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THE EFFECT OF HIGH TEMPERATURE CONTACT TREATMENT
ON HARD SEEDS IN ALFALFA

By

Allyn O. Lunden

A thesis submitted
in partial fulfillment of the requirements for the
degree Master of Science at South Dakota
State College of Agriculture
and Mechanic Arts

June 1956

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ON HARD SEEDS IN ALFALFA

This thesis is approved as a creditable, independent investigation by a candidate for the degree, Master of Science, and acceptable as meeting the thesis requirements for this degree; but without implying that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

The presence of "hard seeds" or seeds which are covered with an impermeable seed coat has long been the topic of much study and interest in the processing, sale, and use of legume seeds. Hard seeds are seeds which fail to germinate or take up water when subjected to moisture and temperature conditions which are favorable to germination. These seeds are inherently viable and are capable of producing normal seedlings but do not initiate growth as rapidly as normal seeds. Hard seed content of samples of seed may be extremely variable and is often an important factor in determining the commercial value of any lot of legume seed. Lots of seed which contain an extremely large percentage of hard seed often meet with much disfavor in the eyes of those who wish to purchase the seed for planting.

The difficulty of selling seed with high percentage of hard seeds and the reduced sale value of such seed has led to many attempts to devise a seed treatment which will overcome this undesirable quality. Proper seed treatment methods should render seed coats of hard seeds permeable to water so they will produce normal growth in the seven days commonly allowed for the germination test. Many seed treatments effectively decrease hard seed content but either are not applicable for use with large amounts of seed or cause an undesirable increase in percentages of dead seeds and abnormal seedlings.

The object of this study was to devise a method of seed treatment which might reduce the hard seed content of legume seeds by use of surface contact with high temperature. This method theoretically should cause slight burning of a small area of the seed coat without causing any damage

to the embryo or the cotyledons. Surface heat would not increase the internal temperature of the seed to any large degree but should be able to increase seed coat permeability. It was hoped that a treatment might be devised which could be used in all legumes to decrease hard seed content with a corresponding increase in germination.

REVIEW OF LITERATURE

Much study and research has been carried on in recent years in connection with the presence of hard seeds in seed lots of many leguminous species. They long have been considered as contributing to volunteer stands of sweet clover, are responsible for longevity in the soil of seeds of many troublesome weeds, and often have been held responsible for poor stands of newly planted fields of legumes.

Hard seeds are common to seeds of most members of the legume family and are present in amounts of a few per cent up to nearly one hundred per cent in extreme cases. It was determined by Stevens and Long (19) that normal mature seeds of sweet clover are one hundred per cent impermeable and also that the varying degrees of hardness in various lots of seeds is due to partial scarification during harvest operations. Lute (12) compared the hard seed content of several samples by both hand harvesting and machine threshing samples from given fields. Her results give about twenty-four per cent hard seed on machine threshed seed and about fifty-three per cent hard seed from similar seed when hand harvested. She attributed the difference to a variable amount of scarification from the harvesting implements used. She also studied the effect of environmental conditions upon the hard seed content of seed lots of alfalfa seed and determined that the altitude of the area of production was not correlated with the quality of seed. She observed that percentage of impermeable seed was higher for seed produced in the fall than for that produced in the summer indicating a temperature and/or humidity effect. It was also determined that no correlation existed between the seed of a certain field

or plant for any two successive years.

The value of hard seeds has been the subject of a great deal of study by several workers. A clipping experiment by Lute (13) in 1942 showed that these seeds had a very high inherent viability. By removing a small portion of the seed coat with a scalpel she rendered hard seeds highly germinable. It was found by Harrington (5) as early as 1916 that alfalfa seed with high hard seed content produced very nearly the same stand in the field as did seed with low hard seed content. Similar results were obtained by Weihing (22) who stated that samples with few hard seeds had a more rapid emergence in the field but this was almost balanced at from two to four weeks of growth. His field tests of seed ranging from fourteen to fifty-four per cent hard seeds all produced between sixty and seventy per cent field emergence in seventeen days. In 1927 by use of field plantings with both alfalfa and sweet clover Leggart (9) determined that alfalfa hard seeds have about the same value as permeable seeds but that sweet clover hard seeds are detrimental. Whitcomb (23) rated alfalfa, red clover, and sweet clover according to the value of their hard seeds for planting purposes. He stated that hard seeds are of equal value to permeable seeds in alfalfa, but are only one-half the value of permeable seeds in red clover, and only one-third the value of permeable seeds of sweet clover. Dexter (2) showed that presence of hard seeds may actually cause an improved stand of alfalfa in the advent of adverse weather conditions shortly after planting. These results point out that hard seeds are not always undesirable in alfalfa but are very undesirable in seed of some other legume crops.

Impermeability and delayed germination result from structural fact-

ors of the seed coat which prevent entry or exchange of compounds necessary for the growth of the embryo. The factors necessary for prompt germination are generally believed to be a proper carbon dioxide-oxygen ratio and availability of moisture within the seed. The seed coat may then cause a seed to be "hard" by preventing the availability of either of these factors within the seed. The cause of hard seeds is attributed by Staker (17) to the presence of an impermeable resinous substance on the cuticle on the outside of the seed coat. Lute (12) believes that impermeability is caused by thick cell walls in the outer end of the palisade tissue of the seed coat.

Many workers have attempted to devise seed treatments which would be effective in reducing hard seed content of samples of legume seed. The result of these studies has been the development of a number of different types of seed treatments, most of which are not applicable to use on large lots of seed. Some of the methods which have been devised and tested are the use of bran dusters, scarification, shaking, hydraulic pressure, low temperature, high temperature, alternate temperature, hot water, live steam, sulphuric acid, treatment by exposure to various soil extracts, alkalis, acids and ferments, as well as several variations or combinations of these methods.

Scarification is the most common method of treatment used to reduce content of hard seeds. This method is very effective in reducing the amount of hard seeds to a very low percentage with a corresponding increase in total germination. An experiment was reported by Lute (12) in which the average hard seed content was reduced from sixty-three per cent in untreated alfalfa seed to less than two per cent in seed treated

with the Eddy Huller and Scarifier. Hopkins (6) obtained similar results with birdsfoot trefoil. The fact that seed which has been scarified loses its viability very rapidly and should be planted within one year of the time of treatment is emphasized by Graber (4) and Stevens (18). Leggart (10) states that seedling vigor can be reduced by this treatment to such a degree that the yield may be affected even though the germination is increased. Stewart (20) also found that seedling vigor is decreased and that the number of weak and moldy sprouts is greatly increased by treatment.

A treatment which consisted of shaking the seeds a certain number of times in a glass bottle was devised by Erne, Hutton and Porter (3). They used several types of legume seeds and obtained favorable results on several species. This treatment was effective on large seeded legumes but was not of much value in the small seeded crops. Treatment with a bran dusting machine similar to that in the flour milling industry which acts as a polisher instead of a scarifier was reported by Whitcomb (24) in 1941. It was hoped that this treatment could improve germination without the seed breakage and seed injury caused by the normal type of scarification. Statistical results of this type of treatment have not been published.

Another treatment is that of using concentrated sulphuric acid to increase permeability of the seed. Love and Leighty (11) devised this treatment as early as 1912 and obtained favorable results by immersion of seed in acid for a period of fifteen minutes. They increased the germination of alfalfa from an average of fifty-five per cent for the untreated to an average of ninety-five per cent for the treated seeds. The effective-

ness of this treatment in reducing the number of hard seeds in a sample of alfalfa was later substantiated by Hopkins (6). She increased the ten-day germination of seed from sixteen per cent for untreated seed to fifty-nine per cent for seed which had been placed in the acid for ten minutes. This treatment seemed to have no undesirable effect on seedling vigor but is not feasible for use on large lots of seed as the process requires thorough rinsing to remove the acid and also requires drying to remove the excess moisture.

Davies (1) obtained favorable results by use of hydraulic pressure of 2000 pounds per square inch for various lengths of time. This treatment changed a sample of alfalfa from forty-eight per cent germination plus forty-four per cent hard seeds to eighty-two per cent germination plus seven per cent hard seeds by a one minute exposure. This method is effective but is not readily applicable to large lots of seed. Other treatments such as exposure to dilute acids, alkalis, soil extracts, and ferments are mentioned by Whitcomb (24) to produce varying results.

Many types of temperature treatments have been tested by different investigators. Alternate freezing and thawing was shown by Harrington (5) to have little effect on hard seeds. Similar results were obtained by Midgley (14) by subjecting seeds to a constant temperature of -15°C . to -20°C . for various periods of time up to sixty days. Heat treatment was probably first used by Thornber (21) in 1904 by immersing seeds of several species in water at a temperature of 85°C . to 88°C . for two to six minutes. The results were satisfactory although the method is not practical for large volumes of seed. Schmidt (16) found that an exposure to live steam for a period of one minute decreased hard seed content and increased

germination but this method is difficult to employ.

Methods of dry heat treatment have been devised. The use of "dielectric" heat from a Radio Frequency Generator has been tried by Iritani and Woodbury (7) and Lambert, Worzella, Kinch and Cheadle (8). The results of this work show beneficial effects on alfalfa and their result should warrant further research. The use of dry heat as a treatment method has also been studied by Lute (12), Rincker (15), Staker (17), and Stewart (20).

Lute (12) exposed seeds to temperatures of 35°C . to 80°C . for periods of from one to twelve hours. She obtained best results at a temperature of about 75°C . for periods of three to six and one-half hours. A similar procedure was used by Staker (17) to determine the effect of heat on alfalfa seeds. Seeds were placed in narrow necked flasks which were then immersed in a thermostatically regulated circulating hot oil bath. He used temperatures ranging from 60°C . to 105°C . for periods of from one-half to four hours and obtained increasing germination up to a temperature of 85°C . for periods of one-half to four hours. The primary object of his work was to determine the death point on heating; this was found to be between 90°C . and 93°C . Stewart (20) using the same method obtained similar results and reported as did Staker (17), that seed which is of inferior quality (shriveled or discolored) is injured more easily than is bright plump seed.

A dry heat treatment was used by Rincker (15) which consisted of placing the seeds in a thermostatically controlled electrically heated oven. He used temperatures of 38°C . to 104°C . for periods of five minutes to forty-eight hours. Best results were obtained at 87°C . for periods of

five minutes to one hour. He then changed his method to supply the heat by means of a battery of infra-red heat lamps. The seeds were then treated at a temperature of 104^o C. for periods of from one-half to five minutes. He obtained favorable results for a period of one or two minutes in one test but obtained severe injury from the five minute treatment. In a second experiment he obtained an average germination increase of thirty-seven per cent and a hard seed decrease of thirty-seven per cent by a four minute treatment at the same temperature.

No published data were found pertaining to use of an extreme temperature contact treatment such as is being attempted in this study.

MATERIALS AND METHODS

Equipment for this investigation was furnished by the Agronomy Department and the Agronomy Seed Laboratory of South Dakota State College. Preliminary work was begun in September 1954 and the heat treatments and germination tests were completed in February 1956.

Alfalfa seed used in the study was primarily from the 1955 crop and was produced in a wide range of areas over the state of South Dakota. These areas were chosen to obtain the greatest possible variation in altitude, temperature, moisture, humidity, or any other factor which may have an effect on the quality of seed. The seed used consisted of fifteen samples each of hand-harvested alfalfa, Certified Ranger alfalfa, and samples received at the State Seed Laboratory.

Hand-harvested seed was obtained from fields in fifteen different counties of the state, eight of which were east of the Missouri River and seven west. The seed pods were manually stripped from plants in the fields, bagged, and placed in shallow pans at room temperature until dry enough to thresh. Threshing was accomplished with a simple hand machine consisting of a flat trough nine and one-half inches wide and twenty-two inches long which was surfaced with a layer of corrugated rubber. The seed was shelled out by rubbing the pods between this and a small six inch by eight inch paddle the lower surface of which was covered with similar material. The seed was then cleaned by passing through a 1/15 perforated metal sieve and over a 4/24 rectangular wire sieve. The light material was removed by placing the seed in an Erickson Seed Blower at a setting of thirty. This method of harvest and threshing produced a group of samples which

were similar in regard to a low amount of scarification due to harvest procedures and were correspondingly high in hard seeds.

The second group of samples consisted of Certified Ranger alfalfa which was submitted by various seed producers. The area of production was more limited for these samples since those received up to the time of this study were from only three areas in the state. These samples were fairly low in hard seed content which was probably due to partial scarification in harvest or in processing. These samples of Ranger alfalfa were included in this study to obtain a group of samples which were as similar as possible with respect to varietal purity.

The third group was obtained by selecting samples from those received at the Seed Laboratory. These represent samples that were sent in either by individual farmers or by seed companies or elevators within the state. An effort was made to include in this group, samples which contained a large percentage of hard seed and to obtain samples from areas scattered widely over the state. The hard seed content varied from about eighteen per cent up to sixty-five per cent and samples were obtained from ten counties east of the Missouri River and five west of the river. These samples probably were harvested with a minimum degree of scarification and would be the type of seeds which would normally receive some type of scarification treatment in processing. They were included in this study to determine if a heat treatment could be devised to produce beneficial effects on seeds which would normally be treated by some other method.

Figure 1 shows the location of the areas from which seed samples were obtained for this investigation. Hand harvested samples are numbered from two through forty-two, Certified Ranger alfalfa are numbered from 125

through 314; Seed Laboratory samples are numbered from 1373 through 1752.

Preliminary tests of various types were used in an attempt to discover a method of treating the seed which would give the most accurate control of temperature and time of contact. The most practical procedure was to place an aluminum plate in a slanted position over a number of Fisher burners, heat the plate to the desired temperature and treat the seeds by passing them over a measured distance on the heated plate.

The plate which was used was a "Nordic Ware" griddle. It was an aluminum plate one-eighth inch thick, ten inches wide, and sixteen inches long with a smooth polished surface. It was held in place by three metal stands with metal clamps and was set to allow five and one-half inches of drop in twelve inches of distance. The seeds moved evenly across the plate at this slant although their action was partly of sliding motion and partly of bouncing motion. Three Fisher burners were set below the plate as the source of heat and they were set in a row in the center of the plate at the two inch, six inch and ten inch levels. The lower burner was set on the table, the second burner was set on a two and one-half inch platform and the top one on a five inch platform.

Temperature measurements were made with "Tempiletix", a product of Tempil Corporation, New York. These consist of a chemical compound in the form of a crayon which can be rubbed on a hot surface and will melt when the desired temperature is reached. The plate was heated to the desired temperature and was maintained at that temperature to a very high degree of accuracy by this means of measurement. The right side of the plate was used to check the temperature and the left side was used for all of the treatments. The conductivity of the aluminum plate was

shown by the use of these "Tempilstix" to be uniformly high since only a few degrees of temperature variation could be found between the area directly over a burner and the outer corners of the plate.

Seeds were dropped onto the plate by means of thin aluminum trays clamped at the six and twelve inch levels. These trays were set at a slant opposite to that of the plate and allowed the seeds to drop evenly onto the plate. A stop was set at the lower end of this tray to prevent the seeds from piling up and thus being severely burned. The seeds were allowed to drop off the plate into a receiving tray which was set directly on the table.

The apparatus used for the heat treatments is shown in Figure 2. The tray as seen here is set at the six inch contact level. Seeds were allowed to flow evenly into the upper tray and they moved uniformly from there onto and over the heated surface of the aluminum plate. The right side of the plate was used for temperature measurements and the action of the "Tempilstix" can be seen on the surface of the plate. This picture was taken after the last treatment and streaks across this half of the plate were caused by their melting at the various temperature levels. The temperature was maintained at a level which would cause melting to a point midway in the right half of the plate at the same time at which seeds were treated on the left side of the plate. The receiving tray was omitted for purpose of clarity but was placed directly on the table at the lower end of the plate.

Figure 3 shows a close-up view of the contact portion of the plate, the area used for measurement of temperature, and the tray and stop set at the six inch level.

Figure 2. Apparatus Used for Heat Treatments of Alfalfa Seeds.

Figure 3. Close-up of Contact Portion of Apparatus Used in Treating Seed.

The treatments were set up to allow the four variations in temperature of 68°F., 550°F., 750°F. and 950°F. as well as the three variations in contact of six, twelve, and twenty-four inches. Three replications of each treatment were used. Twelve treatments and three replications required thirty-six tests of each sample. A fifty-four gram sample of seed of each was available to allow one and one-half grams of seed for each test.

On account of a shortage of germination space these replications could not be run concurrently but had to be run at approximately one month intervals. One sample of each of the three groups of seed was treated each day and the second replication was begun immediately after the first one was completed. The samples, temperatures, and contact distances were randomized for each replication and the same order of samples was used after the first replication.

Contact distances in the first replication were accomplished by placing a tray at the six inch level for that contact, at the twelve inch level for twelve, and two runs over the twelve inch level for the twenty-four inch contact. The plate was not cleaned during this replication although excess burning occurred in the last eight days of treatment so it was decided to scour the plate after each days treatment for the last two replications. It was also decided to use a more accurate means of overcoming acceleration of the seeds in the last two replications, so the distances used were changed to two runs over the six inch distance for the twelve and four runs over the six inch for the twenty-four inch contact.

Germination tests were made in the Agronomy Seed Laboratory using

the standard germinators. The seeds were planted between folded blotters and were randomized on the trays. Final counts were reported as an average of 400 seeds and were made at the end of the normal seven day germination period at 20°C. Counts were made according to the Rules for Testing Seeds as Adopted by the Association of Official Seed Analysts. The germination test results are reported as percentages of seeds which produced normal seedlings, abnormal seedlings, hard seeds, or dead seeds. The total germinable or good seeds are then expressed as the sum of normal seedlings plus hard seeds. This total is also a means of expressing seed injury as any decrease in the total of germination plus hard seeds would indicate an increase in dead seeds, abnormal seedlings, or both.

EXPERIMENTAL RESULTS

The results of germination tests of the seed revealed an extreme amount of injury in the last part of the first replication. This was caused by increases in both abnormal seedlings and dead seeds. These two categories were grouped together since it was evident that the difference between the two was merely in degree of injury. This injury was caused by a slight roughening of the surface of the plate which resulted in uneven seed contact, severe burning, and a large degree of variation between the individual samples. Scouring of the plate with steel wool in the later tests was very effective in reducing this variation although it was necessary to discard the results of the first replication because of this variation. The germination percentages which are used in the analysis, charts, and graphs are the results of treatments in the second and third replications.

Germination and the effect of the various treatments will be discussed for each group of samples. Each of these groups can best be analyzed separately as they represent three levels of hard seed content and different types of harvest procedures.

Hand Harvested Seed

Hand harvested seed contained a very high percentage of hard seeds due primarily to lack of scarification which normally occurs during harvest operations. It is interesting to note that a very sharp decrease in hard seed content occurred in the interval between the time in which treatments were made on replications two and three. Table 1 shows the

results of germination tests on the unheated check samples of hand harvested seed for these two replications.

Table 1. Germination of Unheated Check Samples of Hand Harvested Alfalfa Seed (Rep. 2 = Jan. 1956 - Rep. 3 = Feb. 1956)

Sample No.	Germination Per Cent		Hard Seeds Per Cent		Total of Germination Plus Hard Seeds	
	Rep. 1	Rep. 2	Rep. 1	Rep. 2	Rep. 1	Rep. 2
2	53	61	41	32	94	93
9	31	38	63	56	94	94
11	27	46	65	45	92	91
13	51	66	42	28	93	94
20	11	23	34	74	95	97
25	37	49	57	43	94	92
27	11	43	85	51	96	94
28	27	48	65	45	92	93
30	18	48	78	44	96	92
33	30	47	64	47	94	94
34	9	24	88	71	97	95
36	16	28	80	66	96	94
37	12	25	84	69	96	94
40	49	63	42	33	91	96
42	21	42	72	51	93	93
Average	26.9	43.4	67.3	50.3	94.2	93.7

In January when the second replication was treated the hard seed content of the check samples varied from forty-one to eighty-eight per cent with an average of about sixty-seven per cent. One month later for the next replication this range was from twenty-eight to seventy-four per cent with an average of only fifty per cent.

An analysis of variance of the germination results gave significant values between treatments at the one per cent level. The results are here summarized as an average of the fifteen samples and both replications. It

does not seem necessary to report each sample separately since the treatments produced similar results for all samples tested. Table 2 shows the germination data as a result of the various treatment on hand harvested seed.

Table 2. Germination of Hand Harvested Alfalfa Seed When Subjected to Various Temperature Treatments. (Average of Fifteen Samples and Two Replications)

No.	Treatment		Germination Per Cent	Hard Seeds Per Cent	Total of Germination Plus Hard Seeds
	Temperature	Contact			
1	68°F.	6"	34.1	59.6	93.7
2	68°F.	12"	35.4	58.2	93.6
3	68°F.	24"	35.7	58.7	94.4
4	550°F.	6"	35.7	58.1	93.8
5	550°F.	12"	35.1	59.1	94.2
6	550°F.	24"	35.4	58.3	93.7
7	750°F.	6"	37.3	56.0	93.3
8	750°F.	12"	41.7	51.9	93.6
9	750°F.	24"	46.2	46.9	93.1
10	950°F.	6"	54.9	37.4	92.3
11	950°F.	12"	69.1	20.9	90.0
12	950°F.	24"	78.1	10.6	88.7

It is evident that contact at 550°F. was not sufficient to produce any beneficial changes in the treated seed. A temperature of 75°F. was found to produce a noticeable rise in germination with a corresponding decrease in hard seed content. Germination tests reveal that this rise first occurred at the six inch contact treatment at that temperature and continued at a similar rate for the twelve and twenty-four inch contact levels. The 950°F. treatment also gave an increase in germination and this effect was dependent upon the distance of contact as for the lower temperature. The most severe treatment consisting of a twenty-four inch contact at this

temperature was necessary if the hard seed content was to be reduced to a low level. This treatment was found to increase the germination by about forty-four per cent over the check and resulted in a decrease in hard seed content of forty-nine per cent. It should also be noted that a slight increase in injury occurred for the seed treated at 950°F. as evidenced by the drop in the total of germination plus hard seeds.

Figure 4 illustrates a typical germination of hand harvested alfalfa seed when subjected to different treatments. Treatments one, nine, ten, eleven and twelve indicate the various degrees of temperature and periods of exposure.

Treatment number one is the check sample of 68°F. which produced a germination of twenty-five per cent with seventy-one per cent of hard seeds. Treatment number nine resulted in fifty-six per cent germination for a contact distance of twenty-four inches at 750°F. The samples numbered ten, eleven, and twelve produced germination percentages of fifty-nine, eighty-four and eighty-nine resulting from the three contact distances of 950°F. The increase in germination is very noticeable in this illustration and decrease in hard seed content is also evident. Treatments two through eight are not illustrated since only a slight change in hard seed content occurred in these milder treatments. These germination tests were made between folded blotters and the folds were placed under the seeds at the time at which this photograph was taken.

Certified Ranger Alfalfa

Certified Ranger alfalfa was included in group two which also consisted of fifteen samples of seed. This group had an average of about

Figure 4. Germination of Hand Harvested Alfalfa When Subjected To Various Temperatures and Periods of Exposure. (37-1 = normal; to 37-12 = 950° F. at 24" contact)

twenty-one per cent hard seed with the individual samples ranging from nine to thirty-four per cent. An analysis of variance revealed significant variation in germination results at the one per cent level between the treatments. The results of treatments were summarized for the fifteen samples and for replications two and three. Table 3 shows the germination data as a result of the various treatments on Ranger alfalfa seed.

Table 3. Germination of Certified Ranger Alfalfa Seed When Subjected to Various Temperature Treatments. (Average of Fifteen Samples and Two Replications)

No.	Treatment		Germination Per Cent	Hard Seeds Per Cent	Total of Germination Plus Hard Seeds
	Temperature	Contact			
1	68°F.	6"	67.9	21.4	89.3
2	68°F.	12"	68.5	21.5	90.0
3	68°F.	24"	67.4	21.1	88.5
4	550°F.	6"	67.4	21.2	88.6
5	550°F.	12"	68.1	20.8	88.9
6	550°F.	24"	68.8	20.5	89.3
7	750°F.	6"	69.3	19.5	88.8
8	750°F.	12"	70.8	18.4	89.2
9	750°F.	24"	72.6	16.2	88.8
10	950°F.	6"	74.1	14.1	88.2
11	950°F.	12"	79.1	8.2	87.3
12	950°F.	24"	81.4	3.2	84.6

The treatment at 550°F. was not sufficient to produce any significant results. A slight rise in the average per cent of germination resulted from the three contact distances at 750°F. This rise was not as great as that found in treatment of the hand harvested seed but this might be expected since the hard seed content was considerably lower for this group of samples. A further increase was obtained by the three treatments at 950°F. and the effect was directly dependent upon the distance of contact. The twenty-four

inch exposure at this temperature reduced the hard seed content to the very low level of about three per cent which was a drop of eighteen per cent from that of the check. Germination was increased by about thirteen per cent for the same treatment. Some injury was evident at this temperature and was most pronounced for the seed which had been subjected to twenty-four inches of contact.

Seed Laboratory Samples

The third group was made up of Seed Laboratory samples and contained an average of about thirty-five per cent hard seeds. These samples were extremely variable since they included many types of seed from many sources and their hard seed content ranged from eleven to sixty-eight per cent. Significant difference in germination between treatments was found by an analysis of variance of the individual samples. The germination results were summarized to determine the average for the entire group.

Table 4 shows the germination data as a result of different treatment on the Seed Laboratory samples.

Table 4. Germination of Seed Laboratory Alfalfa Samples When Subjected to Various Temperature Treatments. (Average of Fifteen Samples and Two Replications)

No.	<u>Treatment</u>		Germination Per Cent	Hard Seeds Per Cent	Total of Germination <u>Plus Hard Seeds</u>
	Temperature	Contact			
1	68°F.	6"	53.5	35.3	88.8
2	68°F.	12"	55.1	33.9	89.0
3	68°F.	24"	55.6	33.3	88.9
4	550°F.	6"	55.0	34.2	89.2
5	550°F.	12"	54.1	34.3	88.4
6	550°F.	24"	55.4	33.6	89.0
7	750°F.	6"	56.4	32.7	89.1
8	750°F.	12"	58.3	30.6	88.9
9	750°F.	24"	60.9	27.5	88.4
10	950°F.	6"	64.9	23.3	88.2
11	950°F.	12"	73.4	13.3	86.7
12	950°F.	24"	79.5	6.7	86.2

It is evident that contact at 550°F. was not sufficient to produce any beneficial changes in the treated seed. An increase in germination with a corresponding decrease in hard seed content occurred first at the six inch contact level at 750°F. and this beneficial treatment effect continued through the twenty-four inch contact at 950°F. The increase in germination seemed to be a direct result of the increased severity of treatment by both time of contact and increase in temperature. Treatments of samples in this group was intermediate in effectiveness between that of hand harvested seed and Ranger alfalfa seed. This was probably due to the fact that the hard seed content before treatment was also intermediate between that of the other two groups. The twenty-four inch exposure at 950°F. increased the germination by twenty-six per cent over the check and produced a decrease of hard seeds to an average of less than seven per cent which was

a drop of about twenty-eight per cent. As in the other two groups some injury occurred for those samples which were subjected to 950°F. The injury was less than for either of the other two groups although the analysis indicated that the decrease in total of germination plus hard seeds was significant in all three groups.

Figure 5 illustrates the germination of alfalfa seed when subject to different temperature treatments. Treatments one, nine, ten, eleven and twelve show the results at the various contact and temperature levels.

Treatment number one of each sample represents the check sample which germinated fifty-three per cent and contained forty-three per cent of hard seeds. Treatment number nine resulted in fifty-six per cent germination at the contact distance of twenty-four inches at 750°F. Samples of treatments ten, eleven, and twelve produced an increase in germination to fifty-eight per cent for six inches at 950°F, seventy-three for twelve inches and eighty-four for the twenty-four inch level. The increase in germination was accompanied by a corresponding decrease in hard seed content. The increase in germination is not nearly so great as that shown in hand harvested seeds in Figure 4, but it is clear that an increase has occurred. The less severe treatments of two through eight are not illustrated since the treatment effect was very slight and could be recognized only by use of the standard germination test procedures. This sample was chosen as a visual example of treatment effects since it contained near to the average of hard seeds normally found in a regular alfalfa seed lot and it represents a sample which would usually be processed to reduce these hard seeds.

The results of germination of the three groups of seed indicated that

Figure 5. Germination of Seed Laboratory Sample When Exposed to Various Temperature Treatments. (1579-1 = normal; to 1579-12 = 950° F. at 24" contact)

samples which were highest in hard seed had the greatest percentage increase in germination following temperature treatments. Those which were lower in hard seed content showed much less increase but the critical temperatures seemed to be similar for each group of samples. These results also indicated that temperatures of 550°F. or below had little or no effect on increasing the germination of seeds even at a contact distance of twenty-four inches. Germination retests were run on a number of the samples at about one and one-half to two months after treatment. These retests indicated that germination results were similar to those obtained immediately after treatment.

Treatment Effect as Related to Original Hard Seed Content

The average germination of each treatment for each group of seed was plotted on a graph to determine the over-all effect of each treatment. Figures 6, 7 and 8 represent the germination results for the various treatments of hand harvested, certified Ranger and Seed Laboratory alfalfa seed samples in that order. The regression lines on these graphs were plotted directly as the straight lines which would produce the least total deviation from the actual values. These regression lines were not calculated and thus are not represented as exact values but were hand-drawn to represent the approximate values.

It is evident that no significant change in germination resulted from treatments one through six for either of the three groups of seeds. These six treatments included all of the seeds which were treated at 550°F. as well as the seeds which were used as check samples over the unheated plate at the three levels of contact. A straight line was plotted as the

Figure 6. Average Germination of Hand Harvested Alfalfa Seed When Subjected to Twelve Different Temperature Treatments. (treatment 1 = unheated check; to treatment 12 = 950°F. at 24" contact)

Table 7. Average Germination of Certified Ranger Alfalfa Seed When Subjected to Twelve Different Temperature Treatments. (treatment 1 = unheated check; to treatment 12 = 950°F. at 24" contact)

Figure 8. Average Germination of Seed Laboratory Alfalfa Seed Samples When Subjected to Twelve Different Temperature Treatments. (treatment 1 = unheated check; to treatment 12 = 950°F. at 24" contact)

average per cent of germination for these six treatments and in no case did any treatment fall above or below this line by over one and one-half per cent.

The last six treatment which were composed of three contact levels each at 750°F. and 950°F. produced a definite rise in germination which was in the form of a linear effect. A straight line was plotted for each group to determine the relative rise in germination for each type of seed. The degree of slope was directly proportional to the relative percentages of hard seed in the original samples. This ranged from a low of nineteen degrees and thirty minutes in Ranger alfalfa which contained twenty-one per cent hard seed, to thirty-eight degrees in regular laboratory samples of thirty-five per cent hard seed, and to a high of seventy-two degrees for hand harvested seed which had an original content of sixty-eight per cent of hard seeds. This represents an average increase in the total germination of about seventy per cent of the original content of hard seeds for the three groups. The greater part of this increase occurred in the last three treatments in which the seed was exposed to a temperature of 950°F.

DISCUSSION

This investigation was undertaken to determine whether it would be possible to increase the germination and decrease the hard seed content of alfalfa seed by use of a contact treatment at high temperature. The procedures and methods of treatment were set up to obtain an answer to this question. The apparatus used had one severe shortcoming which was failure to obtain equal contact of all seeds. Irregularly shaped seeds such as alfalfa will naturally have a complex sliding, rolling, and bouncing motion when moving over any exposed surface; this was especially evident in these trials.

Germination tests of alfalfa seed which was subjected to contact temperatures of 750°F. and 950°F. indicated a very significant increase in germination and decrease in hard seed content. The temperature of 550°F. was not of sufficient intensity to produce any changes in the seed. Seed treated at a temperature of 750°F. produced a significant increase although this was not great enough to warrant seed treatment at that level for the contact distances of six, twelve and twenty-four inches. The increased germination which resulted for each increase in contact distance at this temperature indicated the possibility that a greater increase in duration of treatment might produce much more favorable results at that temperature. Absence of injury for treatment at 750°F. also indicates that no critical time-temperature relationship has yet been reached so it should be possible to increase the contact distance at that temperature.

Seed treated at 950°F. produced a beneficial increase in germi-

nation which was directly correlated with distance of contact. This effect was accompanied by a slight amount of seed injury as evidenced by a decrease in the total of germination plus hard seeds at the upper contact levels at this temperature. It is logical to assume that a part of this injury was caused by failure of the seeds to move uniformly over the heated surface. Some decrease in the total of germination plus hard seed can also be expected as a consequence of the normal increase in abnormal seedlings since a larger number of seeds are induced to germinate by this treatment.

Beneficial effects of treatments are directly correlated with hard seed content of the original sample since samples very high in hard seed content produced a much greater increase in germination than those of lower percentages of hard seeds. This is to be expected since it is apparent that no great increase in germination could possibly occur by the treatment of a seed lot which is initially low in hard seed percentage. It should also be mentioned that no treatment would normally be attempted on this type of sample.

The three types of seed used in this investigation produced no differential reaction to heat treatments other than that brought about directly from the variable hard seed content. Samples of Ranger alfalfa produced germination results which were neither more or less variable than seed of completely unknown genetic composition. Similar results were found on treatment of hand harvested seed as compared to seed which was harvested by the usual methods. The increase in germination amounted to sixty-three per cent of the original hard seed content in Ranger alfalfa, seventy-three per cent in hand harvested seed and seventy-four per cent in regular labo-

ratory samples. This was an average of seventy per cent for all samples in the three groups of seed which indicates that the final germination results after treatment could probably be predicted with reasonable accuracy if the hard seed content of a sample is known.

Hard seeds seem to be closely related to harvest treatment. Seed which was harvested by hand stripping contained an average of sixty-eight per cent hard seeds and one sample contained a total of eighty-eight per cent. The hard seed content of machine harvested samples will rarely if ever approach this figure. Visual examination shows that hard seed content of samples used in this study is inversely proportional to the relative severity of harvest operations as determined by the degree of scarification or chipping of the seeds.

Studies of alfalfa seed which was harvested by hand from forty-two different locations throughout the state of South Dakota indicated no correlation between the area of production and presence of hard seeds. This seed was harvested from areas in which the altitude ranged from 1100 to 3500 feet above sea level and from a number of different varieties of alfalfa. These samples decreased in hard seed and increased in germinating seed by an average of eighteen per cent from harvest until the germination tests were run in February. This increase is to be expected since this normally occurs for seed that is in storage.

It would be desirable to perform a number of germination tests to determine permanence of the treatments as well as longevity of the treated seed. Several retests have been made which indicate no deterioration of seed quality in the two months which have elapsed since treatment but it would be more desirable to have these tests made at a period of from

twelve to twenty-four months.

The cause of the reduction in hard seed content as a result of temperature-contact treatment is difficult to determine. It is very possible that it was caused by direct physical burning of an area on the cuticle or palisade layer of cells in the seed coat. This reduction may also be due to a physiological effect within the seed or a combination of physical and physiological effects. No attempt has been made to determine the actual effect on the seed but visual examination indicated that a number of seeds obtained slight to severe burning on the outside of the seed coat. No percentage determination was made of this burning and it should be stated that this may have been caused by uneven contact of the seeds.

The results of this study show that it is possible to obtain an increase in germination with a corresponding decrease in hard seed content by use of a high temperature contact treatment of alfalfa seed. The procedures and the apparatus used were devised to determine whether or not the treatment would be effective, with little emphasis on practical application to larger lots of seed. The method used also resulted in somewhat uneven contact which was probably the cause of slight injury at the more severe contact levels. This injury might be reduced by use of an improved system under which more even contact could be obtained. One suggestion as to such a system is that of allowing the seed to come into contact with an electrically heated roller while being carried along on an asbestos belt.

These results indicate that it should be possible to devise a seed treatment whereby contact heat can be utilized to increase permeability

of hard seeds of legumes. Further work would be necessary to determine optimum contact temperature and duration of treatment and to devise a method which would be applicable to large lots of seed. The effect of this treatment on other species of seeds should also be studied.

SUMMARY

Alfalfa seed was subjected to a high temperature contact treatment by allowing small portions of various seed samples to slide over a heated inclined aluminum plate. Fifteen samples each of hand harvested seed, Ranger alfalfa and regular Seed Laboratory testing samples were treated in this manner at four temperature levels and over three contact distances.

Germination tests were made after treatment to determine effect on hard seed content and germination percentages.

Contact heat treatments at 950°F. were effective in increasing germination and decreasing hard seed content.

Treatment at 950°F. caused a slight degree of seed injury but this may be the result of uneven contact of the seeds.

Treatment at 750°F. increased germination but greater contact distance would be necessary for maximum effect.

Treatment was more effective for samples high in hard seed content although the relative effect was similar over all samples.

Relative effect of heat treatment was not affected by genetic differences or method of harvest.

Hand harvested alfalfa seed is extremely high in hard seed content because of lack of scarification during harvest operations.

Seeds will decrease in hard seed content even during only a few months of storage.

Altitude and area of production as represented in this study seemed to have no effect on hard seed content.

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