THE INFLUENCE OF NITROGEN IN EXTENDING THE GRAZING SEASON OF FOUR GRASS SPECIES

by

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A THESIS

submitted to

OREGON STATE UNIVERSITY

in partial fulfillment of
the requirements for the
degree of

MASTER OF SCIENCE

June 1961

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Date thesis is presented May 2, 1961

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ACKNOWLEDGMENTS

The experiment conducted at Badgery's Creek, New South Wales, Australia, was made possible through financial assistance provided by the N. S. W. Metropolitan Milk Board and a University of Sydney Research Grant.

The writer is indebted to Dr. B. D. H. Latter of the New South Wales Department of Agriculture for valuable advice regarding the design and analysis of the Badgery's Creek experiment and to D. M. DeMarco and Meredith Alpine for technical assistance.

The experiment at Oregon State University, Corvallis, Oregon formed part of a research program made possible through a one year Research Fellowship generously provided by the Rockefeller Foundation of New York.

Much credit is due to Dr. J. Ritchie Cowan, Head of the Farm Crops Department at Oregon State University for making all the general arrangements in regard to this work.

Dr. W. S. McGuire of the Farm Crops Department contributed much more in time and energy to this program than could be expected of a Major Professor. He established the plots before I arrived, gave regular and untiring counsel concerning the design and conduct of the experiment, personally assisted in the collection of data, and advised on matters of thesis presentation.

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THE INFLUENCE OF NITROGEN IN EXTENDING THE GRAZING SEASON OF FOUR GRASS SPECIES

INTRODUCTION

The main criticism of pastures as a source of animal nutrients is that they fail to provide the grazing animal with an adequate supply of high quality forage over a sufficiently long period of the year.

Because of this "seasonal" production of both dry-land and irrigated pastures, the rations of grazing animals have to be frequently supplemented by other feedstuffs such as hay, grain and silage. These supplementary feedstuffs, under most conditions in Australia (8, p. 13) cost at least four times, and often ten times, more per food unit than forage grown and grazed in the paddock. It is therefore conceivable that where hand feeding plays a major role in livestock production, feed costs could be greatly reduced if more of the expensive conserved feeds could be replaced by the much cheaper pasture. Attempts were made at the University of Sydney's experiment farm at Badgery's Creek near Sydney, Australia, to achieve this saving in feed costs by studying the production pattern of an irrigated perennial ryegrass (*Lolium perenne* L.) and white clover (*Trifolium repens* L.) pasture and determining how the production pattern of this pasture could be economically improved by the skillful use of nitrogenous and other fertilizers. The details of this investigation are reported here.

The Badgery's Creek investigation showed that the early spring production from the perennial ryegrass-white clover pasture could be economically improved but the late autumn production was little affected by the treatment imposed. This led to further investigations on the production of late autumn and early winter forage (8, p. 3, 6, p. 17, 7, p. 8) which showed that high autumn forage production could be obtained, under these conditions, from annually sod-sown cereals.

However, it would be cheaper and easier to provide additional autumn feed from a perennial grass than an autumn sown annual, if a suitable perennial grass species could be found which, when properly managed in the autumn, could efficiently use nitrogen fertilizer for the production of late autumn forage.

The experiment conducted at the Hyslop Agronomy Farm of Oregon State College at Corvallis was designed to study the effects of different nitrogen carriers applied at different rates and in different forms on the late autumn production of perennial ryegrass and three other perennial species which are of importance or potential importance in parts of both Oregon, U. S. A. and New South Wales, Australia.

The two field experiments described here are directed towards finding ways and means of economically extending the grazing season of irrigated perennial pastures through the use of nitrogenous fertilizer and special purpose perennial grass species. Each experiment is complementary to the other. The first, conducted at Badgery's Creek near Sydney, Australia, studies the effect of nitrogen fertilizer on the annual production pattern of a perennial ryegrass-white clover pasture and delineates the value and limitations of this method of extending the grazing seasons. The second, conducted at Hyslop Agronomy Farm, Corvallis, Oregon, U. S. A., attempts to find out how the limitations of the first method (low autumn response to nitrogen by perennial ryegrass) might be overcome by using different perennial species, nitrogen carriers and methods of application.

REVIEW OF LITERATURE

Because legumes have to photosynthesize carbohydrates for the use of their root nodule bacteria, as well as for themselves (23), one would expect that well adapted grass species supplied with fertilizer nitrogen would outyield equally well adapted legumes not supplied with commercial nitrogen. Furthermore, it would be expected that during late autumn, winter and spring, when a shortage of light commonly restricts photosynthesis, the superiority of the growth rate of the grass with nitrogen over the legume without nitrogen, would be still more marked. In broad principle, there would then appear to be scope for increasing the late autumn, winter and early spring production of grass-legume pastures by the use of nitrogenous fertilizers.

However, the literature on the effect of nitrogenous fertilizers on the production patterns of grass-clover mixtures shows no consistant relationships, the results obtained in any one case depending on the particular conditions of the experiment and more especially the suitability of the grass and clover for the particular environment (1, p. 10-12; 2, p. 13-15; 3, p. 18-22; 4, p. 260-262; 5, p. 163-164; 19, p. 243-244; 20, p. 237).

The literature concerning the response patterns of mixtures containing perennial ryegrass or white clover, are more pertinent to the problem at Badgery's Creek.

Hughes and Evans (13, p. 61-64) and Wheeler (22, p. 201), working independently at two different locations in England on perennial ryegrass-white clover sheep pastures, both concluded that nitrogenous fertilizers had the effect of markedly increasing the early spring production of their pastures but barely altering autumn production. However, Davies and Williams (10, p. 1,321), in summarizing the effect of nitrogenous fertilizers on English pastures, the bulk of which are perennial ryegrass dominant, concluded that the average response to early spring applications of nitrogenous fertilizers was of the same order as that obtained over the whole season.

In North America, Crowder, Sell and Parker (9, p. 52-54), working in Georgia, U. S. A., found that nitrogenous fertilizers failed to increase the autumn production of an oats-ryegrass-crimson clover pasture, but greatly increased its spring production. Gardener (12, p. 24), working with a perennial ryegrass-orchardgrass-ladino white clover pasture on Vancouver Island, Canada, found that nitrogenous fertilizer increased the early spring production of forage but had little effect during the remainder of the year.

Crowder, Sell and Parker (9, p. 52-54) were also able to correlate the response of oats-ryegrass-crimson clover mixtures to nitrogenous fertilizers in late autumn and early spring with the rainfall and temperature conditions at those times, but their data could not be used directly to predict the pattern of response of a white clover-perennial ryegrass pasture at Badgery's Creek.

The only means of satisfactorily determining the response pattern of a white clover-ryegrass irrigated pasture at Badgery's Creek to nitrogenous and other fertilizers seemed to be to conduct a field plot experiment. Such an experiment is described here.

EXPERIMENTAL METHODS

Part I. Experiment at Badgery's Creek

Experimental Site

The experiment was conducted on the McGarvie Smith Animal Husbandry Farm of the University of Sydney, which is located at Badgery's Creek, some 36 miles southwest of the city of Sydney, New South Wales, Australia.

The soils on this property have been described as grey-brown podsolics. They have a heavy clay surface and are underlain by an impermeable lateritic band at one to three feet. They are acid in reaction (pH 5.2 average), low in organic matter, high in free sodium and grossly deficient in nitrogen and phosphorus. The addition of molybdenum is also necessary for the active growth of legumes on these soils.

The paddock in which the experiment was conducted had, until 1954, been repeatedly cropped to oats for about 30 years, without the use of fertilizer, and was very low in fertility. In February 1955, the tall summer growing grasses (mainly of the genera *Digitaria*, *Echinochloa* and *Paspalum*) which had grown as volunteer species in the 1954 fallow, were disced in. After one further cultivation, the paddock was re-seeded with a roller-drill on April 12, 1955. The seed mixture comprised:

New Zealand certified red clover	
(*Trifolium pratense* L.)	3 lbs. per acre
New Zealand certified white clover	1½ lbs. per acre
Tallarook subterranean clover	
(*Trifolium subterraneum* L.)	2 lbs. per acre
New Zealand certified perennial	
ryegrass	12 lbs. per acre

This seed mixture was sown in contact with a superphosphate, molybdenum, carbonate of lime fertilizer mixture which supplied 50 lbs. of P_2O_5, 93 lbs. of $CaCO_3$ and 1½ oz. of M_oO_3 per acre.

The site selected for the experiment was a uniform area on the crest of a gentle slope between the 180- and 190-feet contours in paddock number 16.

Experimental Design and Treatments

There was fragmentary evidence that possible responses to nitrogen might be restricted by an excess of sodium in this soil. Furthermore, it was not known how long the existing reserves of phosphorus in this soil would supply the needs of grasses supplied with repeated higher levels of nitrogen. In order to determine whether sodium excess or phosphorus deficiency did in fact restrict the response of ryegrass to nitrogen topdressing, the experiment was designed on a 2 x 2 factorial base.

The four treatment combinations were:

(1) 125 lb. P_2O_5 with no gypsum symbolized $P_{125}G_o$

(2) 250 lb. P_2O_5 with 1 ton of gypsum symbolized $P_{125}G_1$

(3) 250 lb. P_2O_5 with no gypsum symbolized $P_{250}G_o$

(4) 250 lb. P_2O_5 with 1 ton of gypsum xymbolized $P_{250}G_1$

These treatments were replicated four times in a randomized block design. All of the experimental treatments were imposed as topdressings on the previously described paddock basal treatment.

The four nitrogen treatments, all applied as sulphate of ammonia with 20 per cent nitrogen, were applied as randomly arranged sub-plot treatments on each of the 4 main plots.

These were:

(1) No sulphate of ammonia symbolized No

(2) Sulphate of ammonia at 112 lb/acre or nitrogen at 23 lb/acre symbolized N1

(3) Sulphate of ammonia at 224 lb/acre or nitrogen at 46 lb/acre symbolized N2

(4) Sulphate of ammonia at 448 lb/acre or nitrogen at 92 lb/acre symbolized N4

The main plot treatments were applied only once at the commencement of the experiment on May 16, 1955.

The sub-plot sulphate of ammonia treatments were applied first on May 23, 1955 and repeated immediately after each subsequent sampling occasion on August 16, September 20, November 1 and December 28, 1955 and February 16, April 3, and May 22, 1956.

Experimental Layout

The 16 main plots, each 20 ft. x 20 ft., were arranged in two adjacent columns of eight plots with a 10-foot wide headland between them, along which the sprinkler irrigation line was placed. The overall dimensions of the experimental area were 160 ft. x 50 ft. and each block of four main plots had dimensions of 40 ft. x 50 ft.

The sub-plots imposed on the main plot each had dimensions of 5 ft. x 20 ft. This arrangement insured that all plots were equidistant from the irrigation spray line.

Irrigation

The experimental area was sprinkler irrigated immediately after each application of nitrogen fertilizer and between applications, according to rainfall and temperature. A water balance sheet was kept for this paddock, according to the standards set up by H. L. Penman (16, p. 135-145) and the plots were sprinkler irrigated with 1.05 inches of water as soon as a soil-moisture deficit of 1.05 inches was reached, according to the balance sheet. The figure of 1.05 inches was taken as the "allowable deficit" because this represented half the moisture holding capacity of the top 12 inches of this soil. This would ensure, as far as possible, that the growth of the pasture was not limited by a shortage of water.

The sprinkler irrigations were generally applied over a five-hour period during the night, so as to reduce wind drift and moisture loss by evaporation and run-off.

Temperature

A meteorological station was located at the same altitude as the experimental site and only 500 feet away. The monthly mean maximum and mean minimum temperatures recorded in the standard meteorological screen during the period of the experiment and the 15-year monthly average for the same location are given in Table 1.

Sampling

The sub-plots were sampled at approximately six weekly intervals by cutting out from the center of each sub-plot a strip 20 ft. long and 3 ft. wide with an autosythe. Cutting height was one inch above ground level.

Each herbage sample was then weighed green and a 10 per cent or 2000 gram sub-sample was drawn for determining botanical composition, dry matter yield and crude protein content.

After botanical separation, the sub-samples were dried at 87° C. for 24 hours and weighed. The dry matter yields of the various sub-plots were then calculated from the moisture loss of the sub-samples and the green weight yield per sample.

Kjeldahl nitrogen determinations were made in duplicate from ground samples prepared by bulking the dried sub-samples of all four replicates of each treatment. Crude protein was calculated as total per cent nitrogen multiplied by 6.25.

Table 1

Mean monthly maximum and minimum screen temperatures at Badgery's Creek from May 1955 to August 1956 and 15-year averages for same location in degrees Fahrenheit.

Month	Mean Monthly Maximum 1955-56	Mean Monthly Maximum 15-year av.	Mean Monthly Minimum 1955-56	Mean Monthly Minimum 15-year av.
1955				
May	65.8	76.8	47.1	45.2
June	60.9	62.9	41.4	43.1
July	62.2	61.8	36.2	41.3
August	66.8	63.7	41.0	42.0
September	71.1	69.9	43.2	45.5
October	74.8	74.2	49.0	51.1
November	80.2	79.4	52.2	54.6
December	78.5	83.2	56.5	59.1
1956				
January	87.9	84.2	61.1	60.8
February	77.2	82.2	63.6	62.1
March	78.5	79.0	63.5	59.0
April	75.8	73.9	51.8	51.5
May	66.1	76.8	46.5	46.4
June	62.8	62.9	41.1	43.0
July	61.2	61.8	36.6	40.1
August	64.1	63.7	39.3	41.9

There were seven sampling occasions: August 16, September 20, November 1, and December 28, 1955; February 16, May 22, and August 6, 1956. A further group of samples were to have been taken on April 3, 1956, but this sample was lost through cows breaking through the fence the day before.

There were seven groups of data derived from sampling the 64 sub-plots on seven occasions.

Immediately after each field sampling occasion, the unsampled areas of each plot were mowed to the same level as the sampled areas and all herbage was raked off the plots.

At the conclusion of the experiment, on August 6, 1956, in order to determine the effect of the repeated applications of sulphate of ammonia on the pH of the surface soil, five random 0-3" fresh soil samples were drawn from each of the 64 sub-plots. Each set of five samples were bulked, dried and ground, and the pH was determined at a 2:1 water to soil ratio by means of a glass-calomel electrode.

Part II. Experiment at Hyslop Agronomy Farm

The experiment at Badgery's Creek showed that the autumn response in perennial ryegrass to sulphate of ammonia was small and uneconomic. This experiment was designed to examine the hypothesis that other perennial grass species may give a better autumn response to applied nitrogen and that this response might be influenced by the nitrogen carrier used and the way in which it is applied.

Experimental Site

This experiment was conducted at the Hyslop Agronomy Farm of Oregon State University, Corvallis, Oregon. The soil type was a Willamette silt clay loam with a pH of 6.3.

The experimental site had grown a red clover green manure crop in 1957 and was fallowed in 1958-59. It was disc-harrowed twice in September 1959 and tooth-harrowed and rolled in preparation for seeding.

Experimental Design and Treatments

The experiment was planned in order to study the effect of nitrogen fertilizers applied in different ways and at different rates on the autumn production of four established perennial grass species.

To do this, it was necessary to sow the grasses about one year before the nitrogen treatments were imposed. Hence, the four grass species were sown in three randomized blocks on September 20, 1959 by means of a push-type hand-seeder with 60 lb. of P_2O_5 per acre.

Species Treatments

The four species compared in this investigation were selected because they are each useful or potentially useful as perennial grasses in irrigated and dryland pastures in both western Oregon and eastern New South Wales. They were:

1. Oregon perennial ryegrass (Lolium perenne L.), a ryegrass ecotype, probably derived from northern Europe, which has, over more than fifty years, become well adapted to the conditions of the southern part of the Willamette Valley. In clipping experiments carried out near Corvallis, this strain, although morphologically different, has consistently given similar yields to New Zealand certified perennial ryegrass. It is regarded as being agronomically similar to New Zealand perennial ryegrass, the species used in the first part of this investigation at Badgery's Creek, Australia. It is the standard recommended variety of perennial ryegrass for forage production in Oregon. In this experiment it was seeded at

25 lb. per acre.

2. Harding grass (Phalaris tuberosa Hack.), a strain from Turkey numbered P.I. 24,950 and obtained via plant introduction, Experiment, Georgia. This strain has been increased in Oregon for further study because of its freedom from leaf diseases. It has some potential value in both western Oregon and eastern Australia. It was seeded at 15 lb. per acre.

3. Orchardgrass (Dactylis glomerata L.), strain number S-143, selected at Welsh Plant Breeding Station, Aberystwyth, Great Britain in 1950 and grown in western Oregon and elsewhere as a recommended variety for both forage and seed production in dryland and irrigated pastures. It is also grown in eastern Australia. It was seeded at 12 lb. per acre.

4. Alta tall fescue grass (Festuca arundinacea Schreb.), a tall fescue ecotype selected at Corvallis in 1927 from material previously introduced from Germany. It is a standard recommended variety for both dryland and irrigated pastures in Oregon and elsewhere and is being carefully studied in eastern Australia. It was seeded at 12 lb. per acre.

These four species were randomly arranged in each of three replicated blocks, giving twelve main plots. All headlands and the land immediately adjoining all plots was sown with chewings fescue (*Festuca rubra commutata* L.) to reduce border effect, prevent weed invasion, and provide areas for handling experimental equipment.

Rains in late September 1959 germinated seed in all plots, but caused an invasion by annual bluegrass (*Poa annua* L.)

In June 1960, all plots were clipped to control weeds, the clipped residue being raked off the plot area.

On August 9, 1960, all plots were hand-weeded and the next day they were mown, raked, and irrigated with approximately one inch of water through a spray line. At this time all species showed extreme nitrogen deficiency symptoms. Two three-inch irrigations were applied to all plots on August 12 and 16.

Nitrogen Fertilizer Treatments

The effect of two rates of nitrogenous fertilizer (45 lbs. and 90 lbs. of N per acre) in combination with three means of application (as ammonium nitrate pellets topdressed, as urea pellets topdressed, and as urea applied half as pellets initially and half as a liquid spray treatment six weeks later) on the production and nitrogen recovery of the four different grasses, was studied by imposing seven nitrogen treatments (six with

N and one nil N control) on each of the four main plot species treatments. The sub-plots, each 7 ft. by 20 ft., had their nitrogen treatments assigned to them at random on each main plot.

The nitrogen sub-plot treatments, applied on August 18, 1960, were:

1. No nitrogen, symbolized No.
2. Pelleted ammonium nitrate topdressed at 45 lb. of N per acre or 195 grams of 33% N fertilizer for sub-plot, symbolized N45A.
3. Pelleted ammonium nitrate topdressed at 90 lb. of N per acre or 390 grams per sub-plot, symbolized N90A.
4. Pelleted urea topdressed at 45 lb. N per acre or 143 grams of 46% N fertilizer per sub-plot, symbolized N45U.
5. Pelleted urea topdressed at 90 lb. N per acre or 286 grams of 46% N fertilizer per sub-plot, symbolized N90U.
6. Pelleted urea applied at 45 lb. N per acre, half as solid urea on August 18 and half as a 1% foliage spray on September 1, 1960, symbolized N45L.

7. Pelleted urea applied at 90 lb. N per acre, half as solid urea on August 18 and half as a 2% foliage spray on September 1, 1960, symbolized N90L.

Immediately after the solid fertilizers were applied on August 18, all plots were given 1.5 inches of irrigation. No irrigation was applied until 14 days after the urea spray treatments.

Experimental Layout

The twelve main plots, each 50 x 20 feet, were arranged in six columns with two plots per column and a 5-foot wide headland between each column.

Each block consisted of four main plots and two columns and had overall dimensions of 100 x 45 feet. The experimental area was 100 x 145 feet. There was a total of 7 x 12 or 84 sub-plots.

Irrigation and Rainfall

Sprinkler irrigation was applied, according to the standards set up by H. L. Penman (16, p. 120-145) in an effort to ensure that, during the period of this experiment, moisture was not limiting forage production. In this case, with deep soil of high moisture holding capacity and deep-rooted grasses, the "allowable deficit" was taken as three inches.

A summary of the rainfall, irrigation and evaporation records for the period of the experiment is given in Table 2.

Table 2

Rainfall, irrigation and evaporation record for the experimental site at Hyslop Agronomy Farm from August 12 to October 20, 1960.

Month 1960	Rainfall (inches)	Irrigation (inches)	Total (inches)	Evaporation (inches)
August	.64	7.50	8.14	6.87
September	.52	3.00	3.52	4.72
October	2.52	--	2.52	2.29
Totals	3.68	10.50	14.18	13.88

The evaporation data were from a standard pan evaporimeter which was read daily. As evaporation from a free water surface always exceeds evaporation from a pasture (16, p. 143-145), it is evident from the above figures that water was in adequate supply throughout the period of this experiment.

Temperature

The Oregon State University meteorological recording station is situated near the experimental site. The monthly mean maximum and mean minimum temperatures recorded in the standard meteorological screen during the period of the experiment and the 25-year monthly average for the same period and location are given in Table 3.

Table 3

Mean monthly maximum and minimum screen temperatures at Hyslop Agronomy Farm from August to October 1960 and 25-year averages for same location in degrees Fahrenheit.

Month	Mean Monthly Maximum		Mean Monthly Minimum	
	1960	25-year av.	1960	25-year av.
August	78.0	80.9	49.1	51.4
September	75.7	76.7	46.9	48.85
October	65.3	64.7	41.7	43.5

Sampling

The 84 sub-plots were sampled three times for herbage yield by cutting out from each 20 feet by 7 feet sub-plot a 20 feet by 3 feet strip of herbage with an auto-scythe which cut to a height of approximately one inch. The green weight of this sample was determined in the field and a sub-sample of about 1000 grams was drawn, weighed green, transported to the laboratory, dried for two days at approximately 87° C., re-weighed and then used for Kjeldahl nitrogen determination.

The field plot yield in grams of dry matter was calculated from the original green weight and the moisture loss from the sub-sample on drying.

For the purpose of Kjeldahl nitrogen determinations, the dried sub-samples of each of the three replicates for any one treatment were bulked and ground. Percentage nitrogen was then determined in duplicate on each of the 28 treatments on each sampling occasion.

There were three sampling occasions. On September 14, a strip 3 feet by 20 feet was taken from one side of each sub-plot. The data derived from this sampling were called group (1) data.

On October 19, a similar strip was re-cut from the same part of the plot as was previously cut on September 14. The data derived from this sampling were called group (2) data and the yields obtained represented plot regrowths from September 14 to October 19, 1960.

On October 20, another strip of the same size was cut from the other previously uncut side of each plot. The data derived from this sampling were called group (3) data and the yields obtained representad growth for the whole period from August 18 to October 20.

The sum of the yields for each plot on sampling occasions No. 1 and 2 represented the total yield from each plot for the whole period August 18 to October 20 on the basis of two cuttings. This group of derived data were called group (4) data.

EXPERIMENTAL RESULTS

Part I. Experiment at Badgery's Creek

A. Yield of Dry Matter

The mean dry matter yields of the four nitrogen or sulphate of ammonia sub-treatments at each of the seven sampling occasions are presented in Table 4.

Table 4

Mean yield of nitrogen or sulphate of ammonia sub-treatments in pounds of dry matter per acre at each sampling period.

Sampling Date	Sulphate of ammonia sub-treatments Nil	112 lb/A	224 lb/A	448 lb/A	L.S.D. at P=.01	L.S.D. at P=.05
1955						
Aug. 16	82	149	218	406	38	29
Sept. 20	61	492	1072	2003	152	131
Nov. 1	2835	3058	3541	4097	385	293
Dec. 28	2459	2791	3031	3067	389	296
1956						
Feb. 16	880	880	894	1125	175	220
May 22	120	182	195	180	N.S.	N.S.
Aug. 6	22	49	96	117	55	42
Total	6459	7601	9047	10995		

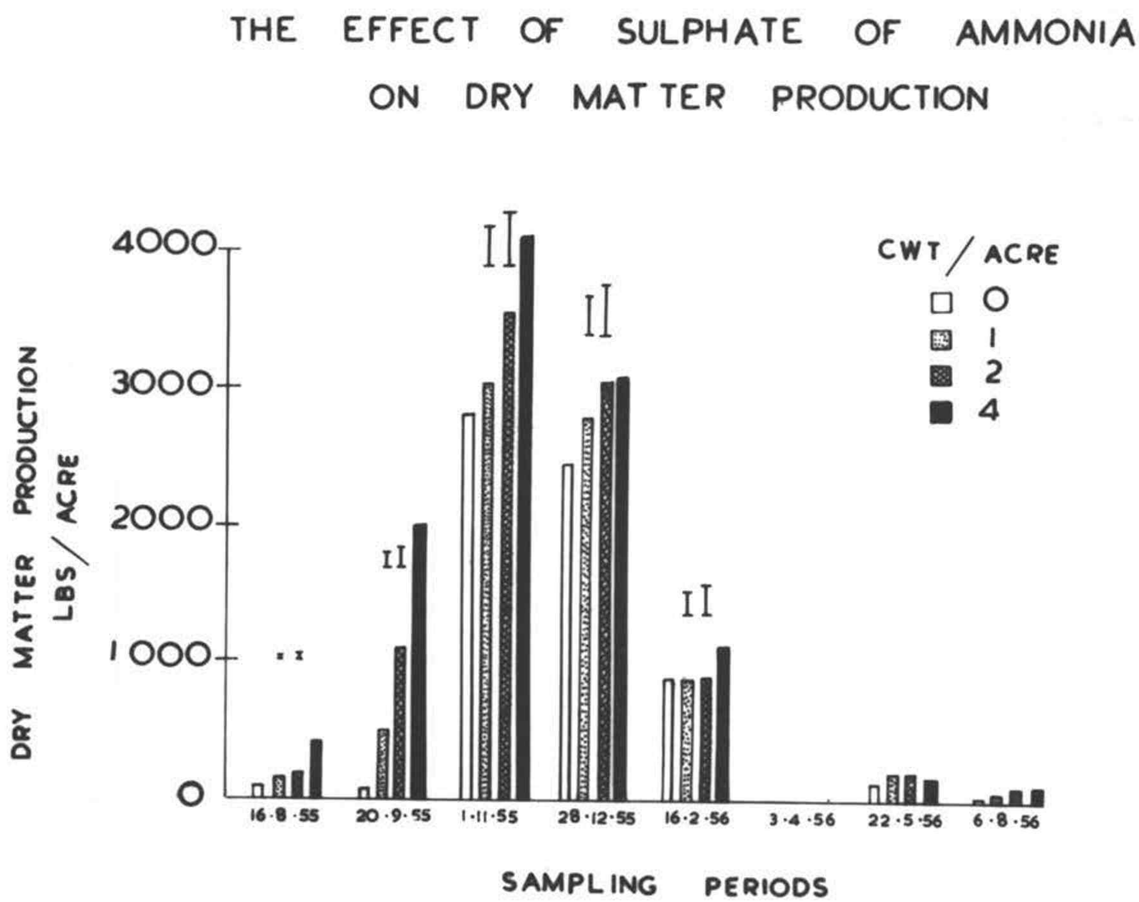

Figure 1

Histogram showing the effect of the four sulphate of ammonia sub-treatments on the dry matter production at each sampling period.

The four sulphate of ammonia treatments correspond to nitrogen applications of 0, 23, 46 and 92 pounds of nitrogen per acre applied first on May 23, 1955 and then immediately after each sampling occasion. The dates of the sampling periods should be read day-month-year. The two short vertical lines above each sampling period indicate the L.S.D.'s at P = .05 and P = .01.

The analysis of variance of the yield data from the 64 sub-plots at each sampling period is summarized in Table 5.

The four main plot treatments (125 lb. of P_2O_5 plus no gypsum, 125 lb. of P_2O_5 plus no gypsum and 250 lb. of P_2O_5 plus one ton of gypsum per acre) failed to significantly influence dry matter yields at all of the seven sampling occasions, as shown in Table 5, and require no further consideration.

Table 5. Analyses of variance of yield data for each sampling period

Source of Variation	Degrees of Freedom	Mean squares of data for following sampling periods						
		1955				1956		
		Aug. 16	Sept. 20	Nov. 1	Dec. 28	Feb. 16	May 22	Aug. 6
Blocks	3	6879	84911	1458487	202338	250447	29173	18238
Main treatments	3	3224*	26952*	144675*	210345*	94386*	6739*	7804*
Error "A"	9	2599	31587	379460	263876	135457	4787	6572
Sub-treatments	3	303277**	11292959**	5022939**	1255946**	232104**	1805*	29956**
Interaction	9	7031	38870	53560	120635	57903	2386	668
Error "B"	36	1772	28185	178891	183831	58370	20485	3660

*Effect not significant
**Effect significant at 1% probability level

B. Per Cent Crude Protein in Herbage

The mean per cent crude protein of total dry matter herbage from each of the four nitrogen or sulphate of ammonia sub-treatments at each sampling occasion is given in Table 6. Per cent crude protein has been calculated as per cent Kjeldahl nitrogen multiplied by 6.25.

Table 6

Mean per cent crude protein in dry matter herbage for each nitrogen or sulphate of ammonia sub-treatment at each sampling period.

Sampling Date	Sulphate of ammonia sub-treatments			
	Nil	112 lb/A	224 lb/A	448 lb/A
1955				
August 16	10.3	9.2	10.2	12.9
September 20	23.4	19.0	15.4	14.7
November 1	17.5	13.9	13.3	11.3
December 28	18.1	15.2	10.2	10.0
1956				
February 16	22.5	20.6	16.8	14.7
May 22	19.2	18.0	14.1	9.7
August 6	18.4	15.9	17.0	22.9

These data are illustrated in Figure 2.

THE EFFECT OF SULPHATE OF AMMONIA ON PERCENT CRUDE PROTEIN

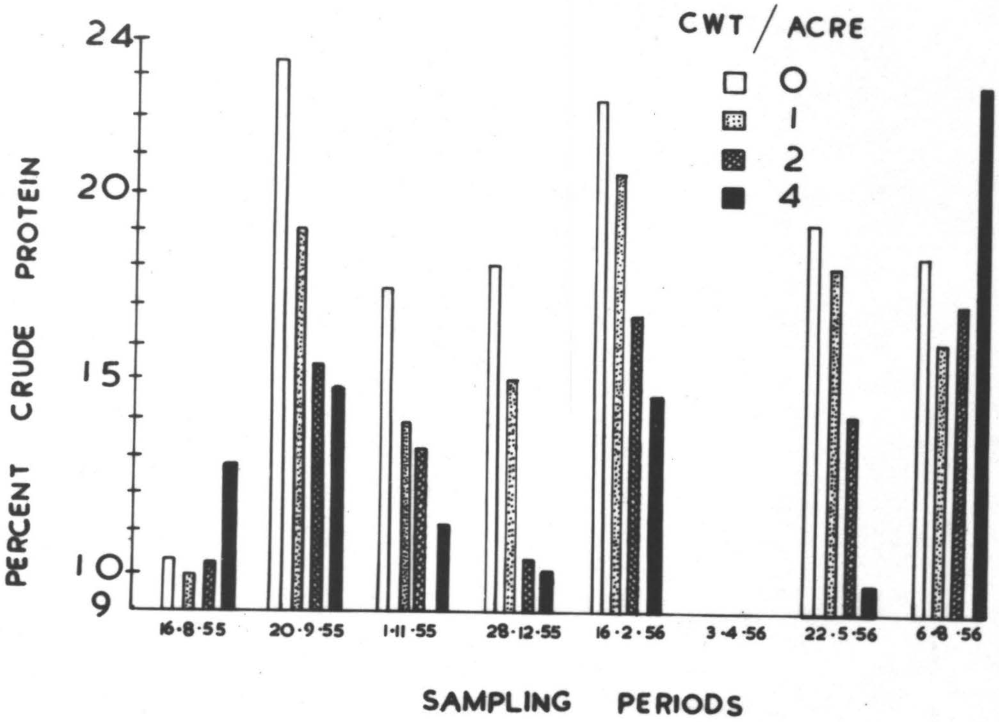

Figure 2

Histogram showing the effect of the four sulphate of ammonia sub-treatments on the mean per cent crude protein of the total herbage at each sampling period. The dates of the sampling periods should be read day-month-year.

C. Nitrogen Recovered in the Herbage

The mean amount of nitrogen recovered in the herbage in pounds per acre for each of the four sub-plot sulphate of ammonia treatments at each sampling occasion is presented in Table 7.

Table 7

Mean nitrogen recovery in pounds of N per acre for each nitrogen or sulphate of ammonia sub-treatment at each sampling period.

Sampling Date	Nitrogen applied as sulphate of ammonia			
	Nil	23 lb N/A	46 lb N/A	92 lb N/A
1955				
August 16	1.3	2.2	3.6	8.4
September 20	2.1	15.0	26.6	47.2
November 1	79.1	68.2	74.7	73.4
December 28	71.4	67.6	49.9	49.4
1956				
February 16	31.6	29.0	24.1	26.6
May 22	3.7	5.2	4.4	2.8
August 6	.7	1.3	2.6	4.3
Total period	189.9	188.5	185.9	212.1

These data are illustrated in Figure 3.

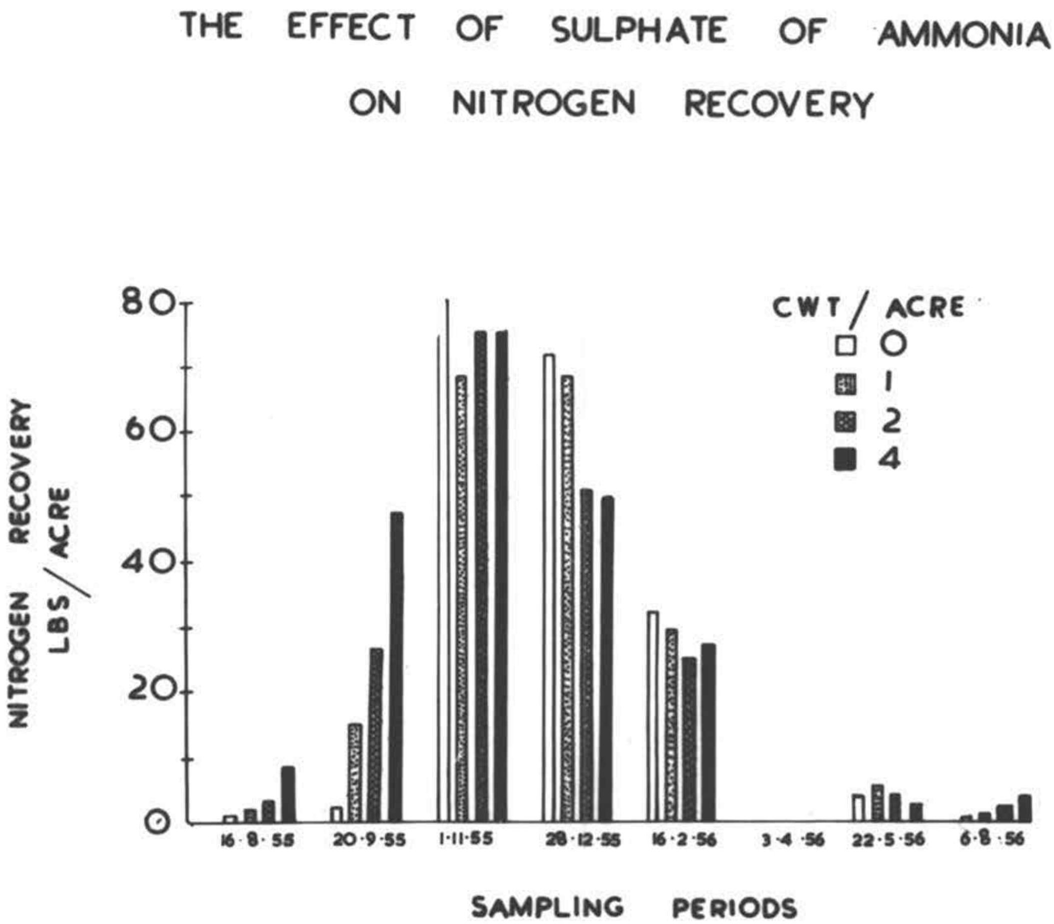

Figure 3

Histogram showing the effect of the four levels of sulphate of ammonia, which correspond to nitrogen applications of nil, 23 lb. N, 46 lb. N and 92 lb. N per acre, on the total recovery of nitrogen in the herbage at each sampling period. The dates of the sampling periods should be read day-month-year.

D. Yield Increase per Pound of Applied Nitrogen

The mean increase in dry matter yield per pound of nitrogen applied as sulphate of ammonia, over that obtained from the no nitrogen treatment, for each subtreatment at each sampling occasion is given in Table 8.

Table 8

Mean increase in dry matter yield per pound of nitrogen applied for each of the three nitrogen or sulphate of ammonia sub-treatments at each sampling period.

Sampling Date	Nitrogen applied as sulphate of ammonia		
	23 lb N/A	46 lb N/A	92 lb N/A
1955			
August 16	3.0	3.1	3.6
September 20	19.5	22.7	21.7
November 1	9.8	15.8	14.1
December 28	14.8	12.6	6.8
1956			
February 16	1.0	2.0	2.7
May 22	2.8	1.7	0.7
August 6	1.3	1.7	1.0

E. Seasonal Production Pattern

The effect of the four sulphate of ammonia sub-treatments on the production pattern of the pasture was determined by estimating the growth rate of each sub-treatment at a point mid-way between each sampling date. This was done by counting the days between each two successive sampling dates, dividing the mean dry matter yield for that period by the number of days counted and plotting the growth rate obtained (in pounds per acre per day) on the time axis midway between the two sampling dates.

Graphs showing the growth rate-time relationships for each of the four nitrogen sub-treatments are presented in Figure 4.

F. Percentage of Clover in Herbage

The mean percentage of clover in each of the four sulphate of ammonia sub-plot treatments was estimated at each sampling occasion by hand-separating part of the sub-samples taken for dry matter estimations or by making a visual assessment of each plot before harvesting. These dry weight estimates of per cent clover are summarized in Figure 5.

The botanical composition of the four sub-treatments on the day that the final sample was drawn on August 6, 1956, is further illustrated by the four photographs presented as Figures 6, 7, 8 and 9.

G. Reaction of Surface Soil

The effect of repeatedly applying sulphate of ammonia at different rates on the mean pH of the 0-3 inch surface soil is reported in Table 9.

Table 9

Sub-Treatment	Amount of sulphate of ammonia applied per acre since May 23, 1955	Mean pH at August 6, 1956
N0	Nil	5.20
N1	896 lb.	5.03
N2	1792 lb.	4.91
N4	3584 lb.	4.58

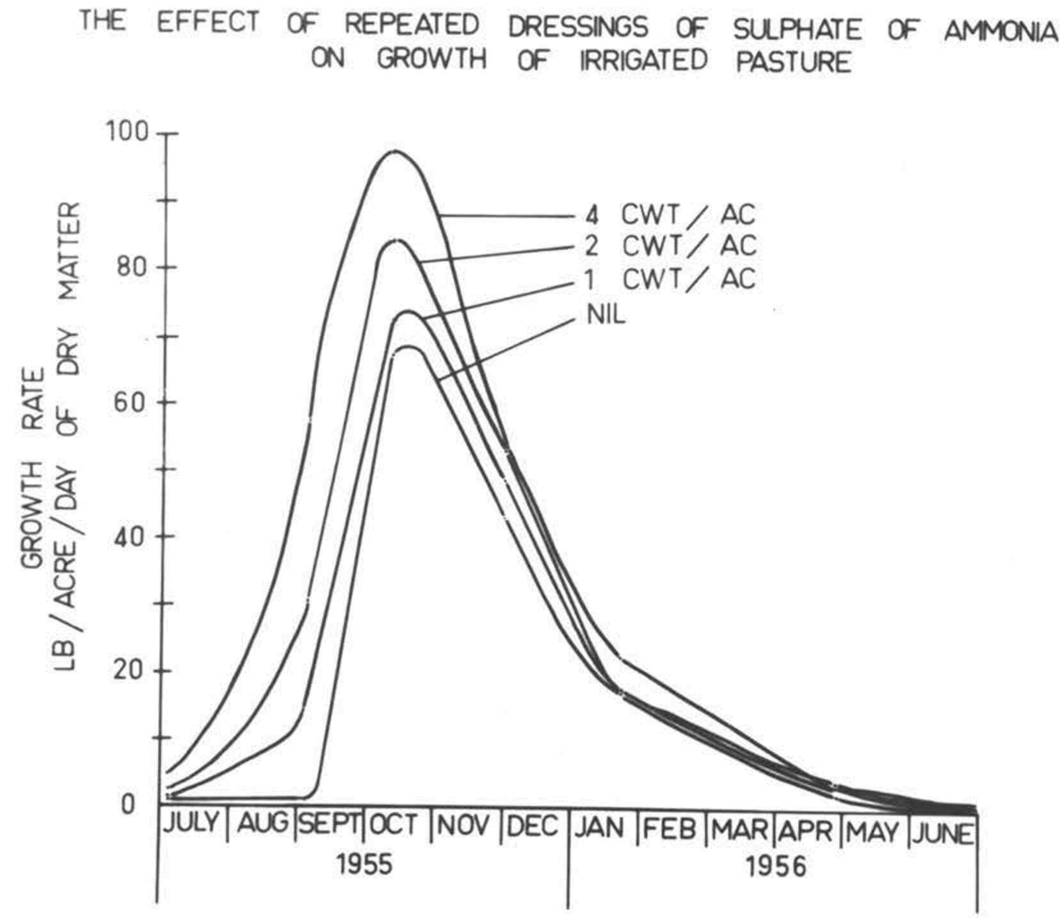

Figure 4

Graph showing the growth rate-time curves or seasonal production patterns of the four nitrogen sub-treatments. The nil, 1 cwt, 2 cwt and 4 cwt/A sulphate of ammonia treatments correspond to nitrogen rates of nil, 23 lb., 46 lb., and 92 lb. per acre applied on May 23, 1955 and after each subsequent sampling occasion.

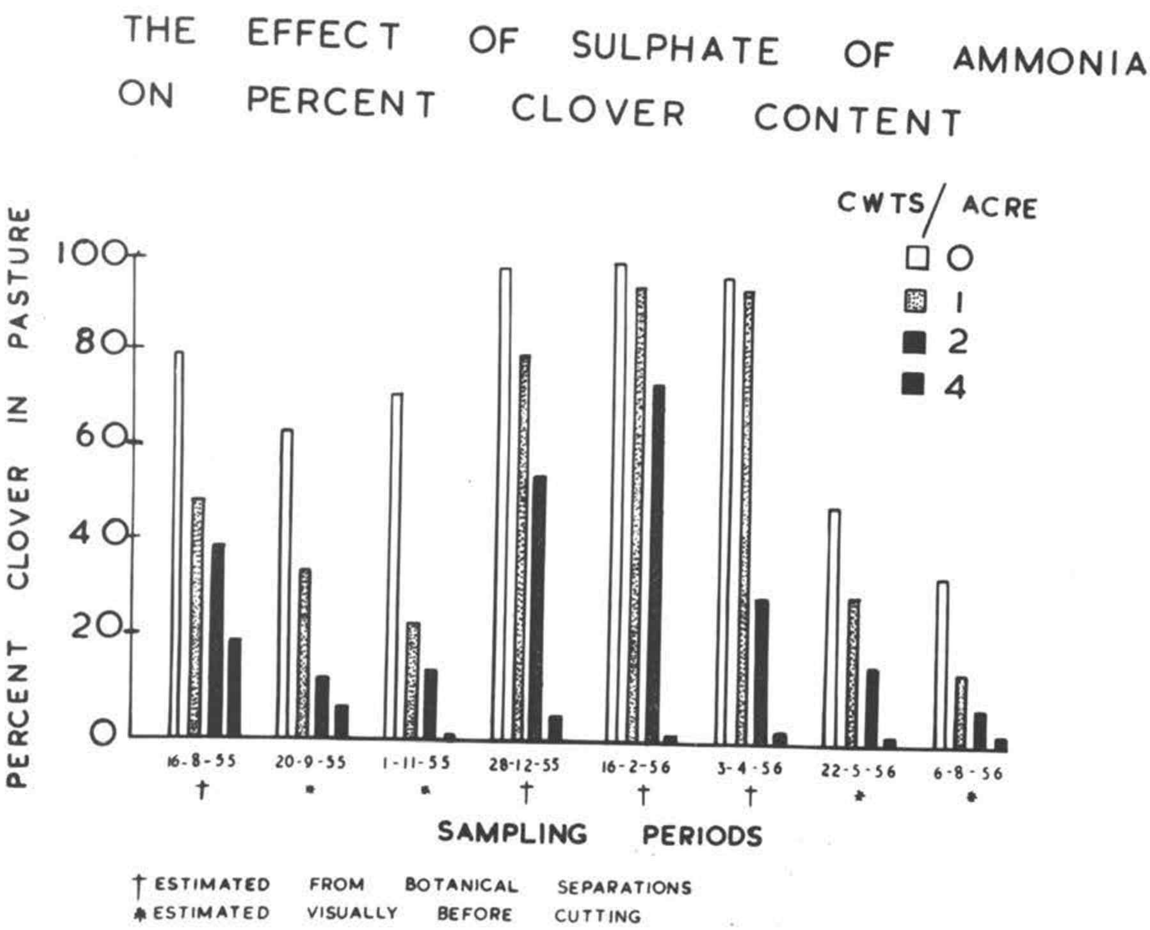

Figure 5

Histogram showing estimated percentage of clover in dry matter for each nitrogen sub-treatment at each sampling occasion.

Figure 6
Photograph of part of a plot representing the no nitrogen sub-treatments on the last sampling occasion on August 6, 1956. Note strong clover dominance but survival of ryegrass.

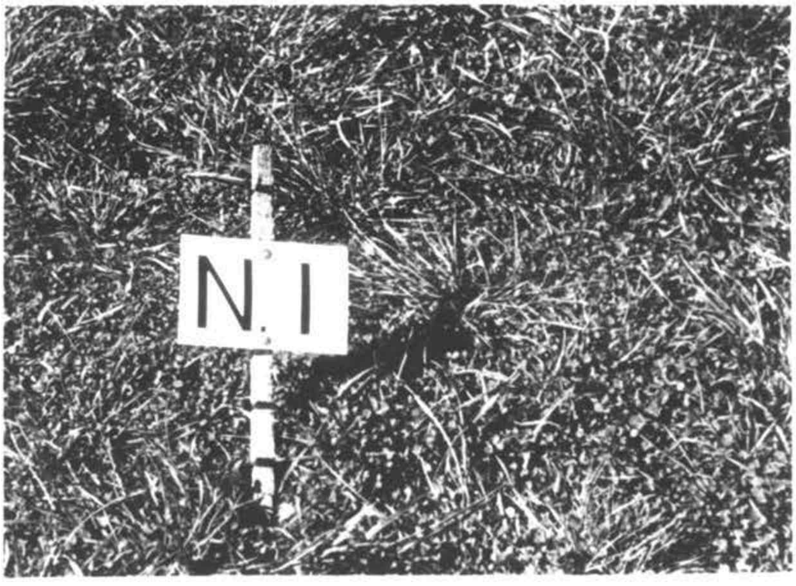

Figure 7
Photograph of part of a plot representing the N1 sub-treatments at August 6, 1956. This plot has received a total of 896 lb. of sulphate of ammonia per acre (184 lb. N) since May 23, 1955. Note increase in ryegrass content and decrease in clover.

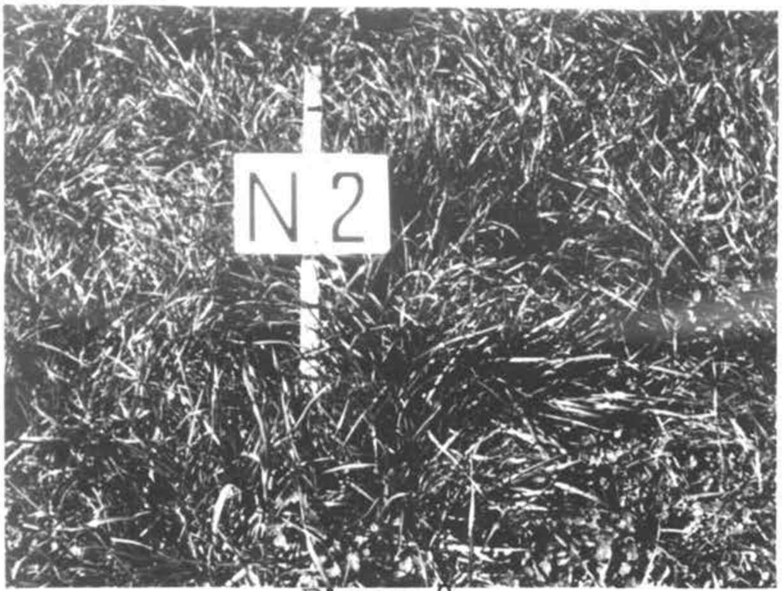

Figure 8
Photograph of part of a plot representing the N2 sub-treatments at August 6, 1956. This plot had received a total of 1792 lb. of sulphate of ammonia per acre (368 lb. N) since May 23, 1955. Note strong ryegrass dominance and small amount of clover.

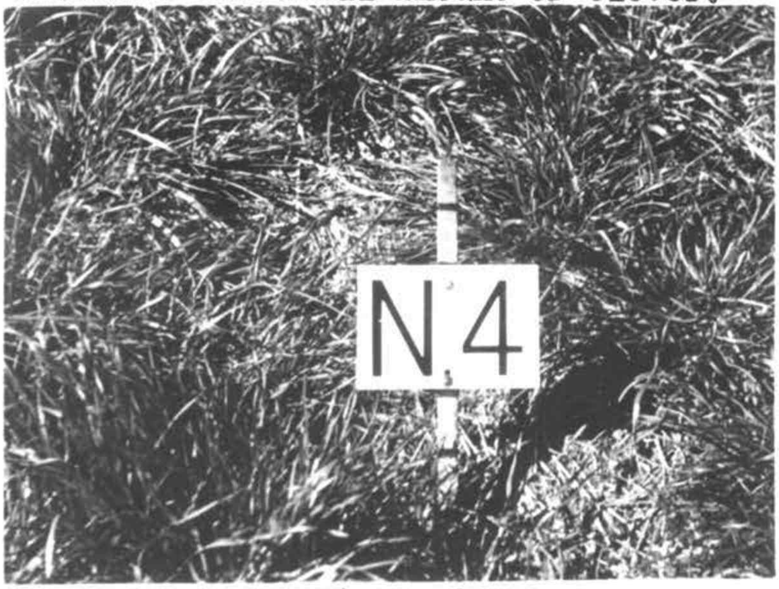

Figure 9
Photograph of part of a plot representing the N4 sub-treatments at August 6, 1956. This plot had received a total of 3584 lb. of sulphate of ammonia per acre (736 lb. N) since May 23, 1955. Note virtual elimination of the clover and open nature of the ryegrass.

Part II. Experiment at Hyslop Agronomy Farm

A. Yield of Dry Matter

The mean dry matter yield for each of the 28 treatments for each of the four groups of yield data are presented in Tables 10 to 13 inclusive.

A summary of the analysis of variance for each of the four groups of dry matter yield data are presented in Table 14.

Table 10

Mean yield of dry matter in pounds per acre for each treatment from August 18 to September 14, 1960. Group (1) data.

	Species				
Fertilizer	Lolium	Phalaris	Dactylis	Festuca	Fertilizer Means
NO	26	10	176	206	105
N45A	247	75	911	646	470
N90A	464	167	1454	771	714
N45U	322	62	939	655	494
N90U	422	59	1438	1140	765
N45L	235	33	655	444	342
N90L	280	23	849	667	454
Species Means	285	61	917	647	

L.S.D. - .05 for fertilizer means = 125
L.S.D. - .05 for species means = 248

Table 11

Mean yield of dry matter in pounds per acre for each treatment from September 14 to October 19, 1960. Group (2) data.

Fertilizer	Species				Fertilizer Means
	Lolium	Phalaris	Dactylis	Festuca	
NO	19	24	27	96	42
N45A	106	206	253	346	228
N90A	588	377	429	438	458
N45U	271	129	230	285	229
N90U	829	478	452	618	594
N45L	130	74	217	281	176
N90L	478	248	347	503	394
Species Means	346	219	279	367	

L.S.D. - .05 for fertilizer means = 122

Effects due to species are not significant.

Table 12

Mean yield of dry matter in pounds per acre for each treatment from August 18 to October 20, 1960 as a single final harvest. Group (3) data.

Fertilizer	Species: Lolium	Phalaris	Dactylis	Festuca	Fertilizer Means
NO	30	33	254	296	154
N45A	606	351	1236	1177	843
N90A	1390	382	2459	2137	1592
N45U	474	173	1159	1324	783
N90U	1384	271	2092	2303	513
N45L	441	69	1029	778	579
N90L	1060	323	1847	1964	1299
Species Means	769	229	1439	1426	

L.S.D. - .05 for fertilizer means = 206

L.S.D. - .05 for species means = 432

Table 13

Mean yield of dry matter in pounds per acre for each treatment from August 18 to October 19, 1960 as sum of two harvests. Group (4) data.

Fertilizer	Species: Lolium	Phalaris	Dactylis	Festuca	Fertilizer Means
NO	44	34	204	302	146
N45A	353	281	1165	992	698
N90A	1052	544	1883	1209	1172
N45U	594	191	1168	940	723
N90U	1252	537	1889	1757	1363
N45L	366	107	871	725	517
N90L	758	271	1195	1171	848
Species Means	631	281	1196	1014	

L.S.D. - .05 for fertilizer means = 153

L.S.D. - .05 for species means = 232

Table 14. Summaries of the analysis of variance for each of the four groups of dry matter yield data.

Source of Variation	Degrees of Freedom	Mean squares for each group of data			
		Group (1)	Group (2)	Group (3)	Group (4)
Blocks	2	833.10	34616.18	74356.65	60241.75
Species	3	1184101.20*	36895.31	2785480.66*	1368354.83*
Error "A"	6	58443.60	9434.33	142621.50	51100.23
Fertilizer	6	232366.23*	166569.58*	1298568.66*	762684.75*
Species x Fertilizer	18	40956.74*	8907.88*	114301.11*	43259.73*
Error "B"	48	7755.73	7392.38	20919.52	11637.12
Total	83				

*Effect significant at 5% probability level.

The mean yields obtained from each species over all fertilizer treatments at each sampling period are summarized in Figure 10.

During the first four weeks of the trial, August 18 to September 14, 1960, *Dactylis* and *Festuca* gave higher yields than *Lolium* or *Phalaris*, and the yield from *Dactylis* was greater than from *Festuca*.

During the period September 14 to October 19, 1960, the yields from the four grass species were similar.

For the full period August 14 to October 20, 1960, the yield of *Dactylis* and *Festuca* were not different from each other but both yielded more than *Lolium*, which in turn was superior to *Phalaris*. The same relationships occurred for the period August 14 to October 19 on the basis of two harvests, although total yields were less for all species except *Phalaris*.

The mean yields obtained from each fertilizer treatment at each sampling period over all four species are summarized in Figure 11. The 45 pound N per acre treatments increased the dry matter yield at each harvest, regardless of the nitrogen carrier. The 90 pound N per acre treatments gave higher yields than the 45 pound N per acre treatments at all sampling periods.

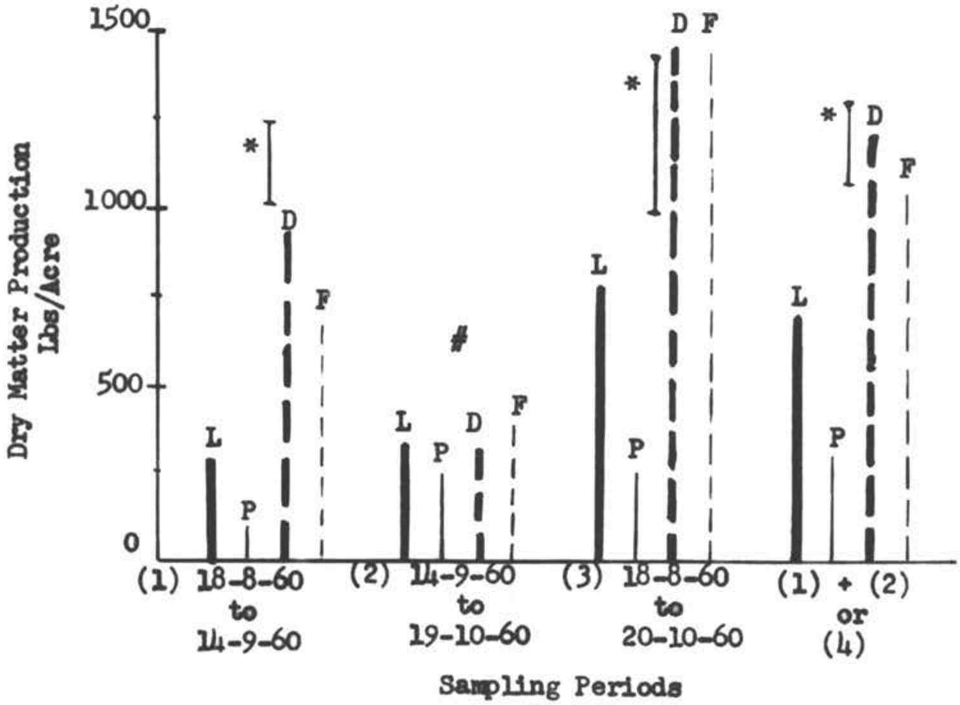

Figure 10. Histogram showing mean yield of each species for all fertilizer treatments at each sampling period.
L = Lolium perenne
P = Phalaris tuberosa
D = Dactylis glomerata
F = Festuca arundinacea
* = L.S.D. at P = .05
# = Differences not significant

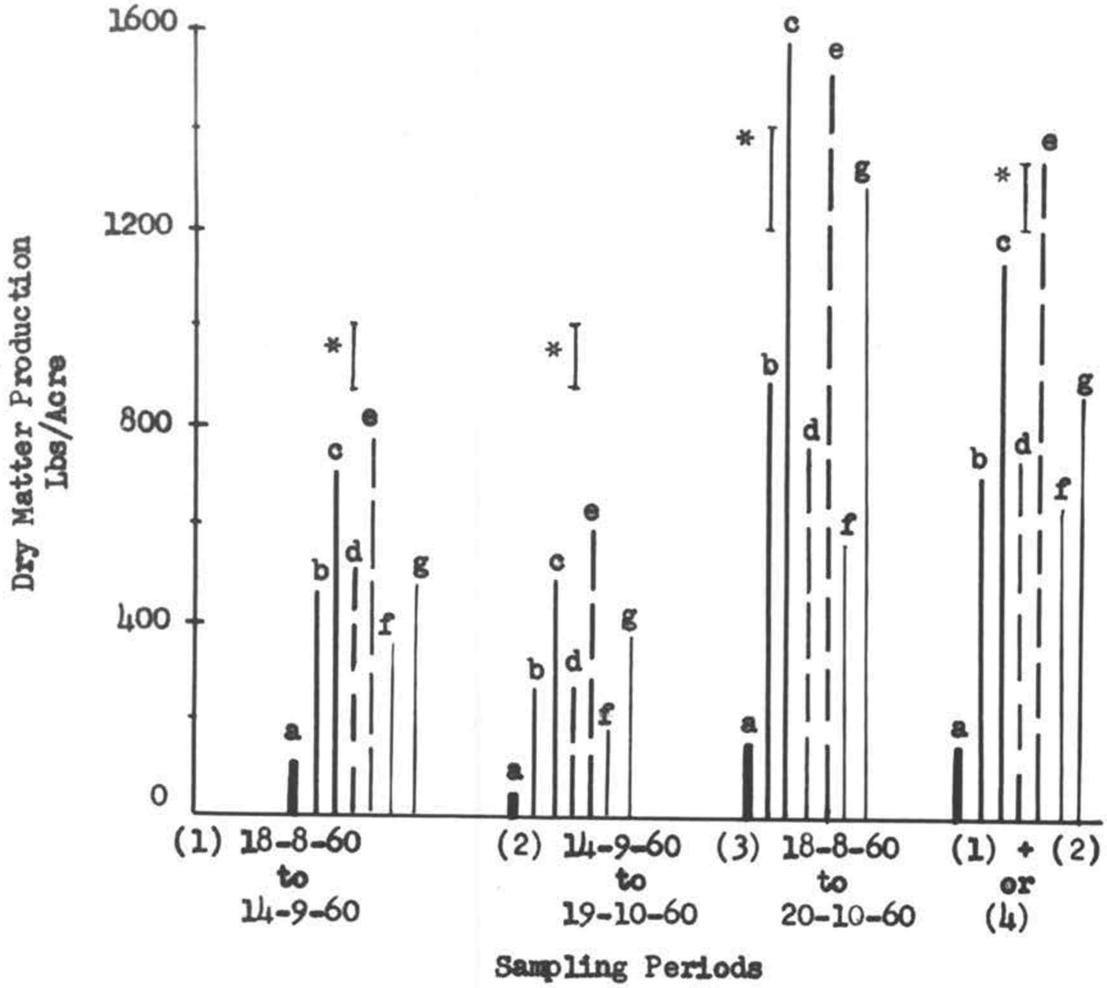

Figure 11. Histogram showing mean yield from each fertilizer over all species at each sampling period.
a = NO d = N45U f = N45L
b = N45A e = N90U g = N90L
c = N90A * = L.S.D. at P = .05

The liquid urea treatments (N45L and N90L) gave lower yields than the corresponding pelleted urea (N45U and N90U) and pelleted ammonium nitrate treatments (N45A and N90A) at each sampling period.

The corresponding pelleted urea (N45U and N90U) treatments and pelleted ammonium nitrate treatments (N45A and N90A) gave similar yields throughout except that the N90U outyielded N90A when the yield data from the first two sampling periods was summed.

The effect of ammonium nitrate applied August 18 at 90 pounds N per acre on the yield of forage to September 28, 1960, for each of the four species, is illustrated further in photographs presented as Figures 12 to 19.

B. Per cent Crude Protein in Herbage

The mean per cent crude protein of total herbage from each of the 28 sub-plot treatments at each of the three sampling periods is given in Table 15.

Figure 12
Photograph of Lolium perenne at September 28, 1960 with no nitrogen applied previously. Vertical scale is in feet.

Figure 13
Photograph of Lolium perenne at September 28, 1960, topdressed with 90 pounds of nitrogen per acre as ammonium nitrate on August 18, 1960.

Figure 14
Photograph of Phalaris tuberosa at September 28, 1960 with no nitrogen applied previously.

Figure 15
Photograph of Phalaris tuberosa at September 28, 1960, topdressed with 90 pounds of nitrogen per acre as ammonium nitrate on August 18, 1960.

Figure 16
Photograph of Dactylis glomerata at September 28, 1960 with no nitrogen applied previously.

Figure 17
Photograph of Dactylis glomerata at September 28, 1960, topdressed with 90 pounds of nitrogen per acre as ammonium nitrate on August 18, 1960.

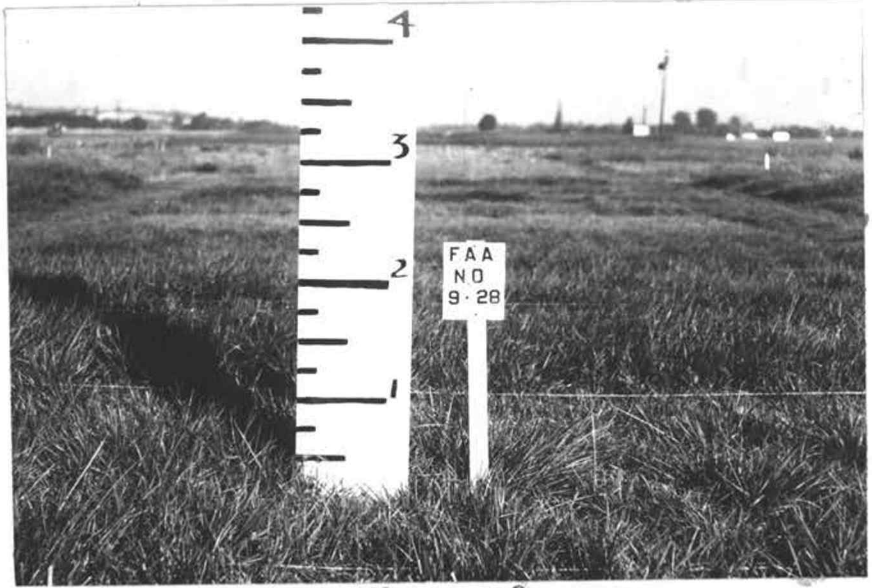

Figure 18
Photograph of Festuca arundinacea at September 28, 1960 with no nitrogen applied previously.

Figure 19
Photograph of Festuca arundinacea at September 28, 1960, topdressed with 90 pounds of nitrogen per acre as ammonium nitrate on August 18, 1960.

Table 15

Mean per cent crude protein of total herbage

Sampling period	Fertilizer	Lolium	Phalaris	Dactylis	Festuca
18-8-60 to 14-9-60	NO	11.42	13.05	13.61	15.22
	N45A	17.30	21.63	30.64	18.32
	N45U	18.37	21.42	15.87	17.91
	N45L	17.89	19.54	17.36	17.82
	N90A	25.05	28.63	19.82	21.11
	N90U	25.61	25.72	19.95	21.85
	N90L	22.28	24.42	20.63	21.75
14-9-60 to 19-10-60	NO	10.13	10.24	12.02	12.70
	N45A	10.28	11.44	12.58	13.02
	N45U	9.38	12.83	13.24	14.25
	N45L	9.77	11.40	12.55	13.75
	N90A	13.29	16.88	13.83	14.67
	N90U	12.91	15.46	14.42	14.62
	N90L	11.41	14.90	13.72	14.57
18-8-60 to 20-10-60	NO	8.07	12.59	11.26	12.51
	N45A	9.50	12.28	10.47	11.96
	N45U	8.63	9.90	9.14	11.95
	N45L	8.62	12.62	10.78	12.84
	N90A	11.02	12.76	9.76	12.19
	N90U	11.29	13.31	11.55	11.89
	N90L	10.70	11.46	11.77	11.89

At the first sampling period on September 14, 1960, the N45 lb/A treatments increased protein percentage of all species and the N90 lb/A treatments increased them still further. The increase in protein percentage was less for the liquid than the pelleted treatments.

At the second sampling on October 19, 1960, the N45 lb/A treatment had only a small effect but the N90 lb/A treatments greatly increased protein percentages. The liquid treatments again had less effect than the pelleted treatments.

The crude protein content of herbage which had grown from August 18 to October 20, 1960 was little affected by the initial nitrogen applications except for *Lolium* species which responded to the 90 lb. N/A treatments.

The amount of nitrogen recovered in the herbage of *Phalaris* was very low for all sampling periods and reached a maximum of only 17.83 lb/acre or about 19.5 per cent.

The liquid method of applying urea gave consistently lower nitrogen recovery for both rates of application for all species and at all sampling periods. Maximum recovery was 22.55 lb/acre from a 45 lb. N/A application, or 41.6 per cent and 35.64 lb/acre from a 90 lb. N/A application or 35.3 per cent.

Under the conditions of this experiment, *Phalaris tuberosa* (Turkish strain) and the liquid method of nitrogen application can be considered unsatisfactory treatments. The further examination of data derived from them seems unjustified in terms of the objective of this experiment.

During the first period, August 18 to September 14, *Dactylis* gave consistently higher nitrogen recoveries than *Festuca* for all levels and forms of nitrogen application. *Festuca* in turn gave higher recoveries than *Lolium*.

During the second period, September 14 to October 19, <u>Festuca</u> recovered more nitrogen than <u>Dactylis</u> at both rates of application but at the high rate of nitrogen application, <u>Lolium</u> recovered more nitrogen than <u>Festuca</u> or <u>Dactylis</u>.

For the sum of the two harvests, <u>Dactylis</u> tended to give the highest total nitrogen recovery but for the single harvest on October 20, Festuca gave greatest nitrogen recovery. <u>Lolium</u> recovered less nitrogen than <u>Dactylis</u> or <u>Festuca</u> in each case.

C. <u>Nitrogen Recovery in Herbage</u>

Amount of nitrogen recovered in the herbage for each of the 28 sub-plot treatments at each sampling period is given in Table 16.

Table 16

Mean nitrogen recovered in herbage in pounds per acre.

Sampling period	Fertilizer	Species			
		Lolium	Phalaris	Dactylis	Festuca
18-8-60 to 14-9-60	NO	.47	.21	3.83	5.02
	N45A	6.83	2.60	30.08	18.93
	N45U	9.46	2.12	23.84	18.77
	N45L	6.73	1.03	18.19	12.66
	N90A	18.60	7.65	46.11	26.04
	N90U	17.29	2.43	45.90	39.85
	N90L	9.98	0.89	28.02	23.21
14-9-60 to 19-10-60	NO	.31	.39	.52	1.95
	N45A	1.74	3.77	5.09	7.20
	N45U	4.07	2.65	4.87	6.50
	N45L	2.03	1.35	4.36	6.18
	N90A	12.50	10.18	9.49	10.28
	N90U	17.12	11.82	10.43	14.45
	N90L	8.73	5.91	7.62	11.72
18-8-60 to 19-10-60	NO	.78	.60	4.35	6.97
	N45A	8.57	6.37	35.17	26.13
	N45U	13.53	4.77	28.71	25.27
	N45L	8.76	2.38	22.55	18.84
Two harvests	N90A	31.10	17.83	55.60	36.32
	N90U	34.41	14.25	56.33	54.30
	N90L	18.71	6.80	35.64	34.93
18-8-60 to 20-10-60	NO	.39	.66	4.57	5.92
	N45A	9.20	6.89	20.71	22.52
	N45U	6.50	2.74	16.95	25.31
	N45L	6.08	1.39	17.75	15.98
Single cut	N90A	24.51	7.80	38.40	41.68
	N90U	25.00	5.77	38.66	43.81
	N90L	18.15	5.92	34.78	37.36

The estimated percentage of applied nitrogen recovered in the herbage of the three critical species, *Lolium*, *Dactylis* and *Festuca*, calculated from the expression:

$$\frac{\text{N in fertilized grass - N in control}}{\text{N applied as fertilizer}} \times 100,$$

for the four important fertilizer treatments, N45A, N45U, N90A, and N90U for each sampling period is given in Table 17.

Table 17

Apparent percentage of applied nitrogen recovered in herbage.

Sampling period	Fertilizer	Species Lolium	Dactylis	Festuca
18-8-60 to 14-9-60	N45A	14.1	58.3	30.9
	N45U	20.0	44.5	30.6
	N90A	20.1	47.0	23.4
	N90U	18.7	46.7	38.7
14-9-60 to 19-10-60	N45A	3.2	10.1	11.7
	N45U	8.4	9.7	10.1
	N90A	13.5	10.0	9.3
	N90U	18.7	10.1	13.9
18-8-60 to 19-10-60 Two harvests	N45A	17.3	68.4	42.6
	N45U	28.4	54.2	40.7
	N90A	33.6	57.0	32.7
	N90U	37.4	56.8	52.6
18-8-60 to 20-10-60 One harvest	N45A	19.6	35.9	36.9
	N45U	13.8	27.5	43.1
	N90A	26.8	37.6	39.7
	N90U	27.3	37.9	42.1

Lolium gave low percentage nitrogen recoveries at each sampling period, the high apparent recovery on the basis of two harvests being only 37.4 per cent. Except for the first sampling period, recoveries tended to be higher at the higher level of nitrogen application.

Dactylis gave high recovery percentages throughout. On the two harvest basis this was as high as 65.4 per cent and consistently greater than 54 per cent. Two harvests gave much higher total recovery than a single harvest for the whole period.

Festuca gave recoveries up to 52.6 per cent but these were lower than for Dactylis at the first harvest and on the basis of two harvests, but higher for the single harvest covering the whole period.

D. Yield Increase per Pound of Applied Nitrogen

Dry matter yield increase per pound of nitrogen applied has been calculated for the whole experimental period on the basis of both the sum of the two harvests and the single harvest. These data are presented in Table 18.

Table 18

Increased yield as pounds of dry matter per pound of applied nitrogen

Sampling period	Fertilizer	Species		
		Lolium	Dactylis	Festuca
18-8-60	N45A	6.9	21.4	15.3
to	N45U	12.2	21.4	14.2
19-10-60	N90A	11.2	18.7	10.1
Two harvests	N90U	13.4	18.7	16.2
18-8-60	N45A	12.8	21.8	19.5
to	N45U	9.8	20.1	22.8
20-10-60	N90A	15.1	24.5	20.4
One harvest	N90U	15.0	20.4	22.3

E. Autumn Production Patterns

The production patterns of the three species at the three nitrogen levels, N0, N45 lb/A and N90 lb/A, were constructed for the period of this experiment by the same method as used for the Badgery's Creek data in Part I. The N45 and N90 yield data on which the growth rates were calculated were derived from the mean of the solid urea and pelleted ammonium nitrate treatments. The autumn production patterns of the four species, each at two nitrogen levels, estimated on the basis of two defoliations (August 14 and September 19) are presented in Figure 20.

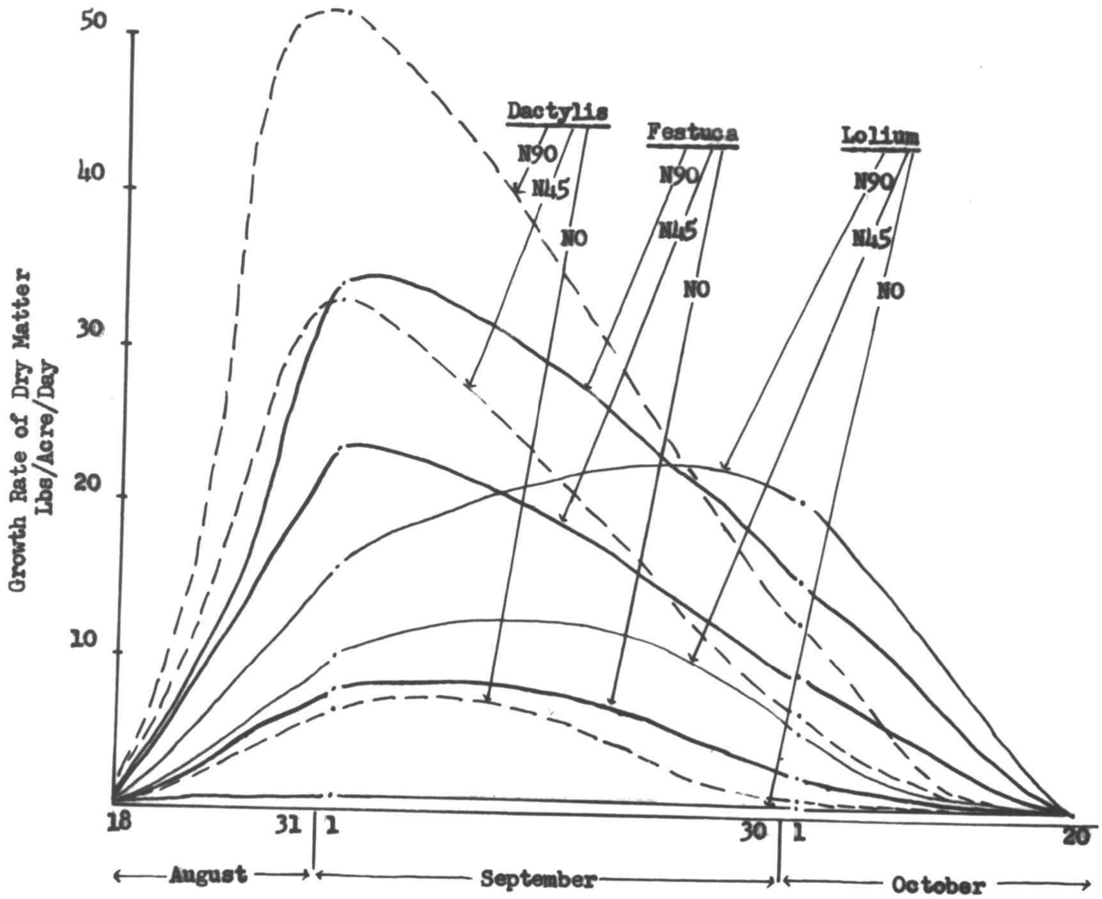

Figure 20. Estimated autumn production patterns of Lolium, Festuca and Dactylis at the three levels of nitrogen application.

In early autumn, Dactylis with nitrogen gave the highest growth rates, Festuca was intermediate and rye-grass grew slowly.

In late autumn the growth rates of the different species, when treated with nitrogen, tended to approach each other. The growth rate of Dactylis dropped sharply, Festuca dropped more slowly and Lolium increased or dropped only slightly.

By October 19 all species had reached a stage of near winter dormancy but Festuca and Lolium remained green while Dactylis was completely brown and dormant.

DISCUSSION OF RESULTS

The results of the Badgery's Creek experiment and the Hyslop Agronomy Farm experiment are closely related and are best discussed together under the same headings.

Production of Dry Matter

At Badgery's Creek, the main plot treatments of superphosphate at 125 lb. or 250 lb. of P_2O_5 per acre and gypsum at nil or one ton per acre, produced no significant effects at any of the seven sampling occasions. This showed that the addition of these fertilizers at levels greater than 125 lb. of P_2O_5 per acre per year were not required, even when heavy rates of nitrogenous fertilizer were used and all herbage was removed as clippings. Under grazing conditions and the return of phosphorus and nitrogen in the form of dung and urine, the superphosphate demand would be still less.

Nitrogenous fertilizers increased the dry matter yields of *Lolium* at each sampling occasion at Badgery's Creek, as shown in Tables 4 and 5 and Figure 1, but the relative increases were large only in the early spring period August 16 to September 20. In the late summer and autumn, the plot yields were hardly affected by the nitrogen sub-treatments.

Likewise, at Hyslop Farm, the response of Lolium to nitrogen applications in the late summer and early autumn, as shown in Table 10 and Figure 11, was small when compared with the responses obtained from Dactylis and Festuca. This poor response of Lolium to late summer and early autumn applications of nitrogenous fertilizers has been a common experience elsewhere (22, p. 199-201; 13, p. 62-64; 9, p. 54; 12, p. 22). It could be due to limitations imposed by the normal physiology of the species or to growth limitations imposed by high maximum day temperatures. Mitchell (15, p. 203) showed from growth chamber studies that maximum day temperatures in excess of 75° F. for short periods will reduce the growth rate of Lolium perenne. From the climatic data for both Badgery's Creek and Hyslop Farm in Tables 1 and 3, it can be seen that the mean monthly maximum early autumn temperatures were in excess of 75° F. for March and April at Badgery's Creek and for August and September at Hyslop Farm. This suggests that high temperatures were limiting early autumn growth at both localities.

During the period September 14 to October 19 (Table 11), when the temperatures were lower, Lolium gave yields comparable with any other species being examined.

Dactylis gave highest yields during the period August 18 to September 14 but not during the period September 14 to October 19, indicating the higher temperature requirement of this species for maximum production.

It appears that (Tables 10 to 13 and Figure 10) in the Corvallis environment, *Dactylis* gives the best nitrogen response in early autumn while *Festuca* and *Lolium* respond more efficiently a little later. *Phalaris* did not respond well at any time.

Tables 10 to 13 and Figure 11 show that for each form of fertilizer and each sampling period, the 45 and 90 lb. N/acre treatments increased dry matter yield in a linear manner. However, although the pelleted urea and the pelleted ammonium nitrate behaved in a similar fashion, the liquid method of applying urea was markedly inferior.

While a liquid foliage application of urea should increase the opportunity for foliar absorption of nitrogen, it also increases the chances of nitrogen escape due to volatilization and denitrification. In this experiment the losses were apparently greater than the gains and it would appear to be difficult to design a system of foliar spray applications that would give a more efficient nitrogen recovery than the solid forms. Jameson (14, p. 336-338) in England and Robertson and Hansen (18, p. 51) in Michigan recently concluded that liquid urea, as well as other liquid forms of nitrogen, could be efficiently applied to pasture only by injection into the soil and this experience seems to support their contention.

Per Cent Crude Protein and Nitrogen Recovered in the Herbage

In the Badgery's Creek experiment, where the treated pasture originally had a high proportion of white clover (Figure 5) and where the sampling interval was about six weeks, nitrogen treatments of 23, 46 and 92 lb/A at each sampling period (Table 6, Figure 2) progressively decreased the crude protein percentage in the herbage except for one winter period when the 92 lb. N/A treatment gave the highest crude protein percentage. Furthermore, total nitrogen treatments of up to 736 lb. N/A per year (Table 7, Figure 3) applied to this mixed legume-grass pasture, had little net effect on the total nitrogen recovered in the herbage.

A similar result was obtained by Gardner (12, p. 86) on Vancouver Island. These results emphasize the fact that nitrogenous fertilizers, used at economic rates, are not efficient tools in increasing the total protein or nitrogen production of good legume-grass pastures. Their scope lies only in improving the dry matter production pattern of such pastures by causing faster growing grasses to partially or wholly replace high protein legumes, as shown in Figures 6, 7, 8 and 9.

At Hyslop Farm, where pure grass stands were used, the 45 and 90 lb. N/A dressings progressively increased the percentage of protein and the total nitrogen recovery of all grass species at each harvest (Tables 15 and 16), but the liquid urea form was less effective than the two solid forms. The estimates of apparent per cent nitrogen recovery in the herbage (Table 17) showed that both Dactylis and Festuca, for the period of this experiment, were efficient nitrogen absorbers, recovering respectively up to 61 and 42 per cent of the applied nitrogen in two months. If we consider a 60 per cent recovery in the herbage as equivalent to about 100 per cent recovery by the whole plant, as suggested by Walker (21, p. 165), then these recoveries represent efficient nitrogen use. Lolium, however, gave recoveries of less than 35 per cent on all occasions.

This efficient utilization of nitrogen by Dactylis appears to contrast sharply with results recently reported by Dotzenko (11, p. 133) from Colorado. He obtained under irrigation, only about 38 per cent nitrogen recovery by Dactylis glomerata when nitrogen was applied at 80 lb/A in the early spring, but much higher recoveries from other grasses. It would appear that a high nitrogen recovery can only be obtained if the grass is able to grow rapidly immediately after nitrogen application. Temperature conditions in early spring in Colorado probably restricted early rapid growth and therefore efficient nitrogen recovery. At Corvallis a higher nitrogen recovery was indicated by the very rapid growth of Dactylis in the first four weeks after nitrogen application.

Yield Increase Per Pound of Nitrogen and Effect on Pasture Production Patterns

By considering the forage increase per pound of nitrogen applied, the quality of this forage, its production pattern, and the value of the nitrogen used, one can make a satisfactory estimate of the practical economic implications of any nitrogen treatment.

In the Badgery's Creek experiment (Tables 8 and 6 and Figures 4 and 2), given the cost of nitrogen per pound of N, one can readily calculate the cost of the additional forage obtained due to nitrogenous fertilizers. By estimating the digestibility of this forage from its crude protein percentage and its utilization as grazed forage from the pasture production pattern, (Figure 4) and comparing its cost in terms of total digestible nutrients with alternative animal feedstuffs, one can reasonably assess the economics of the practice.

Consider the 92 lb. N/A treatment and the early spring sampling period ending September 20, 1955, as shown in Table 8. If nitrogen cost 10 cents per pound, then the additional dry matter forage with 14.7 per cent crude protein (Table 6) cost 10 ÷ 21.7 or .46 cents per pound of dry matter or (with an estimated total digestible nutrient value of 65) 0.7 cents per pound of TDN. If the alternative feed is corn at one dollar per bushel or 2.2 cents per pound of TDN and the increased forage supply is fully utilizable in the paddock (as would be expected from the growth patterns in Figure 4), then the use of nitrogen in that case would permit the replacement of one feedstuff costing 2.2 cents by one costing only 0.7 cents per TDN. This would reduce animal feeding costs by about 66 per cent for the early spring period.

The nitrogen responses recorded on September 20 would be less economical because the increased yield per pound of N was less, the protein content was lower and the high growth rate of the untreated pasture at that time might make full utilization of the forage directly by the grazing animal more difficult or impossible.

On this same basis, the responses to nitrogen in the summer and autumn, under the conditions at Badgery's Creek (Table 8 and Figure 4) would be uneconomical.

The Hyslop Farm experiment was designed to determine whether economic responses to autumn applications of nitrogen could be obtained by applying the nitrogen to species other than Lolium perenne (as at Badgery's Creek). The yield increases per pound of applied nitrogen, the crude protein percentage of the forage and the effect of the nitrogen on the production patterns of the species are reported in Tables 18 and 15 and Figure 20.

It is noteworthy that the increased yields per pound of nitrogen obtained for Dactylis (Table 18) in the early autumn at Hyslop Farm (19 to 24) are similar to those obtained from Lolium at Badgery's Creek (19 to 23) in the early spring. They are also similar to those obtained by Ramage et al (17, p. 60-62) in New Jersey to 50 and 100 pound per acre spring applications of nitrogen to Dactylis glomerata, indicating that this species probably has the capacity to utilize nitrogen with equal efficiency in spring and early autumn. The cost of this additional forage from _Dactylis_, containing from 16 to 20 per cent crude protein would also be about 0.7 cents per TDN.

The increased dry matter yield per pound of nitrogen applied to _Festuca_, on the basis of a single harvest on October 20, 1960, is also 20 to 23 pounds (Table 18), but the crude protein percentage of this forage (Table 15) was only about 12 per cent. This forage, although unsuitable for milk production by dairy cows, would be of adequate quality for dry stock and at about 0.7 cents per TDN would be cheaper than most alternative feedstuffs.

During the same autumn period, _Lolium_ returned 60 per cent less dry matter per pound of nitrogen than _Dactylis_ or _Festuca_ and the protein content of the forage was lower. This result further supports the contention that _Lolium perenne_ is an efficient nitrogen user in the early spring, but inefficient in the autumn.

The autumn production patterns of the three species (Figure 20) indicate that the peak growth rate for _Dactylis_ occurs before that of _Festuca_ which occurs before _Lolium_. It seems probable that efficient nitrogen uptake and utilization depends largely upon rapid growth of the grass. When a species is growing rapidly, then it is rapidly absorbing nitrogen and efficiently utilizing it. Nitrogen recovery data for species with different growth patterns but all treated with the same nitrogen applications at the same time, as collected by Dotzenko (11, p. 131-133), should be treated with extreme caution.

These two experiments at Badgery's Creek, New South Wales and Corvallis, Oregon, suggest that nitrogenous fertilizers, skillfully applied to perennial grass species, can do much to iron out the peaks and troughs in the production patterns of irrigated pastures and to reduce the need for expensive conserved forages. However, these experiments also suggest that this can be achieved economically only by studying the growth response patterns of different species and then applying nitrogen to them only when they are in responsive conditions.

These experiments have shown that Lolium perenne is a suitable species on which to use early spring applications of nitrogen, while Dactylis glomerata responses well in the early autumn and Festuca arundinacea (Alta) in the mid-autumn period, By using the response patterns of these species (Figures 4 and 20) at each locality, one can predict the amount of forage which can be grown with a given level of nitrogen in a given period of time and so plan a forage production program to meet the forage requirements.

Furthermore, by relating the growth pattern of each species in each environment to the temperature pattern of that environment, one should be able, at least under irrigation, to predict a favorable time of nitrogen application for each species in each environment. When this is done for Lolium perenne and Dactylis glomerata on the basis of data presented here and the mean monthly temperature data for each locality, the following results are obtained:

Corvallis: Dactylis glomerata - autumn production - about mid-August.

Lolium perenne - early spring production - about mid-March.

Badgery's Creek: Dactylis glomerata - autumn production - early April.

Lolium perenne - early spring production - early to mid-July.

However, there may be other species or other strains of the species studied which will be more valuable than these in fulfilling specific growth pattern requirements. The further study of forage production patterns would appear to be a requisite for more efficient forage crop production and nitrogen utilization.

SUMMARY AND CONCLUSIONS

Studies directed towards economically extending the growing season of irrigated perennial grasses by the use of nitrogenous fertilizers were carried out at Badgery's Creek, New South Wales, Australia, and Corvallis, Oregon, U. S. A. and the following conclusions were drawn:

1. Nitrogenous fertilizers applied to white clover-perennial ryegrass pastures in early spring at rates of 23 to 92 pounds of nitrogen per acre can, provided other nutrients and moisture are not limiting, provide spring paddock forage four to six weeks earlier and return 19 to 22 pounds of additional dry matter forage with 14 to 19 per cent crude protein for each pound of fertilizer nitrogen applied.

2. In late spring the increased forage production per pound of fertilizer nitrogen applied is lower and in summer and autumn the responses become relatively uneconomic.

3. Nitrogenous fertilizers applied in the early autumn for the purpose of extending the growing season of perennial grass species and providing more late autumn and early winter forage, produce more additional dry matter per pound of fertilizer nitrogen if applied to species capable of rapid growth in the autumn. At

Corvallis, 45 and 90 pounds of nitrogen per acre gave only about 11-13 pounds of dry matter forage per pound of nitrogen when applied to perennial ryegrass in early autumn, but 14-16 when applied to tall fescue and 19-21 when applied to orchardgrass. The crude protein percentages in the forage were similar in each case.

4. It would appear that nitrogen can be efficiently used for extending the grazing season of perennial pastures by applying it to perennial ryegrass pastures in the early spring and to orchardgrass or tall fescue grass pastures in the autumn. A favorable time of nitrogenous application can be estimated by relating the production patterns of these species to temperature data for the locality concerned.

5. At Corvallis, pelleted urea and pelleted ammonium nitrate applied as a topdressing, immediately before sprinkler irrigation, gave similar results per unit of nitrogen, but urea applied as a foliage spray treatment was markedly inferior.

6. One cannot properly assess the efficiency by which a species can utilize nitrogen for the purpose of extending the grazing season of a pasture on the basis of a single massive nitrogen application, because the magnitude of the response obtained appears to be related

to the physiological growth stage of the species, its environmental tolerance and the environmental conditions at the time of and immediately following the application of nitrogen.

Further studies on the relationships between the nitrogen response of forage species and climatic conditions could point the way to the more economical use of nitrogen on pastures and the more economical production of livestock products by the replacement of expensive conserved forages by more late autumn, winter and early spring forage in the paddock.

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