SEED PRODUCTION OF SMOOTH BROME GRASS AS IT IS INFLUENCED BY TIME AND RATE OF APPLICATION OF AMMONIUM SULPHATE

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Willard N. Crawford

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by

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SEED PRODUCTION OF SMOOTH BROME GRASS AS IT IS INFLUENCED BY TIME AND RATE OF APPLICATION OF AMMONIUM SULPHATE

Current interest in the utilization of smooth brome grass (Bromus inermis Leyss.) for forage purposes has created a demand for a supply of high quality seed. Although it has been established that brome grass seed can be produced in Michigan, no information is available on the possibility of increasing the seed yield or improving the seed quality through the use of commercial fertilizers.

The experiment here reported was designed to study the influence of the date and rate of application of ammonium sulphate during the first and second seed harvest years. In conjunction with the study, the yield and protein content of the forage at the time of seed harvest; the number of fertile and barren tillers; various panicle characteristics; and the quality of the seed produced were investigated.

In August, 1937, a field of moderately fertile, slightly acid, Brookston loam soil on the experiment station farm at East Lansing, Michigan, was fertilized with 400 pounds per acre of an 0-20-20 fertilizer. Bromegrass seed was mixed with oats and planted in 28-inch rows with a grain drill set to sow two bushels of oats per acre. Approximately two and one-half pounds of brome grass seed per acre were planted.

The experiment was designed so that 0 (control plots) 100, 250, 500, 750, and 1000 pounds of ammonium sulphate (21.0% N) per acre were applied to triplicate 1/140-acre

plots in mid-April, mid-May, and mid-June. The field was divided into three areas, or replications, and each area was further divided into three blocks, one at random for each date of application. The six rates of application were randomized within each block. This gave, then, a 3 (replications) x 3 (dates of application) x 6 (treatments) plot layout. All of the experimental results were subjected to analysis of variance, and comparisons were made with reference to the average of the nine control plots.

LITERATURE REVIEW

Stapledon and Beddows (14) found that in orchard grass, nitrogen increased the production of seed, fertile tillers, total dry matter, the weight per 1000 seeds and the per cent of germination.

Gilbert (7) obtained largest yields of seed of Rhode Island bent grass from those plats on which fertilizers containing large proportions of nitrogen were applied.

Evans and Calder (5) found that applications of two cwt. and five cwt. of nitrochalk (12.5% N) gave increased seed yields of orchard grass, rye-grass, and timothy; and decreased seed yields of red fescue and meadow fescue. With orchard grass, early applications were better than late and in all instances seed yield was stimulated comparatively more than forage yield.

From their work with pedigree grasses, Evans and Calder further concluded that nitrogen stimulated the production of fertile tillers in rye-grass, orchard grass, timothy, and meadow foxtail; reduced the number of fertile tillers in red fescue; and on the whole, increased the weight per 1000 seeds; and tended to improve germination of grass seeds in dry years.

In a later report, Evans (4) confirmed this earlier work and further concluded that the effect of nitrogen was intensified in a dry year and in crops subsequent to the first harvest year. He found also that nitrogen increased the number of barren tillers in orchard grass, Italian rye-grass, meadow fescue, red fescue, and perennial rye-grass; but in timothy nitrogen "seems to have been efficacious in converting a larger number of barren tillers into seed producing tillers."

North and Odland (9) observed a consistent increase in seed yield of Rhode Island Colonial bent grass with increasing amount of nitrogen applied, but indicated that there was a limit to the amount that could be safely applied due to the danger of lodging. No consistent differences were apparent in the test weight per bushel due to the fertilizer applications.

Under Ohio conditions, Evans (6) obtained increases in yield of both seed and forage of timothy with applications of sodium nitrate. With increasing rates of application there

was a gradual decrease in additional amount of hay and seed for each pound of fertilizer used. The applications in May had a greater relative influence on seed yield than on forage yield. Eighty pounds of sodium nitrate per acre gave an increase in seed yield of 148% over the control, whereas 320 pounds were required to give as great a relative increase in hay yield.

In a review of the work of Nilsson-Leissner (8), Jones reported on the differential response to nitrogen fertilization between non-rhizomatous and rhizomatous types of grasses. Nitrogen produced marked increases in seed yield in the non-rhizomatous types; but, was not effective in the rhizomatous grasses.

In a study of the influence of nitrogen on brome grass seed production in Kansas, Aldous (2) found that 150 and 300 pounds of sodium nitrate increased the seed yield 78% and 167%, respectively, over the control.

Schmitz (12), Osvald (10), Sanders (11), Zahnley and Duly (18), Ahlgren (1), and others (4, 5, 6, 7, 9, 14) have shown that nitrogen fertilization tends to stimulate herbage production of grasses.

Whilson _et_. _al_. (16), working with corn, oats, and barley, and Voorhees (15), working with barnyard millet, found that nitrogen fertilization increased the protein content of the herbage. Wiancko and Walker (17) and Sprague and Hawkins (13) concluded that early applications of nitrogen increased

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the yield of hay, but had little influence on the protein content of timothy at the normal hay harvesting time. The latter two authors found that late applications of nitrogen produced marked increases in the protein content of timothy.

Blair (3) obtained results with timothy indicating that, while an application of 150 pounds of sodium nitrate gave increases in the yield of both seed and forage, the relative increase in seed yield was significantly higher than that of the forage yield.

CLIMATE

The monthly mean temperature and the total monthly precipitation from June 1937, to July 1939, are presented in Figures 1 and 2. The mean monthly temperature and total monthly rainfall during the two months just preceding the planting date are included. The daily rainfall during the months in which the fertilizer applications were made is listed in table I. Climatological data were taken from the U.S.D.A. Weather Bureau recording station at East Lansing, Michigan.

Figure 1. Average and normal monthly temperature from June 1937, to July 1939.

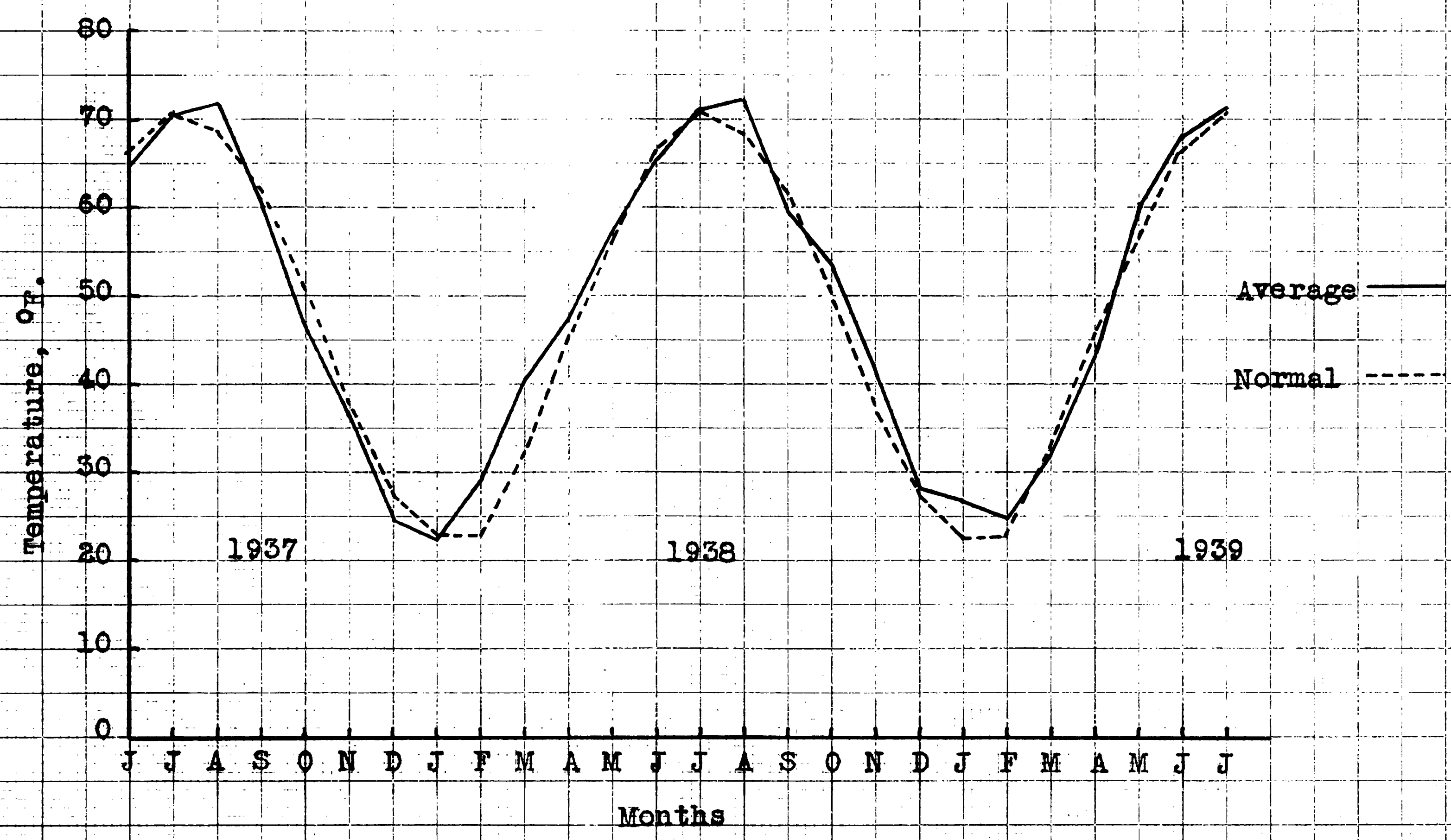
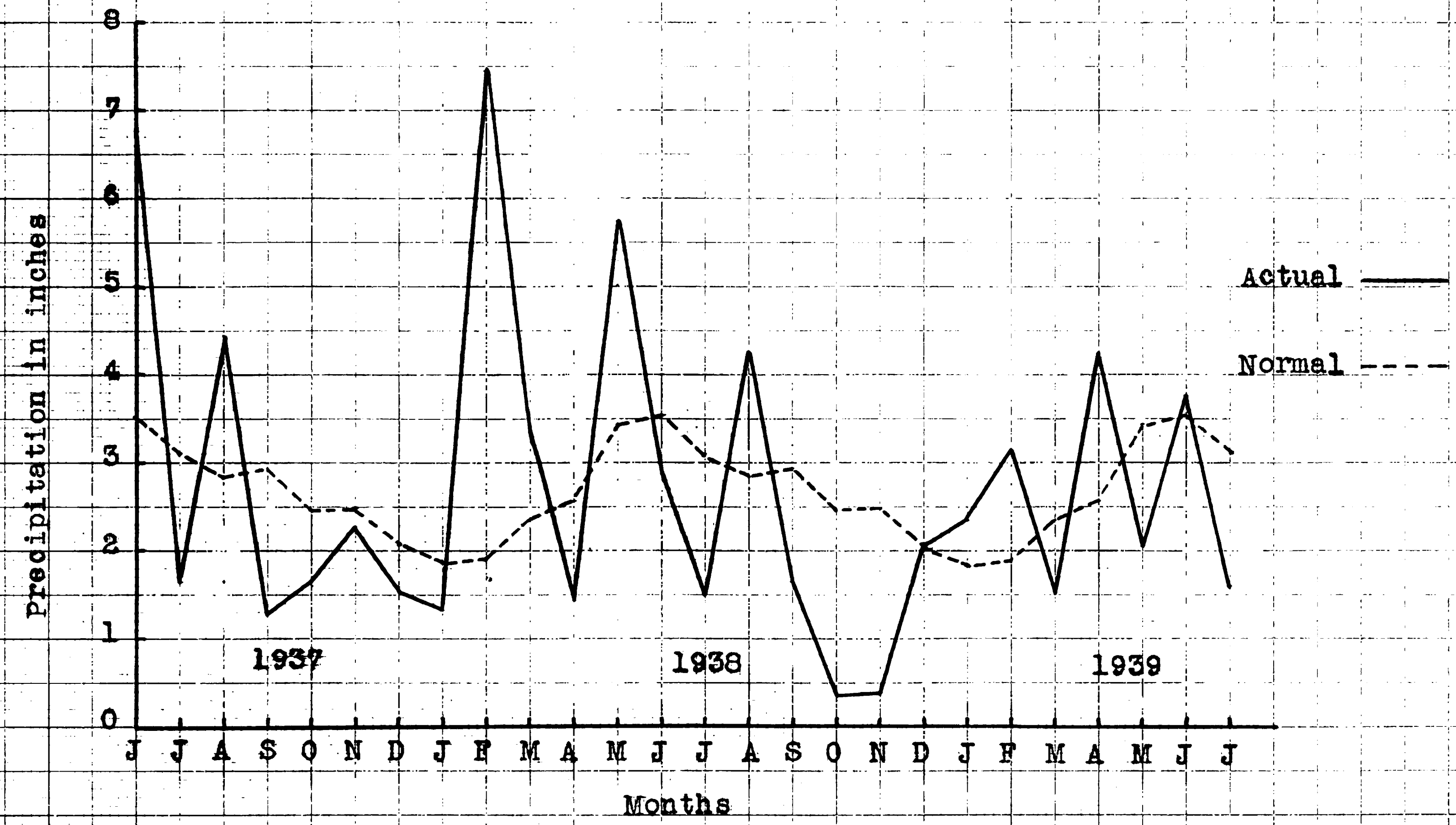


Figure 2. Monthly total precipitation from June 1937, to July 1939.



Daily rainfall during months in which
ammonium sulphate applications were made**

Table I.

	Inches of rainfall					
Day	April 1938	May 1938	June 1938	April 1939	May 1939	June 1939
1	T	0	T	.09	T	T
2	T	0	.01	0	0	.01
3	.30	.07	T	0	0	.13
4	0	0	.30	0	0	0
5	0	0	T	.11	0	0
6	.01	0	.62	T	0	0
7	0	T	.04	.11	T	.87
8	.91	.26	0	.10	.04	.09
9	0	.02	T	T	.48	.07
10	0	0	.19	.78	T	1.23
11	0	T	.12	.11	0	.04
12	T	0	0	.01	0	0
13	0	0	0	0	0	0
14	0	.65	0	.52	T	0
15	T*	.39	.05*	0	.15*	.01*
16	.04	0*	T	0	T	.02
17	T	.81	.03	1.37	T	0
18	T	.49	0	.25	0	.10
19	.02	.49	0	.24	0	.08
20	T	T	0	0	.34	.07
21	.03	.02	0	.46	.13	.18
22	0	0	0	0	T	.43
23	0	1.05	T	0	.15	0
24	.03	0	.55	0*	0	T
25	0	T	.03	0	0	0
26	0	.30	T	T	T	0
27	0	.08	0	T	.34	T
28	.08	1.09	0	0	.44	.36
29	T	.01	0	0	T	T
30	0	0	.95	.06	0	.08
31	---	0	---	---	0	---

*Dates of fertilizer applications.
**Data from the U.S.D.A., Weather Bureau, Lansing, Michigan

1938 EXPERIMENT

The applications of ammonium sulphate were broadcast between the rows of each plot. To decrease border effect, one foot at each end and the outside rows of all the plots were cut prior to seed harvest. The ultimate plots consisted of four twenty-foot rows.

The seed was hand-harvested August 20, dried 30 days at room temperature, and then threshed. The per cent of purity was based upon a random three-gram sample of the threshed seed. The seed yield data presented were calculated to a pure seed basis.

Immediately after the seed was harvested, the forage aftermath was mowed and the green weight taken. A representative sample was dried four days at 60°C. for dry matter determination.

The protein analyses were made by the Division of Agricultural Chemistry of the Michigan Experiment Station, and the data presented were calculated on a dry matter basis.

Table II shows that every rate of application of ammonium sulphate applied in April and May gave a higher yield of seed than the average of the control plots. Because of inconsistencies between replications, however, no increased seed yield was statistically significant when compared to the control. The applications of ammonium sulphate in June had little or no influence on seed production.

Table II. Data from the 1938 experiment showing (1) yield of seed, (2) yield of forage, (3) ratio of per cent increase in seed yield to per cent increase in forage yield, and (4) per cent of protein in the forage calculated to a dry matter basis. The tabular values are averages of the three replications.

Date and rate of application of ammonium sulphate	Seed yield lbs. per acre	Forage yield lbs. per acre	*Ratio, % incr. in seed to % incr. in forage	**Per cent protein, oven-dry forage
Control	50	989	----	9.23
April 15, 1938				
100 lbs./acre	60	1199	.90	----
250 " "	64	1106	2.25	9.49
500 " "	123	1738	1.93	9.75
750 " "	109	1713	1.62	----
1000 " "	139	2378	1.27	10.16
May 16, 1938				
100 lbs./acre	130	1666	2.35	----
250 " "	134	2116	1.48	10.62
500 " "	157	2679	1.85	9.55
750 " "	93	2835	.46	----
1000 " "	107	3465	.46	12.79
June 15, 1938				
100 lbs./acre	54	1463	.17	----
250 " "	55	1801	.12	10.02
500 " "	64	2712	.16	12.25
750 " "	41	2245	----	----
1000 " "	61	3185	.18	15.84
Difference required for significance P=.05	99	791		
P=.01	135	1078		

*Data was not statistically analysed
**Averages of duplicate determinations from 2 replications.

Applications of ammonium sulphate were influential in increasing the amount of vegetative growth at the time of seed harvest. The April treatments were least effective in stimulating vegetative growth; while the plots treated in May gave the highest yields of forage. A 1000-pound application

of ammonium sulphate in April was barely more effective in increasing forage yield than a 250-pound application in either May or June.

While all of the ammonium sulphate treatments were associated with increased percentages of protein in the forage at the time of seed harvest, the June applications were most effective, especially on those plots where the rates of application exceeded 500 pounds per acre. April applications were least effective in increasing the protein content of the forage at the time of seed harvest.

The ratios of increase in seed production to the increase in forage production in table II show that applications of ammonium sulphate in April, with the exception of the 100-pound rate, tended to stimulate seed production relatively more than forage production. Seed yield was similarly favored by the 100, 250, and 500 pound rates of application in May. Seven hundred fifty and 1000 pounds of ammonium sulphate applied in May favored vegetative growth. Applications of ammonium sulphate in June produced marked increases in vegetative growth but had little influence on the seed yields.

1939 EXPERIMENT

In order to study the influence of ammonium sulphate on brome grass which was in the second seed year, a new set of plots was established on an adjacent area in the same field. The plot design and rates of application of ammonium sulphate

were identical with that for the 1938 experiment.

Seed and Forage Yield

On July 20, the mature seed was hand stripped from the plots, dried four days at 100°F., and then threshed in a carefully adjusted small nursery thresher. A three-gram sample of the threshed seed was analysed for the per cent of purity. The yield and protein content of the forage were determined as in 1938.

Table III shows that the ammonium sulphate applied in April or May produced marked increases in seed and forage yields, and that there was a general increase in forage yield as the rate of application of ammonium sulphate increased. Ammonium sulphate applied in June had little influence on the seed or forage yields, and these plots were not visibly different from the untreated plots.

Of all the treatments in 1939, the 500-pound application of ammonium sulphate in April produced the greatest seed yield. It also gave the greatest increase in seed yield per pound of fertilizer applied. Seed yields resulting from the May applications of ammonium sulphate were generally less than the corresponding applications in April; and a decided decrease in seed yield was apparent on the plots receiving the 1000-pound applications in May. Lodging was evident on all the plots treated with more than 500 pounds per acre of ammonium sulphate

Table III. Data from the 1939 experiment showing (1) yield of seed, (2) yield of forage, (3) ratio of per-cent increase in seed yield to per cent increase in forage yield, and (4) per cent of protein in the air-dry forage. The tabular values are averages of the three replications.

Date and rate of application of ammonium sulphate	*Seed yield lbs. per acre	*Forage yield lbs. per acre	**Ratios,% increase in seed to % increase in forage yield	**Per cent protein, in air-dry forage
Control	356	2175	----	5.09
April 24, 1939				
100 lbs./acre	436	2607	1.10	4.04
250 " "	523	2917	1.38	----
500 " "	789	3594	1.86	6.56
750 " "	663	3951	1.05	----
1000 " "	742	4207	1.16	8.50
May 15, 1939				
100 lbs./acre	406	2140		4.87
250 " "	564	2614	2.90	----
500 " "	596	2807	2.31	7.00
750 " "	656	3400	1.50	----
1000 " "	537	3447	.88	10.25
June 16, 1939				
100 " "	327	2060	----	4.21
250 " "	484	2490	2.57	----
500 " "	364	2434	.17	6.06
750 " "	455	2677	1.22	----
1000 " "	472	2737	1.27	6.23
Difference required for significance P=.05	157	980		
P=.01	214	1330		

*A highly significant, remainder-term, coefficient of correlation, r = .811, was obtained between seed and forage yields.
**Data not statistically analysed.

in April or May; and this may account for the decreased seed yields with the heaviest rates of application. There were no apparent differences in the time of seed maturity between the treated and the untreated plots.

The ratios of per cent increase in seed yield to per cent increase in forage yield (table III) indicate that nitrogen stimulated seed production comparatively more than forage yield. The 1000-pound application of ammonium sulphate in May appeared to slightly favor forage production; but, as has been suggested, the seed yield from this treatment may have been low because of the excessive lodging. The ratios calculated from the yield of the plots treated in June have little value, as the yields of neither seed nor forage were significantly greater than the yields from the untreated plots.

On the plots treated in April or May, there was an apparent positive relationship between the amount of nitrogen applied and the per cent of protein in the forage at the time of seed harvest. Applications of ammonium sulphate in June, at the time of heading, were least effective in increasing the per cent of protein in the forage.

Tiller Production and Panicle Characteristics

The average number of fertile and barren tillers within an eight-inch quadrat placed at four predesignated points in each plot was considered a representative sample. One panicle was selected at random from each placing of the quadrat to determine the number of florets and spikelets per panicle. These counts were made just previous to seed harvest.

Table IV shows that while nitrogen fertilization had no apparent influence on the number of fertile tillers, the number of barren tillers bore a positive relationship to

Table IV. Data from the 1939 experiment showing (1) the number of fertile tillers, and (2) the number of barren tillers, per eight inches of row; (3) the number of spikelets per panicle; (4) the number of florets per spikelet; and (5) the calculated total number of florets per eight inches of row. The tabular values are the averages of the three replications.

Date and rate of application of ammonium sulphate	Number fertile tillers, per 8 inches of row	Number barren tillers per 8 inches of row	Number spikelets per panicle	Average number florets per spikelet	Calculated number florets per 8 inches of row
Control	47	39	38	4.43	7723
April 24, 1939					
100 lbs./acre	44	40	42	4.77	8571
250 " "	45	63	36	5.60	9618
500 " "	59	51	42	5.50	13569
750 " "	49	82	48	5.40	12049
1000 " "	50	105	41	5.93	11980
May 15, 1939					
100 lbs./acre	38	34	36	5.03	6843
250 " "	44	48	38	5.63	9275
500 " "	41	77	42	5.40	9124
750 " "	51	83	36	6.40	11780
1000 " "	34	98	40	6.13	8123
June 16, 1939					
100 lbs./acre	41	42	33	3.80	5318
250 " "	50	53	32	4.53	7929
500 " "	32	76	35	4.00	4353
750 " "	43	85	34	4.50	6637
1000 " "	50	99	36	3.90	7027
Difference required for significance P=.05	21	22	11	1.06	1960
P=.01	29	30	15	1.45	2666

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the amount of fertilizer applied, regardless of the date of application. The density of the stand, as measured by the total number of culms per eight inches of row, was increased by every rate of application greater than 100 pounds per acre.

The number of spikelets per panicle did not vary widely between treatments. The average number of spikelets per panicle on the plots treated in April was higher than the average of the controls; the average on the May treated plots closely approximated the controls; and the average number of spikelets per panicle on the plots treated in June was below that of the controls. A statistical analysis showed that the average number of spikelets per panicle on the April-treated plots was significantly higher than the comparable average on the plots treated in June, but that neither differed significantly from the average number of spikelets per panicle on the untreated plots.

All of the applications of ammonium sulphate in April or May increased the number of florets per spikelet over the average of the untreated plots, whereas, applications of ammonium sulphate in June produced no consistent increases in the number of florets per spikelet. The 750 and 1000-pound rates of application in May appear to have been slightly more effective in increasing the number of florets per spikelet than the corresponding treatments in April.

With the exception of the 100-pound May treatment, every rate of application of ammonium sulphate in April or

May increased the total number of florets per eight inches of row. The greatest number of florets were produced on those plots receiving 500 pounds of ammonium sulphate in April. The plots treated in June, in general, produced a slightly smaller total number of florets per eight inches of row than were produced on the untreated plots.

Coefficient of Fertility

The coefficient of fertility is the ratio of the actual yield of seed to the calculated yield of seed expressed in per cent, where the calculated yield is the product of the number of fertile tillers, the number of florets per panicle, and the weight per individual seed. These values are a measure of the numèrical per cent of the florets actually containing seed. The calculated number of florets which produced seed was obtained by multiplying the total number of florets per eight inches of row by the coefficient of fertility.

Table V shows that the rates of application had little influence on the coefficient of fertility; but that the June treatments resulted in coefficients of fertility consistently higher than the corresponding April or May treatments. A comparison between the data on the number of florets per spikelet (table IV) and the calculated coefficients of fertility infers that the fewer florets per spikelet, the greater the percentage of floret fertility. No determinations of the actual number of seeds per spikelet were made.

Table V. Data from the 1939 experiment showing (1) the calculated seed yield, and (2) the actual seed yield per eight inches of row; (3) the coefficient of fertility; (4) the per cent of seed in the hand-stripped unthreshed seed; and (5) the calculated number of florets per eight inches of row which produced seed. The tabular values are the averages of the three replications.

Date and rate of application of ammonium sulphate	Calculated seed yield in grams per 8 inches of row	Actual seed yield in grams per 8 inches of row	Average coefficient of fertility (%)	Per Cent seed in the stripped unthreshed material	Calculated number of florets per 8 inches, producing seed
Control	25.0	5.76	23.6	71.2	1773
April 24, 1939					
100 lbs/acre	28.8	7.05	25.0	72.0	2101
250 " "	33.9	8.46	25.0	74.1	2403
500 " "	47.4	12.77	29.0	72.5	3668
750 " "	42.9	10.72	25.0	73.8	3013
1000 " "	43.3	12.00	30.9	70.0	3305
May 15, 1939					
100 lbs./acre	23.1	6.57	28.6	72.1	1954
250 " "	31.7	9.13	31.1	74.8	2667
500 " "	32.3	9.64	30.4	75.3	2728
750 " "	41.4	10.61	25.6	73.1	3058
1000 " "	28.1	8.68	30.9	73.2	2501
June 16, 1939					
100 lbs/acre	18.2	5.28	32.5	74.5	1547
250 " "	27.5	7.82	32.6	74.6	2255
500 " "	15.3	5.89	41.1	73.8	1673
750 " "	24.4	7.36	32.9	76.3	2017
1000 " "	25.3	7.63	31.7	77.1	2120
Difference required for significance P=.05	14.3	2.53	11.3	3.5	771
P=.01	19.5	3.46	15.4	4.8	1052

A question may be raised as to the reliability of the data on the tiller and floret counts from such small samples as were taken (pg. 14). If the values obtained from the sample counts were representative of the respective plots, there should exist a positive relationship between the actual and the calculated seed yield. The data was statistically analysed and a coefficient of correlation, r = .52, significant at the two per cent point, was obtained.

The seed, as it was stripped in the field at the time of harvest, contained, for the most part, only sterile florets as impurity. The per cent of seed in this stripped material should be somewhat complementary to the coefficient of fertility. Table V shows that, as was true with the coefficient of fertility, the June-treated plots were associated with floret fertility, higher than that of either the April- or May-treated plots. The table likewise shows that a close positive relationship existed between the actual seed yield and the calculated number of florets which produced seed.

Seed Quality

Five hundred seeds were counted at random for each lot of seed used for purity analysis and weighed on a fine balance to determine the weight per 1000 seeds.

Because of the bulkiness of brome grass seed in relation to its weight, a modification of the standard test weight procedure was necessary. With the funnel open and in place two inches above the top of the kettle, the seed was passed

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Five hundred seeds were counted at random for each lot of seed used for purity analysis and weighed on a fine balance to determine the weight per 1000 seeds.

Because of the bulkiness of brome grass seed in relation to its weight, a modification of the standard test weight procedure was necessary. With the funnel open and in place two inches above the top of the kettle, the seed was passed

through a one-half inch mesh screen placed inside the funnel five inches above the outlet. The kettle was filled until the excess seed accumulated above the kettle to the funnel outlet. The seed in the kettle was then leveled by slowly passing a piece of rigid sheet metal horizontally across the surface of the kettle; at the same time raking the surplus seed onto the metal sheet with a serrated blade longer than the width of the test weight kettle. This technique permitted of an accuracy within 0.3 of a pound per bushel between duplicate tests.

Since the purity of the samples was not uniform the test weights were corrected to a 100 per cent pure basis by the formula,

$$\frac{T \times P \times I}{I - (T \times D)} = Ct \quad \text{where:}$$

T = Test weight of the impure sample
P = Per cent purity of the sample
I = Test weight of the impurity in the sample
D = Per cent of impurity in the sample
Ct = Calculated test weight of pure seed in the sample

In the calculations to adjust the test weight to a 100 per cent pure basis, the impurity was assumed to be uniform in all the samples, and to be similar to that which was removed in the cleaning of the seed.

When impurities obtained from the cleaning process was added to a sample of pure seed, trials showed that the test weight of the seed varied inversely with the amount of impurity

in the sample (Table VI). From the test weight of the sample of pure seed and the test weight of a sample of known purity, the test weight of the impurity at the percentage level of the sample of known purity was calculated. Values for the test weight of the impurity in table VI were obtained by solving for "I" in the test weight adjustment formula. The test weight of the impurity in all of the seed yield samples was interpolated from a curve plotted from values of "I" calculated from a uniform sample of seed adjusted to a known percentage of purity by adding the required amount of impurity.

Table VI. The test weight of brome grass seed, and the calculated test weight of the impurity in a sample; as they vary with known percentages of purity.*

Per cent purity of the sample	Average test weight per bushel	Calculated test weight of impurity (I)
100	16.1	----
99	15.75	5.0
98	15.4	4.9
97	15.0	4.7
96	14.6	4.5
95	14.2	4.4
94	13.9	4.4
93	13.6	4.4
92	13.3	4.4
91	13.0	4.4
90	12.7	4.4
80	10.3	4.1
70	8.7	4.2
50	6.2	3.8
25	4.7	3.8
0	3.6	3.6

*Averages of duplicate test weight determinations.

The per cent of germination was based on duplicate samples of 100 seeds, germinated at 25° C. for nine days, between moist blotters in a controlled-humidity germinator. Adequate facilities for the germination of grass seed were not available, consequently the values obtained were low. Since the tests were performed under similar conditions, the values were considered comparative. Duplicate germination tests on a composite sample of the seed when tested by the Michigan state seed analyst, germinated 97 per cent.

Table VII shows that, in this experiment, every application of ammonium sulphate produced weights per 1000 seeds greater than those from the control plots. The various applications of ammonium sulphate in each month responded similarly; but, in general, the June treatments were most effective in increasing the weight per 1000 seeds. Applications of 100, 250, 500, 750, and 1000 pounds of the fertilizer applied in June produced respectively, five, seven, nine, 13 and 11 per cent increase in seed weight, as compared to the control. In May and June, the 1000 pound rates of application of ammonium sulphate were less effective than the 750 pound applications.

Ammonium sulphate applied in April or May had little influence on the test weight per bushel of the seed produced. On the other hand, ammonium sulphate applied in June produced marked increases in the test weight of the seed. All of the applications in June greater than 100 pounds per acre were

about equally effective in increasing the test weight per bushel.

Table VII. Data from the 1939 experiment showing (1) the weight per 1000 seeds, (2) the test weight per bushel, (3) the per cent of germination, and (4) the per cent of purity of the seed. The tabular values are averages of the three replications.

Date and rate of application of ammonium sulphate		Weight per 1000 seeds. gm.	Test weight per bushel pounds	Per cent of germination	Per cent of purity
Control		3.25	14.7	73.8	95.2
April 24, 1939					
100 lbs./acre		3.36	13.4	68.7	94.5
250 " "		3.52	14.7	67.5	96.2
500 " "		3.48	14.3	73.4	96.4
750 " "		3.58	14.1	72.0	96.7
1000 " "		3.63	15.1	75.0	95.8
May 15, 1939					
100 lbs./acre		3.36	15.0	73.7	96.5
250 " "		3.42	14.8	77.2	96.6
500 " "		3.53	14.3	75.8	97.5
750 " "		3.52	15.0	79.0	97.1
1000 " "		3.47	14.0	75.2	95.0
June 16, 1939					
100 lbs./acre		3.41	15.7	72.5	96.5
250 " "		3.49	16.8	80.0	97.4
500 " "		3.53	16.7	78.5	96.3
750 " "		3.66	17.1	79.5	96.8
1000 " "		3.60	17.0	77.2	97.7
Difference required for significance	P=.05	.12	1.2	7.3	1.8
	P=.01	.16	1.7	10.0	2.5

The rate of application of ammonium sulphate had little influence on the per cent of germination; although there appeared to be a slight general increase in germination with the May and June fertilizer treatments. The per cent of purity was generally improved with the applications of ammonium sulphate, especially when the fertilizer was applied in May or June.

RESIDUAL INFLUENCE OF THE 1938 TREATMENTS ON THE 1939 CROP

The plots which were treated in 1938 were maintained to study the residual influence of nitrogen applications upon the subsequent season's growth. These plots were kept free from weeds, and no further treatment was applied in 1939. All of the methods of analysis in this experiment were identical with those in the 1939 experiment.

The data in table VIII shows that the plots which were treated with 750 and 1000 pounds of ammonium sulphate per acre in June 1938 were the only ones which produced seed yields materially above the average yield from the untreated plots. Throughout the growing period in 1939, these plots were visibly taller and had a more dense stand (i.e., more culms per unit length of row) than the other plots.

The yields of forage in 1939 were significantly increased by the 1000 pound application of ammonium sulphate in April, 1938, the 750 and 1000 pound applications in May, 1938, and the three highest rates of application in June, 1938.

The data on the protein content of the forage in table VIII, while not conclusive, suggest an inverse relationship between the rate of application of ammonium sulphate in 1938 and the protein content of the forage at the time of seed harvest in 1939.

While the rate of application of ammonium sulphate in 1938 had little influence on the test weight in 1939, the test weight of the seed from the plots treated in June 1938 was

Table VIII. Data from the study of the residual influence of the 1938 fertilizer treatments on the 1939 crop showing (1) seed yield, (2) forage yield, (3) protein content of the forage (4) test weight per bushel of seed, (5) weight per 1000 seeds, and (6) per cent of germination. The tabular values are averages of the three replications.

Date and rate of application of ammonium sulphate	Seed yield lbs./acre	Forage yield lbs./acre	*% protein in air-dry forage	Test weight per bu.	Weight per 1000 seeds, gms.	Per cent of germination
Control	334	1540	5.09	14.9	3.22	66.0
April 15, 1938						
100 lbs./acre	319	1633	5.00	14.3	3.17	67.0
250 " "	360	1727	----	14.6	3.20	66.0
500 " "	364	1913	4.91	14.1	3.19	63.5
750 " "	276	1470	----	15.1	3.18	67.5
1000 " "	338	2123	4.87	14.6	3.23	65.5
May 16, 1938						
100 lbs./acre	316	1867	5.00	15.1	3.17	67.8
250 " "	261	1727	----	14.9	3.19	63.3
500 " "	309	1797	4.61	14.7	3.18	71.5
750 " "	336	2147	----	14.5	3.21	65.8
1000 " "	378	2380	3.99	14.4	3.20	63.0
June 15, 1938						
100 lbs./acre	299	1517	5.00	14.1	3.16	68.7
250 " "	321	1470	----	14.7	3.19	60.3
500 " "	348	2100	4.21	14.6	3.18	59.8
750 " "	475	2497	----	14.4	3.19	63.8
1000 " "	495	2127	3.69	14.1	3.07	54.0
Difference required for significance P=.05	92	443		1.0	.09	11.6
P=.01	126	607		1.3	.12	15.8

*No statistical analysis of the data was made.

generally lower than that of the seed from the corresponding plots treated in April or May.

With one exception, applications of ammonium sulphate in 1938 had no material influence on the weight per 1000 seeds or the per cent of germination of the seed harvested in 1939. Both the weight per 1000 seeds and the per cent of germination of the seed from the plots receiving 1000 pounds of ammonium sulphate in June were significantly lower than the average of the controls.

Relationship Between Seed Yield and Cost of Fertilizer In 1939

The data on the seed yield from the 1939 experiment in table IX show that, on an acre basis, fertilization with ammonium sulphate increased the value of the seed yield from $35.60 on the untreated plots to as much as $78.90 on the plots receiving 500 pounds of the fertilizer per acre in mid-April; while the cost of the fertilizer was but $17.00 for the 1000 pound rate of application. Every application of ammonium sulphate in April or May in 1939 was profitable; but the June treatments did not in general pay for the fertilizer applied.

Table IX. The seed yield and the profit in dollars per acre resulting from the applications of ammonium sulphate fertilizer in 1939* The tabular values are averages of the three replications.

Date and rate of application of ammonium sulphate	Seed Yield lbs. per acre	Increase in seed yield lbs./acre	Value of increased yield per acre	Fertilizer cost per acre	Profit from fertilizer treatment per acre
Control	356	----	----	----	----
April 24, 1939					
100 lbs./acre	436	80	8.00	1.70	6.30
250 " "	523	167	16.70	4.25	12.45
500 " "	789	433	43.30	8.50	34.80
750 " "	663	307	30.70	12.75	17.95
1000 " "	742	386	38.50	17.00	21.60
May 15, 1939					
100 lbs./acre	406	50	5.00	1.70	3.30
250 " "	564	208	20.80	4.25	16.55
500 " "	596	240	24.00	8.50	15.50
750 " "	656	300	30.00	12.75	17.25
1000 " "	537	181	18.10	17.00	1.10
June 16, 1939					
100 lbs./acre	327	----	----	1.70	----
250 " "	484	128	12.80	4.25	8.55
500 " "	364	8	.80	8.50	----
750 " "	455	99	9.90	12.75	----
1000 " "	472	116	11.60	17.00	----

*The seed was valued at 10¢ per pound; the fertilizer cost at $34.00 per ton.

DISCUSSION

Ammonium sulphate applied during the first seed year in mid-April or mid-May of 1938 appeared to have a slightly more beneficial effect on the seed yield than did similar applications in mid-June; but no rate of application was significantly more effective than another. The May-treated plots in general produced slightly more seed than the corresponding plots treated in April. The treatments in April 1938 were least effective in stimulating the yield and protein content of the forage; therefore, it is suggested that perhaps much of the stimulating effect of the nitrogen in these treatments was dissipated in the drainage water, since the fertilizer was applied too early in the season for the seedling grass plants to take up or utilize the soluble nitrogen.

On the plots established in 1939, when the brome grass plants were in the second seed year, all of the applications of ammonium sulphate in April or May greater than 100 pounds per acre resulted in seed yields significantly greater than the control. The fertilizer applications in April were generally more effective than in May, while the treatments in June resulted in seed yields only slightly above the average of the untreated plots. In 1939 the plants had developed root systems large enough so that the fertilizer put on in April was taken up to a much greater extent than it was in 1938, when the grass plants were in the seedling stage of development.

Regardless of the date or rate of application of ammonium sulphate in 1939, a close positive relationship existed between the seed and forage yields. (See footnote, table III).

Plants must possess photosynthetic tissue in order for food storage to take place. In general when all of the green tissue is removed from perennial plants, the "recovery growth" temporarily causes an exhaustion of the previously stored foods; while the greatest food storage occurs when comparatively large amounts of chlorophyll-bearing tissue are present. Seed production in grasses is a form of food storage and consequently does not take place until food materials, in excess of vegetative growth requirements, are manufactured by the photosynthetic tissue. The data from this experiment indicate that the yield of seed depended upon the amount of chlorophyll-bearing tissue produced throughout the growing season. The ammonium sulphate applications had little influence on the number of fertile tillers, whereas it did result in marked increases in the number and size of the barren tillers. A comparison of the data from the tiller counts with the data on the forage yields, (table III) indicates that size was more important than the total number of tillers, in determining the yield of forage at the time of seed harvest. This relationship suggests that not only the carbohydrates manufactured by the increased area of green tissue on the seed bearing culms, but also a portion of that manufactured in the barren stems was available for storage in the seed producing culms.

While it was true that the plots which received the heaviest applications of ammonium sulphate produced the greatest amount of foliar tissue, they did not necessarily produce the greatest seed yields. Extreme lodging resulted from the rank vegetative growth on these plots, and this probably interfered with the normal development of seed.

The yield of seed bore a close positive relationship to the calculated number of florets which produced seed, so it was evident that the nitrogen fertilization either directly or indirectly stimulated the development of florets which did not develop without the addition of nitrogen. The plots receiving 500 pounds of ammonium sulphate in April produced the greatest number of florets per eight inches of row, the greatest number of florets which produced seed, and the greatest seed yield.

The total number of florets per eight inches of row on the plots treated in June was generally less than that on the untreated plots, while the seed yield, with one exception, was slightly higher. The June applications of ammonium sulphate were made at heading time when normal food storage had begun. The nitrogen applied stimulated vegetativeness at the expense of reserve carbohydrates and resulted in a partial depletion of the carbohydrate food reserves. As a result, some of the floret primordia which would have developed failed to do so because of this return to a vegetative condition of the plants. The higher coefficient of fertility, the increased weight per

1000 seeds, and the comparatively high test weight per bushel of seed obtained from the plots treated in June probably compensated for the decrease in the number of florets produced when compared to the controls.

From the study of the residual influence of ammonium sulphate on the succeeding season's growth, it was observed that only the heaviest rates of application in 1938 resulted in seed and forage yields in 1939 materially greater than the yields from the untreated plots. It is inferred that part of the fertilizer remained in the soil throughout the season, or was stored in the plants in the fall, to become utilized by the plants after the inception of growth in 1939. The prolonged period of drought during the fall of 1938 (fig. 2) favored such a condition.

SUMMARY

Three sets of plots of smooth brome grass were fertilized with ammonium aulphate at five different rates of application: one set of plots was fertilized in April, a second in May, and a third in June. The experiment was carried out during the first seed harvest year, and repeated on a new set of plots during the second seed harvest year.

Ammonium sulphate applied in April or May of the first seed year resulted in seed yields greater than the controls: whereas the same fertilizer applied in June did not consistently

stimulate seed yields. In the second seed year, applications of ammonium sulphate in April resulted in marked increases in seed yield when compared to the control. The May applications were generally not as effective as those in April, while applications in June resulted in seed yields only slightly greater than the control.

Lodging was evident with the highest rates of application of nitrogen in June in the first seed year, and in April and May in the second seed year.

There were no apparent differences in the time of maturity of the seed between the treated and the untreated plots.

Forage production was stimulated most by the applications of ammonium sulphate in May in the first seed year, whereas April applications resulted in the greatest increases in forage yield in the second seed year.

The number of fertile tillers and spikelets per panicle were only slightly influenced by the applications of ammonium sulphate: whereas, the number of barren tillers and florets per spikelet were significantly increased.

The applications in June were most effective in improving the quality of the seed, as measured by the weight per 1000 seeds, the test weight per bushel, and the per cent of germination.

In both years of the experiment the protein analyses showed that the protein content of the forage at the time of

seed harvest consistently increased as the rate of application of ammonium sulphate increased. June was the most effective date of application in the first seed year: whereas, in the second seed year, the percentage of protein in the forage was highest from those plots treated in April and May.

Heavy applications of nitrogen in May or June in the first seed year were associated with increased seed and forage yields in the second seed year when no further treatment was applied. The protein content of the forage, the weight per 1000 seeds, and the per cent of germination were slightly reduced in the second seed year on those plots receiving the heaviest rates of application in June of the first seed year. No residual influence of the 100 or 250 pound rates of application in the first seed year was apparent in the second seed year.

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