factors should be investigated.

It is evident that this method of treating seeds with relatively impermeable seedcoats (so-called "hard-seeds") is much more convenient than the acid treatments commonly used and should be investigated further.

The way heat acts to increase germination has not been studied by many investigators. Three possible things that could happen have been suggested by Stone and Juhren (14): 1. the permeability of the seedcoat could be changed, 2. a chemical inhibitor in the seed could be destroyed, and 3. the metabolism of the embryo could be altered. They concluded that the increase in germination of *Rhus ovata* Wats. after heat treatment was due to increased permeability of the seedcoat by cracking and permitting water to enter. Scarification or chipping of the coats of field bindweed resulted in an increase of germination from approximately 27 percent to 89 percent. Radio-frequency heat treatment increased germination to 55 percent.

Thus, it seems fairly obvious that heat played some part in altering permeability of the seedcoat. On the basis of evidence at hand, however, it would be unwise to dismiss the possibility of changing the condition of an inhibiting substance within the seed or altering the seed's metabolism. As a matter of fact, these treatments could very well increase germination both of bindweed and alfalfa but not necessarily for the same reason. There is need for investigation along these lines.

The results obtained in destruction of weevils in rice with radio-frequency heat warrant further investigation. This is commercially important not only with weevils but with other insects which infest seed. Pea weevils were killed at voltages between 1250 and 1600 volts (Table 4). When weevils were removed from the peas 1500 volts was enough to kill them all.

These voltages are less than those which injure peas. The germination of Early Perfection variety was slightly affected at 1600 volts (Table 3). Early Dwarf Sugar variety was able to withstand voltages as high as 2000 volts. Considering these results, it can be concluded that weevils and possibly other insects can be killed by radio-frequency heat without injury to the seeds and with possible beneficial results if hard seeds are present. The results reported by Soderholm (12), who found it was possible to kill adult rice weevils at exposures which did not injure germination of wheat, offer further evidence of the possibility that this method of disinfestation may become of value for commercial use.

Each kind of insect and the seed which it infests presents a situation in itself and must be handled separately. Each has different dielectric properties which should be determined before any treatments are used. Soderholm (12) reports an apparatus consisting of a Boonton Q meter and a special test cell by which it is possible to measure the electrical characteristics of a substance. An apparatus of this kind would be invaluable in estimating the thermal-death points of various living organisms.

SUMMARY

Studies were made on the influence of radio-frequency heat on germination of seed, on germination of so-called "hard seed", on seed of various moisture contents, on control of insects in infested seed, and on inactivation of weed seed.

Peas, beans and corn seed were injured at exposures between 1700 and 2800 volts. Alfalfa, red clover and bindweed were able to withstand exposures of 4500 volts.

Small seeds showed some tendency to be more resistant to injury than large seeds; but, since these size differences were between species, size alone may not be important.

Seeds with low moisture content are more resistant to injury than those with high moisture content.

Germination was increased in hard seed of alfalfa, red clover, peas and bindweed with treatments as high as 4500 volts.

Pea weevils were killed at exposures of approximately 1500 volts, which was not sufficient to cause reduction in germination of Early Perfection peas.

With the equipment available, it was not possible to kill all weed seed from seed screenings. However, where the moisture content was raised, it was possible to inactivate all the weed seed.

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