A STUDY OF THE EFFECTS OF FERTILIZERS ON THE GERMINATION OF SEEDS WHEN PLACED IN CONTACT FOR VARYING PERIODS OF TIME

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EFFECT OF FERTILIZER ON GERMINATION OF SEED.

Farmers add fertilizer to their soils for the purpose of supplying plants with nutrient material to secure increased yields of crops. Besides increasing the yields of crops fertilizers may produce a number of desirable and undesirable results as follows:

(1) The quality of the crop may be improved.

(2) Early growth, root development and hardiness may be promoted.

(3) Lodging may be lessened and maturity hastened.

(4) Effects of disease, insects and weather may be lessened.

(5) Increases yields.

(1) Germination may be impaired.

(2) Maturity may be delayed.

(3) Leaching losses may be increased.

(4) Fertilizers once used must be continued if yields are to be maintained.

(5) May cause soil acidity or alkalinity to develop more rapidly.

OBJECT

The present investigation was undertaken for the purpose of studying the effect of fertilizers on the germination of grass and clover seeds when placed in contact with such seeds for varying periods of time. The question arose as to whether the common practice of farmers mixing seed and fertilizer together and drilling both in a single operation affected the germination of the seed which thus came into direct contact with the fertilizers. Not infrequently such a mixture remained in the drill for long periods because of the inclemency of the weather or for other causes.

MATERIALS AND METHODS.

The experiment was conducted in the greenhouse during the years of 1924-25-26. Hagerstown silt loam was the type of soil used. All seeds were allowed to reach the seedling stage when the seedlings were counted and discarded. A careful record was kept of the percentage of seeds germinating. Every fifth row was a check row. Additional checks were made by methods which will be described later. The soil was kept at the same percentage of saturation. All seeds were planted at the same depth in rows three feet long and four inches apart.

The following kinds of seeds were used in the experiment: Timothy, red top, orchard grass, tall meadow oat grass, Rhode Island bent grass, Kentucky bluegrass, Canada bluegrass, sheep's fescue, meadow fescue, red clover, alsike clover, sapling clover, crimson clover, biennial white sweet clover, Japan clover and white Dutch clover.

The following kinds of fertilizers were used in each case: Acid phosphate, ammonium sulphate, potassium sulphate, potassium chloride, ground limestone, ground burnt lime, synthetic urea, calcium cyanamid, ammonium chloride, ammonium phosphate, ammonium nitrate, and calcined phosphate.

The seeds were placed in contact with the fertilizers in small envelopes for four weeks, three weeks, two weeks, and one week when all were planted. Two hundred seeds of each kind were used in every case and the germination was carefully tabulated. The amounts of fertilizers with which seeds were placed in contact was determined by the normal rate of sowing, the percentage composition and the weight of an acre of soil to a depth of 4 inces according to the following table.

Table I. Rate of Application of Fertilizers.

Fertilizers.	Rate per acre.	Grams used.
CaH4PO4 Acid Phosphate	200	2.08
NH4SO4 Ammonium Sulfate	100	1.04
K2 SO4 Potassium sulfate	100	1.04
K CL Potassium Chloride	100	1.04
Ca CO3 Calcium Carbonate	500	5.20
Ca O Calcium Oxide	250	2.60
CH4 N2O Urea	50	.52
NH4 CL Ammonium Chloride	100	1.04
NH4 N2 PO4 Ammonium Phosphate	100	1.04

Table I. (Cont'd.) Rate of Application of Fertilizers.

Fertilizers.	Rate per acre.	Grams used.
Nh4 NO3 Ammonium Nitrate	100	1.04
Ca P Calcined Phosphate	200	2.08

All seeds were placed in direct contact with the fertilizers mentioned when all were planted on the same day with the checks.

Review of Literature.

Lipman (3) claims that the formation of CHN dicyanodiamide in $CaCN_2$ causes a low germination when this fertilizer is used. With urea unsatisfactory distribution is given as the cause for lower germination by the same author. Truog (2) believes that there are three inherent factors in the seed or sprout itself, which determine the amount of injury of fertilizers on the germination of seed; viz; osmotic pressure of seed, osmotic pressure of sprout, and amount of protective covering on sprout. It can be readily seen that the lower the osmotic pressure of the seeds, the more difficult it is for the seeds to compete with the fertilizer salts for the water required for germination. This is especially true when seed and fertilizer are drilled together in the same drill row. Delays in germination according to McLean (4) may be caused by a concentrated soil solution which inhibits the absorption of water by the seed. Synthetic urea because of the union of ammonia and carbon dioxide, will not affect the germination as markedly as urea from calcium cyanamide. Applications of fertilizer five days before planting seeds did not affect germination as much as applications at the time of planting. Sherwin (5) found that the class of soil used bore no relation to the effect of fertilizers. In this experiment, therefore, Hagerstown silt loam was used during the three years that it has been conducted. Sherwin likewise found that the seeds of cotton and corn placed in contact with fertilizer germinated less than in tests where the soil and fertilizer were mixed and the seeds then planted. Fertilizers inhibit germination, the amount of inhibition depending on the amount of fertilizer used. This inhibition was due to the retarding influence upon the osmotic absorption of water from the soil by the seed where soluable salts were used. Hicks (2) claims genuine fertilizer injury occurs after germination has taken place and during the period that the young plant is in the seedling stage. He further claims that the chief injury to germination from the use of 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. Shieve (6) supports Hicks viewpoint demonstrating burning of root tips when the concentration of soil solution was greater then two atmospheres of osmotic pressure. Allison (1) showed that ammonium phosphate had little effect on the germination of seeds when placed in actual contact as great as 2.5 grams in 200 grams of soil. That when injury did occur because of excessive amounts it was because of concentration of soluble salts and not to any impurities that might be present. His analysis of commercial ammo-phos showed it to contain 13.5 percent ammonia and 43 percent phosphoric acid.

RESULTS

Discussion of the Effect of Fertilizers on Germination of Seeds.

A brief discussion of the seeds and the character of plant growth from the seeds which were slow to germinate when in contact with certain fertilizers, and the apparent reasons for this condition is given below:

Red clover germination was affected markedly by the fertilizers calcium cyanamide and urea. These two fertilizers when in contact with seeds in the soil undergo chemical changes with the formation of dicyandiamide gas and a heavy ammonia gas which apparently enters through the seed coat into the seed and destroys the germ before germination takes place. Seeds in contact with these fertilizers germinate poorly, the majority of them swell slightly, turn dark brown in color and decay. With the same seeds ammonium sulfate, ammonium chloride and ammonium nitrate caused a lowered germination and abnormal seedling growth. This condition was apparently caused by a concentration of the salt solution because of poor distribution. The osmotic pressure of the soil solution was undoubtably greater than the osmotic pressure within the seeds, resulting in plasmolysis rather than osmosis. The seeds

Table No. 2. Percentage germination of clovers and grasses with different fertilizers when placed in contact for varying periods of time.

Fertilizers used.	Germination: Red clover %				Alsike clover %				Sapling clover %				Crimson clover %				Bi. White clover %				Japanese clover %				Dutch clover %			
Weeks Contact	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Check	38	39	42	45	61	50	48	45	35	41	35	38	29	23	20	21	24	22	20	19	70	60	59	53	42	37	66	52
$(NH_4)_2SO_4$	23	51	42	50	44	35	22	47	17	18	18	10	12	17	18	11	15	6	5	8	54	44	57	57	16	29	29	58
$CaH_4(PO_4)_2$	30	24	24	50	39	53	27	61	78	39	31	28	21	15	16	9	15	14	12	14	61	48	67	51	55	38	33	47
CaO	28	35	31	25	32	34	42	31	35	32	49	43	14	12	14	13	20	14	16	19	42	34	57	21	24	32	24	24
NH_4CL	34	22	22	20	35	49	28	45	14	11	7	4	18	15	6	18	9	6	6	7	21	36	30	35	33	31	29	59
Check	50	55	60	61	59	65	57	60	33	45	56	49	28	25	21	17	23	22	14	24	68	82	83	58	50	33	59	55
CaP	54	42	54	55	54	54	56	55	41	36	36	40	27	22	21	14	22	21	12	10	56	36	45	54	23	31	66	40
K_2SO_4	64	33	50	59	45	58	61	60	30	26	26	14	26	16	15	14	18	15	9	7	26	56	62	38	16	34	50	26
NH_4NO_3	42	29	22	39	55	60	52	28	14	22	11	4	14	15	21	13	7	6	5	4	23	40	45	32	19	16	48	32
KCL	48	33	42	53	45	40	54	54	28	25	20	16	48	28	29	32	20	12	9	10	28	34	51	38	26	28	35	28
$NH_4H_2PO_4$	28	20	27	25	18	38	38	37	12	19	12	8	22	8	9	12	5	7	5	3	46	47	47	58	4	9	27	28
Check	65	63	66	59	51	52	59	61	40	36	47	42	31	20	19	18	25	20	18	21	50	72	71	59	44	54	59	41
CH_4N_2O	8	10	6	10	10	14	25	16	19	27	18	13	14	8	5	12	5	4	3	2	52	62	50	62	18	10	29	23
CaCn	3	3	1	2	5	6	4	7	3	2	2	2	4	1	2	2	3	2	4	2	8	5	6	14	10	2	11	7
$CaCO_3$	51	61	60	61	67	59	48	39	42	36	53	34	28	14	27	14	20	19	19	18	62	48	61	40	30	24	55	42

Table No. 2, Cont'd. Percentage germination of clovers and grasses with different fertilizers when placed in contact for varying periods of time.

Fertilizers used.	Germination																											
	Kentucky bluegrass %				Canada bluegrass %				Meadow Fescue %				Sheep's fescue %				T.M.Oat grass %				R.I. Bent grass %				Orchard grass %			
	Weeks Contact																											
	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4	1	2	3	4
Check	22	18	28	24	20	44	36	34	20	29	28	26	18	18	20	18	52	43	36	43	12	9	10	14	20	32	22	28
$(NH_4)_2SO_4$	14	14	12	8	28	8	19	26	30	33	29	27	20	24	28	17	50	49	49	43	3	11	8	7	8	16	8	6
$CaH_4(PO_4)_2$	8	8	4	4	14	14	22	14	28	29	42	34	14	11	6	3	49	51	34	38	8	9	11	12	16	20	20	18
CaO	8	8	8	10	18	16	8	20	27	26	16	31	27	19	31	20	37	35	44	41	2	0	3	4	24	16	24	24
NH_4CL	6	6	14	6	18	6	4	28	25	28	30	26	23	12	12	14	40	32	44	35	7	9	9	8	24	10	16	22
Check	22	28	24	20	24	20	36	30	22	26	22	22	22	27	19	21	44	44	49	44	9	17	11	14	24	22	28	30
CaP	16	22	20	10	20	26	28	30	26	30	30	23	15	8	23	24	36	33	33	31	4	6	5	6	28	28	24	36
K_2SO_4	2	4	8	6	20	22	28	18	29	33	30	30	22	20	20	13	38	40	34	31	3	7	9	6	10	20	16	18
NH_4NO_3	8	20	12	6	14	16	10	22	27	32	25	22	15	18	17	12	46	66	37	36	7	6	8	5	22	18	22	18
KCL	9	16	4	6	8	10	12	12	29	32	36	28	24	25	25	18	45	39	51	40	10	8	10	12	14	18	22	10
$NH_4H_2PO_4$	8	6	6	6	8	12	12	24	22	36	27	34	25	21	14	6	45	42	56	42	7	8	11	9	24	24	16	14
Check	18	24	14	20	42	28	18	16	17	22	29	27	19	22	20	19	48	46	38	46	9	17	8	14	24	22	24	30
CH_4N_2O	9	10	4	8	10	20	22	10	24	18	22	27	25	19	9	11	26	27	33	22	11	14	9	5	14	12	6	4
CaCn	2	0	0	2	0	2	0	0	0	0	0	0	0	0	0	0	0	0	1	3	2	0	1	0	4	2	6	4
$CaCO_3$	26	26	34	16	30	32	22	32	27	19	20	14	20	33	21	20	45	39	35	30	4	7	9	8	18	16	20	18

Table No. 2, Cont'd. Percentage germination of clovers and grasses with different fertilizers when placed in contact for varying periods of time.

	Creeping B. Grass %				Timothy grass %				Germination
	Weeks Contact								
	1	2	3	4	1	2	3	4	
Check	38	42	29	51	92	90	86	88	
$(NH_4)_2SO_4$	23	36	31	34	81	74	74	72	
$CaH_4(PO_4)_2$	14	38	30	39	84	90	86	84	
CaO	31	30	40	34	74	72	70	67	
NH_4CL	18	33	34	36	58	74	74	70	
Check	50	44	56	46	84	83	88	84	
CaP	34	48	33	55	91	90	90	86	
K_2SO_4	30	25	43	32	36	78	71	82	
NH_4NO_3	10	22	28	34	26	70	72	56	
KCL	13	21	31	51	38	80	82	70	
$NH_4H_2PO_4$	8	18	14	24	48	82	68	76	
Check	38	54	68	60	86	90	82	80	
CH_4N_2O	8	9	23	9	77	44	52	44	
CaCn	2	0	3	0	1	0	2	2	
$CaCO_3$	49	52	62	64	88	91	90	91	

which did not germinate normally swelled to an extent in which the seed coat became broken and the strong soil solution entered in destroying the protoplasm within the swollen cells and gradually destroying the germ. With those seeds which did germinate in the majority of cases the growth was abnormal. The plumule and foliage had a thickened, dark green appearance and the plants were off type because of some physiological factor.

Alsike clover germination was lowered by the application of calcium cyanamide and urea. These fertilizers or the compounds they form in the soil while undergoing chemical reactions apparently kill the germinating power of the seed which takes on a dark brown appearance and gradually decays. Here again where seeds were in contact with ammonium sulfate,ammonium nitrate and potassium chloride, a lowered germination resulted. The seedlings in this case were slow to appear above the ground, the plumule and foliage were thickened, the color was dark green with a general abnormal appearance.

Sapling clover germination was lowered by the application of calcium cyanamide and urea. The few seedlings which did appear above ground were abnormal in appearance, being short, thick and a very dark green in color. There was some retardation also from the use of ammonium chloride, ammonium sulfate, ammonium nitrate, and ammonium phosphate. A lower germination resulted from their use and the seedlings which did appear were off type, being abnormally thick, short and dark green in appearance.

Crimson clover seed germination was affected by the application of calcium cyanamide and urea. But few seedlings resulted and these were abnormal. The majority of the seeds swelled slightly, turned dark brown and slowly decayed. Here again the two ammonium fertilizers, ammonium chloride and ammonium nitrate delayed germination and caused those seedlings which did appear to be short, thickened and abnormal in appearance.

With Biennial White Sweet clover, calcium cyanamide and urea were most injurious to germination. The seedlings which did appear in the rows where these fertilizers were used were abnormal in appearance. The majority of the seeds swelled slightly and gradually decayed. Ammonium chloride, ammonium nitrate, ammonium sulfate and ammonium phosphate gave a lower germination than the checks or other fertilizers, with an abnormal seedling growth. Seedlings in this case were short, thick, black green in color and slow in growth. A number of the seeds swelled slightly and then slowly decayed.

Lespedeza or Japan clover on the whole germinated very well. Here, again, however, calcium cyanamide in contact with seeds in the row apparently killed the germs in the majority of the seeds. The protective seed coat undoubtably helped the germination of the seeds. Those seeds which did not germinate swelled slightly before decay set in. Potassium chloride, burnt lime, ammonium chloride, ammonium sulfate, and ammonium nitrate caused seeds to germinate slowly and the resulting seedlings were short, thick and abnormal in growth.

With White Dutch clover calcium cyanamide gave a lowered germination. The majority of the seed decayed while those seedlings which did appear were abnormal, being short, thick, and black green. The germination was likewise retarded by the use of ammonium sulfate, ammonium chloride and ammonium nitrate. Many of the seeds swelled slightly and decayed while those seedlings which did result were decidedly off type. Acid phosphate in this case hastened germination. The seedlings in the row where this fertilizer was used appeared first above the ground and grew rapidly attaining about twice the size of those in any of the other rows when count was made.

Kentucky bluegrass germinated slowly and rather poorly. Calcium cyanamide apparently killed the germs of a majority of seeds with which it was in contact. The eight seedlings which appeared above ground had a thin appearance, were short and of a light green color. Urea, burnt lime, ammonium phosphate and acid phosphate in rows with seeds slowed up their germination and gave the resulting seedlings an abnormal appearance, rather short, thick and a darker green color than is generally commom with this grass. In this experiment the rows in which ground limestone was used appeared first above ground and grew normally until counted at which time they had the best appearance of the lot.

Canada Bluegrass likewise germinated very poorly. Here again calcium cyanamide or the dicyandiamide gas formed by chemical action with the soil moisture apparently killed the germ in the majority of the seeds, which swelled slightly, became dark brown in color and slowly decayed. The four seedlings which resulted from 800 seeds planted were last to appear above ground and were twisted and abnormal in appearance. Here again germination was retarded and growth was abnormal where urea, ammonium sulfate, ammonium chloride, and ammonium phosphate were in contact with seeds in the row.

Meadow fescue germinated reasonably well. Of the 800 seeds planted in contact with calcium cyanamide not a single seed germinated. The germ in the seeds was apparently destroyed by the dicyandiamide gas and all of the seeds decayed. In regard to the other fertilizers urea and burnt lime delayed germination and the seedlings resulting from contact with these fertilizers were short thick and very abnormal in appearance.

With Sheep's Fescue calcium cyanamide apparently caused the death of the germs in the 800 seeds planted as no growth resulted. The seeds swelled slightly and then slowly decayed. With this grass seed germination was retarded by acid phosphate ammonium chloride, ammonium nitrate and urea. Seedlings of this grass in contact with these fertilizers were slow to appear above ground and had a short, thickened, abnormal appearance.

Tall Meadow Oat Grass seeds germinated reasonably well. But few of the seeds in contact with calcium cyanamide germinated. The seeds swelled slightly, the germ apparently was killed by the dicyandiamide gas and decay took place. The eight seedlings which appeared from 800 seeds planted in contact with this fertilizer were short, weak and twisted. Here again seeds in contact with urea and ammonium chloride gave seedlings which were short, thick and very slow in their growth.

Rhode Island Bent Grass germinated very poorly. With this grass seedlings were normal except in the rows where calcium cyanamide, ammonium sulfate, calcium oxide, and urea were in contact with the seeds. In these rows seedlings appeared last above ground and grew very slow. They lacked vigor and color and were abnormal in appearance.

With Creeping Bent grass only ten seeds out of the 800 planted in rows with calcium cyanamide germinated. These 10 seedlings were slow to appear above ground and had a weak and colorless appearance. Here, again, seedlings from the rows in which ammonium sulfate, ammonium nitrate and urea were used were slow to germinate and had an abnormal appearance.

Timothy germinated very well. In the rows where calcium cyanamide was in contact with seeds but 10 seedlings appeared from the 800 seeds planted. The seeds not producing seedlings swelled slightly and then decayed. The seedlings which did appear above ground were weak and colorless. In regard to the other fertilizers growth was normal in comparison with the checks except in the rows where ammonium chloride, ammonium nitrate and potassium sulfate were used. These rows showed a slow germination and a short, stocky growth, apparently lacking vigor as they attained only about half the size of the other seedlings at time of counting.

Effect of Time of Contact on Germination of Seeds.

In regard to the contact for one, two, three, and four weeks, before planting of seeds, no difference could be detected from this difference in time of contact. The injury in all cases apparently taking place after the seeds were planted in the soil where soil moisture could enter into the chemical reactions. Checks made to determine just where injury took place showed that this was indeed the case.

Table No. 3. Blotter paper germination of seeds.

Seed.	% Germination.
Creeping bent grass	64
Crimson clover	88
Red clover	92
Sapling clover	72
Alsike clover	90
White Sweet Clover	86
Japan clover	68
White Dutch clover	75
Timothy	97
Red top	62
Orchard grass	51
Tall meadow oat grass	85
Rhode Island Bent grass	67
Kentucky bluegrass	57
Canada bluegrass	63
Meadow fescue	83
Sheep fescue	87

Table No. 4. Comparison of Percentage Germination of Seeds Separated before Planting and of Seeds Planted in Contact.

	Percent Germination				
	Crimson clover seed			Tall Meadow Oat Grass	
	Separate	Contact	5 days	Separate	Contact
K CL	57	32	56	23	40
Ca Cn	65	2	17	18	3
CH4N2O	65	12	14	35	22
Ca O	63	13	31	30	41
NH4H2PO4	71	12	28	47	42
Ca P	61	14	50	26	31
NH4 NO3	68	13	20	30	36
(NH4)2 SO4	66	11	43	42	43
Ca CO3	64	14	45	35	30
NH4 CL	46	18	12	33	35
Ca H4 (PO4)2	54	9	24	41	38
K2 SO4	49	14	58	47	31

Check tests were made with crimson clover and Tall Meadow Oat Grass as shown above. In general the seeds placed in contact with fertilizers and separated at the end of four weeks had a bright vigorous appearance and germinated better than seeds placed in contact and planted with fertilizer in the same rows. This check was made to determine just where injury occurred. It can be seen from the germination of crimson clover in Table 3 that the seed which was in contact and wax separated from the fertilizer before planting germinated higher in every case except one than the seed planted in the rows with the fertilizer. From the above experiment it would seem that the greatest injury occurs in the soil after the seeds have been planted along with the fertilizer and come into direct competition for the soil moisture.

Another check was run to determine to what extent the soil moisture neutralized the injurious effect of the fertilizers on the germination of seeds. Table No. 3 on the germination of crimson clover planted five days after the fertilizer had been sown is given above. Apparently the injurious effects of the fertilizer salts are overcome depending on the number of days that elapse between the sowing of the fertilizer and the planting of the seeds. It can readily be seen that the time factor plays an important part in the effect of fertilizers on the germination of seeds.

Nature of the Injury to the Germination of Seeds by Fertilizer Salts.

The results agree with Lipman (3) showing that poor germination of seeds in combination with various salts is caused by improper distribution of such salts throughout the soil. The concentration of such salts in contact with seeds brings about a condition wherein the osmotic pressure of the soil solution is greater than the osmotic pressure of the seed or seedling causing plasmolysis of the cells. Experiments with various seeds in Petri dishes containing 50 grams of sand and 500 milligrams of the various salts placed in a row with the seeds and 9.3cc of distilled water added (this being 50% of maximum water holding capacity) showed a dry line where the seeds and fertilizer were in contact, although the water had been equally distributed over the sand in the dishes. Some of the seeds swelled slightly but within 10 days they had all decayed. This dry line along the row where the fertilizer and seeds were in contact showed that the concentration of the salt solution exerted an osmotic pressure greater than that of the seeds, the seeds being unable to compete with the salts for soil moisture. The moisture they did receive contained too strong a concentration of the salts which rapidly broke down the cells causing decay. Further experiments were then conducted to determine what normality of salts brought about plasmolysis of cells.

In these determinations salts were prepared at different normalities and seedlings of crimson clover and timothy were placed in them for 30 minutes when thin sections were stripped off under the solution and mounted on a slide moistened with a few drops of the solution. These slides were then properly stained and examination was made for plasmolysis of the cells and root hairs. A table of results is given below:

Table 5. Effect of Fertilizer Salts on the Plasmolysis of Seedlings.

Salt	Normality	Seedling	Injury	
NH_4NO_3	N/2	Crimson clover	Great plasmolysis	
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
Urea	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
$CaH_4(PO_4)_2$	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
$(NH_4)_2SO_4$	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
K CL	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
K_2SO_4	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
$NH_4H_2PO_4$	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"
NH_4 CL	N/2	Crimson clover	Great	"
"	"	Timothy	"	"
"	N/5	Crimson clover	Slight	"
"	"	Timothy	"	"

In explaining Table No. 5 it might be well to state that solutions of the salts were made up in normalities ranging from N/1 to N/500. The normal solutions were very destructive while all normalities greater than N/10 showed no injury to cells when examined under the microscope within 1 hour after seedlings were placed in solutions of such concentrations. A point between N/2 and N/10 was determined for all the salt solutions. Normalities of less than N/5 showed no plasmolysis under the microscope although it is quite possible that some plasmolysis occurred which could not be detected owing to the limited range of the microscope. N/5 salt solutions were the weakest salt solutions in which plasmolysis of cells could be detected after a 30-minute contact. In the majority of the cases where salt solutions of N/5 were in contact with seedlings the cells did not show protoplasm pulled away from the cell walls but showed a wrinkled or shriveled condition of the protoplasm within the cell wall. Seedlings of crimson clover and timothy placed in N/5 salt solutions failed to grow but gradually became plasmolized and slowly disintegrated. Seeds placed in N/5 salt solutions failed to germinate although they exhibited a swellen appearance before decay took place. Likewise, seeds placed in N/10 salt solutions failed to germinate. From experiments conducted, it is the writers belief that salt solutions of a normality in which seeds will sprout will not materially injure the seedlings thus produced.

CONCLUSIONS

The chief conclusions to be derived from these experiments are as follows:

1. The mixing of the seeds and fertilizers before drilling in the same drill row did not injure the germination of the seeds to a noticeable extent.

2. Injury to germination occurred in the soil where fertilizers and seeds were drilled in the same drill row and soil moisture entered into the reaction.

3. A lowered germination was caused where calcium cyanamide was used when the moisture in the soil combined with this fertilizer resulting in the formation of dicyandiamide gas which turned the seed coats dark brown and destroyed the power of the seeds to germinate.

4. Lowered germination with the remainder of the fertilizers other than Ca Cn_2 was attributed to unsatisfactory distribution of the salts in the soil resulting in the formation of a concentrated soil solution with a greater osmotic pressure than the osmotic pressure exerted by the seeds causing plasmolysis and decay.

5. Solutions of the salts with a greater normality than N/5 caused plasmolysis of seedlings. A solution of this normality is readily formed in soils where seeds and fertilizers are drilled together in the same drill row.

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