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on

A STUDY OF SOME ECONOMIC FACTORS

IN THE

SCARIFICATION OF RED CLOVER AND ALFALFA SEED

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A STUDY OF SOME ECONOMIC FACTORS IN THE SCARIFICATION OF RED CLOVER AND ALFALFA SEED.

INTRODUCTION

Hardness of seed coats has been recognized as a limiting factor in the germination of clover and alfalfa seeds for more than half a century. Apparently Nature has so planned that some of the seed shall germinate at once on ripening while in other plants a part or all of the seed may remain seemingly dormant for long periods of time. Each of these tiny seed structures confines within itself the greatest mysteries of biology -- the mysteries of life and death, the mysteries of fertilization and of hereditary transmission. Whether this is a result of inheritance or environment is not definitely known.

The practical farmer is not interested in the strange phenomenon manifested by this grain of seed, greatly endowed as it is, but he is concerned in its potential crop-producing power -- how many tons of hay or how many bushels of grain will be produced on a given area of land at a cost sufficiently low to return a reasonable profit. Growers of red clover and alfalfa are keenly interested in the fact that probably not to exceed 50 per cent of the seed from these plants when planted will grow to maturity. These same growers would be still more interested were they to realize that investigations indicate that some of the 50 out of 100 plants that do mature will not be strong and vigorous.

STATEMENT OF THE PROBLEM

The purpose of this study was an attempt to find a seed treatment that would increase the percentage germination of red clover and alfalfa seeds without impairing the vigor of the subsequent growth and production power of the plant. Obviously, this treatment must be cheap, simple, easily applied, and not liable to cause serious injury to the seed or to the operator.

REVIEW OF LITERATURE

FACTORS WHICH MAY INFLUENCE GERMINATION OF RED CLOVER AND ALFALFA SEEDS

One of the most absorbing chapters in the science of seeds is that which relates to the study of the life within the individual seed.

After maturity, is there, in part or in all of the seed, an after-ripening process that must be completed before germination can begin?

A review of the investigations made on this subject may be arranged into two groups: seeds in which delayed germination is due to the characters of the embryo, and seeds in which delayed germination is due to seed coat characters.

THE RELATION OF INHERENT EMBRYO CHARACTERS TO DELAYED GERMINATION

Harrington (37) states: "Embryos which, though morphologically mature, are physiologically incapable of germination." Even when free from all external restrictions, the process of germination does not begin until certain fundamental changes have taken place in the embryos themselves. Such changes may require a few minute's time or they may require a great many years.

Some of the major conceptions of after-ripening changes of the embryo are: results of a chemical process in which divers purely chemical changes occur; a part of the germination process; a fermentation process; the chemical stimulus derived from oxygen; a combined enzymatical and chemical process; and the effect of light on the ovule, pollen, and nutrition of the plant.

Crocker and Groves (14) believe that the fall of longevity with the rise of temperature indicate that the loss of vitality is due to a slow coagulation of the proteins in the plasma of the embryo.

Ewart (23) states: "As long as the inert proteid molcules, into which the living protoplasts disintegrate when drying, retain their molecular grouping, the embryo will remain dormant."

Lehman and Ottenwalder (55), Eckerson (21), Harrington (36), and others, hold that hydrolysis of proteins, alterations in the acidity and water-holding power of the embryo, metabolism of fats, fluctuations in sugars and amide nitrogenous compounds, increase of oxygen and the rendering active of dormant embryonic protoplasms by (H) and (OH) ions, are all purely chemical processes.

Recent work by Rudolfs (88, 89) and Salter and McIlvaine (92) indicate that the H-ion concentration of solutions markedly change upon immersion of seed. The change continues until a certain equilibrium is reached. The point of equilibrium seems to be specific for different seeds and also for different seeds in different mediums. Apparently, seed has the power to change the solution in which it is placed to a point which is favorable for its development. This increase or raise in the ion concentration was even found to be evident after the seed had changed one solution and then thoroughly washed and placed into another solution, where the change again took place but reached equilibrium at a different point.

Eckerson (21) compares the after-ripening process with the common germination process.

Detmer (17), Brown and Morris (9), Green (31), Hotter (45), Maze (62), Abderhalden und Dammhahn (1), Appleman (3), Crocker and Harrington (15) consider after-ripening more as a process of ferments; for instance, the presence of peptolytic ferments, liberation of enzymes, development of acidity, increased catalase, oxidase, and peroxidase activity and increased diastatic content.

Pack (78) thinks that after-ripening in certain seeds is accompanied by three representative changes: First, an accumulation of cell-building materials -- acids, phosphatids, active-reducing substances, soluble sugars, pentoses, amino acids, soluble proteins, and other nitrogenous compounds; second, the accumulation of enzymes, dispersion of materials and the transformation of storage materials; third, this accumulation of cell-building and cell-active materials, together with the culmination of enzymes, probably leads to the after-ripening of dormant organs.

Kinzel (52) and Heinricher (38) have shown that light rays play an important part in the protoplasmic changes taking place during the delayed germination.

THE RELATION OF SEED COAT CHARACTERS TO DELAYED GERMINATION

The conception that delayed germination is the result of seed coat characters has many advocates. Six of the many cases are distinguished as follows:

(1) Impermeability of the seed coat to water

Pammel and King (79), Nobbe and Haenlein (77), Nobbe and Ewart (24), and Hiltner (41) assume that the cause of the resistance of clover seed to water must originate in the outer cell layer or the palisade layer.

Martin (59) says: "The epidermis of the ovules forms the much elongated cells known as the Malphigian cells of the seed coat. The outer walls of the Malphigian cells are much thickened and composed of layers differing in physical properties. One of these layers is the light line which in most seeds is impervious to water until it is modified by weathering or by some artificial means. The light line is apparently only more compact cellulous for it hydrates quickly in water at 80° C. and then gives a distinct cellulose reaction and is permeable to water. The action of the weather is to open the line and thus permit the embryo of the seed to obtain water."

Schmidt (94) states: "Hard seeds are the result of the condition of the seed coat which prevents entrance of moisture. The two outer layers are of the greatest interest. The very outside layer, which is relatively thin, is of material of varying composition and no definite structure. The second layer, which is rather thick, is made up of a single layer of long, narrow cells placed closely against one another with the outer ends projecting into the outside layer. Due to this fence-like appearance under the microscope, it is called the palisade layer. The outside layer frequently contains a waxy resinous material."

Ewart and Guppy (24) bring out the point that seeds of legumes generally have an open micropyle. Water fails to enter because it will not wet the walls of these minute openings.

(2) Subminimal quantity of oxygen able to reach the embryo.

Crocker (12), Keiszling (51), Shull (100), Atwood (5), Hoffman (43), and Rose (85), assert that delayed germination or failure to germinate is more generally due to the seed coat limiting or entirely excluding water or oxygen than to embryo characters as has been generally assumed.

According to Atwood (5), it is possible to accept either that the embryo in the case of after-ripening decreases its demand for oxygen whereby seeds become able to grow in gases poor in oxygen or that there is no decrease in oxygen demands but rather an increased permeability in the coat to oxygen.

(3) Partial inhibitive pressure of carbon dioxide in the tissues of the embryo

Kidd and West (49) consider that the resting condition of seeds in apparently suitable conditions of temperature, moisture, and oxygen supply is a sort of narcosis caused by the carbon dioxide produced by the seed itself.

Annonymous (2): "Complete redrying or removal of the seed coat was necessary to bring about germination after carbon dioxide inhibition." Like results were obtained in soil when carbon dioxide was produced by means of rotting manure and other organic matter. Lower temperatures and decreased oxygen seemed to intensify this condition.

(4) Acetic Aldehyde Inhibition

Maze (61) demonstrated that the presence of acetic acid inhibits germination.

(5) Expanding embryo meets at
the seed coat a mechanical resistance
greater than the growing force of the embryo

Crocker and Harrington (15) and Rose (86) mention that an initial rapid water absorption ceases before the imbibitional and osmotic forces of the embryo are satisfied. Evidently, the force created by the contents of the seed when swelling is not sufficient to expand the outer coats.

(6) Exclusion of chemical compounds
necessary for germination

Crocker (13) and Brown (8) conclude that certain seeds are enclosed within a semi-permeable or selective covering which permits the passage of water to the interior of the seed but which prevents the passage of various acids and salts of metals when they are in aqueous solutions.

Discussion of some factors responsible for delayed germination

Whether or not the embryo or the seed coat, or both acting together, are responsible for delayed germination is one of the kindred questions of life that remain almost entirely unanswered.

To the practical worker it matters not what may be the cause. The seed coats are hard -- impermeable to moisture and to oxygen. In some seeds -- perhaps all -- the power of selecting the salts that shall or shall not pass through their membranes, seems apparent. Suffice it to say, the hard seed will not germinate unless the hard coat be modified.

True, it may be merely a pectin, a tannin, or some other chemical substance in the outer or inner layers that must be reacted upon to open up clefts. The seeds may be covered with an oil film that must be modified. The micropyle openings may be lined with an oily substance which inhibits the entrance of moisture. Manifestations of all of these are evident in red clover and alfalfa seed germination.

METHODS THAT HAVE BEEN USED TO QUICKEN AND INCREASE GERMINATION

Distilled water

Kidd and West (50), by soaking dwarf beans in distilled water for six hours, increased the germination (total for one month) 26 per cent. All of the treated seed of the same species showed more rapid germination and vigorous growth than the checks. However, about 12 days after germination, the growth of the treated seed was only about one-sixth the length of the untreated seed. These results indicate that while the treatment stimulated germination, it also reduced the actual production of the plant.

Soft water versus hard water

Dodge (19) reports that corn pre-soaked in rain water and planted in sand gave entirely different results from a sample of the same lot of seed treated with hard water. Corn seed pre-soaked in hard water and planted in boxes germinated 45 per cent after 60 hours, while a sample of the same seed pre-soaked in rain water germinated only 29 per cent. The results of this experiment indicate that the kind of water used may help to account for some of the variations obtained by different investigators in certain experimental work with seed germination.

Hot water

McNair (65), Duggar and Tisdale (108) after scalding bur clover burs in water at 212° F. for one minute, obtained 76 per cent germination with blotters against eight per cent with no treatment; and 52 per cent against four per cent when planted in the field. Alfalfa seeds, unless hand-hulled, were killed at boiling temperature.

Chlorine water

Spotschil (105) found that seeds containing oil germinated rapidly when soaked in chlorine water. The acceleration was thought to be due to the action of nascent oxygen liberated through decomposition of water by chlorine in the presence of light.

Lime water

The author and others have found that lime water in weak solutions has a marked effect on the germination of red clover and alfalfa seeds.

Sulphuric acid

Both in Europe and America investigators have found that by treating hard coated legume seed with concentrated sulphuric acid, germination could be hastened and increased. Indian fakers are said to have used this treatment to mystify some of the native indian farmers.

Todaro (110), who was probably one of the earliest experimentors, perfected the treatment which, with some modifications, is still being used.

Hard seeds were immersed in sulphuric acid, specific gravity 1.84, for one hour. Then the seeds were removed and thoroughly washed. With seeds where the hard coats had received no mechanical damage of any kind, Todaro claimed that washing was unnecessary.

Love and Leighty (56) obtained like results with red clover seed. They found, however, that with alfalfa some of the seeds were killed by such long immersions in concentrated sulphuric acid.

Hopkins (44) increased the germination of hard coated alfalfa seed from 16 per cent to 64 per cent by immersing it in concentrated sulphuric acid for only ten minutes.

Bianchi (6) concludes that sulphuric acid accelerates and increases the germination of all seeds impermeable to water. He thinks that the acid acts on the Malphigian layer in the seed coats of red clover and alfalfa.

While done on an entirely different seed, it is of interest to note the results obtained by Russell (91) who, by treating camphor seed with sulphuric acid, increased the germination 525 per cent with a subsequent increase of 600 per cent in the amount of seedling growth; also the germination occurred two weeks earlier than normal.

Discussion on pre-soaking

Any pre-soaking treatment will nearly always require an after-drying before the seed is planted in the field. With red clover or alfalfa seeds this extra labor cost, plus the cost of materials for soaking added to the loss of seed that is likely to occur from any wet treatment, would be an equal if not a larger cost than the amount of extra seed needed to get the same stand.

Because of its extreme caustic action, concentrated sulphuric acid will probably never be used as a commercial treatment to increase the germination of either red clover or alfalfa seeds.

Sulphuric acid treatment of commercial alfalfa seed is especially hazardous. A long time treatment will kill the soft seed and also some of the hard seed that happen to have been scarified in the threshing process. This is particularly true if the mechanical injury was made directly over the embryo. Unless treated for a long time, the really hard coated seeds will not be acted upon sufficiently to increase the germination.

Sulphuric acid treatment does, however, have considerable value for experimental purposes and for small lots of especially hard seed. If it were possible to devise a method whereby the acid could be sprayed upon the seed in such minute particles as to make washing after the treatment unnecessary, commercial applications might be practicable.

Other Chemicals

Michigan Bulletin 40 reports some very interesting experiments dealing with comparative effects of oxodizing agents, reducing agents, and neutral agents, et al., using ordinary well water as a check. The results with beans were as follows: lime 63 per cent, permanganate of potash 61 per cent, acetate of lead 60 per cent, nitrate of lead 49 per cent, chlorate of potash 31 per cent, peroxide of hydrogen 29 per cent, and ordinary well water 24 per cent. The comparatively high percentage germination due to the lime water treatment corresponded somewhat closely to the results obtained by the author with red clover and alfalfa seed in 1924.

Mercury salts has been reported by Harrington (34), Tisdale (109), et al., to have a stimulating effect on germination, Tisdale (109) agreeing with Voigt (113) that mercuric compounds not only increase germination but also improve the yield of certain crops.

A great many exhaustive investigations have been carried on attempting to explain the influence that various chemicals have on the germination of seeds and the subsequent growth of the plant. Professor Voigt (113) in an address before the International Seed Conference at Copenhagen, Denmark, stated that some remarkable work along this line had been carried on recently in Europe. He stated that Popoff had obtained not only an increased germination, but also a large increase in yield as a result of soaking seed in a solution of magnesium chloride. Similar results slightly less in extent were obtained with germisan and uspulun.

Various chemicals such as chloropicrin (Miege 69), copper sulphate, uspulun, formaldehyde, mercury salts, mercuric chloride, and copper carbonate have been used in an experimental way to accelerate or increase the germination of various seeds. The few experiments carried on with red clover and alfalfa seeds, in general, accelerated and increased the germination. Like results were obtained with copper carbonate in 1924 by the author.

Corrosive sublimate seems to be especially injurious to clover seed (Davis, Elliot, and Pierce (16).

Fertilizers

An exhaustive experiment with fertilizer salts carried on by Rusche (90) in Germany brings out the following very interesting data:

Chemical	Red Clover	Alfalfa
Potassium Chloride	Unfavorable	Unfavorable
Sodium "	Esp. harmful	Esp. harmful
Magnesium "	About normal	About normal
Calcium "	Slightly unfav.	Slightly unfav.
Ammonium "	Injurious	
Potassium Nitrate	About normal	About normal
Nitrate of Soda	" "	" "
Calcium Nitrate	" "	Favorable
Ammonium "	Injurious	Injurious
Potassium Sulphate	Favorable	Favorable
Sodium "	Slightly fav.	Slightly fav.
Magnesium "	Favorable	Favorable
Calcium "	"	"
Sodium Carbonate	Very favorable	Very favorable
Potassium "	" "	" "
Sodium Phosphate	Slightly fav.	Slightly fav.
Calcium "	Favorable	Favorable
Ammonium "	Injurious	"

Chemical	Clover Root	Clover Top	Alfalfa Root	Alfalfa Top
Potassium Sulphate	Long		Long	Good
Sodium "	"		Injurious	
Magnesium "	"		Long	
Ammonium "	"			Poor
Potassium Carbonate	"		Long	Good
Sodium "	"		"	"
Magnesium "	"		"	
Ammonium "			"	Poor
Sodium Nitrate	Long	Poor		
Potassium "	Short	"	Short	
Magnesium "	"	"	"	
Ammonium "	"	Good	"	Poor
Sodium Phosphate	"			
Potassium "	"			
Magnesium "	"			
Ammonium "	"			Poor
Sodium Chloride	"	Poor		
Potassium "	"	"		
Magnesium "	"	"		
Ammonium "	"	"		Poor

Ten grams of each of the fertilizers were mixed with 11.5 kilograms of soil. These results, while only for one year and only on one type of soil, indicate that further trials with clover and alfalfa fertilizers might furnish information that would have economic bearing on the germination problem.

All of the foregoing data were included in this paper as it is closely related to the experiments carried on by the author at the Oregon Agricultural College in 1924.

Gases

Various gases have been found to have an accelerating effect on the germination of legume seeds. Mercier (68) found hydrocyanic gas accelerated the germination and gave a normal growth. The speed of the growth seemed to vary with the strength of the gas. Seed, if thoroughly dry, may be subjected to gas treatments for long periods of time without lowering the viability. Formaldehyde gas has generally manifested itself by a decrease in the germination of red clover and alfalfa seed.

Samek (93) found that alfalfa seed after having been stored in hydrogen gas for 16 years, germinated 56.56 per cent. A sample of the same seed stored in carbon dioxide gas for 16 years germinated 84.2 per cent. This experiment gave results similar to those obtained by Harrington (33), Crocker (12), and Shull (99) who found oxygen to be necessary for the germination of legume seeds. The amount of oxygen required seemed to be specific with the variety of seed.

Organiz gases have been found to accelerate and to increase the germination in seeds (Howard 46). It was believed that these treatments contributed to the nutrition of the growing embryo.

Hydrogen peroxide (Sievers 101), alcohol, iodine, and various other materials have been used experimentally on seeds but the results are rather indefinite.

Anaesthetics

Hempel (Howard 46) summarizes the many investigations with anaesthetics by recognizing three phases of narcotization: "(1) Exciting (small doses for short periods) during which time the normal plant activities are accelerated; (2) narcosis proper (small doses for long periods or large doses for short periods) characterized by a retardation of the normal processes; and (3) toxic (large doses for long periods) causing all the phenomena characteristic of the death of the plant."

Dodge (19) found that clover and alfalfa, when thoroughly dried and stored in ether or chloroform for a year, retained their viability.

Enzymes

Enzymes, or the so-called unorganized ferments, are believed by botanists to play nearly as important a part in the various processes of plant digestion as they do in animal digestion. Professor Waugh (115), in experiments with various enzymes to determine their effect on seed germination, obtained some definite results with diastase. Apparently, each specie of seed required one enzyme or a certain group of enzymes. Sharpe (96) found that alfalfa seed soaked for 12 hours in solutions of asparagin, leucin, and pepsin gave results as follows:

	Average	Check
Asparagin	98.7	89
Leucin	92	89.5
Pepsin	Not important	

Stone (107) used asparagin which he states is a typical amide. Since amids increase when legume seeds germinate, he believes that pre-soaking the seed in an asparagin solution will at least accelerate, if not increase, germination.

McHargue (63) thinks that peroxidase tests may be used to determine the viability of alfalfa seed.

Nemec and Ducon (73) reported in 1921 that by the use of catalase the viability of seed could easily be determined. They found that the catalase content of the seed had a definite relation to the germination percentage.

Since Crocker and Harrington (15), and others, obtained variable results, and because of the difficulty and expense involved in any enzymatic treatment, this means of determining the viability or affecting the germination of seed is probably better suited to experimental purposes only.

Electricity

Many investigators (Howard 46) have studied the effects of electric current on different forms of plant life. Nollet (46) was probably the first person to study the effect of electricity on seeds. Later, Specnew (46) subjected different seeds to electric treatment and found that germination was very greatly hastened. Paulin (46) found that electric current would seemingly awaken life in seeds which appeared to have lost their vitality. Tschinkel (46) showed that certain seeds germinated rapidly in a soil through which an electric current had been passed. Woolny (46) secured only negative results from the use of this treatment on the seed of summer squash, rye, radish, and rape. Kinney (46) concludes that: "Electricity exerts an appreciable influence upon the germination of seeds, and the application of certain strengths of current to seeds for short periods accelerates germination." It has also been reported that a galvanic current of high frequency gives beneficial results while a continued current is detrimental to germination.

More recent work indicates a definite relationship between the strength of electrical response and germinating power of bean seed. Waller (114) and Frazier (28) believe that seed of high vitality give a strong electrical response and, on the average, a high per cent germination.

Fick and Hibbard (25) studied three methods of determining seed viability by using electrical conductivity - first, measuring the resistance of the seeds themselves; second, comparing the relative absorption and excretion of salts; and third, measuring the relative outward diffusion of electrolytes as indicated by conductivity readings. The third method was adopted. The data indicate a correlation between electrical conductivity and seed viability which, with further improvement, may be capable of practical application.

Mercier (67) claims that electricity, properly applied, will increase the production of wheat, oats, barley, or corn, from 4 to 20 bushels. The method is very simple and the cost is negligible.

Rothamstead Station, Great Britian, (87) in their 1926 report of the pot experiments carried on under electricity showed a consistent increase in grain yields. There were fewer sterile flowers, less shrivelled grains, and a marked increase in weight.

Light, X-rays, and Radium

Pickholtz (80) and Gillot (29) think light has a very important stimulating effect on germination.

Lehman and Ottenwalder (55) say light functions in the hydrolysis of proteins.

Promsy and Drevon (Howard 46) found that x-rays increased or decreased the germination of potatoes, radishes, lentils, wheat, beans, and lupines in varying degrees, depending upon the temperature and exposure. The greatest regularity in effect was noticed during a rather high temperature when, with a certain exposure adopted as the best, irradiation (Sheard and Higgins 97) always favored germination and accelerated the development of the resultant plants.

Dodge (19) reports that Doctor Gager placed the end of a sealed glass tube containing radium below the surface of the soil in some nursery pots to determine the effect of radium on germination of bean seed. The seed, which was subjected to the radio-active force of radium, germinated first and produced stronger seedlings than seed planted in control pots. Apparently the effect of radium depends quite largely on the thickness of the seed envelope, the distance of the seed from the radium, and the quantity of moist soil covering the seed.

In all probability, specific electrical treatments or tests will never have other than an experimental value. The same is true of light waves, radium, etc. Such treatments, although they might be successful, would doubtless cost more than would be saved by the use of less amounts of seed.

Temperature

Artificial after-ripening of seed at from 35° to 40° C. has been recommended and approved by Hiltner (41), Hiltner (42), Hoffman (43), Atterberg (4), Kieszling (51), Maze (61), Gumbel (32), Kidd and West (49), Harrington (35), Hile (40), et al.

Hoffman (43) supposes that the high water content of freshly harvested seed hinders the penetration of oxygen and because of this, at the same time, the after-ripening process. When seeds dry up, the seed coat shrivels and forms canals and clefts through which oxygen from the air is easily admitted. Kolkwitz (53) and Maze (61) regard the transformation, occurring when seeds are dried, as an evaporation of volatile stuffs, the presence of which hinders the evolution of the embryo. The aldehyde, which accumulates in seeds that are not after-ripened, does not, according to Maze (61), kill the embryo, but it does prevent diastase activity and, with it, germination.

Some advise that after-ripening should be done at low temperatures. This has been done by putting the seed, previous to germination, in an ice box at a temperature of 3° to 6° C. and then by germinating at a temperature varying between 8° and 15° C. Varying degrees of temperature for germination have been recommended by Whitcomb (117), Toole (112), Harrington (36), Rose (85), Atterberg (4), Qvam (82), and Hiltner (42).

Henrich (39) observes that low temperatures quicken the germination of poorly after-ripened seeds, but have a retarding influence when full ripeness has been obtained.

Harrington (36) recommends that any seeds remaining ungerminated after the peak at a low temperature be removed to germinating chambers at higher temperatures. The new rules for seed testing of the New York State Agricultural Experiment Station read: "In the case of cereals and timothy grown under such conditions that they are frosted or exposed to cold weather before harvest, germination tests should be made at lower temperatures, 15° to 20° C., and continued for longer periods than for normal seed."

Nagai (72), Reynolds (83), Nevada Station (74), Duvel (20), Stoker (106), Dixon (18), Todaro (111), and Ritter (84) have found that subjecting hard seed to high temperatures increased the percentage germination.

Stapleton (102) and Ritter (84) found that dark colored, small, shrivelled red clover and alfalfa seeds were less resistant at 40° C. than large, bright colored seeds. Incubation at 35° C. did not decrease the hard seed. The average increase in germination for 26 samples of seed treated at 40° C. was 19 per cent.

Bonnet (7) reports that, while temperature influences the rapidity of germination, it cannot increase the yield. He says that the total energy cannot be made greater; therefore the yield cannot be increased by stimulating germination.

Lute (58), in an experiment with hand-threshed seed compared to machine-threshed seed, found the number of impermeable seed with hand-threshed seed after heating one hour at 53° C. was 53 per cent compared to 80 per cent before heating. The germination of the machine-threshed seed after being heated two hours at 60° C. was increased from 65 per cent to 92 per cent. Similar reductions at higher temperatures for a longer time indicate no danger of killing live seed. A temperature below 50° C. had no effect after an eight hour exposure. 75° C. from three to six and one-half hours gave the best results. A 94 per cent germination with five per cent hard seed was obtained after six hours at 75° C. The same seed tested after five months showed no loss of vitality.

Dodge (19) writes that alfalfa survived a temperature of 121° C. and retained its viability. Red clover seed lost its vitality when subjected to temperatures above 95° C.

Doubtless artificial drying will be one of the most fruitful avenues for the investigator to follow in the future. Results obtained so far indicate a wide margin of safety between the point where acceleration of germination begins and the point where the viability of the seed is killed by the treatment. Whitcomb's (117) results do not substantiate the assertion that increased germination may be attained by using alternate temperatures.

Stratification and Clipping

Stratification in sand and earth to hasten or increase germination of various agricultural seeds is one of the oldest practices used to obtain a large number of seedlings from a given number of seeds. Apparently this method has never been used with red clover or alfalfa seed. The small size of the seed would probably make its use impracticable.

Clipping has been practiced with such grains as oats, but has never been used with clover and alfalfa seed only in connection with other treatment.

Scarification

Scarification of clover and alfalfa seeds has been a common practice for a long time. Many types of machines have been used for this purpose; the most common and successful one at the present time is the Ames Huller and Scarifier. The principle involved in practically all scarifying machines is to bring the seed in contact with some sort of an abrasive surface, either by pressure or by the force of gravity. With a machine tried out in Germany, the seeds were thrown against a myriad of fine points which were supposed to pierce through the outer hard covering of the seeds. Apparently it was unsuccessful. Hulling machines that are now being used to hull clover and alfalfa seeds affect a partial scarification of the seed during the hulling process. It appears to be difficult with all of these machines to regulate the severity of the abrasive action on the seed. It is claimed by seed concerns and others who have tested these machines, that germination percentage of hard seed is greatly increased. It is also claimed that a larger percentage of the seed will germinate at one time.

The removal of part or all of the seed coat has been done in an experimental way to determine whether or not delayed germination was due to embryo characters or to the seed coat characters. The results obtained on this point are not entirely in accord.

Investigators agree that in hand-hulled red clover and alfalfa seeds there is always a high percentage of the so-called hard seeds. Whether these seeds are immature or whether they are mature and must go through a pre-change before germination may begin, is beside the point. They are hard and apparently will not germinate when planted in the ground. Lute (58) reports as high as 90 per cent hard seed in alfalfa. A great many investigators have reported as high as 80 to 85 per cent for both red clover and alfalfa seeds. The author hand-hulled one sample taken from an alfalfa plant grown on the East Farm near Corvallis, Oregon, which germinated only eight per cent in 23 days. Undoubtedly there is great variation in the germination of hand-hulled seeds of both red clover and alfalfa. This may be due to the environmental conditions under which the crop of seed was grown, to the temperature and moisture at the time of ripening, or to the strain of seed.

There seems also to be an agreement among those investigators that scarification, if carefully done, will in some cases increase the total germination percentage as much as 75 per cent. However, nothing has been definitely proven as to how many of these seed that germinate will grow a normal plant and mature an average crop.

Schmidt (95) reports that recent investigations in Sweden indicate that the value of hard seed is very doubtful.

Recent work by Graber (30), Lute (58), and Whitcomb (Unpublished data) indicates that the practice of scarification is doubtful. Apparently there is a rapid loss of vitality after the seeds are scarified. This will occur in the soil as well as in storage. Hard seed will remain viable almost indefinitely unless the seed coat is broken, particularly over the embryo. The curve of viability goes down very rapidly after the seed coat is ruptured; in fact, the germination percentage will average very low after the seed has been scarified for more than one or two years.

The author found that alfalfa seed scarified in 1924 had almost lost its viability in 1926. Whether this was due to attacks from fungi or to the immaturity of the seed is not known.

ACTUAL FIELD GERMINATIONS USUALLY LOWER THAN THE REPORTED LABORATORY TESTS

Variation in seed characters

Ivanov (47) in a series of analyses on flax, hemp, poppy, mustard, castor bean, colza, sunflower, sesame, safflower, and camelina glabrata, grown under widely different environmental conditions, found that within a given species these seeds have the same chemical composition.

Stewart (104) in an exhaustive study of the influence of color and weight on germination, found distinct differences in favor of plump, bright yellow, and bright olive green seed. A summary of his results are given in Table 1.

Table 1 - Variations in color and weight

	Rel. Weight	Germination Blotters	Sand	Rel. Ag. Value
True color	114	68.8	59	122
Light green	94	67.4	33.8	100
Light brown	111	67	45	62
Dark green	76	53	34	53
Dark brown	98	40	14.6	38
Shriv'd.gr.	60	25.4	4.4	34
Shriv'd.br.	78	41.8	9	20
Check	100			

Similar color and weight effects with alfalfa and clover seeds were obtained by Ritter (84), McRostie (66), Findlay (26), Stoker (106), Stapledon (102), McKee (64), Pammel and King (79), Eisenmenger (22), Whitcomb (116), and others.

Wolfe (119) found that corn kernels taken from the tip of the ear germinated first. These were followed by the kernels from the middle and butt positions of the ear. His results also showed that small kernels from the tip, middle, and butt positions germinated more rapidly than large kernels from the same locations on the same ear.

Miller (70) reports that kidney-shaped alfalfa seeds not only germinated 8.2 per cent more than did irregularly shaped seeds, but also produced in five months 6.67 per cent more top growth. The height of the two plants grown from both shapes of seeds was practically equal. This experiment correlates somewhat with the experimental results obtained in relation to size and weight.

Byron and Halstead (10) found a possible correlation of location of the seed on the plant with germination. Apparently the most viable beans were found in the center of the pods.

Whitcomb (116) writes: "The relationship of maturity to the presence of hard seeds has become an important problem in certain sections." Natural colored alfalfa seeds show 55 per cent higher germination in laboratory tests than brown seeds; and 33 per cent higher germination than green seeds. The percentage of hard seeds in alfalfa were found to be the same in green and natural colored seeds and small in comparison to the number found in the brown colored seeds. Natural colored alfalfa seed produced ten times as many plants in the field as did either brown or green seeds.

These investigations indicate that size, weight, and shape of alfalfa and certain clover seeds have some influence on the percentage of germination and the resulting crop yield. Smaller, light colored seeds seemed to germinate more rapidly than the others. Medium size yellow and light green colored seeds seemed to have the highest percentage viability.

If the light green alfalfa seed are immature, maturity is indeed an economic factor of major importance. Perhaps, then, the suggestions made by a number of recent investigators that the source of the seed, the weather conditions previous to and at harvesting time, and the temperature and moisture conditions during the storage period should be carefully studied.

Variations in soils

Dodge (19) quotes Professor Stone as follows: "The driving out of the gases and the subsequent absorption and renewal of fresh oxygen in sterilization practices is beneficial to the soil and induced the seed to germinate more quickly."

Lumiere (57) found a substance in the water extract of soil which inhibited germination. Heating for one hour at 120° C. did not destroy the substance; therefore it is neither toxin nor enzyme. The substance appeared to be comparable to the extract produced by the growth of a micro-organism of the coli type. Lumiere says: "This substance is a marked reducing agent which robs the soil of the oxygen needed in the germination process."

Johnson (48) found that different soils vary markedly, both in toxicity and in beneficial action. Legume seeds were relatively more susceptible to variations in soil conditions. This marked sensitiveness to toxicity seemed to be genetic in legumes.

Salter and McIlvaine (92) determined that a slightly acid soil reaction was found favorable to the germination of red clover and alfalfa seed.

Probably no other one factor reduces the germination of the average planting of red clover or alfalfa seeds as much as do unfavorable soil conditions. No doubt, the physical condition, the amount of moisture in the soil, the humidity of the soil air, the temperature, and the number of active bacteria present are more important factors than the chemical constitution of the soil itself.

Variations in germination reports

Seed laboratories are not agreed on the manner of reporting hard seed. New Jersey (75), New York (76), and others, state that hard seed should not be counted until they are proven viable. Montana (Unpublished data), and others, report all hard seed as viable.

False germinations, abnormal sprouts, broken cotyledons, dead primary roots, and various other forms of abnormal germinations are being reported.

Stevens and Long (103) believe that scarification is responsible for practically all abnormalities.

California Bulletin 16 (11) states that mechanical injury in scarification, and in some cases threshing, may damage from 30 to 50 per cent of the alfalfa seed. The clean, bright appearance of the seed after scarification is very deceptive.

REPORT

OF

EXPERIMENTAL WORK

The following data cover the results of experiments made at the Oregon Agricultural College in 1924, and in Yuba County, California, in 1925 and 1926.

Tests were made to determine the effect of (1) mechanical scarification; (2) dusting with chemicals; (3) soaking commercial and hand-hulled red clover and alfalfa seeds in lime water; (4) comparative germination with the same lot of seed on blotters, in greenhouse flats, and in the field; (5) longevity of seed scarified in 1924.

MECHANICAL SCARIFICATION

EXPERIMENT 1

Materials and Methods

In this experiment, three lots of seed were dropped 18 feet down a zigzag chute lined with sandpaper. Data on the effect of the different number of times run are given in Table 2.

Table 2 - Effect on number of times run

	Check	1	2	3	4	5	6
Grimm	75	81	79	89	84	77	86
Alfalfa	74	82	81	86	82	80	83
Mixed	79	81	84	85	79*	80	83
Alfalfa	76	84	85	84	78*	79	81
Washed	77	84	89	78*	93	82	83
Red Clover	79	89	91	82*	93	86	87
Washed	74	86	80	80	82	89	83
Red Clover	72	84	81	76	79	85	80

Germination results of scarified seed

As was expected, the percentage increased with the number of times run up to a certain fairly definite point after which it started downward. An increase in the number of soft seeds and weak sprouts was noticed as the degree of scarification was increased. The figures marked with an asterisk were probably run too rapidly.

DUSTING WITH CHEMICALS

EXPERIMENT II

Materials and Methods

Seeds of red clover and alfalfa were dusted at the rate of about one pound of acid to 100 pounds of seed. Data on the effect of acids are noted in Table 3.

Table 3 - Effect of time interval on alfalfa seed

Acid	At once	One day	Two days	Three days	Check	No.of tests
Benzoic	94	23	3	4	65	1
"	64	13	14	5	68	4
"	54	27	22	11	66	2
"	63	19	18	3	67	2
Boracic	14	49	49	56	68	4
"	15	46	42	54	71	4
Citric	67	63	55	61	63	4
"	69	22	51	62	65	4

Results of the action of acids

Benzoic and Boracid acids decreased germination. Citric acid showed a slight increase with a decrease when allowed to stand. Results with both Salicylic and Pyrogalic acids were too low and varied to be of any value. Allowing the seeds to set, after treating, for a given interval of time, gives a noticeable difference in the effect on germination. Red clover seed gave like results.

EXPERIMENT III

Materials and Methods

An attempt was made in this dusting experiment to approximate soil conditions from a moisture standpoint. The seeds were well coated with fine particles of acid and then placed in slightly dampened blotters and allowed to stand -- four samples for one day, four samples for two days, and four samples for three days. The moisture was increased gradually after each lot had stood for the one, two, or three day period. The data are averaged in Table 5.

Table 5 - Combined effect of moisture and acid treatment

Acid	Days in slightly damp blotters One	Two	Three	Check	No. of Tests
Benzoic	16	2	4	65	4
"	25	19	5	68	4
Boracic	49	20	5	67	4
"	27	27	21	68	4
Citric	74	54	7	64	4
"	70	20	0	63	4

Results obtained by varying the amount of moisture

Apparently there is some relation between the amount of moisture used and the percentage germination with the acid treated seed. This is particularly evident with citric acid which showed ten per cent increase over the check.

Ordinary tap water may influence germination tests.

EXPERIMENT IV

Materials and Methods

This dusting experiment was made to determine the caustic or wrinkling effect, if any, when alfalfa seeds were well coated with Sodium Hydroxide, Hydrated Lime, or Aluminum Nitrate. Three different lots of seeds were treated by each chemical and then allowed to set for one, two, or three days respectively before starting the regular germination process. The data are noted in Table 5.

Table 5 - Caustic or Wrinkling effect on germination

Acid	At once	One day	Two days	Three days	Check	No. of tests
NaOH	70	3	0	0	67	2
"	62	1	0	0	67	2
Lime	55	64	61	72	57	2
"	54	71	73	72	59	2
$AlNO_3$	67	3	0	0	64	4
"	62	1	0	0	65	4

Germination results from accumulative chemical effect

Either Sodium Hydroxide and Aluminum Nitrate reacted too severely with seed coat substances or too much was applied. Alfalfa seed when treated with smaller amounts of Sodium Hydroxide, mixed half and half with fine soil, germinated slightly less than the check. Lime gave a definite increase in germination.

EXPERIMENT V

Materials and Methods

In this dusting experiment several different chemicals were used. The seed samples were taken from commercial lots of scarified seed. The data on the treated seeds are noted in Table 6.

Table 6 - Comparative germination with various chemicals

Chemical	Small amount	Fairly well covered	All seed would hold	Check
$KMnO_4$	78	67	79	65
"	79	74	74	65
$ALNO_3$	80	Lost	78	65
"	78	"	79	65
$KHSO_4$	68	71	65	74
"	69	65	64	68
Copper	73	82	70	68
Sterate	64	62	67	74

Germination results of Oxidizing Agents

The definite increase obtained with each of these chemicals indicate a sterilizing effect on the seed. Many weak sprouts were detected; this was probably due either to scarification or to chemical injury.

Results with Copper Sterate were extremely varied. So many of the sprouts were weak that it was difficult to make a true count.

EXPERIMENT V1

Materials and Methods

This dusting experiment was made to determine the effect of the free Sulphuric Acid contained in $CaH_4\ (PO_4)_2$. Two lots of alfalfa seeds were used. One of the samples had a high percentage of hard seeds. Both samples were thoroughly coated with the finely powdered chemical. One was placed in the germinator at once and the other allowed to stand for two weeks. The data are given in Table 7.

Table 7 - Effect of time interval on chemical treatment

Chemical	Small amount	Fairly well covered	All seed would hold	Check	No.of tests
$CaH_4\ (PO_4)_2$	82	74	81	65	2
"	81	74	80	67	2
After two weeks	65	Omitted	66	34	2
	59	"	67	27	2

Germination results from Free Sulphuric Acid

Apparently this chemical had a definite action on the hard seeds. After standing two weeks, the germination of the treated seed was double that of the check. It should be noted here that this particular sample had not been scarified.

EXPERIMENT V11

Materials and Methods

A large sample of alfalfa seed was dusted with Hydrated Lime to check the favorable results obtained. The seeds used were taken from a mixed lot of laboratory samples containing high percentages of hard seed. The germination tests were run in the seed laboratory by the ordinary blotter method. The data reported in Table 8 are averages of two (100 seed) samples.

Table 8 - Effect of varied coatings of Lime

No.	Light	Medium	Heavy	Check
1	21	31	40	
2	22	29	31	
3	27	22	23	
4	27	30	45	
5	18	25	28	24
6	29	29	31	27
7	24	30	26	
8	27	26	31	
9	28	29	28	
10	25	23	32	
11	29	33	25	20
12	25	30	31	25
Ave.	25.1	27.2	30.9	23.0
Increase	9%	18%	34%	100% equals 23

Germination effect of Lime-coated seeds

The tabulated results from 7200 alfalfa seeds, which showed an increase in germination from 9 per cent to 34 per cent, were definite evidence of the effect of lime.

In duplicate tests, in which the treated samples were allowed to stand for varied periods of time, similar increases were obtained. No appreciable increase or decrease in germination of seeds heavily coated with lime was noted when the samples were allowed to stand for periods of one, two, or three weeks. However, when light applications were made, there was a slight increase in the average germination.

Results obtained with unusually wet blotters, particularly where heavy applications of lime were made, indicated that large amounts of moisture reduced the germination percentage.

Sprouts on the seeds treated with lime seemed to be more vigorous than those on the seeds in the checks. This vigorous appearance was probably the result of accelerated germination.

SOAKING IN LIME WATER

EXPERIMENT V111

Methods and Materials

As a further check on the use of Hydrated Lime to increase germination, four lots of about 1,000 seeds each were suspended in a saturated solution of lime water. The four samples were allowed to soak for 18 hours, 36 hours, one week, and one month, respectively. Checks of four (250 seeds) samples were suspended in tap water for the same periods of time. After soaking, the seeds were scattered (250 each) on 16 unfolded germinating blotters. Each lot was covered with a blotter and germinated in the ordinary way.

Unfortunately, no photographic equipment was available to take pictures of the germination. The interpreted results as seen by the author are given as follows:

Germination of treated seeds compared to checks

Time	Accelera-tion	Increased per cent	Uniformity of duplicates	Vigor of Sprouts
18 hours	Marked	30 to 50	Uniform	Vigorous
36 "	Equal	10 " 20	"	"
1 week	Less	Decrease	Varied	Watery
1 month	Very little	"	"	Weak

Some of the seed remained hard but apparently viable after soaking in lime water for one month.

COMPARATIVE GERMINATION IN LABORATORY, GREENHOUSE, AND FIELD

EXPERIMENT IX

Methods and Materials

In this experiment the seeds were dusted with lime and then planted in regular greenhouse flats.

A large lot of mixed seeds containing a high per cent of hard seeds was soaked for 18 hours in tap water. The seeds were then spread out on a galvanized screen and allowed to drain and dry for about two hours, after which all of the swollen seeds were screened out. The remaining hard seeds were thoroughly dried on uncovered blotters in a warm room (60° to 70° F.).

River bottom, sandy loam soil free from any contaminating seeds was used. About four inches of soil was placed in the bottom of the flats, leveled, and thoroughly moistened. The seeds were dropped 100 in each row and covered with about one inch of moist soil.

A duplicated blotter germination test was started at the same time the seeds were planted in the flats. Only the vigorous sprouts are recorded in Table 9.

Table 9 - Comparative germination in flats and blotters

No.	Light	Medium	Heavy	Untreated Flats	Untreated Blotters
1	24	28	31		
2	31	28	30		
3	24	21	43	22	
4	27	22	27	25	
5	21	26	39	24	
6	23	24	27	27	
7	28	31	42	20	
8	31	23	42	25	
9	20	31	23	20	18.5
10	24	32	40	25	21.5
Ave.	24.7	26	35.2	23.5	20.5
Increase	1/2%	1%	5%	100%	
"	2%	2½%	50%		100%

Germination results with lime in flats

A study of the foregoing tabulated data indicate that lime has a consistent effect on germination. The average untreated check planted in flats germinated 15 per cent more than the checks on blotters. A 50 per cent increase in flats over the blotter check, on seeds covered with all the lime that would adhere to the coats, is further evidence of the wide spread between the actual and the reported germinations.

COMPARATIVE GERMINATION IN LABORATORY, GREENHOUSE, AND FIELD

EXPERIMENT X

Methods and Materials

This experiment was planned to determine the difference in germination between scarified and unscarified alfalfa seed treated with lime. The seeds were hand-hulled from three year old samples of Eastern Oregon alfalfa. Treated tests were made in flats and checks were made in flats and blotters. Data on this experiment are noted in Table 10.

Table 10 - Effect of Lime on unscarified seed

No.	Small amount	All seed would hold	Untreated checks Flats	Blotters
1	38	47	39	33
2	47	48	37	31
3	39	39	40	37
4	45	48	34	29
Ave.	42.2	45.5	37.5	32.5
Increase	12%	21%	100%	
"	30%	40%	4½%	100%

Germination results of lime on unscarified seed

Lime treatments apparently increased the germination in proportion to the number of hard seed present regardless of whether or not the seed had been scarified.

EXPERIMENT XI

Methods and Materials

To determine the effect of lime treatments on freshly gathered hand-hulled alfalfa seed, a small lot of the 1924 crop was gathered by the author on the East Farm near Corvallis, Oregon, in the spring of 1925. Unfortunately, there were only 225 seeds in the sample. A test with 200 seeds was run, one on blotters and onein flats. The remaining 25 seeds were placed in a tightly corked bottle for about three months when they were treated with a heavy coating of lime and allowed to stand for three days before germinating. Just as in preceding experiments, only strong, vigorous sprouts were counted. The data are noted in Table II.

Table II - Effect of lime on freshly gathered seed

No.	10 seeds treated with lime	50 seeds untreated Flats	50 seeds untreated Blotters
1	8	7	6
2	9	9	5

Results of lime on new seeds

Not enough seeds were tested to justify definite conclusions. However, it was apparent that local alfalfa seeds contained a high per cent of hard seed. Lime again seemed to have a definite effect.

EXPERIMENT XII

Methods and Materials

Field trials were run on several lots of seed to compare the reported germination of commercial samples with the actual germination in flats and in the field. Both hand-hulled and scarified seeds were used to get comparative data.

A sample of Eastern Oregon seed was hand-hulled and treated with Lime. The data are noted in Table 12, page 59.

Another sample of hand-hulled Eastern Oregon seed was scarified in the zigzag chute described in Experiment 1, page 45. This seed was treated with Lime, Copper Sulphate, and Copper Carbonate. The data are given in Table 13, page 60.

An extensive field trial was made with a commercial sample reported by the seed laboratory to have a 75 per cent germination. Adjacent rows of 100 treated seeds and 100 untreated seeds were planted in the field. A check of 400 seeds was planted in flats. The data on this trial will be found in Table 14, page 61.

Another lot of the commercial seed was treated with Lime, Copper Carbonate, and Copper Sulphate and planted just before a period of cold, rainy weather. While this was not done intentionally, it gave an indicative check on the effect of unfavorable soil and climatic conditions on germination percentage. The data are noted in Table 14, page 61.

Field tests were run on a sample of Grimm alfalfa seed from Montana. The seeds were treated with Lime, Copper Carbonate, and Copper Sulphate. The results are noted in Table 15, page 62.

Table 12 - Effect on Field-planted hand-hulled seeds

	Treated (field)		Untreated		
Lime	Light	Heavy	Field	Flats	Blotters
1	36	42	16	39	33
2	32	36	27	37	31
3	30	33	25	40	37
4	25	31	20	34	29
Ave.	31.7	35.5	22	37.5	32.5

Table 13 - Effect of scarification on field plantings

Lime	Treated (field) Light	Heavy	Field	Untreated Flats	Blotters
1		43	39		
2		37	44		
3		41	46		
4		39	48		
Ave.		40.	44.2	37.5	31.
$CuCO_3$					
1	31	50			
2	28	51			
3	30	47			
4	29	41			
Ave.	29.5	47.2	44.2	37.5	31.
$CuSO_4$					
1	29	53			
2	23	41			
3	27	27			
4	31	33			
Ave.	27.5	38.5	44.2	37.5	31.

Table 14 - Field effect of treated commercial seed planted

	Treated (field)		Untreated		
Lime	Light	Heavy	Field	Flats	Tag
1	48	57	53		
2	36	63	47		
3	32	61	41		
4	41	67	49		
5	45	58	44		
6	38	53	50		
7	41	49	40	65	
8	46	52	51	60	
9	49	49	49	67	
10	32	57	48	64	
Ave.	40.8	56.6	47.2	64	75
Lime	Same seed planted just before cold rain				
1	31	36	30		
2	33	29	34		
3	35	35	29		
4	38	33	30		
Ave.	34.2	33.2	31.7	64	75
$CuCO_3$					
1	28	24			
2	25	31			
3	30	37			
4	23	26			
Ave.	26.5	29.5	47.2	64	75
$CuSO_4$					
1	24	26			
2	26	28			
3	21	17			
4	19	23			
Ave.	22.5	23.5	47.2	64	75

Table 15 - Effect of field treatment on Grimm Alfalfa

Lime	Treated Heavy	Untreated Field	Untreated Flat	Untreated Tag
1	31	11	16	
2	25	11	13	
Ave.	28	11	14.5	64

LONGEVITY OF SCARIFIED SEED

EXPERIMENT XIII

Methods and Materials

A small lot of the alfalfa seed scarified in November, 1924, (Experiment 1, page 45) was placed in a tightly corked glass bottle and taken to Yuba County, California, by the author. The 1924 tests were made on blotters immediately after the seeds were scarified. All of the tests made in California were planted in flats. Weak, sickly sprouts were not counted. The averages reported in Table 16 are the only data that were recorded.

Table 16 - Longevity of scarified seed

	Nov. 1924	Nov. 1925	Nov. 1926	May 1927
Ave.	83.7	23.1	11.2	3.6

Longevity results on scarified seed

While the foregoing tabulated germinations cannot be taken as conclusive evidence, they do indicate that the problem of scarification has just been stated rather than solved. Whether the lime acted on the few hard seeds left in the sample or had a sterilizing effect on the scarified seed, would be difficult to determine.

DISCUSSION OF RESULTS
OBTAINED IN EXPERIMENTAL WORK

While the review of literature included a study of many types of hard seeds, the experimental work was confined to red clover and alfalfa seeds. Only reference was made to red clover seed as the results were quite similar to those of alfalfa.

From the results of the experiments performed and from the review of literature noted, it is logical to assume that the hard coats of legume seeds are but Nature's protection against an early loss of embryonic vitality. It seems probable that the function of the outer covering of the seed is to prevent the intake rather than the outlet of moisture, gases, toxins, or whatever may cause the seed to die.

Experimental results showed that scarification not only hastened and increased germination, but also brought about a rapid decline in viability. The relatively large number of abnormal and broken cotyledons and weak, sickly radicles found in the germination trials of scarified seed indicates that the embryos exposed by the scarification treatment were open to the attacks of outside agencies such as molds.

By the use of machines, such as the "Ames Scarifier and Huller" and even the improvised zigzag sandpaper lined chute used by the author, seeds that were almost 100 per cent hard have been made to germinate more than 75 per cent. At first this seemed to be a wonderful discovery. However, the results of experiments made by the author and others indicate very definitely that the appearance of scarified alfalfa seed is very deceiving; that the high per cent of sprouts appearing on the germinating blotter is still more deceiving; and that the tags stating that this or that lot of seed will germinate so many per cent is not a true measure of the number of vigorous plants that will grow in the field.

If the experimental results obtained may be taken as a criteria, pre-soaking treatments with water, dilute acids and salts, concentrated Sulphuric Acid, and other chemical solutions have little practical value in the treatment of commercial seeds. The results are too variable and the treatments either too complex or too expensive. Even the classical Sulphuric Acid treatment is far too difficult and hazardous a method to be used by anyone only a laboratory technician.

An accelerated and increased percentage germination was obtained by dusting with various finely powdered chemicals, including oxidizing agents, reducing agents, and neutral salts. While part or all of these chemicals may have had a direct action on some substance in the seed coat, or may have helped to bring the soil solution to a point nearer the germination equilibrium, it seems logical to conclude that their chief function has been to prevent attacks of micro-organisms.

Heavy applications of Hydrated Lime and $CaH_4(PO_4)_2$ increased the germination greatly. Because of the limited trials, no conclusions could be drawn regarding $CaH_4(PO_4)_2$. With Lime, however, the large number of consistent results obtained from trials made under varying conditions seemed to be sufficient evidence to conclude that it had a value as a treatment for hard seeds, particularly for soils needing Lime.

A study of the treatments noted in this paper suggests that dusting with Lime, or similar chemicals, or subjecting the seed to extremes of temperature, have been the most practicable and probably the only economical methods yet reported.

The results obtained so far indicate that seed laboratories should adopt a uniform method of reporting germination per cents. Their reports have varied in some cases as much as 30 per cent on samples taken from the same lot of seed germinated at the same time and in the same way. Comparative studies of laboratory and field germinations showed that the reports of seed analysts were fifty per cent higher than the number of seed that actually germinated when planted in the field.

Apparently, then, the economic problem is not how to modify the hard seed coat and how to change the environmental conditions of the seeds previous to and at the time of maturity and during the so-called after-ripening period, but how or where a variety that does not have hard seeds may be obtained.

Surely this is a problem for the plant breeder to solve.

SUMMARY AND CONCLUSION

1. Seeds are naturally hard.

2. Scarification of red clover and alfalfa seeds is a doubtful practice.

3. Acid treatments of commercial red clover and alfalfa seeds are impracticable.

4. Lime has a definite place as a combined hard seed treatment and soil amendment.

5. Percentage germinations of alfalfa seeds as reported by seed laboratories and as indicated by the tags on commercial lots are not an accurate measure of field results.

6. The problem is not how to scarify or treat seeds, but how to prevent the need for scarification and treatment.

7. Selecting and breeding rather than treating will probably be the best way to reduce the economic losses from hard-coated seeds.

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