COMPARISON OF THE EFFICIENCY OF SINGLE APPLICATIONS WITH REPEATED TOP DRESSINGS OF NITROGENOUS FERTILIZERS IN INCREASING THE YIELD OF DRY MATTER, NITROGEN, AND VITAMIN C (ASCORBIC ACID) OF SUDAN GRASS[1]

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Introduction

The rapid response of grasses to top dressings of nitrogenous fertilizers is well known. Many types of grass crops such as permanent pastures, golf courses, and lawns obviously may not be fertilized once they have become established except by surface applications. This practice is also frequently followed in the culture of other crops. The general belief is that a light top dressing with nitrogenous fertilizer shortly before harvest induces a rapid increase in the protein content of the crop. There is considerable evidence that this sudden increase in the absorption of inorganic nitrogen may not always increase the protein content significantly because of disturbed synthetic processes which may accompany it. This problem, however, lies beyond the scope of the present study.

The purpose of the present study was to investigate the comparative efficiencies of nitrogenous fertilizers added in a single application at the time of seeding and when only a part was added at this time with the remaining part added as a top dressing at a later period. This problem seems especially worthy of investigation in view of the increasing production of artificially dried immature grasses in this country. The rapid growth following the repeated cuttings of these crops exerts a heavy drain on the available nitrogen in the soil, and hence nitrogenous fertilizer usually must be added during the season to maintain the high nutritional value of the crop. The increasing difficulty of obtaining adequate supplies of nitrogenous fertilizers especially emphasizes the necessity of their use under conditions of maximum efficiency.

Methods

The experiments were carried out on a field of typical Brennan Fine Sandy Loam near Elsa, Texas, which was selected on the basis of its previous history of a high and uniform productivity of Sudan grass. The field was plowed eight inches deep July 3, 1941. It was then single-disked, harrowed, and levelled. The experimental plots were each one-hundredth of an acre in size. Control plots were arranged adjacent to each treated plot. The

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calculated amounts of ammonium sulphate and ammonium phosphate were added by hand July 10. The field was then double-disked and immediately seeded to Sudan grass. One series of plots received at this time the entire amount of fertilizer at the rates indicated in the table. Another series received half of the amount at this time and the remaining half was added as a top dressing immediately after the first cutting. Immediately following the second application of fertilizer all plots were irrigated by an overhead sprinkler system which leached the fertilizer into the upper few inches of soil.

The efficiency of the fertilizer was calculated as the percentage increase in the yield of dry matter, nitrogen, and vitamin C per acre per "unit" of nitrogen added in the fertilizer. These yields are the sums of the first and second cuttings. The percentage increase in these yields was calculated in respect to the yields of the individual adjacent control plots. For this reason, the yields themselves are not directly comparable.

A "unit" of nitrogenous fertilizer is considered to be 100 pounds of ammonium sulphate per acre or an equivalent amount of nitrogen as ammonium phosphate. On this basis, 400 pounds of ammonium sulphate and 600 pounds of ammonium phosphate would each represent 4 "units" of nitrogen fertilizer per acre, and 500 pounds of ammonium sulphate and 750 pounds of ammonium phosphate would each represent 5 "units" of nitrogen. These equivalencies are based on the chemical analysis of the particular commercial brands of fertilizer used.

The first cutting was made August 3, 25 days after seeding. The second cutting was made August 14, 36 days after seeding, or 11 days after the first cutting. The harvested material was quickly dried at 180° F. in a forced draft dehydrator.

Vitamin C was determined in fresh material as follows, and the results calculated in terms of yields in grams per acre: An aliquot of 25 milliliters of an acid extracting solution was added to 2 grams of fresh grass and the mixture then thoroughly ground in a mortar with 5 grams of pure Ottawa sand. The extracting solution contained 2 per cent. metaphosphoric acid and 3 per cent. trichloracetic acid. The triturated sample was filtered through no. 202 Reeve Angel filter paper, and 3 milliliters of the filtrate was titrated with a standard dye solution. All titrations were made in triplicate and the average values were used as the basis for calculating the yields per acre. The standard dye solution was prepared by dissolving 55 mg. of sodium 2,6-dichlorobenzenoneindophenol in 40 ml. of hot water in a 50-ml. volumetric flask. After cooling to room temperature, the solution was made up to 50 ml., filtered, and standardized by titration against a known amount of ascorbic acid. The standard solution of ascorbic acid was

made up by dissolving 10 mg. of ascorbic acid in 50 ml. of the acid extracting solution.

The total nitrogen content in the Sudan grass was determined by the Kjeldahl procedure modified to include nitrate nitrogen. One gram of the dried sample was placed in an 800-ml. Kjeldahl digestion flask and treated with 30 ml. of a digestion mixture. This digestion mixture was prepared by dissolving 15 gm. of copper sulphate in a small amount of hot water and adding this solution and 125 gm. of salicylic acid to 2.5 liters of sulphuric acid. After standing for 1 hour in the digestion mixture, the flask was heated for 5 minutes and then 5 gm. of sodium thiosulphate were added. After rotating the flasks on the burners for a few minutes, 10 to 15 gm. of powdered potassium sulphate were added and the mixture digested for 2 hours. The digested sample was cooled, diluted to 250 ml., 100 ml. of 50 per cent. sodium hydroxide added and distilled into 4 per cent. boric acid. The distillate was titrated with 0.01714 N hydrochloric acid.

Results

The data concerning yield in dry matter are presented in table I. It is apparent that there is a considerable increase in the efficiency of both ammonium sulphate and ammonium phosphate when the entire indicated amounts were added at the seeding time. For the ammonium sulphate, there was an 8 per cent. increase in the efficiency at the 400 pounds per acre level when the entire amount was added at seeding time. At the 600 pounds per acre level, this increase in efficiency was 14 per cent.

TABLE I

TOTAL YIELD IN DRY MATTER IN THE FIRST 2 CUTTINGS OF SUDAN GRASS. COMPARISON OF SINGLE WITH DOUBLE APPLICATIONS OF FERTILIZER

DATA	AMMONIUM SULPHATE				AMMONIUM PHOSPHATE			
	400 LB. PER ACRE		600 LB. PER ACRE		500 LB. PER ACRE		750 LB. PER ACRE	
	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.
Control plots, yield, lb. per acre	1470	1745	1470	1745	1470	1745	1470	1745
Fertilized plots, yield, lb. per acre	2255	2595	2300	2615	2182	2250	2530	2665
Pounds per acre increase due to fertilizer	785	850	830	870	712	505	1060	920
Percentage increase due to fertilizer	53	49	57	50	49	29	72	53
Percentage increase per nitrogen unit of added fertilizer	13.2	12.2	9.5	8.3	12.2	7.2	12.0	8.8
Percentage increase in efficiency	8	.....	14	.....	70	.....	37	.....

The ammonium phosphate applications present even more striking results. At the 500 pounds per acre level, there was a 70 per cent. increase in efficiency when the entire amount was added at seeding time. At the level of 750 pounds per acre, the increase in efficiency was 37 per cent. It is evident that ammonium phosphate is much superior to ammonium sulphate, at equivalent nitrogen levels, in increasing the yield of Sudan grass under the conditions of the experiment. This is especially true at the lower levels of application.

The data concerning the recovery of nitrogen by the crop are presented in table II. The results are roughly similar to those obtained for the yield

TABLE II

TOTAL NITROGEN RECOVERED IN THE FIRST 2 CUTTINGS OF SUDAN GRASS. COMPARISON OF SINGLE WITH DOUBLE APPLICATIONS OF FERTILIZER

DATA	AMMONIUM SULPHATE				AMMONIUM PHOSPHATE			
	400 LB. PER ACRE		600 LB. PER ACRE		500 LB. PER ACRE		750 LB. PER ACRE	
	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.
Control plots, N recovery in lb. per acre	44.5	43.9	44.5	43.9	44.5	43.9	44.5	43.9
Fertilized plots, N recovery in lb. per acre	79.4	75.6	82.6	79.7	66.2	57.5	81.8	76.1
Lb. per acre increase due to fertilizer	34.9	31.7	38.1	35.8	21.7	13.6	37.3	32.2
Percentage increase due to fertilizer	76	69	86	79	49	29	84	71
Percentage increase per nitrogen unit of added fertilizer	19.0	17.2	14.3	12.2	12.2	7.2	14.0	11.8
Percentage increase in efficiency	10	.....	15	.....	70	.....	19	.....

in total dry matter. In each instance there is an increased efficiency in the total nitrogen recovered by the crop when the entire amount of nitrogenous fertilizer was added at seeding time. When 400 pounds of ammonium sulphate were added per acre, this increased efficiency was 10 per cent. At the 600 pounds per acre level, this figure increased to 15 per cent.

The ammonium phosphate applications yield efficiency values of greater magnitude. At the 500 pounds per acre level, there was an increase of 70 per cent. in the efficiency per nitrogen unit of fertilizer added to the soil when the total amount was added at seeding time. At the 750 pounds per acre level, the increased efficiency was 19 per cent.

Just as in the case of total yields of dry matter, ammonium phosphate appears to be superior to ammonium sulphate, at equivalent levels of nitrogen, in increasing the amount of nitrogen recovered by Sudan grass under

the conditions of the present experiment. This appears to a remarkable degree at the lower levels of fertilizer application.

The yields in vitamin C are presented in table III. An examination of

TABLE III

TOTAL YIELD OF VITAMIN C IN THE FIRST 2 CUTTINGS OF SUDAN GRASS. COMPARISON OF SINGLE WITH DOUBLE APPLICATIONS OF FERTILIZER

DATA	AMMONIUM SULPHATE				AMMONIUM PHOSPHATE			
	400 LB. PER ACRE		600 LB. PER ACRE		500 LB. PER ACRE		750 LB. PER ACRE	
	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.	1 APPL.	2 APPL.
Control plots, vitamin C yield in grams per acre	1649	1487	1649	1487	1649	1487	1649	1487
Fertilized plots, vitamin C yield in grams per acre	2420	3010	2270	3000	2060	1855	2230	2700
Grams per acre increase due to fertilizer	771	1523	621	1513	411	368	581	1213
Percentage increase due to fertilizer	147	203	138	202	125	125	135	182
Percentage increase per nitrogen unit of added fertilizer	37	51	23	34	31	31	23	31
Percentage increase in efficiency	.....	35	.....	50	.....	0	.....	35

these data shows that the greatest efficiency per unit of nitrogenous fertilizer applied is obtained when the total amount is added in 2 applications rather than as a single initial treatment. This is directly opposite to the results of the yield of total dry matter and the recovery of total nitrogen by the crop. When ammonium sulphate was added at the rate of 400 pounds per acre, there was an increase of 35 per cent. in the efficiency of the fertilizer per unit of added nitrogen when one half of the total amount was added at the time of seeding and the remaining half added as a top dressing immediately following the first cutting. At the level of 600 pounds per acre of fertilizer, this efficiency had increased to 50 per cent. The greater efficiency thus appears to exist at the higher rates of application.

The efficiency of ammonium phosphate is of smaller magnitude than that of ammonium sulphate. In fact, at the lower rate of application, no change in efficiency was noted in the yield of vitamin C per acre. At the higher rate of application, however, an increase of 35 per cent. in fertilizer efficiency was noted.

Discussion

The general belief that top dressing is the most economical method of applying nitrogenous fertilizer is based on 2 considerations. In the first place, the shallow root system of many species of grass presumably would

have an opportunity to come into more immediate contact with the added nutrients; and second, that loss of nitrogen from the soil by leaching is reduced to a minimum. If the grass which is being studied actually is a shallow-rooted species, and if there is real danger of nitrogen loss from the soil, then frequent, light top dressings of fertilizer would probably be the most efficient method of its application.

Many agriculturally important plants, however, possess root systems of much greater depth than is commonly supposed. For example, Sudan grass 25 days after planting, under the conditions of the present experiment was about 20 inches tall when measured from the surface of the soil to the average extreme extension of the leaves. The plants had not yet developed joints. Bunches of the plants could be easily pulled up by hand and such superficial examination as this made possible indicated that most of the roots were confined in the upper few inches of soil. Yet careful dissection of the soil profile showed that a considerable quantity of young, feeding roots had penetrated to a depth of 3.5 feet! This evidence alone indicates that fertilizer added as a top dressing does not necessarily come into immediate contact with the majority of the feeding roots.

The loss of soluble nitrogen from the soil by leaching presumes that the rain water and irrigation water percolates to a depth beyond the effective feeding range of the roots. In regions of humid climates this percolating water would reach the water table and hence such substances as were in solution at this depth would be lost permanently from the soil profile. This is one of the important characteristics of the podsolic type of soils. On the other hand, in the more arid regions in which the typical pedocal soils develop, only rarely does surface water reach the water table. The average depth of penetration of rain water in the climatic area which includes the Brennan soil series is from 3 to 5 feet, depending on the texture and structural variations in the soil profile. This indicates that leaching cannot remove soluble nitrogen from the feeding zone of the roots of Sudan grass when grown on soils of this series.

The deep root system of a "tall grass" species such as Sudan grass and the limited depth of soil leaching furnishes a basis for interpreting the greater efficiency of nitrogenous fertilizer in increasing the yield of dry matter and also the recovery of nitrogen by the crop when the entire amount is applied at the time of seeding. When the entire amount is added at seeding time, the combined action of rainfall and irrigation tends to move the fertilizer downward and distribute it throughout the soil profile. It then comes in contact with the expanding root system in the lower zones of nutrient absorption. On the other hand, when a smaller application is made at the time of seeding, the added nitrogen is largely absorbed by the first crop. The fertilizer added as a top dressing after the first cutting, and

only 11 days before the subsequent cutting, is necessarily limited to the upper few inches of soil and it does not have time to become distributed throughout the profile through which the feeding roots are themselves already distributed.

Further studies are in progress to determine the efficiency of nitrogenous fertilizer when added at various periods in the life history of the plant and the relation of their efficiency to the distribution of the fertilizer in the soil profile.

Summary

1. Sudan grass was grown on Brennan Fine Sandy Loam. The first cutting was made 25 days after planting. A second cutting was made 11 days later.

2. The relative efficiencies of ammonium sulphate and of ammonium phosphate were studied when a given amount was added at the time of seeding and when part was added at seeding and the remainder as a later top dressing.

3. The greater efficiency per unit of added nitrogen in increasing the total yield of dry matter was found when the entire amount of fertilizer was added at seeding time. Ammonium phosphate was significantly more efficient per unit of added nitrogen than was ammonium sulphate.

4. The greater efficiency per unit of added nitrogen in increasing the recovery of nitrogen by the 2 cuttings also was obtained when the entire amount of fertilizer was added at seeding time. Ammonium phosphate was more efficient per unit of nitrogen added than was ammonium sulphate.

5. The total yield of vitamin C per acre varied inversely as the yield of dry matter and the recovery of nitrogen by the crop. The greater efficiency per unit of nitrogen added was found when part of the fertilizer was added at the time of seeding and part just following the first cutting. Ammonium sulphate was more efficient per unit of nitrogen than ammonium phosphate.

6. A tentative explanation is offered of the comparative efficiency of nitrogenous fertilizer based on its distribution throughout the soil profile and on the depth of the root system of the plant.

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