THE RESPONSE OF FIELD CROPS TO LIQUID FERTILIZER APPLIED AS A PRE-PLANTING SEED TREATMENT

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CHAPTER I

INTRODUCTION

Modern intensive agriculture is rapidly depleting our soil's store of readily available nutrients. The need for fertilizer to supplement the diminishing supply in the soil is recognized. The use of conventional fertilizer to supplement the soil has proven profitable when applied in accordance with proven recommendations. The placement of dry fertilizer is very important as many seedlings are extremely sensitive to large concentrations of mineral salts.

At the present farmer interest in pre-planting seed treatment with liquid fertilizer is extremely high. From this interest many questions have arisen. The question, "Are liquid fertilizers practical for pre-planting seed treatment?", is worthy of investigation. This arose from the farmers' need for a starter fertilizer in areas of low fertility, and in many instances where weather conditions prevent the release of available nutrients to the seedlings. The practice of pre-planting seed treatment is as old as modern agriculture. Francis Bacon's experiment along this line was recorded in 1628. The rate of mineral application to the seed as liquid fertilizer must be low due to the seed's limit of tolerance for soluble salts. Potential benefits, if any, must be reflected in the seedling stage in better stands, increased vigor, and earlier establishment of the plants.

In areas where supplementary plant food is necessary pre-planting seed treatment alone, would not be sufficient for profitable field crop production, but should be followed by the application of conventional dry fertilizer appropriately placed.

This study was made to determine the effect of liquid fertilizer on germination, seedling growth and vigor. Experiments were carried out under field conditions to study the effect of liquid fertilizer as reflected in crop yield.

If the effects are favorable, certain dry fertilizers could then be applied to good stands of healthy seedlings and prevent waste of expensive fertilizer materials through leaching and erosion, which would be of economic importance. It is usually recognized that phosphate fertilizers should be incorporated into the soil, and are probably most economically applied at seeding time.

CHAPTER II

REVIEW OF LITERATURE

Buttress and Dennis (1) in a review of literature date the practice of pre-planting seed treatment in the early 1600's. During this era many of the solutions were used as a fungicide to prevent smut, however, some work with these materials to promote growth was recorded. They state "Some have I seen their seed, to sow, prepare with nitre and oil of lees, for they by care will grow far greater and be sooner ripe."

Francis Bacon's work was among those reviewed by the above writers. In an attempt to test the fertilizer value of various solutions several experiments were used. In an experiment with cow dung liquor he reported seedlings emerging in two days whereas without the treatment four times as long would have been required. In another experiment wheat was steeped for twelve hours in solutions of cow dung, pigeon dung, horse dung, urine, chalke, soot, ashes, bay salt, claret wine, malmsey and spirit of wine. Plants grown from seed treated with these solutions were rated in the order of their improvement on seedling growth and vigor. The solutions were rated as follows: urine, dungs, chalke, soot, ashes, bay salt and wheat simple (dry wheat). Others in this review reported beneficial results from solutions prepared from manure.

Volk and Wilson (8) in modern experiments with prepared liquid fertilizers did not obtain favorable results. They found there is no significant increase in growth or yield which can be attributed to liquid fertilizer. Smith (7) conducted experiments with these materials and his results are in complete agreement with those obtained by Volk and Wilson.

Popoff (5) in his treatise Die Zellstimulation (the cell stimulation) reported favorable results in growth and yield when seed are soaked in high concentrations of such solutions as magnesium sulfate 20% plus manganese sulfate 20%, or potassium iodide 2% and others.

Loo and Tang (4) obtained results indicating that manganese sulfate in dilute concentration does accelerate germination of wheat and rice, and promotes vigorous early root development.

Lysenko and Stepanenko (6) found that by soaking seeds in water or chemical solutions that they swelled considerably and that on drying to the original weight they did not regain their original volume. This must be considered when planting pre-soaked seed.

Katowski (3) found that the nature of the seed coverings limited the intake of salts and that there was a considerable loss in salts when the treated seed were washed for one minute.

Roberts (6) in an attempt to conserve scarce fertilizer materials during the war years conducted many experiments using fertilizer materials in solutions. She found that after soaking subsequent drying must be held at low temperatures. In an experiment with oats she applied 4.6 pounds of P_2O_5 per acre by soaking oats in molecular tribasic potassium phosphate. This seed was planted in phosphorus deficient soil and a 46 per cent increase in grain resulted with a 74 per cent recovery of the P_2O_5 in the grain over the check plots.

CHAPTER III

METHODS AND MATERIALS

The materials selected to be used in this experimental work are commercial fertilizer products. The liquid formulations were applied to the seed without dilution. Those materials, which were originally solids, were dissolved in distilled water and diluted to desired concentrations as given in Table I.

Germination Tests

The field crop seed that were used in the germination tests were cotton, grain sorghums, wheat and oats. One-fourth pound of seed for each test was weighed and the solutions added at various rates as given in Table I.

The fertilizer solutions were added to one-fourth pound of seed. The seed were stirred until the entire mass was uniformly moist and then spread on waxed paper to dry. The waxed paper was used to prevent a loss from the seeds which did not readily imbibe all the solution. The excess was allowed to crystallize on the surface of the seed.

The treated seed was germinated in a Mangelsdorf germinator by placing them on moistened "kempak." They were germinated at recommended temperatures for each crop seed.

The seeds were counted at three and five day intervals and the per cent germination recorded (Appendix) Tables 12, 13, 14, and 15. The germination tests were replicated four times for each crop seed. Dry untreated seed was used as a check in each replication.

TABLE I. MATERIAL, CONCENTRATION AND RATE OF APPLICATION OF VARIOUS FERTILIZER MATERIAL USED IN THE STUDY OF LIQUID FERTILIZER APPLIED ON THE SEED

No.	Type of Material	Concentration pounds per quart	Rate of application in quarts per bushel	Solutions used in germination tests	Solutions used in greenhouse studies		Solutions used in field studies
					sterile sand	soil	
1.	No treatment			x	x	x	x
2.	Water		4	x	x	x	x
3.	3-18-9*		4	x			
4.	3-18-9*		2	x	x		
5.	3-18-9*		1	x		x	x
6.	6-9-7*		4	x		x	
7.	6-9-7*		2	x	x	x	
8.	6-9-7*		1	x		x	x
9.	16-20-0**	1	1	x	x	x	x
10.	16-20-0**	1/2	1	x			
11.	33-0-0***	1	1	x			
12.	33-0-0***	1/2	1	x			
13.	33-0-0***	1/4	1	x			
14.	46-0-0****	3/4	1	x			
15.	46-0-0****	3/8	1	x		x	
16.	10-52-17*****	1	1	x	x	x	x
17.	10-52-17*****	1	2	x			
18.	10-52-17*****	2	1	x		x	
19.	10-52-17*****	2	2	x			

* A prepared commercial liquid formulation applied without dilution.
** Commercial ammo-phos.
*** Commercial (33%N) ammonium nitrate.
**** Commercial (46%N) urea.
***** Commercial formulation.

Greenhouse Studies

Cotton was selected to be grown in the greenhouse under controlled conditions so as to study the effect of liquid fertilizer, when used as pre-planting seed treatment, on the growth of seedlings and dry material produced.

The soil used in this experiment was Reinach silt loam, an alluvial soil of moderate fertility. It was obtained two miles west of Stillwater along Stillwater Creek. It was mixed with sand to improve water penetration.

The ten different treatments used for this study were selected from the seed treated for the germination tests and are indicated in Table I. The plants were measured at seven day intervals and the results recorded in (Appendix) Table 16. At the end of twenty-four days the plants were harvested. The above ground portion was dried in an oven at 105 degrees centigrade and weighed directly from the oven to determine total dry material produced.

Five seeds were planted in each pot and the number of plants was recorded. This was to determine if the dilution effect of the soil would reduce the toxicity of the mineral salts which was indicated by the germination tests.

In an attempt to discover if the solutions accelerated or retarded root development, seed which were treated with six fertilizer treatments were grown in sterile sand as shown in Table I.

Field Experiments

The field crops of wheat and oats were grown in field plots as shown in Figure 1, to study the effects of liquid fertilizer on crop production under field conditions. The seed were treated with six different liquid fertilizers as indicated in Table I.

Two pounds of seed were used for each treatment. The solutions were added and the seed stirred until the entire mass was uniformly moist. The seed were spread in a thin layer and allowed to dry overnight.

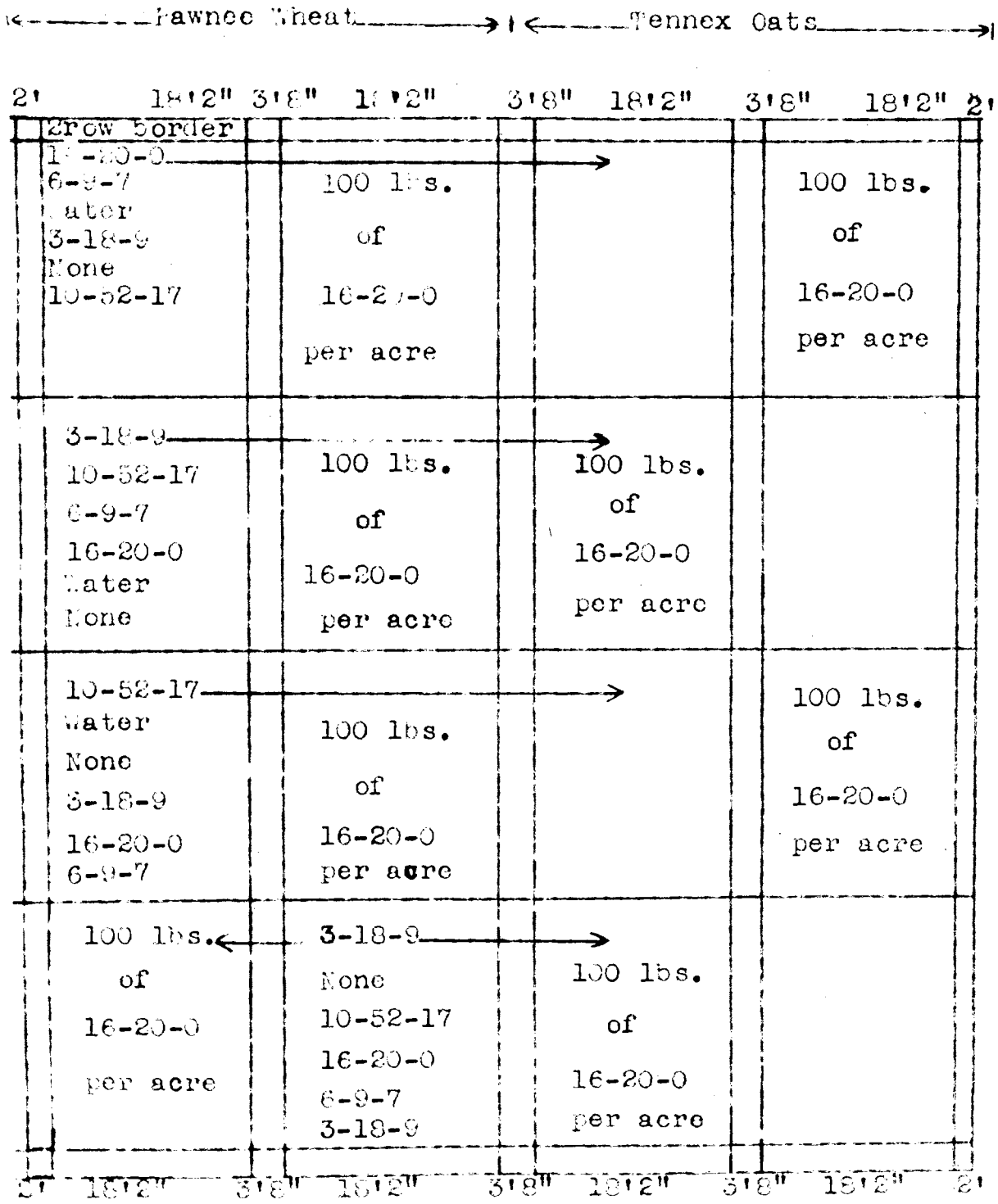
Each of the plantings was observed during the early stages of growth and data recorded. The wheat and oats were harvested at maturity and yields computed. Each plot consists of 4 rows 18 feet 2 inches in length with the rows 12 inches apart. The outside rows were discarded and the remaining two rows were harvested by cutting at ground level. The bundles were protected from birds by placing paper bags over the heads of the plants. The grain was threshed by using a custom built nursery thresher.

Other crops grown under field conditions were cotton and corn. The procedure used in treating the seed of these crops was the same as used on the wheat and oats.

The field plots consisted of three rows 30 feet in length with the rows 42 inches apart. A split plot was used and that portion which received one hundred pounds of dry 16-20-0 per acre required one hundred and thirty grams of fertilizer for each three rows.

Each of the plantings was observed and measured during the early growth period and data recorded.

Figure I. Diagram showing field layout of wheat and oats experiments conducted at Stillwater Agronomy Farm.



CHAPTER IV

RESULTS AND DISCUSSION

Germination Tests

Cotton was sensitive to the higher concentrations and rates of application of many fertilizer solutions. Root development was retarded by those solutions which severely reduced germination.

Some solutions produced visible signs of toxicity. In the seedlings which exhibited symptoms of toxicity it was noted, that as the radicle emerged from the seed coat it became brown and ceased to function. This was possibly due to the osmotic concentration of the solution near the seed being raised by the liquid fertilizer to a point that plasmolysis and death of the radicle resulted. In many instances the radicle was not killed, however it became enlarged except for the growing tip and elongation ceased. In many plants lateral roots formed near the seed coat and the plant continued to develop.

Toxicity occurred in various degrees of severity. It was noted that as the concentration or rate of application was increased a uniform decrease in germination resulted.

These tests cannot be considered conclusive for all types of cotton seed. Lint cotton seed was used in these tests and much of the fertilizer solutions were absorbed by the lint rather than by imbibition directly into the seed. The results of this and the following germination tests are shown in Table 2.

The limit of tolerance to mineral salts when applied as a liquid fertilizer is low in grain sorghums as indicated by these tests. Others have obtained similar results in emergence work with these crops, when dry

Table 2. Effect of liquid fertilizer treatment on germination of wheat, oats, cotton and grain sorghums

Treatment	Concentration in lbs. per quart	Rate of application qts. per bu.	Per cent germination* wheat	oats	cotton	grain sorghum
No treatment			96	98	91	94
Water		4	95	97	90	89
3-18-9**		4	60	98	74	40
3-18-9**		2	82	98	82	56
3-18-9**		1	82	99	87	80
6-9-7**		4	58	94	72	35
6-9-7**		2	79	97	88	55
6-9-7**		1	90	98	94	68
16-20-0	1	1	83	99	82	67
16-20-0	1/2	1	86	98	88	75
33-0-0	1	1	84	97	97	66
33-0-0	1/2	1	87	99	95	79
33-0-0	1/2	1	92	98	95	87
46-0-0	3/4	1	87	97	81	67
46-0-0	3/8	1	92	98	91	81
10-52-17	1	1	91	99	92	82
10-52-17	1	2	87	98	93	73
10-52-17	2	1	93	99	94	85
10-52-17	2	2	90	94	94	79

* Mean of four replictions.

** A prepared commercial liquid formulation applied without dilution.

fertilizer was applied (2). All solutions used in these tests reduced germination in amounts sufficient to question their use on these crops.

The starchy nature of sorghum seed caused rapid imbibition of the solution. If the solution is imbibed into the endosperm, prevention of germination could be due to the catalytic action of the mineral salts inhibiting the enzymatic release of plant food. Loo and Tang (4) have accelerated germination of rice with manganese sulfate solution which acts as a catalyst accelerating enzymatic release of plant food.

The trend of reduced germination as the rate of application or concentration increases is clearly shown by this test. Those seed which germinated exhibited no visual ill effect due to the treatment, however considerable difference was noticed in the root growth. This could be of importance if solutions less toxic would stimulate root growth.

The germination tests on wheat follow a similar pattern to those conducted on grain sorghum and cotton. The wheat, however, exhibits more tolerance to the liquid fertilizer than the grain sorghums. This may be attributed to the selective absorption of various solutions. Distilled water was readily imbibed by the seed, however, the fertilizer solutions were imbibed rather slowly. This could be due to the outer layers of the seed coat acting as a semi-permeable membrane excluding most of the mineral salts from the endosperm. The additional resistance found in cotton is probably due to a large portion of the solution being absorbed by the lint on the seed.

Seed treated with the 3-18-9 solution at four quarts per bushel imbibed a portion of the watery liquid but an oily residue remained which was allowed to crystallize on the seed. Other solutions applied at the higher rates were not readily imbibed by the seed and a deposit of mineral salts formed on the surface of the seed. These treatments severely reduced germination. None of

the liquid fertilizers affected the root system of the wheat to any appreciable extent.

The pre-planting seed treatment of oats with liquid fertilizer did not materially reduce germination. This does not follow results obtained by Smith. (7) However, Roberts (6) in England found oats to be very tolerant to some liquid fertilizer substances.

The liquid formulations 3-18-9 and 6-9-7 applied at the rates of four quarts per bushel approached the seeds' limits of tolerance for these substances. The development of the root system was not appreciably altered except by the above solutions. The roots of the plants treated with these solutions became brown and failed to develop normally.

Greenhouse Studies

Cotton grown in soil under greenhouse conditions provided interesting material for studying the effects of liquid fertilizer when used as pre-planting seed treatment. The principal difference noticed was the rate of new leaf formation and size of the leaves. The 6-9-7 solution at two quarts per bushel and the 46-0-0 solution used in this test produced the most vigorous plants. Two solutions of 6-9-7 formulation which produced toxicity in the germination tests did not reduce stands in these studies. The effect of rate of application on amount of dry matter produced by the seedlings receiving the 6-9-7 solution is illustrated by Table 4. In view of this trend seeds treated with 6-9-7 solution at the rate of two quarts per bushel would be expected to make more rapid growth than planted in the field.

In the greenhouse study of cotton grown in acid washed sand striking differences were noticed. In this experiment there was less variation between replicates treated with the same solution. This was attributed to the fact that little plant food could be obtained from the sand.

Table 3. Growth of cotton as affected by various liquid fertilizer treatments when grown in the green house in soil culture.

Treatment		Fertilizer applied as pre-planting seed treatment 7 da.	14 da.	21 da.
		(height in inches)*		
6-9-7	1qt./bu.	3.1	5.2	7.5
6-9-7	2qt./bu.	3.0	5.2	7.1
6-9-7	4qt./bu.	2.4	4.3	6.2
46-0-0 3/8lb./bu.	1qt./bu.	2.9	5.4	7.5
10-52-17 2 lb./bu.	1qt./bu.	2.8	4.9	7.2
10-52-17 1 lb./bu.	1qt./bu.	2.4	4.9	6.5
None		2.5	5.0	7.5
Water	4qt./bu.	2.9	5.0	7.2
3-18-9	1qt./bu.	2.6	4.7	6.7
16-20-0 1 lb./bu.	1qt./bu.	2.4	4.7	7.1

* Mean of 4 replications.

Table 4. The effect of liquid fertilizer on amounts of dry matter of cotton produced after 24 days of growth in a soil culture.

Treatment		Fertilizer applied as pre-planting seed treatment	Weight in grams*
6-9-7		4qts./bu.	2.4
6-9-7		2qts./bu.	3.3
6-9-7		1qt./bu.	3.0
3-18-9		1qt./bu.	2.6
46-0-0	3/8 lb./qt.	1qt./bu.	3.3
None			3.0
Water		4qts./bu.	3.1
10-52-17	1 lb./qt.	1qt./bu.	2.4
10-52-17	2 lb./qt.	2qts./bu.	2.6
16-20-0	1 lb./qt.	1qt./bu.	2.7

* Mean of 4 replications.

Those plants grown from the seed treated with the 10-52-17 and 16-20-0 solutions were sturdier and the leaves larger than other plants in this test. In Figure 2 an attempt is made to illustrate the difference in growth and size of the leaves.

The check plants and those treated with water had stopped growing and were showing signs of nitrogen deficiency. Their rate of growth had been extremely slow for several days before the experiment was terminated.

The plants from seed treated with the 6-9-7 solution were first to emerge, however these did not grow rapidly and the plants were small when compared to the others in this test. The rate of growth of the plants which received the 3-18-9 solution was about the same as the check plants. The latter two treatments reduced germination and visible signs of toxicity were noticed in the root system of the seedlings in the germination tests. They were selected to see if the toxic effects would be noticed when grown in sand. This effect was evidently present in the plants treated with the 3-18-9 solution as these plants were smaller than the check plants. However, they did not show signs of a nutrient deficiency.

Figure 3 is offered to show the difference in root development of these plants.

FIELD EXPERIMENT

There was not a wide range of difference in the emergence and early growth of the wheat. The wheat in the check plots was first to emerge. Table 5 shows that stands were uniform in most plots. Those receiving the 16-20-0 solution had the poorest stand and some tip burn was noticed in the seedlings. This may have been due to the toxic effects of the solution. On November 5, 1951 the plots treated with 10-52-17 solution appeared more vigorous. The leaves of the plants were wider and the plants were slightly larger as shown by growth measurements in Table 6. The growth differences were small between

Figure 2. Variations in growth of twenty-four day old cotton seedlings after pre-planting seed treatment.

Rate of application:

10-52-17	1 lb./qt.	1 qt./bu.
16-20-0	1 lb./qt.	1 qt./bu.
3-18-9		2 qt./bu.
Water		4 qts./bu.
None		
6-9-7		2 qt./bu.

Figure 3. Differences in root development of twenty-four day old cotton seedlings after pre-planting seed treatment.

Rate of application:

10-52-17	1 lb./qt.	1 qt./bu.
16-20-0	1 lb./qt.	1 qt./bu.
3-18-9		2 qt./bu.
Water		4 qts./bu.
None		
6-9-7		2 qt./bu.

Table 5. Effect of liquid fertilizer on the stand of wheat observed October 23, 1951.

Treatment	Fertilizer applied as pre-planting seed treatment Rep. I	Rep. II	Rep. III	Rep. IV
16-20-0	x*	xx	xx	xx
6-9-7	xxx	xxx	xx	xx
Water	xxx	xx	xx	x
3-18-9	xx	xx	xx	x
No treatment	xxx	xx	xx	xx
10-52-17	xxx	xxx	xxx	xx

* x poor stand
xx fair stand
xxx good stand

Table 6. Effect of liquid fertilizer on the stand and growth of wheat observed November 5, 1951.

Treatment	Fertilizer applied as pre-planting seed treatment Rep. I	Rep. II	Rep. III	Rep. IV	Average height in inches
16-20-0	xx*	xxx	xx	xx	1 3/4
6-9-7	xxx	xxx	xxx	xx	2
Water	xxx	xxx	xxx	xx	2
3-18-9	xxx	xxx	xx	xx	2
No treatment	xxx	xxx	xx	xx	1 3/4
10-52-17	xxx	xxx	xxx	xxx	2 1/2

* xx fair stand
xxx good stand

plants on these plots receiving different pre-planting seed treatments. However, there was a uniform increase in growth obtained in those plots receiving one hundred pounds of dry 16-20-0 per acre compared to the growth due to liquid fertilizer. This was true except in the check plots. These data are shown in Table 7.

The oats were observed during the early growing period, but stand counts or growth measurements could not be made as the plots remained extremely wet throughout the early seedling stage.

The wheat and oats were harvested and the yields were computed on a bushel per acre basis as given in Tables 8 and 9. A statistical analysis of the yields revealed no significant difference due to liquid fertilizer, however the one hundred pounds of dry 16-20-0 gave a highly significant increase in yield.

The dry fertilizer data agree with results obtained from previous experiments. The average increase in the yield of wheat and oats was 5.2 bushels and 6.7 bushels per acre respectively. These increases would be sufficient to warrant the use of fertilizer on these crops in this locality on this soil.

Spring oats were grown under field conditions to study the effect of liquid fertilizer on crops maturing in a shorter period of time. Due to weather conditions planting was delayed two weeks and only two replications were planted. A severe greenbug infestation drastically reduced the yield. The crop was harvested to see if a trend could be established by comparing with other crops. The results of this experiment are given in Table 10.

In another field test corn receiving liquid fertilizer alone was to be compared with corn receiving liquid fertilizer plus one hundred pounds of dry 16-20-0 per acre. In the planting procedure small amounts of the dry 16-20-0 came in contact with the seed. The stand obtained was poor as a

Table 7. Effect of liquid fertilizer on the stand count and growth of wheat observed December 9, 1951.

Treatment	Liquid Fertilizer		Liquid Fertilizer plus 100 lbs. 16-20-0	
	No. of plants in 3 ft. of row	Height in inches	No. of plants in 3 ft. of row	Height in inches
16-20-0	37*	2.4*	36*	2.6*
6-9-7	52	2.7	54	3.1
Water	48	2.5	47	3.0
No Treatment	48	2.5	49	2.5
3-18-9	54	3.0	51	3.5
10-52-17	53	2.6	55	3.0

* Mean of 4 replications.

Table 8. Effect of liquid fertilizer pre-planting seed treatment on yield of wheat* under field conditions. 1952

Treatment	Liquid fertilizer	Liquid fertilizer plus dry fertilizer***	Difference in yield
		(bushels per acre)**	
No treatment	28.8	34.9	6.1
16-20-0 1 lb./qt.1qt./bu.	30.0	34.1	4.1
6-9-7 1 qt./bu.	34.8	36.8	2.0
Water 1 qt./bu.	28.8	33.5	4.7
3-18-9 1 qt./bu.	28.0	35.4	7.4
10-52-171 lb./qt.1qt./bu.	30.6	37.2	6.6
Average of treatments	30.1	35.3	5.2

* Pawnee variety.
** Mean of 4 replications.
*** One hundred pounds of 16-20-0 per acre.

Table 9. Effect of liquid fertilizer pre-planting seed treatment on yield of oats* under field conditions. 1952

Treatment	Liquid fertilizer	Liquid fertilizer plus dry fertilizer***	Difference in yield
		(bushels per acre)**	
No treatment	77.1	85.7	8.6
16-20-0 1 lb./qt.1qt./bu.	76.2	80.8	4.6
6-9-7 1 qt./bu.	78.9	83.6	4.7
Water 1 qt./bu.	73.2	83.0	9.8
3-18-9 1 qt./bu.	78.9	84.0	5.1
10-52-17 1 lb./qt.1qt./bu.	83.1	89.7	6.6
Average of treatments	77.7	84.4	6.7

* Tennex Variety.
** Mean of 4 replications.
*** One hundred pounds of 16-20-0 per acre.

Table 10. Effect of liquid fertilizer pre-planting seed treatment on yield of Kanota oats under field conditions. 1952

Treatment	Liquid fertilizer	Liquid fertilizer plus dry fertilizer**	Difference in yield
		(bushels per acre)*	
None	8.6	7.5	-1.1
16-20-0 1 lb./qt.1qt./bu.	6.5	7.8	1.3
6-9-7 1 qt./bu.	5.6	10.3	4.7
Water 1 qt./bu.	2.6	7.7	5.1
3-18-9 1 qt./bu.	8.5	9.9	1.4
10-52-18 1 lb./qt. 1qt./bu.	9.2	9.7	0.5
Average of treatments	6.9	8.8	2.4

* Mean of 2 replications.
** One hundred pounds of 16-20-0 per acre.

Table 11. Growth of corn under field conditions treated with various liquid fertilizer grown at Perkins.

	May 21	July 7
Treatment	Height in inches	Height in inches
6-9-7	4.6	50
3-18-9	4.4	50
10-52-17	4.6	49
None	4.7	48
16-20-0	3.4	46
Water	4.0	48

fifteen per cent stand was the best recorded. The dry fertilizer retarded the emergence of the corn in these plots, however after two rains the corn in these plots came up to a thin stand. Good stands were obtained in all plots receiving pre-planting treatment only.

There was no observable difference on July 7 between the plants receiving different liquid fertilizer treatments. The growth measurements of this crop are shown in Table 11.

Difference in growth measurements of cotton under field conditions after receiving pre-planting seed treatment with various liquid fertilizers was not considered significant. There was no observable difference between the plants receiving liquid fertilizer alone and those receiving an additional one hundred pounds of dry 16-20-0 per acre.

CHAPTER V

SUMMARY AND CONCLUSIONS

Germination tests were used to determine the limit of tolerance to liquid fertilizer solutions of various field crops. The germination tests clearly indicate limit of tolerance for those crops tested. Cotton exhibits considerable tolerance, however symptoms of toxicity were noticed on many of the seedlings. Grain sorghums were very sensitive to all of these solutions. Germination of wheat was reduced by some of the higher concentrations, however the wheat seedlings did not exhibit any visible signs of toxicity. Oats were very tolerant to the solutions.

Greenhouse studies on the growth of seedlings receiving various liquid fertilizer as pre-planting seed treatment did not give conclusive evidence for or against the treatment when grown in soil culture. The growth of the plants grown in sand varied between different treatments. Two of the fertilizer treatments, the 10-52-17 and 16-20-0, produced larger and more vigorous plants. If this can be considered indicative of results to be expected in poor soils it could be of practical importance.

Cotton, corn, wheat and oats were grown under field conditions to study the effect of these treatments on seedling growth and yield of these crops. The results of these experiments did not indicate a statistically significant increase in growth or yield due to seed treatment with liquid fertilizers. Further research with these and other materials is necessary to gain concrete evidence as to their value. Dry fertilizer in these experiments produced significant increases of practical importance.

While the results of these tests on seed treatment with liquid fertilizer are inconclusive, the evidence is rather clear that their use will not satisfy the needs of the general field crops for best yield and that they cannot take the place of the conventional type fertilizers.

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APPENDIX

Table 12. The effect of various seed treatments on the germination of Stoneville 62 cotton.

Treatment**	Rep. I		Rep. II		Rep. III		Rep. IV		Average
	3da.	5da.	3da.	*5da.	3da.	5da.	3da.	5da.	
	per cent		per cent		per cent		per cent		per cent
1.	94		38	90	53	86	73	95	91
2.	95		0	84	78	93	77	91	90
3.	89		29	78	27	63	12	68	74
4.	89		6	80	66	85	29	74	82
5.	81		8	86	71	91	51	90	87
6.	75		25	79	75	75	59	71	72
7.	96		57	91	64	72	72	92	88
8.	93		60	94	85	93	87	94	94
9.	77		4	83	88	93	25	76	82
10.	89		29	86	84	94	48	83	88
11.	89		84	96	95	95	86	98	97
12.	94		72	94	93	97	86	95	95
13.	95		61	91	87	97	83	97	95
14.	69		66	88	78	81	77	84	81
15.	91		60	92	76	85	79	96	91
16.	96		38	94	61	82	81	97	92
17.	90		17	92	85	96	54	93	93
18.	95		5	93	72	96	50	91	94
19.	95		18	96	77	93	44	91	94

* Germination was delayed due to lack of moisture.
** As indicated in Table I.

Table 13. The effect of various seed treatments on the germination of Plainsman grain sorghums.

Treatment*	Rep. I		Rep. II		Rep. III		Rep. IV		Average
	3da.	5da.	3da.	5da.	3da.	5da.	3da.	5da.	
	per cent		per cent		per cent		per cent		per cent
1.	93	94	92	92	95	96	93	93	94
2.	78	85	89	89	89	89	90	93	89
3.	27	34	40	42	24	39	32	43	40
4.	54	55	52	59	50	56	50	54	56
5.	76	77	75	81	83	84	71	79	80
6.	25	25	33	39	28	34	29	32	35
7.	57	57	58	59	57	60	44	45	55
8.	69	75	64	64	73	76	67	67	68
9.	57	57	77	80	69	73	55	56	67
10.	62	64	85	87	73	77	74	75	75
11.	70	72	71	71	58	62	55	62	66
12.	77	77	72	80	67	78	80	82	79
13.	86	89	82	84	83	85	92	93	87
14.	63	66	76	77	55	56	72	72	67
15.	78	79	83	83	74	77	83	88	81
16.	81	81	81	85	85	85	77	77	82
17.	67	70	78	80	73	73	66	69	73
18.	81	82	88	90	86	86	81	83	85
19.	73	74	80	84	80	82	75	77	79

* As indicated in Table I.

Table 14. The effect of various seed treatments on the germination of Pawnee wheat.

Treatment*	Rep. I		Rep. II		Rep. III		Rep. IV		Average
	3da.	5da.	3da.	5da.	3da.	5da.	3da.	5da.	
	per cent		per cent		per cent		per cent		per cent
1.	85	94	86	95	91	98	86	97	96
2.	83	92	92	98	86	96	87	93	95
3.	43	52	56	56	57	64	51	68	60
4.	73	80	75	81	74	82	71	85	82
5.	68	80	68	81	75	81	75	86	82
6.	49	54	55	60	38	57	54	60	58
7.	80	88	64	73	72	74	68	80	79
8.	71	84	88	89	89	92	84	96	90
9.	75	84	59	82	65	82	69	84	83
10.	89	94	69	82	62	85	68	84	86
11.	56	81	63	83	84	87	75	85	84
12.	70	88	88	88	76	90	62	80	87
13.	85	92	91	93	87	96	78	86	92
14.	79	88	82	91	68	87	65	88	87
15.	85	91	87	91	69	91	71	93	92
16.	76	88	91	95	75	87	85	94	91
17.	66	84	80	85	81	90	88	90	87
18.	88	94	90	91	82	93	90	94	93
19.	80	87	87	95	74	88	80	90	90

* As indicated in Table I.

Table 15. The effect of various seed treatments on the germination of Forkedeer oats.

Treatment**	Rep. I		Rep. II		Rep. III		Rep. IV		Average
	3da.	5da.	3da.	5da.	3da.	5da.	3da.	5da.	
	per cent		per cent		per cent		per cent		per cent
1.	93	97	90	98	98	99	97	97	98
2.	96	98	91	97	97	99	93	95	97
3.*	86	96	84	92	95	98	94	96	96
4.	92	95	95	100	94	98	97	99	98
5.	91	98	95	99	97	100	95	97	99
6.*	82	93	88	94	91	96	92	92	94
7.	88	96	87	95	93	98	94	97	97
8.	99	99	96	97	93	98	94	99	98
9.	91	98	97	100	95	98	96	98	99
10.	95	97	96	99	93	98	94	98	98
11.	95	97	95	98	91	95	98	99	97
12.	98	100	97	100	98	99	93	97	99
13.	94	98	96	99	97	97	99	99	98
14.	94	96	92	97	95	97	94	96	97
15.	93	98	91	97	95	98	95	98	98
16.	95	98	98	100	97	98	95	98	99
17.	92	97	95	99	92	99	97	98	98
18.	97	100	95	98	97	100	98	99	99
19.	96	97	94	99	92	94	92	95	94

* Seedlings developed slowly, roots short and brown.
** As indicated in Table I.

Table 16. Growth of cotton as effected by various liquid fertilizer seed treatments when grown in the greenhouse in soil culture.

Treatments*	Height of plant in inches											
	Rep. I			Rep. II			Rep. III			Rep. IV		
	7da.	14da.	21da.	7da.	14da.	21da.	7da.	14da.	21da.	7da.	14da.	21da.
6-9-7***	3.0	4.8	7.4	3.2	5.9	8.8	3.3	5.9	7.3	2.7	4.3	6.4
6-9-7***	3.0	5.5	9.1	3.2	6.1	8.3	3.2	5.0	6.2	2.7	4.4	6.8
6-9-7***	2.0	4.0	6.3	2.7	4.2	5.7	2.0	4.0	5.4	2.9	5.2	7.5
46-0-0****	2.7	5.2	7.2	2.8	4.9	6.8	2.6	5.3	7.0	3.4	6.1	9.1
10-52-17**	2.8	5.0	7.7	2.8	5.3	7.2	2.8	4.5	6.9	2.7	4.8	6.9
10-52-17**	2.5	4.6	6.4	3.0	5.2	7.3	3.3	5.2	6.2	2.4	4.5	6.0
None	2.4	4.4	6.8	2.4	5.0	7.7	2.7	5.0	6.8	2.5	5.6	8.7
3-18-9*****	2.2	4.6	6.0	3.0	4.8	6.2	2.6	5.2	8.4	2.7	4.3	6.3
Water*	3.4	5.3	7.0	2.7	4.3	8.0	3.2	5.0	6.5	2.1	5.5	7.4
16-20-0*****	2.7	5.8	8.1	2.5	4.5	7.0	2.0	3.8	6.5	2.3	4.6	6.9

* Concentrations and rates of application as shown in Table I.
** Concentration 2 lb. and 1 lb. per qt. respectively. rate 1 qt. per bu.
*** Added at the rate of 1, 2 and 4 qt. per bu. respectively.
**** 3/8 lb. per qt. 1 qt. per bu.
**** Added at the rate of 1 qt. per bu.
***** 1 lb. per qt. 1 qt. per bu.

Table 17. Field data on the effect of liquid fertilizer on yield of Pawnee wheat at Stillwater. 1952

Treatment	Liquid fertilizer only			Liquid fertilizer plus 100 lbs. 16-20-0 per acre		
	wt.bundle	wt.straw	bu.*/A	wt.bundle	wt.straw	bu./A
	(pounds)		(bushels)	(pounds)		(bushels)
			Rep. I			
16-20-0	5.8	3.9	37.1	6.8	4.6	44.2
6-9-7	5.3	3.5	36.8	7.1	4.9	44.7
Water	4.0	2.7	26.4	7.5	5.6	38.7
3-18-9	4.1	3.7	27.4	7.0	5.3	34.8
None	4.9	3.5	29.0	6.8	5.2	32.8
10-52-17	4.8	3.3	29.5	7.3	5.6	33.6
			Rep. II			
3-18-9	5.0	3.5	30.3	7.5	5.5	40.5
10-52-17	4.5	3.1	28.7	5.8	3.7	42.1
6-9-7	5.3	3.6	33.1	6.8	4.0	39.4
16-20-0	4.0	2.7	25.4	5.7	3.9	36.4
Water	3.8	2.6	23.9	5.9	4.4	30.1
None	3.4	2.3	21.4	6.0	4.2	36.9
			Rep. III			
10-52-17	3.4	2.1	25.6	7.2	5.1	42.7
Water	3.2	2.1	22.8	6.1	4.3	35.7
None	3.4	2.1	25.8	5.9	3.9	39.3
3-18-9	3.5	2.2	25.6	5.3	3.5	36.5
16-20-0	3.4	2.1	25.6	5.1	3.5	31.8
6-9-7	3.2	1.9	25.5	5.5	3.7	36.6
			Rep. IV			
3-18-9	4.8	3.4	28.7	4.1	2.6	29.8
None	5.5	3.6	39.0	4.1	2.5	30.7
10-52-17	5.2	3.3	38.7	4.1	2.5	30.4
16-20-0	4.4	2.8	31.9	3.2	2.0	23.6
6-9-7	6.1	3.9	43.7	3.5	2.2	26.9
Water	5.7	3.6	42.3	3.9	2.4	29.4

*Yields were calculated to bushels per acre directly from thresher weights in grams. Bundle weight was originally in pounds and ounces and weight of straw obtained by difference.

Table 18. Summary of results on Pawnee wheat with yields expressed in bushels per acre.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
	Yield per acre with liquid fertilizer only				
			(bushels)		
16-20-0	37.1	25.4	25.6	31.9	30.0
6-9-7	36.8	33.1	25.5	43.7	34.8
Water	26.4	23.9	22.8	42.3	28.8
3-18-9	27.4	30.3	25.6	28.7	28.0
None	29.0	21.4	25.8	39.0	28.8
10-52-17	29.5	28.7	25.6	38.7	30.6
	Yield per acre with liquid fertilizer plus 100 pounds of 16-20-0 per acre.				
16-20-0	44.2	36.8	31.8	23.6	34.1
6-9-7	44.7	39.4	36.6	26.6	36.8
Water	38.7	30.1	35.7	29.4	33.5
3-18-9	34.8	40.5	36.5	29.8	35.4
None	32.8	36.9	39.3	30.7	34.9
10-52-17	33.6	42.1	42.7	30.4	37.2

Table 19. Field data on the effect of liquid fertilizer on yield of Tennex oats at Stillwater. 1952

Treatment	Liquid fertilizer only			Liquid fertilizer plus 100 lbs. 16-20-0 per acre		
	wt.bundle	wt.straw	bu.*/A	wt.bundle	wt.straw	bu./A
	(pounds)		(bushels)	(pounds)		(bushel)
			Rep. I			
16-20-0	5.3	2.4	89.2	5.7	2.6	95.8
6-9-7	5.1	2.3	85.9	5.5	2.2	83.3
Water	5.7	2.2	83.9	6.0	2.6	96.3
3-18-9	5.5	2.5	92.7	5.8	2.5	95.4
None	5.7	2.5	94.7	6.5	2.6	98.6
10-52-17	6.3	2.7	100.8	6.7	2.5	93.3
			Rep. II			
3-18-9	6.3	2.4	89.4	5.8	2.4	89.9
10-52-17	7.0	2.6	98.7	5.7	2.3	86.3
6-9-7	6.4	2.9	108.5	5.5	2.5	92.6
16-20-0	5.6	2.5	93.1	4.1	1.9	72.6
Water	5.7	2.6	97.4	4.5	2.0	75.9
None	5.0	2.3	84.8	5.2	2.3	86.8
			Rep. III			
10-52-17	4.0	1.8	68.8	5.4	2.4	91.5
Water	3.7	1.6	58.2	5.5	2.2	81.2
None	4.5	1.8	66.5	5.0	2.1	78.3
3-18-9	4.0	1.6	60.3	4.6	1.9	72.3
16-20-0	4.1	1.7	62.4	5.0	2.1	79.4
6-9-7	3.8	1.6	60.3	4.8	2.1	89.9
			Rep. IV			
3-18-9	3.8	1.6	73.4	4.7	2.1	78.6
None	3.9	1.7	62.6	4.8	2.1	79.2
10-52-17	3.8	1.7	64.3	5.0	2.3	87.6
16-20-0	3.4	1.6	60.3	4.4	2.0	75.5
6-9-7	3.5	1.6	61.2	4.1	1.8	68.6
Water	3.1	1.4	53.6	4.5	2.1	78.6

*Yields were calculated to bushels per acre directly from thresher weights in grams. Bundle weight was originally in pounds and ounces and weight of straw obtained by the difference.

Table 20. Summary of results on Tennex oats with yields expressed in bushels per acre.

Treatment	Rep. I	Rep. II	Rep. III	Rep. IV	Average
	Yield per acre with liquid fertilizer only				
			(bushels)		
16-20-0	89.2	93.1	62.4	60.3	76.2
6-9-7	85.9	108.5	60.3	61.2	78.9
Water	83.9	97.4	58.2	53.6	73.2
3-18-9	92.7	89.4	60.3	73.4	78.9
None	94.7	84.8	66.5	62.6	77.1
10-52-17	100.8	98.7	68.8	64.3	83.1
	Yield per acre with liquid fertilizer plus 100 pounds of 16-20-0 per acre.				
16-20-0	95.8	72.6	79.4	75.5	80.8
6-9-7	83.3	92.6	98.9	68.6	83.6
Water	96.3	75.9	91.2	78.6	83.0
3-18-9	95.4	89.9	72.3	78.6	84.0
None	98.6	86.8	78.3	79.2	85.7
10-52-17	93.3	86.3	91.5	87.6	89.7

Table 21. Growth of corn as of May 21, 1952 under field conditions with seed treated with various liquid fertilizer, Perkins farm.

Treatment	Growth* as height, in inches Rep. I	Rep. II	Rep. III	Rep. IV
6-9-7	4.8	4.7	4.4	4.4
3-18-9	4.2	3.8	4.5	5.0
10-52-17	3.7	5.1	4.8	4.7
None	4.1	5.3	4.7	4.7
16-20-0	3.2	3.6	3.6	3.4
Water	3.6	3.8	4.6	4.2

* Measured to the tip of longest leaf.

Table 22. Growth of corn as of July 7, 1952 under field conditions with seed treated with various liquid fertilizers Perkins farm.

Treatment	Growth* as height, in inches Rep. I	Rep. II	Rep. III	Rep. IV
6-9-7	50	52	52	47
3-18-9	55	48	50	47
10-52-17	57	51	40	49
None	55	47	43	45
16-20-0	56	42	43	43
Water	52	47	48	45

* Measured to the tip of longest leaf.

THESIS TITLE: THE RESPONSE OF FIELD CROPS TO LIQUID FERTILIZER APPLIED AS A PRE-PLANTING SEED TREATMENT

AUTHOR: HAROLD B. WARD

THESIS ADVISER: FENTON GRAY

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