THE EFFECT OF CERTAIN NITROGENOUS FERTILIZERS ON THE GROWTH BEHAVIOR OF BROMEGRASS (BROMUS INERMIS LEYSS) AS INFLUENCED BY RATE OF APPLICATION

by

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B. S., Kansas State College
of Agriculture and Applied Science, 1948

A THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE COLLEGE
OF AGRICULTURE AND APPLIED SCIENCE

1949

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INTRODUCTION

Increasing attention has been given in recent years, particularly during and since the first World War, to the improvement of pastures and to their composition.

In the past, most of the work with fertilizers has been with cash crops, relatively little attention being given to the improvement of grass and other forage crops by fertilization.

When fertilized with nitrogen, early pasture grasses in Kansas have been found to contain from 10 to 15 per cent crude protein on the dry basis. Not only is this early pasture grass rich in digestible protein, but it is also rich in minerals and vitamins so essential to a well balanced ration. Well fertilized pasture grasses when three to five inches in height compare favorably in feeding value with bran, pound for pound, on the dry basis.

One pound of nitrogen applied as fertilizer to grass, if all were recovered, would produce about six pounds of grass protein. Chapman (1947) stated that under favorable soil moisture conditions it is possible to recover in the form of protein feed about 75 per cent of the nitrogen applied.

If rainfall in the spring is insufficient to make possible the conversion of all this nitrogen, it normally remains in the soil and becomes available with late summer and fall rains, or may even be carried over to the following spring.

Bromegrass (Bromus inermis Leyss), the leading cultivated grass in the eastern half of Kansas, is one of our important cool season grasses, especially well adapted to a cool subhumid-climate. It was introduced into the United States about 1884 (Whitman, 1941) and has been grown extensively in this country. According to Newell and Keim (1943) the earliest recorded importation of seed was made by the California Agricultural Experiment Station, from Hungary through France.

Bromegrass has extended the grazing season of the Midwest from two to four months. Native pastures can often be deferred until after the first of June by the early grazing of bromegrass. In many years it is possible to harvest a seed crop after early pasturing.

After three to five years in a pure stand bromegrass will become "sod-bound". This condition is characterized by yellow dwarfed plants of low productivity. The chief cause of this condition is a depletion of the supply of available nitrogen. In densely sodded areas this occurs more quickly because the soil is completely filled with feeder roots of the grass which remove large quantities of the nitrogen from all portions of the soil.

Fertility in the soil will delay the appearance of the condition. The use of a legume such as alfalfa in a planting with bromegrass is often an effective method of delaying the appearance (Frolick and Newell, 1941). The use of nitrogenous fertilizers will overcome the condition and will increase the yield of forage and seed.

For the most part the response of bromegrass to nitrogen has been studied from the standpoint of top growth and seed yield. Newell and Keim (1943) has shown marked increases in forage yield, per cent protein in the forage, and yield of bromegrass seed as a result of nitrogen applications.

Various investigators, Enlow and Coleman (1929), Dodd (1935), McClure (1929), Gardner (1939), Eheart and Ellett (1941), and Ahlgren et al. (1944), have reported increases in both dry matter and per cent of protein in the forage resulting from applications of nitrogen to native grasslands.

Although considerable work has been reported relative to the effects of nitrogen on the root system of grasses, information on this subject is much more limited than on the response of the above ground part of the plant.

Most of the results reported on thus far have been on application of fertilizers on established stands of grasses. Preliminary investigation at the Kansas Agricultural Experiment Station has indicated that under greenhouse conditions bromegrass responds to phosphorus fertilizer applied at the time of seeding.

An important feature of our soil management systems is the use of nitrogen fertilizers for meeting the crop's nitrogen requirements. Because fertilizer materials increase the production and improve the quality of crops, they have become an essential element in farming in all countries practicing modern agricultural methods. It probably is true that there has never been a greater need than now of aiding farmers to secure maximum returns from fertilizer materials.

It was the purpose of this study to determine the effect of various nitrogen and phosphate fertilizers upon bromegrass, considering seed and forage yield and root development. These factors were studied in the greenhouse and under field conditions.

REVIEW OF LITERATURE

The effect of fertilizers on grasses has been studied by many investigators. Brown, at the Connecticut Experiment Station, has published numerous papers on the effects of fertilizing and management on pastures. With regard to the effects of fertilizer treatments on the seasonal production (1932), the results over a five year period showed that total production was greatly increased by fertilizing.

Vinall and Hein (1933) published the results of fertilizer experiments on grasses and legumes at the Beltsville Station, Maryland. On a pasture mixture, fertilizer produced more dry matter in four out of five months on Kentucky bluegrass pasture but did not markedly change the seasonal trend with the highest production in May.

In 1935, Dodd (1935) reported on the results of 141 tests over a four year period in Ohio on the effect of nitrogenous fertilizers on Kentucky bluegrass pastures receiving also phosphate and potash. The average annual increase for the nitrogen treated plots compared with the mineral plots was 863 pounds dry matter per acre for the 25 pound application of nitrogen and 1,622 pounds for the 50 pound application. The returns of dry matter per pound of nitrogen were thus 34.5 pounds and 32.4 pounds.

Dodd concluded that grass fertilized with nitrogenous fertilizer was more palatable and was grazed more closely than grass receiving no nitrogen. Nitrogenous fertilizers applied in early spring increased production, not only in early spring but throughout the season as indicated by regular and mechanical harvests. A second or third application of nitrogen later in the season materially increased autumm growth. The law of diminishing returns from increased applications of nitrogenous fertilizers appeared to operate at a much higher level than had been generally assumed and the rate of application of such fertilizers up to at least 60 pounds nitrogen per acre should in general practice be determined largely by the amount of pasture required.

Munsell and Brown (1939) reported on the effect of eight different nitrogenous fertilizers on pure stands of Kentucky bluegrass, Poa pratensis and Rhode Island Bent, Agrostis tenuis. Only ammonium carbonate gave no significant increase in total nitrogen over the no-nitrogen plots. There were no differences among the other seven fertilizers.

The percentage recoveries of nitrogen as averages over two seasons on Kentucky bluegrass were sulphate of ammonia 40, nitrate of soda 41, calcium nitrate 48, calnitro 41, cyanamid 25, and urea 25. On the Rhode Island Bent, the recoveries were sulphate of ammonia 53, nitrate of soda 53, calcium nitrate 60, calnitro 63, cyanamid 41, and urea 46. In all cases the applications contained 84 pounds nitrogen per acre per annum.

Shutt et al. (1932) in Canada, obtained an average yield of 4,046 pounds dry matter per acre containing 832 pounds crude protein over a five year period on fertilized pasture cut every three weeks. In a later publication (1934) the results of an experiment with increasing amounts of nitrate of soda (15 per cent nitrogen) on a thick uniform sward of Meadow Foxtail Alopecurus pratensis was reported. For five years four plots received 160 pounds nitrate of soda, 350 pounds superphosphate and 160 pounds muriate of potash per acre per annum. The plots were then re-arranged and nitrate of soda applications in one, two, three and four dressings, each at 160 pounds per acre were compared for two years. The average results in pounds per acre were: one dressing 2,537 pounds dry matter and 549 pounds protein; two dressings 2,878 pounds dry matter and 628 pounds protein; three dressings 3,036 pounds dry matter and 658 pounds protein and four dressings 8,252 pounds dry matter and 723 pounds protein.

The results of fertilizing permanent pastures in Germany with nitrogenous fertilizers were reported by Zorn and Christoph (1927). Part of the pasture received urea at the rate of 60 kg nitrogen per hectare (53.4 pounds per acre); part received 120 kg per hectare (106.8 pounds per acre) and part was unfertilized. All areas received the same amounts of phosphate and potash. Milk cows grazed as the "first line", followed by young stock and colts.

The production was expressed in terms of starch values. The unfertilized area produced 934.6 kg starch value; 60 kg nitrogen as urea, 1,277.1 kg; 60 kg as calcium nitrate, 1,208.7 kg while the area receiving 120 kg nitrogen as urea produced 2,017.6 kg starch value per hectare.

The effect of fertilizer applications on Paspalum dilatatum and carpet grass, Axonopus affinis, with and without legumes was studied by Lovvorn (1944) at the North Carolina Experiment Station. In these experiments on two soil types, the response to applications of phosphates and potash was low but the response to nitrogen was marked. On the Norfolk fine sandy loam Paspalum dilatatum over five seasons produced from 18.9 to 21.5 pounds air dry matter per pound of nitrogen, and Carpet grass from 19.3 to 20.9 pounds per pound of nitrogen. On the Lynchburg fine sandy loam Paspalum dilatatum over three seasons gave a return of 12.4 pounds air dry matter per pound of nitrogen.

It was found that there was little response to nitrogenous fertilizers after legumes were established in pasture mixtures.

The roots of grasses have commanded the attention of investigators for many years. Much of the early work was in the form of descriptions and habits of root systems. TenEyck (1904) and Weaver (1920) described the root system of bromegrass. This early work has led to the study of various factors which affect the root systems of plants.

The root system of a plant includes all its roots considered collectively. The root system of a given species, in its general appearance can be distinguished from that of another type of plant. Weaver (1926) stated that the general characters of the root systems of species are often as marked and distinctive as are those of the aerial vegetative parts.

The general behavior of roots in the soil is the resultant of the influence of many factors, the most important of which are moisture, nutrients, oxygen supply, temperature, physical texture of the soil, light, and gravity. A knowledge of root competition under different natural and cultural conditions is not only of much practical value but also it readily finds numerous scientific applications.

Hays (1889) obtained useful information on the development of corn roots by washing away the soil with water. King (1893) devised a new method of washing the soil from roots. An isolated prism of soil was surrounded by poultry wire netting. Sharpened wires were pushed through the prism of soil and netting to hold the roots while washing away the soil. Plaster of Paris was then poured on the top surface to hold all plants in place.

A different method was devised by Laird (1930) in his studies in Florida. Perforated iron cylinders eight inches in diameter and 40 inches long were constructed from 12 gauge sheet iron. This sleeve was then driven into the soil to obtain root samples. From his studies with Bermuda, Centipede, and St. Augustine grass he concluded that mowing often enough to prevent seed formation not only increases the root development, but also produces a better sod than does non-mowing.

Studies to determine the time of year new roots are produced on perennial grass plants were made by Stuckey (1941). The behavior of all species tested was much alike for the first year. The seminal roots remained alive six to eight weeks, and were gradually replaced by adventitious roots from the plant crown. Some species reproduce the entire root system each year, with an active production of new roots beginning in October, continuing slowly through the winter months and increasing rapidly after the first spring thaw, with maximum growth in April. Few if any roots are produced after June. Most of the old roots disintegrate soon after the new ones develop. Species in this group include timothy, meadow fescue, perennial rye grass, colonial bent and redtop. With other species the development of roots was essentially the same as described above, but only a small percentage of the roots disintegrated each year. Only a few new roots were developed after the first season except at the nodes of rhizomes. Species with "perennial" roots are Kentucky bluegrass, Canada bluegrass, orchard grass, and crested wheatgrass.

Biswell and Weaver (1933) reported on experiments indicating that for at least several weeks in the spring, all, or nearly all, of accumulated storage material was used by the growing shoots and only after these were fairly well established were new roots developed. If topgrowth were removed at this time the development of roots was greatly retarded.

Stevenson and White (1941) found that 87.75 per cent of the roots of bromegrass were produced in the first foot of soil, seven per cent in the second foot, and a decreasing percentage as depth increased to five feet. Of the roots in the top foot, 50 per cent were concentrated in the first three inches, about 25 per cent in the three to six inch depth, 15 per cent in the six to nine inch depth, and 10 per cent in the nine to 12 inch depth. They found that bromegrass continues to build up fiber year after year at a fairly rapid rate. A ten year old field has produced 8803 pounds of root fiber per foot per acre. The total increase in weight with ageing of stand took place uniformly throughout the top foot of soil.

Turner (1922) reported that the increased ratio of stems to roots which results from increasing the amount of nitrate in the soil may be explained on the basis of increased use of carbohydrates in the tops because the greater nitrogen supply makes for greater growth. This results in a decrease in the supply of carbohydrates for the roots which may bring about an absolute or a relative reduction of root growth.

Bell and DeFrance (1944) reported on the effect of fertilizer treatment upon root accumulation, sod plugs were removed periodically during 1939 and 1940. The weight of roots in the plugs were then estimated. A steel tube seven-eights of an inch in diameter and eight inches long was used to take the sod plugs. The top inch of each plug was removed because of top growth and an accumulation of leaves and other material.

A gentle stream of water was sprayed on the plugs to remove the soil. After washing the roots were dried rapidly and placed in porcelain crucibles. The organic matter was completely ashed by igniting at a dull red heat. The loss on ignition was used to measure the organic portion of the roots in each plug. This is believed to be a more satisfactory method of estimating root weights than simply using dry weights, since dry weights include considerable fine sand which clings to the roots.

Haynes (1943) stated that an increase of roots near the surface and a decrease of roots below two inches was associated with surface application of nitrogen. He called attention to the importance of this increase in root concentration at the surface, in erosion control.

There has been considerable controversy regarding the cause of the so called "sod-bound" condition in bromegrass. Benedict (1941) grew plants in sand watered with nutrient solutions and found that when dried bromegrass roots were added to the sand, the yield of bromegrass was materially decreased. His results indicated that "sod-binding" of bromegrass might result from an accumulation of growth inhibiting substance in the soil.

Myers and Anderson (1942) concluded that excessive carbon in relation to nitrogen brought about by the continued growth of bromegrass probably was the cause of the so called "sod-bound" condition. They suggest deficiencies in soil fertility as possible causal factors responsible for the "sod-bound" condition.

Singleton (1946) reported that the immediate effect of applications of readily available nitrogenous fertilizer at the rate of 100 pounds nitrogen or more per acre to established stands of bromegrass has been a reduction in the amount of roots below the level of unfertilized plots. The end result of application of nitrogen has been an increase in the amount of roots by all rates of nitrogen. Applications of phosphorus had no effect on root development in the field.

Singleton also found that bromegrass seedlings gave significant responses to applications of phosphorus and greater response to combinations of phosphorus and nitrogen.

MATERIALS AND METHODS

Response of Bromegrass to Different Nitrogen Carriers and Phosphorus in the Greenhouse

In order to study the response of bromegrass to fertilizer treatment under greenhouse conditions, soil was obtained from an established field of bromegrass and brought into the greenhouse in December 1947.

In obtaining the soil the surface litter was removed and the upper six inches of soil taken for the experiment. The entire lot of soil was taken from one area in the field.

The root material of the bromegrass sod was removed, dried, run through a hammer mill, and returned to the soil. The soil was then put into glazed pots, seven inches in diameter at the top, and approximately nine inches deep. The soil was potted on a dry basis using 6.7 pounds of dry soil to each pot.

Fourteen fertilizer combinations with five replications of each were applied to the soil, making a total of 70 pots. Three nitrogen fertilizers were used at rates of 0, 100, and 200 pounds of elemental nitrogen per acre. Each nitrogen rate appeared with and without phosphatic fertilizer which was supplied at the rate of 80 pounds per acre of P_2O_5. The fertilizer was thoroughly mixed with the entire soil mass of each pot concerned. The source of phosphate was superphosphate (20 per cent P_2O_5). The three nitrogen fertilizers were ammonium nitrate (32.5 per cent nitrogen), calcium cyanamid (20.6 per cent nitrogen), and uramon (42 per cent nitrogen).

Bromegrass shoots or rhizomes taken from the same area as the soil were placed in a sand bed and allowed to grow for about four weeks and then transplanted, six to each pot. All plants that died in the first week were replaced with other plants. The five replications were placed in five separate blocks on a greenhouse bench. Pots were randomized within replications, and the arrangement within replications, as well as the arrangement of the blocks, was changed at each watering every three to five days.

The moisture equivalent was determined on the soil and the amount of water required for the soil in each pot was calculated. On this basis the pots were weighed every three to five days and water added as required to bring the soil up to its moisture equivalent.

A measurement of rate of growth was obtained by taking the length of the longest leaf of each plant in centimeters every seven days for seven weeks.

The top growth was clipped March 25, 1948 and again May 15, 1948. After the second clipping root yield was determined by washing the soil from the roots. The experiment was terminated at this date.

All material was dried at 98°C. for 24 hours and weighed to the nearest one-hundredth of a gram.

Response of Bromegrass to Different Nitrogen Carriers in the Field

In March, 1948 a series of fertilizer plots was established on the Agronomy Farm. The bromegrass was of the Achenbach strain and was seeded in the fall of 1946. The soil was low in fertility and was classified as Geary silty clay loam.

Ammonium nitrate, calcium cyanamid, and uramon were applied using four rates 0, 100, 200 and 300 pounds of the element nitrogen per acre. The series was laid out in three blocks and the treatments were randomized within the blocks as follows.

Block I					Block II					Block III				
A_2	CK	C_2	U_3	C_3	U_1	C_3	A_1	U_2	A_2	U_1	A_1	C_1	A_2	C_3
C_1	U_2	A_3	U_1	A_1	C_2	A_3	CK	C_1	U_3	C_2	U_3	CK	U_2	A_3

Treatments making up each block

A_1 - Ammonium nitrate, 100 lbs. N per acre
A_2 - " " 200 " " " "
A_3 - " " 300 " " " "
C_1 - Calcium cyanamid, 100 lbs. N per acre
C_2 - " " 200 " " " "
C_3 - " " 300 " " " "
U_1 - Uramon, 100 lbs. N per acre
U_2 - " 200 " " " "
U_3 - " 300 " " " "
CK - Unfertilized plots (check).

Yields of forage and seed were obtained in the spring of 1948. In taking forage yields, an area three feet by 12 feet was cut from each plot with a power mower having a three-foot sickle. The forage was cut about two inches above the ground, the weight of the forage from the clipped area was determined and a moisture sample weighed and placed in a kraft bag. After oven drying the moisture sample, the moisture per cent was determined for each plot and from this the yield of oven dry forage per acre was calculated.

Seed yields were obtained by harvesting all seed from an area of 12.5 square feet from each plot. After drying and threshing, the seed yield per acre was calculated.

On March 23, 1949 root samples were taken from the field series. The samples were dug with a sod cutter which removed a core of soil and roots three inches in diameter and five inches in depth. Five such samples were dug from each plot. Each sample was taken from an area which appeared to be representative of the plot concerned, and the sod cutter was placed directly over a bromegrass plant.

The soil was removed from the roots by washing with a fine spray of water over a 15-mesh wire screen. It was necessary to soak the cores of soil thoroughly to facilitate washing, and it was generally necessary to knead the soil with the hands during the washing. Water was sprayed over the roots until no evidence of soil remained. Some of the very fine roots escaped through the screen, but losses were low. The roots tended to form a mat on the screen which helped to hold those broken loose by the washing.

The roots were then dried at 98° C for 48 hours and the net weight recorded to the nearest one-hundredth of a gram.

CLIMATOLOGICAL DATA

Table 1 gives the daily precipitation at Manhattan from July 1, 1947 to July 1, 1948. Rainfall was deficient in July 1947 and a very warm period began July 26 that continued almost without a break for three months. Little or no growth was made on bromegrass. Fall yields on the fertilizer plots could not be taken due to insufficient growth.

1948 began with a three-month period of cold weather and heavy snows. This was followed by the warmest April on record and with warm and comparatively dry weather in May. Forage yields were taken on June 3 before the occurrence of heavy rainfall from June 15 to July 1. Although the weather of 1948 was abnormal, good responses were obtained from the fertilizer applications. There was no lodging of the bromegrass even on the heaviest nitrogen rates.

Table 1. Daily precipitation, Manhattan, Kansas, July, 1947 to July, 1948.

Days of Month	1947						1948					
	July	Aug.	Sept.	Oct.	Nov.	Dec.	Jan.	Feb.	Mar.	Apr.	May	June
1	-	-	-	T	T	-	.47	-	.07	.01	-	-
2	-	-	-	-	T	-	-	T	.85	-	.91	-
3	-	-	T	.80	-	.50	-	.13	T	-	-	-
4	-	-	-	-	T	1.21	-	.02	T	T	.01	-
5	.06	-	-	-	-	-	-	-	.17	-	-	-
6	T	-	-	-	-	-	-	T	.27	-	.09	-
7	-	.08	-	-	-	T	-	T	-	-	-	.06
8	-	-	-	.25	-	-	-	-	-	-	-	-
9	-	-	-	T	-	.60	-	-	-	-	-	-
10	-	-	-	-	.03	.01	-	T	.08	-	.06	-
11	T	-	.13	-	-	-	-	.05	.04	-	T	-
12	-	-	-	.13	-	-	-	.03	-	-	-	T
13	T	-	-	-	-	-	-	.05	-	T	-	-
14	-	.84	-	-	.38	-	T	-	-	-	-	-
15	-	1.23	-	-	.03	-	-	-	-	-	-	2.41
16	-	.32	-	T	-	T	-	-	T	-	-	-
17	T	-	-	-	.04	T	-	-	-	-	-	.17
18	.03	-	-	-	T	-	-	-	-	-	-	.10
19	-	-	-	-	T	-	-	-	.85	-	-	-
20	.01	-	-	-	.04	-	-	-	-	-	-	.92
21	-	-	.08	-	.13	-	-	T	T	-	-	1.02
22	-	-	-	-	.11	-	T	-	-	1.27	T	.03
23	-	-	-	.14	T	-	-	T	-	.35	.17	3.14
24	.36	-	-	.41	-	-	.02	.38	-	.07	1.42	-
25	.18	1.43	T	-	T	-	-	T	-	1.95	-	.28
26	-	.01	-	-	T	-	.05	-	.26	T	-	.01
27	-	-	-	-	-	-	-	1.67	T	T	-	.45
28	-	-	-	-	-	-	-	-	T	-	-	3.02
29	-	-	T	-	-	-	T	-	-	-	-	.07
30	-	-	.04	T	-	T	.05	-	-	T	.55	-
31	-	-	-	-	-	.35	T	-	T	-	.43	-
Total	.64	3.91	.25	1.73	.76	2.67	.59	2.33	2.59	3.65	3.64	11.68
Normal	3.99	4.28	3.94	2.08	1.81	.81	.68	1.25	1.64	2.64	4.40	4.40

EXPERIMENTAL RESULTS AND DISCUSSION

Greenhouse Experiment

Rate of Growth. Greenhouse studies indicated that the source of nitrogen has little effect on rate of growth. This is shown in Table 3 and illustrated by the graph in Fig. 1. Rate of growth was measured by determining height of plant each week in centimeters. There was significant difference among treatments as shown in Table 4; however, the growth rate of no one of the treated groups was better than the unfertilized plants. Growth rate was not affected by phosphorus, alone or in combination with nitrogen.

Calcium cyanamid may have retarded growth slightly after the fourth week as indicated by the graph in Fig. 1 although this difference was not significant in the analysis. Uramon appeared to produce more growth than the other carriers, these differences are not significant, however, except between uramon and cyanamid.

The 100 pound rate of nitrogen produced taller plants than the 200 pound rate as shown in Table 2.

Table 2. Effect of nitrogen rates on growth rate expressed in height of plant.

Fertilizer	Pounds nitrogen per acre	
	100	200
Ammonium nitrate	16.1	15.8
Calcium cyanamid	15.4	14.7
Uramon	16.4	15.8
Average	16.0	15.4

Table 3. Rate of growth of bromegrass in the greenhouse as affected by nitrogen and phosphorus fertilizer. *

Dates of Clipping	Carrier and Pounds N per Acre						
	Ammonium Nitrate		Cyanamid		Uramon		Check
	100	200	100	200	100	200	None
				No P_2O_5			
February 3	8.3	8.0	7.7	7.3	7.9	8.1	7.3
February 11	11.6	10.1	10.8	10.4	10.9	10.7	9.9
February 18	13.9	13.1	13.7	12.4	13.9	13.2	11.8
February 25	16.3	15.9	16.3	14.4	16.8	16.5	14.5
March 3	19.1	19.7	20.3	16.8	20.6	21.2	18.0
March 10	21.6	21.5	22.5	18.8	22.1	23.3	20.2
March 17	22.6	21.5	22.9	19.0	22.6	23.5	20.5
Average	16.2	15.7	16.3	14.2	16.4	16.6	14.6
				80 Lbs. P_2O_5			
February 3	7.9	7.8	7.6	7.3	7.8	7.6	7.5
February 11	11.2	11.0	10.0	10.0	10.0	10.0	10.0
February 18	13.0	13.0	12.0	12.9	12.6	12.7	12.4
February 25	16.1	15.8	14.3	15.6	15.7	15.3	16.0
March 3	19.2	19.9	17.8	18.7	20.8	18.6	19.1
March 10	21.6	21.7	19.9	20.8	24.2	20.2	22.3
March 17	23.0	22.0	20.0	21.0	24.5	20.8	22.3
Average	16.0	15.9	14.5	15.2	16.5	15.0	15.7

* Measurements are expressed as the average height of plants in centimeters for each treatment at seven dates.

Table 4. Analysis of variance of measurement data on height of bromegrass plants in the greenhouse.

Source of Variation	DF	SS	V
Total	489	15903.79	
Treatments	13	294.03	22.62 **
Treat. vs. check	1		20.92
Nitrogen rates	1		32.82 *
P_2O_5	1		15.16
Am. nitrate vs. cyan. & uramon	1		10.86
Cyan. vs. uramon	1		84.81 **
Interactions			
N rates X P_2O_5	1		6.34
N rates X P_2O_5 X C. vs. U.	1		90.86 **
Replications	4	344.12	
Dates of Clipping	6	12803.15	2133.86 **
Linear effect of clipping dates	1		9207.32 **
Quadratic effect of clipping dates	1		83.79 **
Interaction			
Treat. X Dates	78	121.12	2.20
Error (a)	394	2373.63	6.024

* Indicates significance at five per cent level.
** Indicates significance at one per cent level.
(a) Error variance includes six degrees of freedom from treatment effect.

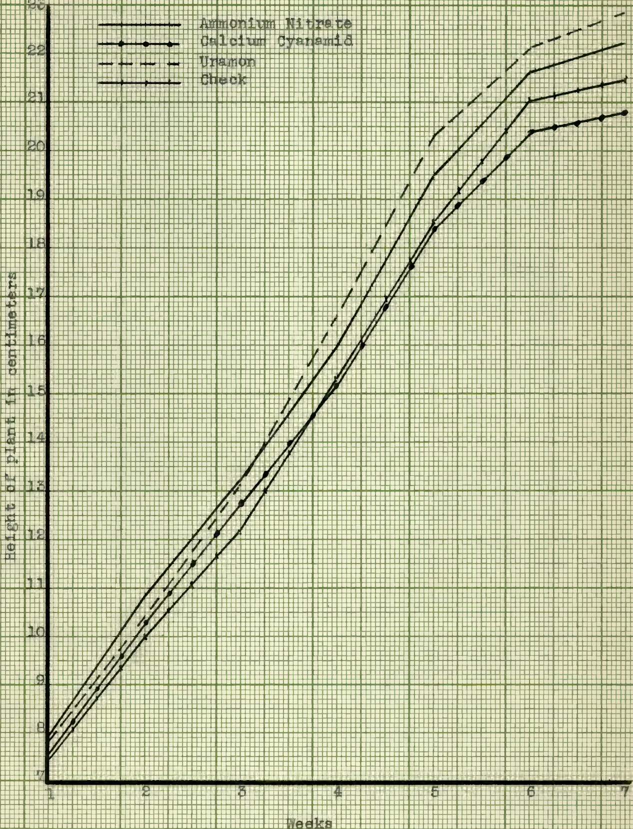

Fig. 1. Rate of growth of bromegrass.

A test for linearity of growth was made on the clipping data and the growth rate was found to be linear to a high degree of significance. The quadratic effect of clipping dates was also significant but to a lesser degree. This can be explained by noting the graph in Fig. 1. For the first five to six weeks the growth produced a relatively straight line on the graph. After five weeks a leveling off was noted on all pots. The test for quadratic effect proved this leveling off tendency to be significant. Thus it is apparent that bromegrass plants increase in length for the first five to six weeks and then level off. Since only the length of longest leaf was taken, the leveling off may have been due to the fact that that particular leaf was approaching maturity, and that the main growth was taking place in new leaves and shoots.

In order to obtain evidence concerning the number of shoots in relation to forage production, a count was made after the first cutting. The data indicated that there was a certain amount of correlation between number of shoots and forage yield. This would indicate that the previous statement concerning plant growth after the fifth week was true.

Yield of Topgrowth. Table 5 gives the data for yield of topgrowth of the five replications clipped March 25 and May 8. The analysis is shown in Table 6. The only significant main effects were dates of cutting and nitrogen rates.

Table 5. Yield of topgrowth of bromegrass in the greenhouse. Yield expressed as dry weight (grams) per pot.

	No P_2O_5				80 lbs. P_2O_5			
	100 lbs. N		200 lbs. N		100 lbs. N		200 lbs. N	
	March	May	March	May	March	May	March	May
				Ammonium nitrate				
	1.27	3.42	1.68	4.75	1.76	2.91	2.44	4.45
	1.55	3.50	1.73	3.96	1.69	3.23	1.57	5.47
	2.38	2.89	2.80	5.00	1.55	3.20	2.10	4.34
	1.78	2.89	2.01	4.57	1.60	3.22	2.08	5.42
	2.50	3.29	2.07	4.32	2.24	3.43	1.45	4.37
Sum	9.48	15.99	10.29	22.60	8.84	15.99	9.64	24.05
				Cyanamid				
	2.13	3.20	1.36	4.85	1.32	3.36	1.39	4.37
	1.24	3.11	1.37	4.06	1.29	2.93	1.87	4.20
	2.13	2.98	1.80	3.60	1.67	3.87	2.89	4.01
	1.83	3.09	0.99	3.37	1.49	3.37	1.36	4.76
	2.31	3.03	1.69	3.85	2.41	3.20	2.86	4.55
Sum	9.64	15.41	7.21	19.73	8.18	16.73	10.37	21.89
				Uramon				
	1.68	3.04	2.26	5.32	1.61	3.78	2.43	4.33
	2.65	2.72	3.36	4.76	2.32	2.87	1.03	3.88
	1.48	4.06	3.37	4.98	2.60	2.47	1.78	4.41
	1.61	2.83	1.42	3.51	2.95	2.56	2.20	4.82
	1.76	3.89	1.63	3.92	1.62	4.05	2.17	6.43
Sum	9.18	16.54	12.04	22.49	11.11	15.73	9.61	23.87

	No P_2O_5		80 lbs. P_2O_5	
	0 Nitrogen March	0 Nitrogen May	0 Nitrogen March	0 Nitrogen May
		Check		
	0.84	1.92	1.29	2.04
	1.25	3.04	1.09	2.44
	0.75	2.43	1.13	1.78
	1.55	2.10	1.12	1.98
	1.57	2.11	1.32	2.00
Sum	5.96	11.60	5.95	10.24

Table 6. Analysis of variance of weight of topgrowth of bromegrass plants in the greenhouse.

Source of Variation	DF	SS	V
Total	119	1,701,656	
Treatment-date combinations	23	1,416,701	61,596 **
Dates of cutting	1	1,110,340	1,110,340 **
P_2O_5	1	2,439	2,439
Nitrogen rates	1	139,878	139,878 **
Carriers	2	16,950	8,475
Interactions			
D X P	1	2,604	2,604
D X N	1	106,876	106,876 **
D X C	2	1,708	1,708
P X N	1	1,865	1,865
P X C	2	4,276	2,138
N X C	2	7,402	3,701
Replications	4	18,686	
Error (a)	101	288,632	2,883

** Indicates significance at one per cent level.
(a) Error variance includes six degrees of freedom from treatment effect.

The yield data regarding these two points are summarized in Table 7. There was an interaction between these effects.

Table 7. Effect of date of clipping and nitrogen rates on forage.

N Rate	March	May	Average
0	5.95	10.92	8.44
100	9.41	16.07	12.73
200	9.86	22.44	16.15
Average	8.41	16.48	

All of these effects are illustrated by the graph in Fig. 2. Decidedly higher yields were obtained in May than in March as shown in Table 7. The interaction of cutting dates and nitrogen rates was due to the low forage production of the 200 compared with the 100 pound nitrogen rate in March. This may have been due to unfavorable weather and its effect on light in the greenhouse.

Source of nitrogen appeared to have no effect on forage yield in the greenhouse.

The yield of topgrowth was not affected by phosphorus except in the case of cyanamid where the addition of 80 pounds of P_2O_5 per acre increased the yield as shown in Table 8. This was especially true for the 200 pound rate of cyanamid. The significance of this effect was determined by calculating the least significant difference between means of treatment effects.

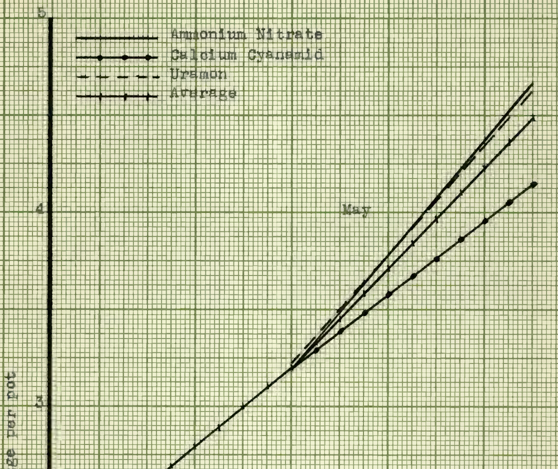

Fig. 2. Forage production in the greenhouse.

Table 8. Effect of phosphorus and nitrogen on topgrowth.

Fertilizer	No P_2O_5	80 lbs. P_2O_5
Ammonium nitrate	14.59	14.63
Calcium cyanamid	13.00	14.29
Uramon	15.06	15.08
No fertilizer	8.78	8.20
Average	13.44	13.73

Number of Shoots. Prior to the second cutting a count was made of the number of shoots per pot. The data from this count gave a significant effect for phosphorus and nitrogen rates as indicated in Table 9. These data indicate that the

Table 9. Effect of nitrogen rate and phosphorus on number of shoots per pot.

N Rate	No P_2O_5	80 lbs. P_2O_5
0	23.6	24.6
100	29.2	32.1
200	34.4	37.6
Average	30.6	33.4

number of shoots is not correlated with yield of topgrowth since phosphorus failed to affect forage yield. On the other hand increased nitrogen caused both forage and shoot number to increase. This may mean that forage yield is determined by such factors as leaf thickness and width instead of by shoot number and height of plant.

Yield of Roots. The data reported in Table 10 indicated that the effect of fertilizer treatments on root production was similar to the effect on forage yield. This is illustrated

Table 10. Yield of roots of bromegrass in the greenhouse. Expressed as dry weight (grams) per pot.

Carrier	Ammonium Nitrate		Cyanamid		Uramon		Check
Lbs. N per acre:	100	200	100	200	100	200	None
No P_2O_5							
	6.95	8.46	8.86	7.71	8.22	11.88	8.02
	8.50	7.73	6.64	7.22	8.65	13.71	7.93
	8.14	11.56	9.47	7.51	7.68	12.51	6.74
	7.61	10.42	9.19	6.33	8.22	7.26	6.07
	9.71	9.20	4.88	7.88	8.70	7.98	5.46
Sum	40.91	47.37	39.04	36.65	41.47	53.34	34.22
80 lbs. P_2O_5							
	8.15	9.40	6.77	7.63	8.92	9.81	5.45
	8.46	9.42	7.69	9.89	8.54	7.85	6.57
	7.95	8.76	9.38	12.54	8.38	8.17	5.51
	8.77	10.89	12.49	12.90	9.61	9.43	6.10
	8.97	11.00	7.56	6.70	8.75	10.72	5.62
Sum	42.30	49.47	43.89	49.66	44.20	45.98	29.25

Table 11. Analysis of variance of root growth of bromegrass in the greenhouse.

Source of Variation	DF	SS	V
Total	69	2,442,029	
Treatments	13	1,102,811	84,832 **
Treat. without check	11	517,396	47,036 *
P_2O_5	1	46,593	46,593
Nitrogen rates	1	156,673	156,673 *
Carriers	2	64,887	32,443
Interactions			
P X N	1	[illegible]47	247
P X C	2	129,705	64,853
N X C	2	35,089	17,544
P X N X C	2	84,202	42,101
Replications	4	77,365	
Error	52	1,261,853	24,266

* Indicates significance at five per cent level.
** Indicates significance at one per cent level.

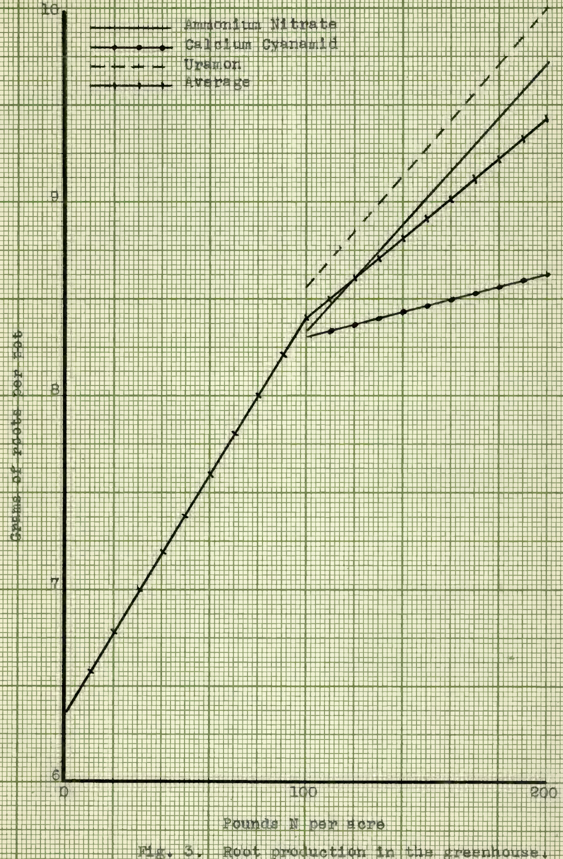

Fig. 3. Root production in the greenhouse.

also in Fig. 3. All treatments were decidedly better than check as indicated in the analysis in Table 11, and the 200 pound rate was better than 100 as shown in Table 12. The 200

Table 12. Effect of different rates of nitrogen on roots.

Fertilizer	Pounds nitrogen per acre		
	0	100	200
Ammonium nitrate		41.6	48.4
Calcium cyanamid		41.5	43.2
Uramon		42.8	49.7
No fertilizer	31.7		
Average	31.7	42.0	47.1

pound rate of both uramon and ammonium nitrate was better than cyanamid. Phosphorus did not affect root yield significantly except for the 200 pound rate of cyanamid. In that case it was beneficial. The effect of the 200 pound rate of cyanamid was improved with phosphorus in the case of both root and forage production. Krenzin (1947) obtained significant increases in root yield resulting from phosphorus applications to bromegrass seedlings in the greenhouse. He obtained the greatest yield of roots when phosphorus was applied in combination with nitrogen. Singleton (1946) obtained similar results at this station when working with bromegrass seedlings in the greenhouse. This apparent conflict may have been due to the fact that established bromegrass plants were used in this study.

Field Experiment

Yield of Forage. A series of field plots using three nitrogen carriers was established on the Agronomy Farm on March 20, 1948. The yields of topgrowth from these plots are given in Table 13 and the analysis of variance of topgrowth in Table 14. The statistical treatment of the field studies include, in addition to the simple analysis of variance, a breakdown of the treatment effects to individual degrees of freedom by using a table of orthogonal comparisons. The nitrogen fertilizers used in the field are the same as those used in the greenhouse studies. Phosphorus was not used in the field experiment because of lack of space and also because phosphorus applications in the field at Manhattan prior to 1948 had not benefited bromegrass.

Fig. 4 illustrates the results of forage studies in the field.

Ammonium nitrate was better than either cyanamid or uramon. The overall effect of increasing nitrogen rates from 100 to 300 pounds per acre was linear. This was due largely to the outstanding effect of the 300 pound rate of ammonium nitrate. Increasing the calcium cyanamid rate over 100 pounds per acre caused a decrease in yield of forage. This was due to the toxic effect that cyanamid had on the plants. This was observed after growth had started in the spring. The plants had a yellow stunted appearance for several days.

Table 13. Yield in pounds per acre of topgrowth of bromegrass from field plots.

Fertilizer	Pounds of nitrogen per acre 0	100	200	300	Average
No fertilizer	2633				
	2120				
	1829				
Average	2194				
Ammonium nitrate		3964	4655	5986	
		3922	4141	4770	
		3963	4933	4063	
Average		3950	4576	4940	4489
Calcium cyanamid		3194	3449	3304	
		3830	3263	3622	
		4397	3763	3978	
Average		3807	3492	3635	3644
Uramon		3530	4149	4567	
		3002	4795	3381	
		3370	3488	4611	
Average		3301	4144	4186	3877
Average of Rates		3686	4071	4254	
Grand Average					3822

Table 14. Analysis of variance of the yield of topgrowth of bromegrass in established stands.

Source of Variation	DF	SS	V
Total	29	21,358,248	
Treatments	9	15,412,587	1,712,510 **
Treat. vs. check	1		8,838,955 **
Linear rate effect	1		1,450,672 *
Quadratic rate effect	1		61,206
Am. nitrate vs. uramon and cyanamid	1		3,178,448 **
Cyanamid vs. uramon	1		243,369
Interactions			
LRE X A vs. C & U	1		401,111
QRE X A vs. C & U	1		2,821
LRE X C vs. U	1		839,523
QRE X C vs. U	1		396,480
Replications	2	338,498	
Error	18	5,607,163	311,509

* Indicates significance at five per cent level.
** Indicates significance at one per cent level.

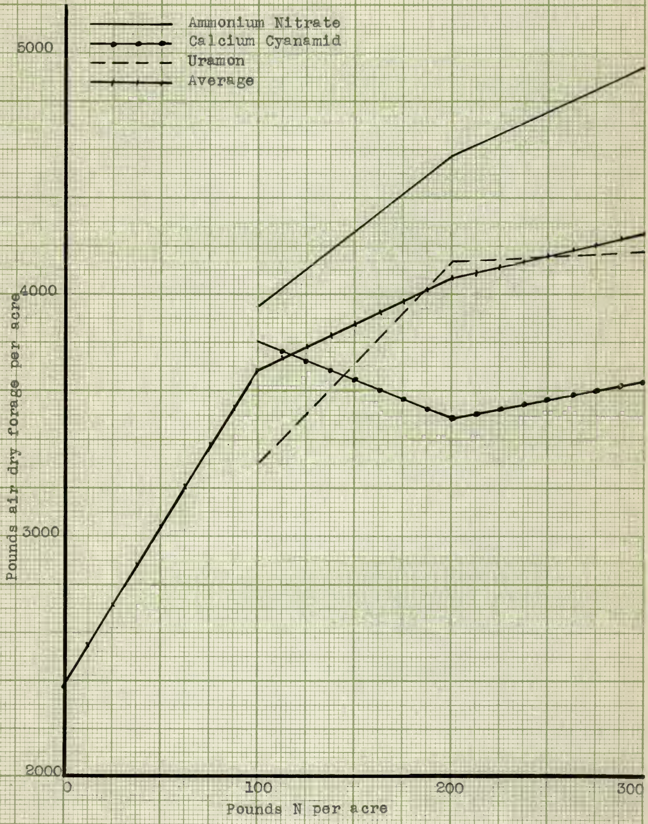

Fig. 4. Forage production in the field.

<u>Yield of Seed</u>. The effect of different nitrogen carriers on seed yield in the field is similar to the effect on forage yield. This is shown by the data in Table 16 and the analysis in Table 17. Fig. 5 gives a graphic picture of the data. All treatments were better than check except cyanamid and the 300 pound rate of uramon. The 300 pound rate of ammonium nitrate was better than all rates of cyanamid and better than the 100 pound rate of ammonium nitrate. This is shown in Table 15. There was an interaction between carriers and nitrogen rates. A graphic picture of this interaction is given in Fig. 5. It is caused by the decreased seed production resulting from increasing uramon beyond the 100 pound rate. Singleton (1946) found that rates of nitrogen over 100 pounds per acre caused severe lodging to the extent that no seed was produced. Rates up to 300 pounds nitrogen per acre in this experiment failed to cause lodging. This may have been due to unfavorable weather conditions in the early part of the growing season and a consequent lack of utilization of available nitrogen by the plants.

Table 15. Effect of different rates of nitrogen on seed yield.

Fertilizer	Pounds nitrogen per acre			
	0	100	200	300
Ammonium nitrate		410	471	588
Calcium cyanamid		330	349	352
Uramon		465	445	347
No fertilizer	258			
Average	258	402	421	429

Table 16. Yield in pounds per acre of bromegrass seed from field plots.

Fertilizer	Pounds of nitrogen per acre				
	0	100	200	300	Average
No fertilizer	260				
	270				
	244				
Average	258				
Ammonium nitrate		405	550	871	
		334	381	392	
		491	481	501	
Average		410	471	588	490
Calcium cyanamid		354	422	359	
		230	243	302	
		407	382	396	
Average		330	349	352	344
Uramon		433	521	313	
		488	451	343	
		473	362	386	
Average		465	445	347	419
Average of Rates		402	421	429	
Grand Average					401

Table 17. Analysis of variance of seed yield of bromegrass in the field.

Source of Variance	DF	SS	V
Total	29	446,643	
Treatments	9	237,769	26,419 *
Treat. vs. check	1		68,641 **
Linear rate effect	1		3,417
Quadratic rate effect	1		216
Am. nitrate vs. uramon and cyanamid	1		70,200 **
Cyanamid vs. uramon	1		25,313
Interactions			
LRE X A vs. C & U	1		50,925 *
QRE X A vs. C & U	1		3,536
LRE X C vs. U	1		14,560
QRE X C vs. U	1		961
Blocks	2	57,295	
Error	18	151,579	8,421

* Indicates significance at five per cent level.
** Indicates significance at one per cent level.

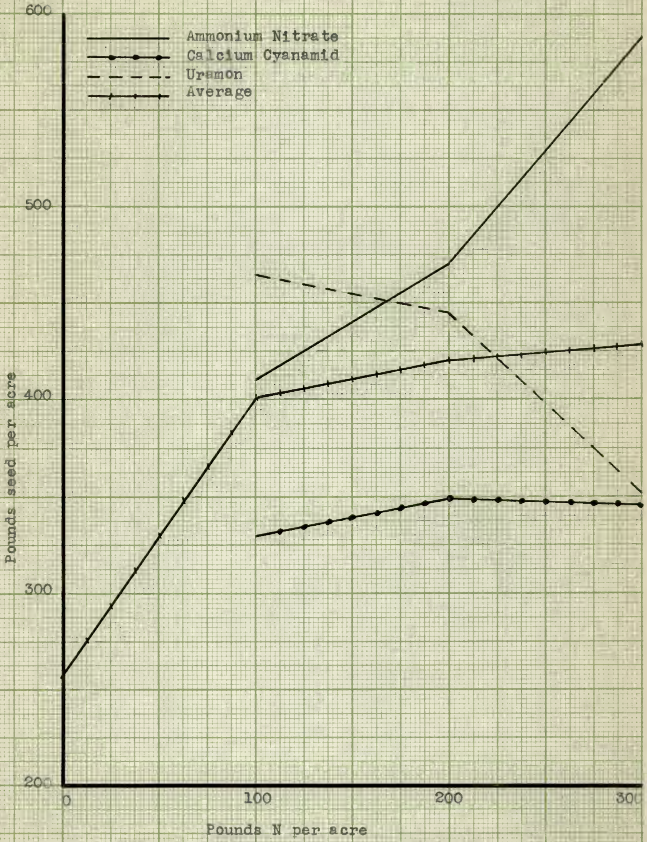

Fig. 5. Seed production in the field.

Yield of Roots. Surface application of different nitrogen carriers to bromegrass in the field increased root production but did not give differences among treatments. Root data are given in Table 18 and the analysis in Table 19. This lack of correlation of root with forage yield may be due to a number of factors. The sample that was taken may have been too small. The upper five inches of soil was removed in sampling roots; therefore, the sample may not have been representative of the entire root system. According to Turner (1922) the addition of nitrogen to the soil causes an increased ratio of stems to roots. He believed that this could be explained on the basis of increased use of carbohydrates in the tops because the greater nitrogen supply makes for greater growth. This causes a decrease in the supply of carbohydrates for the roots which may bring about an absolute or a relative reduction of root growth. Krenzin (1947) working at this station found that increasing amounts of nitrogen in the form of ammonium nitrate failed to give an increase in root production over the lowest rate. All rates however gave an increase of roots over check.

Table 18. Yield of roots in grams per plot of bromegrass from field plots.

Fertilizer	Pounds of nitrogen per acre				
	0	100	200	300	Average
No fertilizer	17.49				
	15.77				
	16.24				
Average	16.50				
Ammonium nitrate		19.07	20.38	20.33	
		14.39	18.57	19.46	
		20.00	19.42	20.53	
Average		17.79	19.46	20.11	19.13
Calcium cyanamid		18.46	22.30	18.55	
		17.37	15.19	21.04	
		17.68	17.21	17.63	
Average		17.84	18.23	19.07	18.32
Uramon		22.81	21.97	20.64	
		18.68	18.20	16.66	
		15.58	23.10	21.03	
Average		19.02	21.09	19.44	19.85
Average of Rates		18.23	19.59	19.54	

Table 19. Analysis of variance of yield of roots of brome-grass.

Source of Variation	DF	SS	V
Total	29	152.987	
Treatments	9	46.160	5.13
Treat. vs. check	1		18.54 *
Linear effect of nitrogen rates	1		7.77
Quadratic effect of nitrogen rates	1		3.02
Cyanamid vs. uramon	1		9.74
Replications	2	35.568	
Error (a)	23	78.348	3.406

* Indicates significance at the five per cent level.
(a) Error variance includes five degrees of freedom from treatment effect.

SUMMARY

1. The effects of varying rates of nitrogen and phosphorus fertilizers on the growth behavior of bromegrass (*Bromus inermis* Leyss) are reported. Fertilizers used in the field were ammonium nitrate, calcium cyanamid, and uramon. The rates used were equivalent to 300, 200, 100, and 0 pounds of elemental nitrogen per acre. Rates of the same fertilizers used in the greenhouse were 200, 100, and 0 pounds of elemental nitrogen per acre. Superphosphate applications in the greenhouse were equivalent to 80 and 0 pounds per acre of P_2O_5.

2. Yields of top growth are expressed as pounds of moisture free material produced per acre of bromegrass. Root yields are expressed as grams of moisture free root material per pot in the greenhouse study. In the case of field studies root yields are expressed as grams of moisture free root material in five sod plugs per plot.

3. Bromegrass failed to give a response to applications of phosphorus in the greenhouse except in combination with calcium cyanamid.

4. Increased yields resulting from fertilization of bromegrass in the greenhouse were accompanied by significant increases in number of culms and in height of plants.

5. When applied to bromegrass in the field nitrogen fertilizers gave increased root yield but failed to show significant differences among various treatments.

6. Increasing the rate of nitrogen up to 300 pounds per acre gave a significantly linear effect on forage yield in the field. Of the three nitrogen carriers used, ammonium nitrate gave the highest yield of forage.

7. The effect of fertilizers on seed yield of bromegrass in the field was similar to the effect on forage yield.

8. All rates of calcium cyanamid in the field produced a burning effect on the top growth of bromegrass. This was indicated by a light green color and a stunted appearance of the plants.

ACKNOWLEDGMENTS

The writer wishes to express his appreciation to those who have given helpful suggestions and advice throughout this study. Special acknowledgment is due to Professor K. L. Anderson for his helpful suggestions and aid in preparation of the thesis. Acknowledgment is also due to Dr. H. H. Laude, major instructor, for his aid and suggestions concerning the treatment of the data of the thesis.

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