ALFALFA SEED PRODUCTION AS AFFECTED
BY VARIOUS FERTILIZERS AND BY SOIL MOISTURE LEVELS

by

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INTRODUCTION

The value of alfalfa (Medicago sativa L.) as a forage crop has long been recognized. A large amount of experimental work has been done in an effort to increase the yield of forage and to facilitate the handling of the crop. However, alfalfa seed production is, in many respects, a hazardous undertaking for the farmer. The uncertainty of producing a profitable seed crop has discouraged many alfalfa growers from entering the field of seed production. Only in recent years has there been any appreciable attention given to methods whereby the yield of alfalfa seed might be increased.

This study was undertaken as a preliminary step in determining the role of soil fertility in alfalfa seed production. A considerable amount of investigational work has been done on such phases of seed production as the control of harmful insects at blooming time, and various studies concerning the pollination processes have been made. However, comparatively little has been done with respect to the use of various fertilizers to increase alfalfa seed yields. Fertilizer studies have been made on most of the economically important crops of the country. The value of the use of fertilizers on many crops and in many areas has been proven. If the yield of such crops as wheat and corn can be increased through the use of fertilizers, then it seems logical to suppose that the yield of alfalfa seed also can be increased if properly fertilized. It was with this hypothesis in mind that this study was begun.

The major emphasis in this work was placed on the three elements; calcium, magnesium, and boron. Nitrogen, phosphorus and potassium were used in a number of cases to raise the general level of fertility of the soil. Alfalfa is known to be a relatively heavy feeder on calcium and magnesium, and in recent years boron has attracted wide attention as a trace element.

In addition to the fertilizer applications, the effect of the level of soil moisture on seed production, under greenhouse conditions, was considered.

REVIEW OF LITERATURE

Literature concerning fertilizers as they affect alfalfa seed production is rather limited. A considerable amount of work has been done with boron in areas where this element is known to be deficient, but few reports were found of experiments with the other elements included in this study. Results obtained on some related and non-related crops are, therefore, included in this review of literature.

Blinn (2) stated in 1920 that soil fertility must be a factor in alfalfa seed production. He cited as evidence the fact that average yields obtained 25 years previous were nearly three times those being obtained at the time of writing. He presented an opinion that excess nitrates depress seed yields but did not support this opinion with experimental evidence. Carlson and Stewart (6) showed that the seed yield was highest on plots receiving no manure and lowest on those receiving 15 tons per acre.

Nelson et al. (17), working in North Carolina with soybeans, found that magnesium had little effect on the seed yield while potassium greatly increased production of seed. Adequate potassium more than doubled the number of pods per plant but magnesium had no consistent effect on their number. Although neither potassium nor magnesium greatly affected the size of the pods, potassium did increase the filling. Plants receiving potassium produced larger seeds than unfertilized plants but those receiving magnesium did not. Both fertilizers retarded maturity and potassium exerted a favorable influence in pod retention. Another North Carolina experiment reported by Brady and Colwell (3) showed that, in general, magnesium had an unfavorable effect on peanut development. Potassium increased the yield if there was sufficient calcium and if the potassium level in the soil was very low.

Sommer et al. (21) studied the effect of magnesium on six different crops on 16 different Alabama soils. Of the six crops, cotton, crotalaria, corn, crimson clover, turnips, and peanuts, the yield of peanuts was increased the most by the addition of magnesium. It was found that for most of the crops superphosphate contained sufficient magnesium to supply the needs of the crop.

Knoblauch and Odland (14) found that a high level of potassium in the soil tended to cause magnesium deficiencies to occur. The high concentration of potassium ions is believed to displace the available magnesium ions on the soil particles.

The literature on boron is somewhat conflicting, but the need for this element in alfalfa production is generally recognized. No attempt is made here to summarize all of the available information but several of the more applicable papers are discussed briefly.

Brown and King (4) described typical boron deficiency symptoms on deficient Connecticut soils as follows.

> The upper leaves turned yellow, then deep creamy yellow and finally became almost orange. The buds withered and turned brown. Failure of the top leaves and buds to develop gave the entire plant a dwarfed appearance.

Alfalfa on plots that received 20 pounds of boron per acre was normal.

Dawson and Gustafson (8) in New York obtained no significantly increased hay yields through the use of boron, but completely eliminated boron deficiency symptoms with surface applications of boron.

The toxic effect of excess boron is well known but the amounts recommended as fertilizer applications vary from 15 pounds to 60 pounds per acre. Grizzard and Matthews (13) produced from 82 to 184 pounds of alfalfa seed per acre with applications of 15 pounds of boron. Untreated plots failed to set any seed. Work reported by Midgley (16) led to tentative recommendations of 30 pounds of borax per acre every three years on certain Vermont soils. This work in Vermont indicated that the application of boron was more effective at the time of seeding than on established stands. Seed production was increased more than 35 times as a result of additions of boron. Baur et al. (1) noted that alfalfa on boron deficient land in Washington rarely formed flowers. They observed good responses from both spring and fall applications. They recommended 50 to 60 pounds borax per acre on silt and clay soils and 30 to 40 pounds on lighter soils. Their work indicated that barnyard manure does not contain sufficient boron to correct a serious deficiency and poultry manure often accentuated the deficiency of boron. Work done in Oregon as reported by Dregne and Powers (9) showed sandy soils, peat land, and old, badly leached soils to be most deficient in boron. They believed that up to 60 pounds borax per acre may prove economical.

It is noted that there have been few if any proven boron deficiencies reported in the region where much of the alfalfa seed of the United States is produced. There is no doubt that boron is an essential element in producing alfalfa seed but it appears doubtful that the soils of this region are seriously lacking in this element.

The literature concerning the effect of soil moisture on alfalfa seed production is somewhat less limited than is the case with that on the effect of fertilizers. It is, however, somewhat contradictory. In field and greenhouse experiments, Tysdal (24) found indications that high soil moisture, as such, is not an inhibiting factor in seed production. His findings collaborated to a large extent with those found by Grandfield (12).

Blinn (2), in earlier years, found that under abnormally wet weather conditions during the spring and summer little or no seed was set under field conditions. Yet plants grown in pots and watered heavily set at least a moderate amount of seed. He found that the seed yield could not be controlled by the application of any definite amount of water. His conclusion was that factors other than a given water supply influence seed production.

Stewart (23) writes that an abundant water supply gives a high hay yield but low seed production. He found that for good seed production the alfalfa plant should have a constant water supply which was not so readily available as to induce rapid vegetative growth. This seems to disagree to some extent with the previously discussed publications. Stewart also states that all of the large alfalfa seed producing areas are found in the arid and semi-arid regions. This would tend to substantiate his findings concerning the water relationships, but Blinn (2) indicates that high temperature and low humidity, rather than a definite amount of water, seem to be among the most essential requirements for successful seed production. Spencer and Stewart (22) are more or less in agreement with Blinn. They listed hot days, cool nights and dry air as prerequisites for extensive production of alfalfa seed.

Knowles (15) and Sexsmith and Fryer (19), working on tripping and pollen fertility, respectively, found rather high temperatures to be advantageous. The latter found a linear relationship between pollen tube length and increase in temperature from 70° to 100° F. At 50° F.

there was no germination of pollen even after 30 minutes.

Carlson and Stewart (6) found a limited water supply sufficient to produce a slow but even vegetative growth to be the most desirable for seed production. Engelbert (10) presents the situation as follows.

> Summing up in general from various writers' statements it may be said that before the blooming period there must be sufficient moisture for vigorous plant growth of the alfalfa plants. Near and during the first part of the bloom period, a dry spell sufficient to put the necessary "strain" on the plant to induce seed setting, is needed; during the rest of the blooming period light showers now and again are beneficial, as a certain amount of moisture is needed for fertilization. When the young pods are formed heavier rains are favourable to provide the moisture necessary for the filling of the pods.

Carlson (5), in his studies on alfalfa seed setting, found that other things being equal high seed production depends on adequate plant size. He found a high correlation between plant size and seed yield in plants from the same clone, due at least in part to a greater number of flowers. This would seem to indicate that a high level of soil fertility and an optimum water supply are very desirable in securing satisfactory yields of seed.

MATERIAL AND METHODS

Fertilizer elements used in all the experiments were applied in the following forms: boron as sodium borate, calcium as calcium sulphate, magnesium as magnesium sulphate, nitrogen as ammonium nitrate, phosphorus as 45 per cent commercial superphosphate, and potassium as commercial muriate of potash fertilizer containing 60 per cent potassium oxide equivalent. The sulphate forms of calcium and magnesium were used in order to eliminate possible effects on seed setting due to a change in pH. Cubbon (7) found that calcium sulphate had no effect on the acidity of any soil which he studied.

The fertilizers were applied on the field experiments at the rates given in Table 1. The applications were doubled in the greenhouse experiment.

Table 1. Rate of fertilizer application.

Fertilizer	Pounds per acre
Boron	20
Calcium	250
Magnesium	150
Nitrogen	75
Phosphorus	55
Potassium	30

The field experiments were conducted on established stands of alfalfa. On the Kansas State College Agronomy Farm at Manhattan and on the Branch Experiment Station at Hays, the fertilizer applications were made on fields of Buffalo alfalfa. The experiment on the Branch Experiment Station at Garden City was located on a field of A-8. The Garden City field was under irrigation.

Field applications of fertilizer were made with a 24 inch garden fertilizer spreader. All fertilizers were weighed and mixed, then added to dry sand so that a uniform amount of material was applied to each plot, thus eliminating the necessity of calibrating the spreader for each treatment.

The fertilizer applications were made at Manhattan March 28, 1947. The Hays treatments were applied April 1, and the Garden City treatments were applied April 2.

The randomized block system was used in laying out the plots on all three fields. Six replications were used at Manhattan and Hays, while at Garden City the treatments were replicated eight times. At Manhattan and Hays the plots were 6 feet wide and 25 feet long; at Garden City they were 4 feet wide and 50 feet long.

Because of drought and a serious infestation of webworms no seed was harvested at Manhattan. The method of harvesting at the other two locations was similar. A power mower was used to cut a strip three feet wide the full length of the plot. The hay was allowed to dry in the field, then sacked and threshed at a later date. The yields from the plots at Hays were converted to a per acre basis, but those from Garden City are given as grams of seed per plot.

The plants used in the greenhouse studies were obtained by vegetative propagation of cuttings from a clonal line of alfalfa. The variations observed between plants were, therefore, not due to inherent genetic differences present in the various plants.

Greenhouse work included using two moisture levels as well as the fertilizers described previously. The desired soil moisture was retained in the pots by the method described by Grandfield (11). This consisted of placing a coiled copper tube in a glazed pot with the open end of the tube extending from the bottom of the pot. The water was forced through the tube and was evenly distributed throughout the soil by means of small holes in the tube. Thus it was possible to maintain the soil mass at a moisture level below its field water holding capacity.

At the time the pots were filled the moisture present in the soil being used was determined. The amount of soil used in each pot was weighed and converted to an oven dry basis. The weight of the desired percentage of moisture was then added. The plants were watered by placing the pot on a scale and injecting water through the tube until the desired weight was reached.

The soil used in the 1947 experiment was a light sandy soil obtained south of Manhattan. The pH was 4.6 and the moisture equivalent 10.3 per cent. The high moisture pots were held at 18 per cent, the low at 10 per cent.

The plants were set in pots November 28, 1946. They were allowed to grow and establish themselves until January 24, 1947, at which time they were cut and the fertilizer treatment applied. The applications were made as top dressings. The pots were watered from the top a number of times in order to leach the fertilizers down through the soil.

Blooming started March 1, 1947 and continued for a period of six weeks. During this time the plants were examined daily and all new flowers were hand tripped. Each raceme was tagged and numbered. The number of flowers tripped on each raceme each day was recorded. After the blooming ceased, the plants were cut and dried. The number of pods was then determined. No cross pollinating was done. Carlson (5) found that selfing could be used to predict seed setting potential.

Soil for the 1948 greenhouse experiment was obtained from Thayer, Kansas. It was a grayish brown silt loam which was quite low in available phosphorus and potassium. The moisture equivalent was 20 per cent and the pH 4.88. The high moisture pots were held at 20 per cent, the low at 12 per cent. As the plants were not seedlings it was possible to grow them in soil with a rather low pH.

After planting a period of five weeks was allowed for the establishment of the plants. The top growth was removed and the treatments were then applied. The plants grew to the bloom stage at which time they were cut again and the seed setting readings were taken on the regrowth.

Experience gained in the 1947 experiment showed that there apparently was a close correlation between the number of racemes and the number of seed pods. For this reason the tedious and time consuming task of tripping and counting flowers was eliminated. The only determination made in 1948 was to count the number of racemes per plant.

Statistical procedures described by Paterson (18) and Snedecor (20) were followed in analyzing the results of the experiments.

EXPERIMENTAL RESULTS

Field Experiment at Hays

This experiment was divided into two sections. One study was devoted to the six single element fertilizers and no treatment plots. The other section included plots receiving nitrogen, phosphorous and potassium plus boron, calcium and magnesium singly and in all possible combinations. This resulted in eight different treatments. Hereafter this latter group of treatments will be referred to as the NPK plots.

Table 2 gives the yield of seed in pounds per acre for the NPK treatments. It may be noted that the calcium-magnesium plots gave the highest average seed yield. This treatment gave an average seed yield of 54.8 pounds per acre more than the average of the boron-calcium plots which ranked second. The plots receiving nitrogen, phosphorous and potassium only gave the lowest yield. The calcium-magnesium treatment was the only one which gave a substantial increase or decrease from the average yield of all NPK plots which was 252.3 pounds per acre.

An analysis of variance of the data presented in Table 2 failed to indicate any significant differences between the fertilizers. The calculated F ratio is .58. A ratio of 2.29 is necessary for significance

Table 2. Seed yields in pounds per acre obtained from the NPK plots at Hays, Kansas.

Treatment	Replication						Average
	1	2	3	4	5	6	
N-P-K	248.2	275.2	171.2	286.2	182.0	232.5	232.5
N-P-K : Boron	253.6	339.2	139.9	93.1	291.7	292.5	235.0
N-P-K : Calcium	289.2	125.8	278.6	331.0	248.7	170.7	233.8
N-P-K : Magnesium	366.3	204.2	112.3	287.0	209.0	303.6	247.0
N-P-K : B-Ca	374.7	125.8	344.6	110.9	250.0	367.1	262.1
N-P-K : B-Mg	422.4	297.7	245.2	84.8	149.1	241.2	240.0
N-P-K : Ca-Mg	322.0	269.6	407.2	291.0	245.7	366.3	316.9
N-P-K : B-Ca-Mg	394.5	334.1	172.8	130.9	312.9	115.8	243.6

at the 5 per cent level of probability. The F ratio of 1.99 for between replication variation also lacks significance at the 5 per cent level. Table 3 summarizes the analysis.

Table 3. Summary of analysis of variance for NPK plots at Hays, Kansas.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
Total	47				
Between fertilizers	7	4,595.86	.58	2.29	3.20
Between replications	5	15,851.40	1.99	2.47	3.50
Error	35	7,978.91			

The yields from the single element plots are given in Table 4. Although the average yields varied from 202.8 pounds of seed per acre from the nitrogen plots to 283.7 pounds from the magnesium plots the analysis of variance failed to indicate statistically significant differences between fertilizers or between replications. This lack of significance is probably explainable in part by noting the great variation between replicates of the same treatment.

Field Experiment at Garden City

The data from Garden City were handled in much the same manner as those from Hays.

The seed field at Garden City was badly infested with foxtail and other weeds at the time the plots were harvested. This resulted in a large amount of foreign material in many of the yield samples. The seed from each plot was thoroughly mixed and a five gram sample was taken. These samples were hand picked to remove the foreign material and the percentage of clean seed was determined. This percentage was used to

Table 4. Seed yields in pounds per acre obtained from the single element fertilizers at Hays, Kansas.

Treatment	Replication						Average
	1	2	3	4	5	6	
Boron	287.2	310.2	318.0	153.2	246.5	112.4	237.9
Calcium	405.4	188.3	91.2	190.4	303.1	212.0	231.7
Magnesium	434.1	334.4	281.0	192.6	160.5	329.7	288.7
Nitrogen	78.4	230.8	251.3	317.4	126.9	212.1	202.8
Phosphorus	291.2	135.3	318.6	327.0	152.5	80.3	217.4
Potassium	188.8	190.7	438.7	317.1	103.1	208.0	241.0
No treatment	172.8	102.4	272.1	280.7	330.7	193.2	225.3

calculate the yield of clean seed per plot.

Table 5 gives the grams of clean seed per five gram total for the NPK plots. An analysis of variance gave a calculated F value of 1.55 for between fertilizers. A ratio of 2.20 is needed for significance at the 5 per cent level. The F ratio for between replications was found to be 2.98, which is significant at the 5 per cent level and approaches significance at the 1 per cent level. These findings tend to substantiate visual observations made at the time the plots were harvested. It appeared at that time that the weedy areas of the field were due to some factor or factors other than the application of the various fertilizers.

Tables 6 and 7 give, respectively, the results of the NPK treatments and the single element treatments. Statistical analysis of the data indicated that in no case were there significant differences between fertilizers or between replications.

Of the NPK plots those receiving calcium had the highest average yield, while the calcium-magnesium combination ranked sixth. At Hays the calcium-magnesium treatment ranked first and calcium seventh. It seems impossible to arrive at any conclusions or trends in studying the data from either of the two experiments alone, or in combination.

Greenhouse Experiment, 1947

As previously stated, the greenhouse experiments were quite similar to the field experiments except that each fertilizer was applied to pots of high and low moisture levels.

As much of the data are tabular in nature, they are presented in table form with brief discussions of each table.

Table 5. Grams of clean seed obtained from a five gram sample of seed from the Garden City plots.

Treatment	Replication								Average
	1	2	3	4	5	6	7	8	
N-P-K	4.66	4.90	4.92	4.36	4.78	4.80	4.53	4.48	4.68
N-P-K : Boron	4.56	4.68	4.84	4.80	4.82	4.78	4.92	4.84	4.78
N-P-K : Calcium	4.68	4.96	4.92	4.72	4.84	4.64	4.74	4.75	4.78
N-P-K : Magnesium	4.88	4.66	4.70	4.74	4.91	4.50	4.66	4.66	4.71
N-P-K : B-Ca	4.64	4.66	4.96	4.88	4.62	4.72	4.90	4.74	4.77
N-P-K : B-Mg	4.86	4.96	4.94	4.68	4.72	4.74	4.63	4.84	4.80
N-P-K : Ca-Mg	4.46	4.42	4.80	4.46	4.76	4.14	4.89	4.82	4.59
N-P-K : B-Ca-Mg	4.68	4.66	5.00	4.22	4.92	4.49	4.86	4.73	4.70

Table 6. Grams of clean seed per plot obtained from the NPK plots at Garden City, Kansas.

Treatment	Replication								Average
	1	2	3	4	5	6	7	8	
N-P-K	153.8	243.0	327.7	232.0	349.9	204.5	198.4	342.3	256.5
N-P-K : Boron	280.9	239.6	271.0	285.1	264.1	198.8	300.1	219.7	257.4
N-P-K : Calcium	232.1	221.2	391.6	412.5	302.0	306.2	330.9	286.9	310.4
N-P-K : Magnesium	231.3	281.5	207.7	297.7	369.2	349.2	261.9	266.6	283.1
N-P-K : B-Ca	287.7	302.0	277.8	341.6	192.2	366.2	346.9	287.2	287.7
N-P-K : B-Mg	203.1	224.2	313.2	245.2	293.6	223.7	256.5	243.0	250.3
N-P-K : Ca-Mg	246.2	234.3	323.5	267.6	196.1	203.7	300.2	280.5	256.5
N-P-K : B-Ca-Mg	280.8	204.1	391.0	235.5	389.7	270.3	281.9	314.1	295.9

Table 7. Grams of clean seed per plot obtained from the single element plots at Garden City, Kansas.

Treatment	Replication 1	2	3	4	5	6	7	8	Average
Boron	147.4	260.5	342.0	196.8	258.1	238.5	267.4	357.7	258.6
Calcium	122.0	260.7	286.6	227.7	401.5	236.2	189.6	179.3	238.0
Magnesium	246.4	262.9	358.6	264.1	322.6	436.0	139.6	323.4	294.2
Nitrogen	199.2	248.9	289.7	248.6	196.3	220.9	314.6	346.3	258.1
Phosphorus	236.9	295.8	299.1	214.9	264.1	286.4	312.7	284.4	274.3
Potassium	144.4	215.2	278.4	333.8	221.7	316.5	247.7	237.9	249.5
No treatment	289.5	279.5	309.7	382.0	283.2	300.6	276.8	214.4	292.0

Table 8 gives the number of racemes, flowers, and pods for each of the replicates of the eight different fertilizer treatments and the two moisture levels. Four of the plants failed to flower. As indicated in the table, the values for these plants were calculated by the equation for supplying missing data presented by Paterson (18). For each of these calculated figures one degree of freedom was lost, therefore the total degrees of freedom used in the analysis of variance was n minus 5 instead of n minus 1.

Table 9 presents a summary of the analysis of each of the three sets of data. In each case the only significant F value is found to be between moisture levels. The probability of differences as large as those between moisture levels occurring merely by chance is less than 1 per cent.

In an effort to determine possible effect the various fertilizers might have on the size of racemes, a comparison was made between the number of flowers and the number of racemes on each plant. This involved dividing the number of flowers by the number of racemes. An analysis of variance failed to show any indication of effect on the number of flowers per raceme due to fertilizer or water application. Table 10 summarizes the analysis.

Table 11 shows the results of an analysis involving the ratio of the number of pods to the number of flowers. There was found to be a significant difference between fertilizers at the 5 per cent level. As the experimental design was orthoganal and factorial, it was possible to calculate the sum of squares for individual degrees of freedom and determine the F ratio for each. This was done and it was found that boron-calcium fertilizer gave highly significant fewer pods per number of flowers than the other fertilizers. None of the other differences

Table 8. Number of racemes, flowers and pods per plant, greenhouse experiment, 1947.

Treatment	Repl.	Number of racemes		Number of flowers		Number of pods	
		High moisture	Low moisture	High moisture	Low moisture	High moisture	Low moisture
N-P-K	1	80	24	724	226	248	108
	2	125	38	1226	330	540	137
	3	67	46	582	409	250	250
Average		90.7	36.0	844.0	321.7	346.0	165.0
N-P-K : Boron	1	80	30	719	353	473	209
	2	57	44	420	411	266	239
	3	49	17	384	108	216	64
Average		62.0	30.3	507.7	290.7	318.3	170.7
N-P-K : Calcium	1	106	51	1143	502	614	283
	2	86*	13	863*	113	506*	61
	3	56	30	496	323	333	202
Average		82.7	31.3	834.0	312.7	484.3	182.0
N-P-K : Magnesium	1	69	74	587	731	316	371
	2	75	37	642	319	392	196
	3	43	15	352	156	112	97
Average		62.3	42.0	527.0	402.0	273.3	221.3
N-P-K : B-Ca	1	71	51	595	610	333	294
	2	98	22	956	222	475	114
	3	78	35	720	332	438	158
Average		82.3	36.0	757.0	388.0	415.3	188.7

Table 8. (Concl.).

Treatment	Repl.	Number of racemes: High moisture	Number of racemes: Low moisture	Number of flowers: High moisture	Number of flowers: Low moisture	Number of pods: High moisture	Number of pods: Low moisture
N-P-K : B-Mg	1	37	58	321	582	195	294
	2	76	23	670	199	424	115
	3	99	26*	834	223*	593	133*
Average		70.7	35.7	608.3	334.7	404.0	180.7
N-P-K : Ca-Mg	1	133	68	1343	611	497	288
	2	106	59	879	748	468	396
	3	78	49*	659	512*	416	271*
Average		105.7	58.7	960.3	623.7	460.3	318.3
N-P-K : B-Ca-Mg	1	88	21	901	210	422	110
	2	87	39	937	357	552	188
	3	73*	21	751*	203	424*	97
Average		82.7	27.0	863.0	256.7	466.0	131.7

* Missing data supplied by equation from Paterson (18). $X = \frac{n \times T_v + p \times T_s - T}{(n-1)\ (p-1)}$.

Table 9. Summary of analysis of variance of the data presented in Table 8.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
		Racemes			
Total	43				
Between fertilizers	7	703.14	1.73	2.39	3.42
Between moisture	1	21,931.00	53.83	4.22	7.72
Between replications	2	1,160.50	2.85	3.37	5.53
Fertilizer x moisture	7	235.43	.58	2.39	3.42
Error	26	407.38			
		Flowers			
Total	43				
Between fertilizers	7	83,127	1.75	2.39	3.42
Between moisture	1	1,655,404	34.86	4.22	7.72
Between replications	2	161,463	3.40	3.37	5.53
Fertilizer x moisture	7	41,951	.88	2.39	3.42
Error	26	47,492			
		Pods			
Total	43				
Between fertilizers	7	14,407	.98	2.39	3.42
Between moisture	1	485,616	33.05	4.22	7.72
Between replications	2	21,171	1.44	3.37	5.53
Fertilizer x moisture	7	12,457	.85	2.39	3.42
Error	26	14,695			

Table 10. Summary of analysis of variance for the ratio of the number of flowers to the number of racemes.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
Total	43				
Between fertilizers	7	1.78	.38	2.39	3.42
Between moisture	1	4.32	.92	4.22	7.72
Between replications	2	2.32	.49	3.37	5.53
Fertilizer x moisture	7	1.24	.26	2.39	3.42
Error	26	4.70			

Table 11. Summary of analysis of variance for the ratio of the number of pods to the number of flowers.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
Total	43				
Between fertilizers	7	.0167	3.18	2.39	3.42
Between moisture	1	.0004	.08	4.22	7.72
Between replications	2	.0114	2.17	3.37	5.53
Fertilizer x moisture	7	.0069	1.31	2.39	3.42
Error	26	.00525			

was significant at the 5 per cent level.

To eliminate possible effects from higher order interactions and first order interactions which were not calculated the data were divided into high and low moisture groups. Separate statistical analysis of these data failed to show any differences due to fertilizers.

Greenhouse Experiment, 1948

A factorial experiment was conducted involving the eight treatments used in 1947 plus eight additional treatments including a no-treatment and calcium, boron and magnesium singly and in all possible combinations. As was previously noted the only determination made in 1948 was the number of racemes.

Table 12 gives the number of racemes per plant and Table 13 summarizes the statistical analysis of the data. The results were similar to those obtained in 1947 in that the difference between moisture levels was highly significant, while none of the other F values was significant at the 5 per cent level of probability.

Again to eliminate possible effect from interactions which were not apparent the data were divided and analyzed. Table 14 summarizes these analyses and again there is no indication of differences between fertilizers.

Table 12. Number of racemes per plant, greenhouse experiment, 1948.

Treatment	Number of racemes							
	High moisture				Low moisture			
	Replication				Replication			
	1	2	3	Average	1	2	3	Average
No treatment	93	146	18	85.7	70	54	59	61.0
Boron	24	74	75	57.7	56	73	75	68.0
Calcium	143	115	103	120.3	58	23	47	42.7
Magnesium	107	69	91	89.0	33	104	48	61.7
B-Ca	61	80	93	78.0	80	51	59	63.3
B-Mg	23	88	171	94.0	50	26	64	46.7
Ca-Mg	127	103	64	98.0	60	55	62	59.0
B-Ca-Mg	74	70	85	76.3	58	52	44	51.3
N-P-K	69	66	81	72.0	85	49	49	61.0
N-P-K : Boron	47	107	70	74.7	28	49	106	61.0
N-P-K : Calcium	74	76	162	104.0	112	19	27	52.7
N-P-K : Magnesium	88	55	96	79.7	51	38	40	43.0
N-P-K : B-Ca	109	96	68	91.0	82	36	36	51.3
N-P-K : B-Mg	89	75	72	78.7	62	57	17	45.3
N-P-K : Ca-Mg	72	95	112	93.0	66	67	17	50.0
N-P-K : B-Ca-Mg	64	83	33	60.0	26	125	2	51.0

Table 13. Summary of analysis of variance for the number of racemes per plant, greenhouse experiment, 1948.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
Total	95				
Between fertilizers	7	458	.48	2.14	2.91
Between replications	2	142	.15	3.13	4.92
Between moisture	1	21,871	23.10	3.98	7.01
Between fert. levels	1	667	.70	3.98	7.01
Fertilizer x moisture	7	1,093	1.15	2.14	2.91
Moisture x fert. level	1	5	.005	3.98	7.01
Fertilizer x fert. l.	7	104	.11	2.14	2.91
Error	69	947			

Table 14. Summary of analyses of variance of the divided data, greenhouse experiment, 1948.

Sources of variation	Degrees of freedom	Mean square	Calculated F ratio	F ratio needed for significance 5%	1%
		No N-P-K low moisture			
Total	23				
Between fertilizers	7	234.3	.65	2.77	4.28
Between replications	2	24.5	.07	3.74	6.51
Error	14	361.1			
		No N-P-K high moisture			
Total	23				
Between fertilizers	7	1,003	.57	2.77	4.28
Between replications	2	272	.15	3.74	6.51
Error	14	1,762			
		N-P-K low moisture			
Total	23				
Between fertilizers	7	125.7	.09	2.77	4.28
Between replications	2	1,542.5	1.12	3.74	6.51
Error	14	1,372			
		N-P-K high moisture			
Total	23				
Between fertilizers	7	574	.75	2.77	4.28
Between replications	2	211	.28	3.74	6.51
Error	14	761			

SUMMARY AND CONCLUSIONS

The experiments to determine the effect of fertilizer and moisture were conducted on field scale at the Branch Experiment Stations at Hays and Garden City and under greenhouse conditions at Manhattan. Crops at Hays and Garden City generally do not respond to fertilizer applications but an attempt was made to use soil which was low in fertility for the greenhouse work.

The experiment was begun in the greenhouse during the winter of 1947 and was continued through the summer of 1947 and the winter of 1947-48. The two main objectives of the study were (1) to find the effect of various fertilizers and (2) to find the effect of moisture levels on alfalfa seed production.

None of the fertilizer applications significantly increased seed production. It was impossible to point out any trends toward differences even when the various phases of the experiment were compared. The only conclusion which could be reached was that, under the conditions of the experiment, the fertilizers used failed to increase seed yields.

The results left little question as to the superiority of the higher level of soil moisture. In no case did the high moisture level plants fail to produce more seed than those receiving the smaller amounts of water.

Future studies concerning the use of fertilizers on alfalfa involving different soils may well give results which are not comparable with those presented herein. The results which have been given should be considered valid only on soils represented in the experiment.

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LITERATURE CITED

(1) Baur, Karl, Glenn A. Huber and L. C. Wheeting.
Boron deficiency of alfalfa in western Washington. Wash. Agr. Expt. Sta. Bul. 396. 16 p. 1941.

(2) Blinn, P. K.
Factors that effect alfalfa seed yields. Colo. Agr. Expt. Sta. Bul. 257. 32 p. 1920.

(3) Brady, N. C. and W. E. Colwell.
Yield and quality of large-seeded type peanuts as affected by potassium and certain combinations of potassium, magnesium and calcium. Amer. Soc. Agron. Jour. 37:429-442. 1945.

(4) Brown, B. A. and Allan King.
Soil conditions under which alfalfa responded to boron. Soil Sci. Soc. Amer. Proc. 4:310-313. 1939.

(5) Carlson, John W.
Pollination, Lygus infestation, genotype, and size of plants as affecting seed setting and seed production in alfalfa. Amer. Soc. Agron. Jour. 38:502-514. 1946.

(6) Carlson, J. W. and George Stewart.
Alfalfa seed production. Utah Agr. Expt. Sta. Tech. Bul. 226. 54 p. 1931.

(7) Cubbon, M. H.
Calcium sulphate as a soil amendment. Cornell Univ. Agr. Expt. Sta. Memoir 97. 51 p. 1926.

(8) Dawson, J. E. and A. F. Gustafson.
A study of techniques for predicting potassium and boron requirements for alfalfa: II Influence of borax on deficiency symptoms and the boron content of the plant and soil. Soil Sci. Soc. Amer. Proc. 10:147-149. 1945.

(9) Dregne, H. E. and W. L. Powers.
Boron fertilization of alfalfa and other legumes in Oregon. Amer. Soc. Agron. Jour. 34:902-912. 1942.

(10) Engelbert, V.
A study of the various factors influencing seed production in alfalfa (Medicago sativa). Sci. Agr. 12:593-603. 1931.

(11) Grandfield, C. O.
A greenhouse method of maintaining soil moisture below field capacity. Amer. Soc. Agron. Jour. 33:371-373. 1941.

(12) ________
Alfalfa seed production as affected by organic reserves, air temperature, humidity and soil moistures. Jour. Agr. Res. 70:123-132. 1945.

(13) Grizzard, A. L. and E. M. Matthews.
The effect of boron on seed production of alfalfa. Amer. Soc. Agron. Jour. 34:365-368. 1942.

(14) Knoblauch, H. C. and T. E. Odland.
A magnesium deficiency induced by previous fertilizer treatment. Amer. Soc. Agron. Jour. 26:609-615. 1934.

(15) Knowles, R. P.
Role of insects, weather and plant characters in seed setting of alfalfa. Sci. Agr. 24:29-50. Sept. 1943.

(16) Midgley, A. R.
Effect of lime and organic matter on boron fixation and availability. Vt. Agr. Expt. Sta. Bul. 475. p 20-21. 1941.

(17) Nelson, W. L., L. Burkhart and W. E. Colwell.
Fruit development, seed quality, chemical composition, and yield of soybeans as affected by potassium and magnesium. Soil Sci. Soc. Amer. Proc. 10:224-229. 1945.

(18) Paterson, D. D.
Statistical technique in agricultural research. New York. McGraw-Hill. 263 p. 1939.

(19) Sexsmith, John J. and James R. Fryer.
Studies relating to fertility in alfalfa (Medicago sativa L.) II. Temperature effect on pollen tube growth. Sci. Agr. 24:145-151. 1943.

(20) Snedecor, George W.
Statistical methods. Ames. Iowa State College Press. 485 p. 1946.

(21) Sommer, Anna L., John I. Wear and Aaron Baxter.
The response to magnesium of six different crops on sixteen Alabama soils. Soil Sci. Soc. Amer. Proc. 5:205-212. 1940.

(22) Spencer, J. N. and T. G. Stewart.
Alfalfa seed production. Colo. Agr. Ext. Bul. 314A. 16 p. 1932.

(23) Stewart, George.
Alfalfa growing in United States and Canada. New York. Macmillan. p 312-314. 1926.

(24) Tysdal, H. M.
Influence of tripping, soil moisture, plant spacing, and lodging on alfalfa seed production. Amer. Soc. Agron. Jour. 38:515-535. 1946.