BULLETIN No. 24.

U. S. DEPARTMENT OF AGRICULTURE.

DIVISION OF BOTANY

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AS AFFECTED BY

CERTAIN CHEMICAL FERTILIZERS.

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GILBERT H. HICKS.

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LETTER OF TRANSMITTAL.

U. S. DEPARTMENT OF AGRICULTURE,
DIVISION OF BOTANY,
Washington, D. C., January 25, 1900.

SIR: I have the honor to submit herewith, for publication as Bulletin No. 24, of this Division, a manuscript entitled "The Germination of Seeds as Affected by Certain Chemical Fertilizers," by the late Gilbert H. Hicks, Assistant Botanist. Mr. Hicks left with the manuscript, which fortunately had been completed at the time of his death, a note acknowledging his indebtedness to Mr. John C. Dabney, formerly an assistant in the Division of Botany, for valuable help in conducting the experiments. Dr. H. W. Wiley, Chief Chemist of the Department, has courteously read the manuscript and suggested certain amendments which have been incorporated in the text.

In the rapid extension of the use of chemical fertilizers in recent years, our knowledge of the precise physiological effects of this kind of fertilizers on different plants has not kept pace with the investigation of their purely chemical relationship with the crops and soils on which they are used. The application of chemical fertilizers frequently takes place at the same or nearly the same time as the sowing of seed, and while experience has often shown the partial loss of a crop, apparently from some injurious influence of the fertilizer on the seeds, little definite practical knowledge has thus far resulted from these occasional accidents. The general conclusion that a commercial fertilizer, unless known to be of a noninjurious kind, should not be brought into direct contact with germinating seeds should be made the basis of established practice.

Respectfully,

FREDERICK V. COVILLE,
Botanist.

Hon. JAMES WILSON,
Secretary of Agriculture.

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INTRODUCTION.

A large number of germination experiments have been made to ascertain the effect of different chemicals upon the sprouting of seeds. In earlier times the object of these experiments was principally to discover, if possible, some chemical to assist in the germination of old, weak, or naturally slow-germinating seeds. More recently such investigations have been conducted mainly in connection with the use of fungicides and insecticides, to learn in what strengths chemicals might be applied to seeds without seriously injuring their vitality. As a rule it has been found that the germination of seeds soaked in solutions of bases or salts is retarded or even entirely prevented unless these are extremely dilute, the injury being proportionate to the concentration of the chemical employed.

In some instances it has been claimed that certain chemical solutions quicken the germinating power of seeds, and occasionally these claims have been quite startling.

But interesting and important as have been the experiments in which chemicals were applied to seeds which were afterwards placed in a germinator to sprout, conclusions drawn from the results of such experiments are not to be relied upon as applied to seeds planted in soils to which fertilizers have previously been applied.

Here the problems involved are much more complex. In the former case the seed is in contact for a short time only with a chemical solution and one whose nature is known, and rarely indeed is this solution present after the radicle has appeared through the seed coat. Here the chemicals remain in the soil in more or less direct contact with the seed from first to last. Moreover, the chemical processes continually taking place in the soil have themselves a marked effect upon germination. Add to this the hidden changes which the fertilizer constituents are constantly undergoing in contact with the humic acid, carbon dioxide, and various salts in the soil, and we find that a study of the relation of fertilizers to germination involves one in problems of a very difficult and yet withal of an exceedingly interesting and important character.

Comparatively little research has been made in this field. The present paper is intended to be merely suggestive, and is preliminary to more extended research in the same line which the writer hopes to undertake.

HISTORY OF PREVIOUS WORK.

One of the earliest important contributions to this subject was made by Tautphœus in 1876. In his experiments such salts were employed as are found to a greater or less extent in commercial fertilizers. They were applied to the seeds in solutions of various strength from 0.5 to 5 per cent, and the seeds were then placed in a germinating apparatus. Wheat, rye, rape, maize, beans, and pease were tested in this way, a check test being conducted with distilled water. The checks always germinated best, although rape seed showed scarcely any injury from the use of chemicals, even in solutions concentrated to a strength as great as 2 per cent. In the other seeds the vitality was seriously injured whenever the salt content of the solution was greater than 0.5 per cent.

The chemicals employed by Tautphœus were potassium chloride, sodium chloride, calcium nitrate, sodium nitrate, potassium sulphate, and hydric di-potassic phosphate. The plumule and radicle in all the experiments showed a normal development. The seedlings, however, were more vigorous in the checks, except in the case of sodium chloride, where a 3 per cent solution gave stronger plantlets than where distilled water was used. He concludes that fertilizers which contain plant food in an easily soluble form should not be used in large amounts, at least immediately before the seeds are planted, lest their concentration in the soil become so great as, on the one hand, to destroy the vitality of the seed, or, on the other, to injure the development of the seedlings.

About the same time (1876) Henri Vilmorin published a short article in which he states that when the upper stratum of the soil contains a large proportion of mineral fertilizers, e. g., Chili saltpeter (sodium nitrate), beet seed germinates very slowly or not at all. Vilmorin's experiments were conducted in pots containing earth, to which, after weighing, different fertilizers had been applied in amounts varying from 0.5 to 5 per cent. The germination of wheat and beet seeds sown in these pots was retarded to a marked degree when potassium nitrate, calcium phosphate, and especially sodium nitrate were used in amounts equaling 5 per cent of the weight of the earth. With 10 per cent sodium nitrate the wheat and nine-tenths of the beet seed failed to germinate. It should be stated here that never in actual practice would the proportion of fertilizer to soil amount to anything like 5 per cent. Sodium nitrate is usually employed in quantities ranging from 150 to 300 pounds per acre. The soil on one acre to the depth of 8 in. weighs approximately 2,000,000 pounds.[1] If, however, the fertilizers were drilled in

[1] See Wiley's Principles and Practice of Agricultural Analysis, vol. 1, p. 102.

with the seeds, the percentage of saltpeter in the soil coming into immediate contact with the seeds, might readily reach the danger point.

Hindorf claims that magnesium chloride and calcium chloride used in proper amounts exercise a favorable effect upon the germination and growth of wheat, rye, barley, oats, peas, red clover, and rape, and that they never cause injury unless used in greater amounts than would occur in agricultural practice. The injury which then results he attributes to chlorine.

Nessler (in 1877) stated that he had noticed that hemp seed sown in fields fertilized with ordinary cooking salt at the rate of 250 kilos per hectare germinated unevenly and made a poorer development than in other fields. Experiments led him to conclude:

(1) A 0.5 per cent solution of cooking salt is injurious to the germination of rape, clover, and hemp. Wheat withstands this solution, but is injured by a 1 per cent solution, and hemp by a quarter of 1 per cent.

(2) A 1 per cent solution of ammonium sulphate had no appreciable effect upon wheat grains, but the plants were injured somewhat by a 0.75 per cent solution.

W. Jarius (in 1885) studied the effect on germination of various salts used in commercial fertilizers, and concluded that in general (with some notable exceptions) solutions of these salts in strengths of 0.2 and 0.4 per cent favorably affected germination; also that no ill effects can possibly result from the use of fertilizers, since their solution in the soil can never exceed 0.4 per cent. In his paper the conclusions of Tautphoeus and Nessler are criticised.

Jarius's experiments were conducted in pots of pure sand previously moistened for twenty-four hours with the solution. The seeds were planted so that one-half of each, including the micropyle, projected above the surface, "in order," as the author says, "that observation might be facilitated and an unimpeded access of air be secured." This impractical method of making the tests largely or quite invalidates the conclusions drawn by the experimenter, at least from a practical standpoint.

A more important study of this subject, because conducted under conditions nearer to those of the field, was published in 1896 by Claudel and Crochetelle.[1] In order to make use of an inert substance which would play the mechanical rôle of the soil without giving any chemical reaction in contact with the dissolved salts, they employed chemically pure (as nearly as obtainable) sterilized sand. Four hundred grams of this sand were placed in a porcelain saucer and the seeds laid equidistantly upon the surface; another layer of 400 grams of sand was placed on top of them, the seeds of all the species being planted at a uniform depth of 8 to 10 millimeters. In order to maintain as nearly as possible the same degree of moisture in all the saucers, the amount

[1] Annales Agronomique, 1896, pp. 131 to 142.

of liquid supplied was based upon the amount of sand (800 grams) rather than upon the strength of the solution. After ascertaining the amount of liquid (200 cubic centimeters) necessary to moisten 800 grams of sand, each of the lots after planting received this amount of distilled water, together with a solution of the chemical more or less dilute, according to necessity. Readily soluble materials were used, as potassium sulphate, ammonium sulphate, sodium nitrate, and potassium chloride. Slag and superphosphates were mixed with the superficial layer of the sand, direct contact with the seeds, however, being avoided. The results of these experiments are worth a somewhat extended mention.

Potash fertilizers under the form of sulphate or chloride of potassium in general retarded germination, this retardation being greater for the chloride than for the sulphate; the difference was especially noticeable for the Leguminosae and flax.

Ammonium sulphate had a disastrous effect upon the sprouting, though in unequal degrees, colza, flax, wheat, and mustard being very sensitive to its influence, while sainfoin and wheat were less so than any other seeds. To make sure that this injury was not due to too large an amount of the fertilizer, the experiment was repeated with wheat, oats, barley, colza, clover, and beans in solutions of 0.5, 1.2, and 5 parts per 1,000 of the sulphate of ammonia. The results showed that wheat, barley, and oats are practically insensible to this salt in solutions up to a strength of 2 parts per 1,000, but a 0.5 part per 1,000 affected colza slightly and clover to a marked degree. With 5 parts per 1,000 of the salt, all germination was arrested.

Sodium nitrate acted in a manner similar to ammonium sulphate, but less enegetically. The 1 part per 1,000 solution had no appreciable effect upon wheat, barley, sugar beet, colza, and beans, but seriously injured buckwheat and to a considerable extent clover. The 2 part per 1,000 solution had but little effect upon wheat, barley, and colza, but entirely prevented germination in buckwheat and beans, while sugar beet dropped off considerably and clover was badly injured; all the seeds germinated more slowly in this solution than in those of less strength. In the 5 part per 1,000 solution no seeds sprouted except barley, which germinated 100 per cent.

Phosphoric acid was used in the form of slag and superphosphate, the former being alkaline and the latter acid. In very feeble amounts, 2 parts per 1,000 and less, the addition of superphosphate slightly hastened germination; with 4 parts per 1,000, on the contrary, a considerably less number of seeds sprouted. The authors conclude that in acid soil the use of superphosphate does not retard germination, if the free acid is quickly combined with the bases of the soil.

The slag favored germination in all cases, especially in those of the Leguminosae. An attempt was made to ascertain whether this advantage was due to the phosphoric acid or to the lime, and it was found

that the basic phosphate of lime acted favorably upon the germination of vetches, while the acid phosphates were injurious. Free lime gave better results than the carbonate, but was inferior to the slag.

Summing up, the authors conclude:

(1) In the amounts employed, and leaving the seeds constantly in contact with the material used, sulphate of ammonia, sulphate of soda, chloride of potassium, sulphate of potassium, and the superphosphates, exercised an injurious action upon the germination of seeds in general.

(2) Not all the species sown were influenced to the same extent; for example, the wheat resisted the best among the species tested, whereas lentils, lucerne, and flax were very sensitive to the action of the fertilizers used.

(3) Alkaline substances with a basis of lime or of potash favored in a marked degree the germination of certain seeds, notably those of the Leguminosae. The slag used produced better effects than the lime alone.

In the same paper the authors give the results of experiments conducted to obtain information concerning the acids set free or originating during the germination of seeds, which showed that the amounts of acids thus formed are sometimes very great; hence it is concluded that lime, slag, and liquid manure act by saturating these acids in proportion to the amounts formed. Also, that the loss of phosphoric acid, which is excreted in considerable amount in the germination of wheat, for instance, is hindered by these alkaline substances, and thus conserved for the use of the young plant. These conclusions, in the opinion of Claudel and Crochetelle, explain to a certain extent the beneficial effect of lime, slag, and ashes upon acid soils. Seeds of clover were found to produce more acid for a given weight than any other seeds studied, thus explaining the fact that clover does not appear in acid soils prior to the addition of lime, ashes, or slag.

Professor Buffum, of the Wyoming State Experiment Station, made quite an extensive study of the effect of alkali soils upon germination, and found that even small per cents of alkali in the soil retard germination, although as a rule about as high a per cent of seeds germinated in a soil containing 1 per cent of alkali as in alkali-free soil, provided the seeds were left long enough.

DEPARTMENT EXPERIMENTS.

In any study of the effect of fertilizers upon the germination of seeds planted in the ground the following possibilities should be kept in mind: fertilizers may influence—

(1) The swelling stage.

(2) The nature and availability of the reserve materials.

(3) The awakening and growth of the embryo.

(4) The young sprout before it reaches the surface of the soil.

We expect to show in this paper that the principal effect is upon the

sprout after it has broken through the seed coat. It has already been established by Deherain and other investigators that plants in the seedling stage absorb a proportionally greater amount of mineral matter than in more advanced periods of development. Indeed, in the case of the bean, soda is taken up in the early life history of the plant, whereas none whatever is used when the plant is fully developed.

In experiments conducted by us in one of the greenhouses of the U. S. Department of Agriculture the following kinds of seed were used: Jones's Winter Fife wheat, Curled Simpson lettuce, French Breakfast radish, and crimson clover. Previous tests had shown that all of the varieties were of strong vitality. Common potting soil, sifted and clean, was thoroughly mixed and placed in greenhouse "flats." At the beginning of the experiment each flat was given enough water to suffice while the experiment was in progress, and all were treated alike throughout the test except in the matter of fertilizers. A check flat containing soil only was provided for each kind of seed.

The fertilizers used were the following: Nitrate of soda, muriate of potash, bone black made soluble by treatment with sulphuric acid, and lime made from powdered oyster shells. In addition to these, there was employed a mixed or "balanced" fertilizer consisting of bone black (treated as above), 600 parts (by weight); muriate of potash, 100 parts, and nitrate of soda, 200 parts. This fertilizer contained approximately the following proportions of plant food: Nitrogen, 23.7 per cent; phosphoric acid, 54.7 per cent; potash, 21.5 per cent. It is to be noted that all of these fertilizers are readily soluble in cold water. The seeds in each test were plump and sound and approximately of the same size.

The varieties were all planted at the same depth in four rows, each containing an equal number. In no case was the soil firmed after planting. Fifty cubic centimeters of fertilizer were added to the soil in the following manner: In one flat of each experiment 12.5 cubic centimeters was equally distributed in each row, the seeds sown upon the fertilizer, and a covering of soil added. In another flat the top inch of soil was carefully removed and 50 cubic centimeters of the fertilizer thoroughly mixed with this soil, which was then replaced and the seeds planted therein. A third flat contained soil only, as above stated.

The weight of 50 cubic centimeters of each fertilizer was as follows: Bone black, 43.5 grams; muriate of potash, 43.0 grams; nitrate of soda, 57.5 grams; lime, 31.0 grams; mixed fertilizer, 35.5. The fertilizers were used in the following strengths by weight: Bone black, 1.32 per cent; muriate of potash, 1.31 per cent; nitrate of soda, 1.75 per cent; lime, 0.94 per cent; mixed fertilizer, 1.08 per cent. While these proportions are greater than would obtain in ordinary practice, it is believed that they were not too large to give reliable results.

FIG. 1.—WHEAT EXPERIMENT WITH POTASH. RIGHT, CHECK; LEFT, POTASH SOWN IN THE ROWS.

FIG. 2.—WHEAT EXPERIMENT WITH PHOSPHORIC ACID. RIGHT, SOWN IN THE ROWS; LEFT, MIXED WITH THE SOIL.

FIG. 1.—WHEAT EXPERIMENT WITH LIME. RIGHT, SOWN IN THE ROWS; LEFT, MIXED WITH THE SOIL.

FIG. 2.—WHEAT EXPERIMENT WITH MIXED FERTILIZERS. RIGHT, SOWN IN THE ROWS; LEFT, MIXED WITH THE SOIL.

TRIALS WITH WHEAT.

In the experiments with wheat four rows of 50 seeds each were used in each test (Pls. I, II). In the following table, which summarizes the results, the percentages given are the average of the four rows:

Effect of chemical fertilizers on the germination of Jones's Winter Fife wheat.

Fertilizer.	How fertilizer was applied.	Time required for germination of first sprouts.	Average per cent sprouted.		Average height of sprouts (mm.) on fifth day.
		Days.	In 5 days.	In 10 days.	
Potash (KCl)	Sown in the rows		00	00	
	Mixed with soil		00	00	
Phosphoric acid (bone black).	Sown in the rows	3.0	51.5	85.5	16.6
	Mixed with soil	2.5	87.0	89.0	46.2
Nitrogen ($NaNO_3$)	Sown in the rows		00	00	
	Mixed with soil		00	00	
Lime (oyster shells)	Sown in the rows	2.5	81	93.5	31.5
	Mixed with soil	2.5	85	90.5	48.2
Mixed	Sown in the rows	5.5	00	9.0	00.0
	Mixed with soil	3.5	46.0	80.0	15.4
Check		2.5	89.5	90.5	54.0

Analyzing these results we notice, first, that the potash and nitrogen fertilizers prevented germination entirely.

Second, that in every case at the end of four days the germination was greater when the fertilizers were mixed with the soil than when they were sown in the rows and the seeds placed in direct contact, although the difference in the case of lime was very slight.

Third, that germination was retarded when the fertilizers were in direct contact with the seeds, except in the lime experiment.

Fourth, that on the fifth day the germination of the wheat sown in soils mixed with the phosphoric acid and lime fertilizers was only slightly less than that of the checks, and that it had nearly or quite caught up with the checks on the tenth day.

Fifth, that lime in the rows gave a slightly greater percentage of germination than the check on the tenth day. The increase, however, is not large enough to warrant the conclusion that lime is really beneficial to germination. That it is, on the contrary, to a certain extent detrimental if used in amounts equaling 0.94 per cent may be inferred from the fact that the average length of the sprouts was considerably less on the fifth day, even when the lime was mixed with the soil, and much less when sown in the row.

The experiment teaches that care should be exercised in applying muriate of potash and sodium nitrate to soils in which wheat is to be sown, as an excess of these salts will seriously injure and may prevent germination. Also, that a combination of sulphate of lime with acid phosphate and a little free sulphuric acid is not likely to injure the germination of wheat, even when used in some excess.

The serious damage caused by the mixed fertilizer was undoubtedly due to the potash and nitrogen which it contained.

After the completion of the ten days' experiment the unsprouted grains of wheat were taken from the nitrogen and potash flats and tested between damp blotters in the laboratory, with the following results:

Laboratory test of residual wheat.

Fertilizer.	How fertilizer was applied.	Per cent germinated.
Potash	In the rows	50
	Mixed with soil	70
Nitrogen	In the rows	49
	Mixed with soil	84

Many of the seeds were found to be decayed when taken from the flats.

TRIALS WITH LETTUCE SEED.

Lettuce seed, if kept thoroughly wet for the first forty-eight hours of a germination test, sprouts very freely, even as high as 98 or 100 per cent by the third or fourth day. In these experiments this excessive moisture was not maintained, hence the low germination of the check. The seed was planted in the afternoon of May 19. Four hundred seeds were used in each test.

Effect of chemical fertilizers on the germination of Curled Simpson lettuce seed.

Fertilizer.	How fertilizer was applied.	First sprouts.	Per cent germinated on the fourth day.	Per cent germinated on the twelfth day.
Potash	In the rows		No sprouts.	No sprouts.
	Mixed with soil		No sprouts.	No sprouts.
Phosphoric acid	In the rows	May 26, p. m	No sprouts.	2.5
	Mixed with soil	May 21, p. m	2.5	45.25
Nitrogen	In the rows		No sprouts.	No sprouts.
	Mixed with soil		No sprouts.	No sprouts.
Lime	In the rows	May 23, a. m	0.75	36
	Mixed with soil	May 22, a. m	4.0	39.75
Mixed fertilizer	In the rows		No sprouts.	No sprouts.
	Mixed with soil		No sprouts.	No sprouts.
Check		May 21, a. m	40.5	73

Potash and nitrogen prevented germination entirely, as in the case of wheat; furthermore the mixed fertilizer had the same effect. Phosphoric acid and lime greatly retarded germination, and even prevented it to a large extent. It is noticeable, however, that although the phosphoric acid mixed with soil appeared to be slightly more favorable than lime under the same circumstances, yet the latter really affected germination much less injuriously, as evidenced by the fact that when in direct contact with the seeds the phosphoric-acid fertilizer almost completely prevented germination, giving only 2.5 per cent sprouts on the twelfth day, while 36 per cent sprouted in the lime test within that period.

At the close of the greenhouse experiment part of the sound lettuce seeds were removed for a test between damp blotters in the laboratory. The results are very interesting, since they indicate that the principal injury from the application of the fertilizers, especially when mixed with soil, accrued to the young sprouts after leaving the seeds and while yet beneath the soil, rather than to the seeds themselves. The laboratory tests continued three and one-half days. One hundred seeds were used in each test.

Laboratory test of residual lettuce seed.

Fertilizer.	How fertilizer was applied.	Per cent germinated.
Potash	In the rows	62
	Mixed with soil	93
Phosphoric acid	In the rows	80
	Mixed with soil	Not tested.
Nitrogen	In the rows	36
	Mixed with soil	79
Lime	In the rows	Not tested.
	Mixed with soil	Not tested.
Mixed fertilizer	In the rows	90
	Mixed with soil	93

The sprouts were mostly normal and healthy in the potash and mixed fertilizer tests. Those derived from seeds which had been in direct contact with the nitrogen and phosphoric acid were somewhat sickly and weak. Unfortunately, the record is not entirely complete, since neither the seed tested in phosphoric acid in rows nor the limed seed was given a laboratory test; but the very high germination of the two mixed-fertilizer lots, neither of which had sprouted at all while in the soil, adds further evidence to the apparently established fact that the injurious effects of the fertilizers were principally wrought upon the hypogeous seedlings, and that owing to the protecting power of their teguments, perhaps to some extent also to the dormant condition of the seed contents, the seeds themselves were not injured by the fertilizers employed.

TRIALS WITH RADISH SEED.

The soil experiment represented in the table below occupied ten days. Two hundred seeds were used in each trial. These were planted in the afternoon of May 21.

Effect of chemical fertilizers on French Breakfast radish seed.

Fertilizer.	How fertilizer was applied.	First sprouts appeared.	Per cent of germination.
Potash	In the rows	No sprouts.	1.5
	Mixed with soil		
Phosphoric acid	In the rows	May 26, a. m.	19.0
	Mixed with soil	May 24, a. m.	95.0
Nitrogen	In the rows	May 25, p. m.	2.0
	Mixed with soil	May 26, a. m.	6.5
Lime	In the rows	May 24, a. m.	37.5
	Mixed with soil	do	93.0
Mixed fertilizer	In the rows	May 25, a. m.	34.5
	Mixed with soil	May 24, p. m.	92.0
Check		May 24, a. m.	96.5

Here again it is seen that the potash and nitrogen fertilizers practically prevented germination. The fact is striking, however, that, while the sprouting was seriously injured in all of the tests in which the seeds were sown directly upon the fertilizers, when the latter were mixed with the soil the germination of the radish seed was nearly as high as in the check test.

An examination of the radish seeds remaining at the close of the soil experiments revealed the fact that many of them which had been in immediate contact with the potash and nitrogen were badly decayed, while those taken from the soil-mixed fertilizer lots were generally, to all appearance, quite sound. This I attribute mainly to the fact that in the case of wheat and lettuce "seed" we are really dealing with fruits, in which the proper seed is encased in external teguments, whereas the radish seed has only the true seed coats.

Laboratory tests were made of radish seed taken from the flats of the potash and nitrogen experiments, with the following results:

Laboratory tests of residual radish seed.

Fertilizer.	How fertilizer was applied.	Per cent germinated.
Potash	In the rows	20
	Mixed with soil	56
Nitrogen	In the rows	32
	Mixed with soil	68

These figures are in decided contrast with those given in the table of germinations of radish seed in soil treated with the potash and nitrogen fertilizers, and show that while radish seed is much more susceptible to the action of fertilizers than the others tested, when in direct contact, nevertheless the effect is mainly produced upon the seedlings.

TRIALS WITH CRIMSON CLOVER SEED.

A soil test was made with crimson clover seed which lasted eleven and one-half days. Two hundred seeds were used in each trial. These were planted May 20, p. m.

Effect of chemical fertilizers on crimson clover seed.

Fertilizer.	How fertilizer was applied.	First sprouts appeared.	Per cent of germination.
Potash	In the rows	No sprouts	
	Mixed	do	
Phosphoric acid	In the rows	do	
	Mixed	May 23, a. m.	31
Nitrogen	In the rows	No sprouts	
	Mixed	do	
Lime	In the rows	May 28, a. m.	1
	Mixed	May 23, a. m.	38
Mixed fertilizer	In the rows	No sprouts	
	Mixed	May 24, a. m.	21.5
Check		May 23, a. m.	31

The injurious action of the fertilizers upon the crimson clover seed seems to have been much more marked than in the case of any other seed tested, but any definite conclusions are precluded by the extremely low germination of the check. This seed tested in the laboratory between moist blotters showed a vitality of 97¼ per cent. The seed, however, was 2 years old, as was the case with the wheat also, while the lettuce and radish seed are supposed to have been grown in 1897.

As with wheat, lettuce, and radish (practically), the muriate of potash and sodium nitrate prevented germination. Lime, too, was almost prohibitive when sown in the rows, although it gave better results than any other fertilizer when mixed with soil. Liebenberg claims that the use of lime renders the reserve materials of the seed more available to the developing seedling and therefore helpful to germination. This is certainly not the case when an excessive amount is applied.

CONCLUSIONS.

Summing up the results obtained from these experiments, we may safely conclude:

(1) That muriate of potash and sodium nitrate used as fertilizers in strengths of 1 per cent or more are very detrimental to the germination of seeds, whether applied directly or mixed with the soil.

(2) That fertilizers composed of phosphoric acid or lime are much less injurious to germination than sodium nitrate or muriate of potash, and if not used in excess may be harmless.

(3) That commercial fertilizers should not be brought into direct contact with germinating seeds.

(4) The effect of treating seeds with chemicals before planting is no index to the action of those chemicals when applied as manures to the soil.

(5) That the chief injury to germination from chemical fertilizers is inflicted upon the young sprouts after they leave the seed coat and before they emerge from the soil, while the seeds themselves are injured only slightly or not at all.

(6) It is highly improbable that potash, phosphoric acid, nitrogen, or lime used as fertilizers actually favor germination.

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