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New Hampshire Agricultural
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Durham, New Hampshire

Good yield of early cut hay being trucked to mow at the John Jackson farm in Colebrook.

Experiments With Grass Hay

By

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CLIMATIC and soil conditions in New Hampshire are generally quite favorable for the production of grass hay. It is common practice to seed land to a mixture of clover and timothy and to cut hay on that land for a number of years, long after the clover has disappeared from the stand and oftentimes until the yield has been reduced to an unprofitable level.

Reduction in yield is due largely to the exhaustion of available plant food supplies. It is customary to apply manure and fertilizers at the time of seeding or to the hoed crop which normally precedes it, and usually to both. In the years immediately following the establishment of the stand, fertilizers are often not applied. Desirable hay grasses have moderately high requirements for fertility nutrients, especially so for nitrogen. When the nitrogen level is reduced to the point at which timothy and other high yielding species will not grow so large, grasses of a lower order of fertility creep in, causing severe competition and finally the exclusion of the desirable species with a consequent reduction in yield.

That this process occurs is common knowledge. The length of time consumed in reaching a point at which hay yields are unprofitable depends upon a great many factors such as the soil type, the amount of manure and other fertilizers used prior to seeding, the amount and frequency of top-dressings, the acidity of the soil and the system of farming followed on any particular farm, including the need for roughage, the acreage available for its production and the size of the herd to be fed.

The decline in yield in long rotations is noted by Abell[1] who says, "Those farms where plowing and reseeding occur more frequently—four years or less in hay rather than six or more—obtain considerably larger yields and are able to incorporate the higher protein legume hays in the mixture."

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¹ Bull. 273, N. H. Exp. Sta., M. F. Abell, Roughage Production in New Hampshire.

Further information on this point is presented by Woodworth[2], who gives the amount of digestible protein produced annually from the various crops in a long rotation of nine years' duration.

Year	Crop	Yield Tons	Digestible Protein in Pounds Per Acre
1	Corn silage	10	250
2	Oats	2	188
3	Clover	2	284
4	Mixed hay	1.5	127
5	Grass hay	1.2	67
6	Grass hay	1.1	62
7	Grass hay	1	56
8	Grass hay	.9	50
9	Grass hay	.8	45

The steady decline in yield which occurs from the third year of the rotation, the year in which a good crop of clover is harvested, is reflected not only in tonnage produced, but more especially in the amount of digestible protein that is secured. That this decline in yield can be offset to some extent by top-dressing practices has been noted by many research workers. It has also been abundantly recorded that a system of top-dressing not only produces more forage but may raise the protein level of the hay as well.

Since grass hay plays such an important role in the agriculture of New Hampshire, experiments have been designed to ascertain how the crop can be made of more value to dairy cows to which it is largely fed. Some of these trials have been concerned with fertilization or methods that may be employed to maintain yields. Another long-time experiment has been conducted to indicate how the time of cutting grass hay influences the feeding value from the standpoint of digestibility and protein content.

It is our purpose to present here the results of these findings, not necessarily to influence farmers to practice longer rotations, but to indicate how both yields and feeding value can be enhanced by fertilization and by cutting at the proper time when long rotations are practiced.

Experiments in producing grass hay with varying lime and fertilizer treatments have been reported previously[3] from this station. In this test conducted at Greenland which covered a five-year period, nitrate of soda top-dressed annually at the rate of 100 pounds per acre returned an increase of 807 pounds of cured hay used with manure, 977 pounds used alone, and 737 pounds when used with phosphorus.

Phosphorus, used at the rate of 250 pounds of 16% superphosphate annually, returned 182 pounds of cured hay for each 100 pounds of superphosphate applied, when used alone, and 86 pounds when used with nitrate of soda. This substance failed, however, to increase the yield

[2] The Farm Pocketbook, U. of N. H. Extension Service, May, 1934.

[3] Exp. Sta. Bull. 271, April, 1933, Prince, Blood, Phillips, and Percival, Fertilizer Experiments on Run-Out Hay Land.

of grass hay when used with manure. It was pointed out in the previous report that the increase from phosphorus where it was used alone came largely during the first harvest, apparently due to stimulation of germination and early growth after the crop was seeded.

Each ton of limestone applied at the beginning of the test returned 1,547 pounds of hay used at the rate of two tons per acre, but the returns per ton at the four-ton rate were only 991 pounds of hay.

Manure returned 342 pounds of cured hay per acre for each ton applied. Manure was used on certain plots at the rate of 10 tons per acre. Potash was not introduced as a variable in the test.

A portion of the field on which the experiment referred to was conducted was reseeded in 1934 to grass hay. Prior to reseeding, the land had grown a crop of oats and one of red clover and had received three applications of 300 pounds of 8-16-16 fertilizer per acre spread uniformly over the land, one of which was applied directly for the seeding. Uniform applications were made to iron out any differences in stand that might result if variables were used.

Top-dressing was instituted in 1935 with variables which have been applied annually since that date. The plan of the experiment was changed to include potash and the increment of nitrogen was doubled from the previous work.

The rates of fertilization in the revised experiment were as follows:

Rate Per Acre		Material Used
32 lbs. nitrogen	from	200 lbs. nitrate of soda 16 % N
32 lbs. phos. acid	from	200 lbs. superphosphate 16% or
		160 lbs. superphosphate 20%
32 lbs. potash	from	64 lbs. 50% muriate of potash or
		53.33 lbs. 60% muriate of potash

This is equal to a 1-1-1 fertilizer ratio and the amount applied was equivalent to 400 pounds of an 8-8-8 fertilizer where the complete fertilizer was used, to 400 pounds of an 8-0-0 where nitrogen only was applied and to the same amount of an 0-8-8 on the plots receiving phosphoric acid and potash only.

With the exception of twelve plots of the thirty-nine comprising the experiment, no manure has been used on the land for a long time, twenty years at least. The twelve plots in question received a 10-ton application of manure in 1925. The field is divided into three strips of thirteen plots each and four of the manure plots are located in each strip.

Lime was applied to one of these strips in 1925 at the rate of four tons per acre and to another at the rate of two tons per acre, while the third strip has never been limed. These strips are covered by an equal number of plots of each top-dressing treatment.

The soil of this field is not high in organic matter and hay yields are somewhat dependent upon spring rainfall. Grass hay is responsive to fertilizer treatments on this field as the following three-year summary shows:

TABLE I. *Three-year summary of fertilizer treatments on Whenal farm plots.*

Treatment	Yield Cured Hay Lbs. Per Acre	Difference from Check Lbs. Per Acre
Check (no treatment)	1868	
N	3330	1462
PK	2596	728
NPK	4027	2159

While the check plots were untreated so far as annual top-dressings were concerned, they received the same basic fertilizer application at seeding as the others.

The response for nitrogen is more marked than for the phosphorus-potash treatment. The increase obtained for 200 pounds nitrate of soda was 1,462 pounds of cured hay, or 731 pounds for each hundredweight of nitrate of soda applied. With nitrate of soda currently quoted at about $2.00 per hundredweight, the cost per ton of the increased hay produced with this substance alone was $5.48.

At current quotations the superphosphate and potash used in the PK treatment will cost about $2.87. On the basis of the returns secured with these materials the hay increase produced would entail an expenditure of $7.88 per ton. When the same calculations are made for the NPK treatment it is found that the hay produced from its use cost $6.36 per ton. These calculations do not include the cost of spreading the fertilizer nor of harvesting the increase in the crop due to fertilization. Nor do they take into account any possible increase in the nutrient or mineral content of the hay due to its having been fertilized.

Mathes Field Experiment

A more elaborate top-dressing experiment was laid out in 1933 on a field of the University farm in which nitrogen carriers have been compared with each other and with complete fertilizers, and nitrogen has been applied at different dates and at different rates.

Small plots were used in this test and the material harvested from each plot was transported to a drier where it was reduced to an air-dry condition. This method eliminates any inaccuracies due to unequal drying of the cured hay. Harvests were taken annually on June 10 and the plots, sixty in all, were harvested on the same day. Each treatment was repeated four times and there were twelve untreated plots in all. A sample was secured from each plot. This sample was ground and then analyzed for its protein content.

The field on which this experiment was located was acquired by the University in 1921. The portion on which the plots were established was plowed, heavily manured, and seeded to mixed hay in 1923.

The soil is a clay of the Suffield series, a soil too heavy for short rotations, but one in which grass hay plants live for a long period and yield quite well. Lack of fertilization during the period from 1923 to 1933 may account in large measure for the excellent responses, shown in the data, that have been secured from complete fertilizers.

Fertilizers Carrying Nitrogen

Nitrogen was applied to certain series in this test in different nitrogen carriers at the rate of 32 pounds of the element nitrogen per acre. Due allowance was made for the quickness of availability of the different nitrogen carriers, cyanamid being applied about the last week in March, sulphate of ammonia about April 5, and the carriers of nitrate about April 15. Variations from these dates were due to conditions of weather prevailing at the time.

A summary of the yields of both dry matter and protein is given here, together with the average yield of the check plots and the difference of each treatment from the check plot yields.

TABLE II. *Four-year average of yields of Mathes farm plots after treatment with nitrogen carriers.*

Treatment	Dry Hay Lbs. Per Acre	Diff. from Ch. Lbs. Per Acre	Protein[4] Lbs. Per Acre	Diff. from Ch. Lbs. Protein Per Acre
Check (no treatment)	1703		164	
32 lbs. nitrogen from Cal Nitro	2434	731	251	87
32 lbs. nitrogen from sulphate of ammonia	2344	641	233	69
32 lbs. nitrogen from nitrate of soda	2239	536	229	65
32 lbs. nitrogen from cyanamid	2236	533	219	55
32 lbs. nitrogen from calcium nitrate	2198	495	229	65

The table is arranged in the order of descending yield of dry matter for the different nitrogen carriers. When the protein is considered, cyanamid should come last in the grouping as the nitrogen recovery from this carrier does not appear to have been quite so high as for the other carriers.

The differences between the yields of the nitrogen carriers and the check plot series are all significant. Although there are slight differences between the yields of the carriers themselves. there are no significant ones when they are compared one with another.

From the differences in protein yield it may be inferred that the recovery of nitrogen from the various carriers was not at the same rate. The order of effectiveness of recovery is the same. of course, as for the proteins. The percentage recovery for each carrier is given in Table IV.

Complete Fertilizers

In order to contrast yield responses between nitrogen carriers and complete fertilizers on this soil and to point out the difference which phosphoric acid and potash have made in nitrogen recovery. the series receiving complete fertilizers will now be considered. These are all contrasted with the check-plot yield.

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[4] Protein is computed in this bulletin by multiplying the nitrogen percentage by 6.25.

The home mixed 8-6-6 in this test was made up of soluble materials, Ammo Phos A, 11 N-48 P_2O_5, nitrate of potash, 13 N-44 K_2O, and Cal Nitro, 20.5% N. This was contrasted with an 8-6-6 of commercial origin. The 10-20-20 as listed was used the first two years of the test, but during the last two years an 8-16-16 was employed. The content of nitrogen of the mixed fertilizers applied was 32 pounds per acre or 400 pounds of the 8-6-6 formulas, 320 of the 10-20-20 and 400 of the 8-16-16.

TABLE III. *Four-year average of yields of Mathes farm plots which were treated with complete fertilizers.*

Treatment	Dry Matter Lbs. Hay Per Acre	Diff. from Check	Protein Lbs. Per Acre	Diff. from Check
No treatment (Ch.)	1703		164	
8-6-6 (home mixed)	3335	1632	312	148
8-6-6 (commercial)	2928	1225	284	120
10-20-20	3289	1586	291	127

It will be observed that the increased production due to the use of these complete fertilizers is in two cases more than double the increase recorded for the nitrogen carriers alone; and in the other case, the increase is approximately double that of all the nitrogen carriers, with the exception of Cal Nitro, while in the results reported for another test (Table I), the increase for the complete fertilizer is approximately 50% greater than that for nitrogen alone.

The explanation for this is undoubtedly associated with the previous history of the fields in question, the one at Greenland having been more generously treated with mineral fertilizers than this one, while in the Mathes plots the content of available phosphoric acid and potash may have been so low as to permit of only a low rate of nitrogen recovery at least when nitrogen alone was applied.

In order to emphasize this point more fully, per cent nitrogen recovery has been calculated for the treatments thus far discussed in this test. The calculation used is as follows:

$$\frac{\text{Increase of protein over check} \times 100}{6.25 \times 32 \text{ (pounds of nitrogen applied)}}$$

The result is the percentage of nitrogen recovered in the hay and these percentages are here listed:

TABLE IV. *Percentages of Nitrogen Recovery at Mathes Farm.*

Treatment	% Nitrogen Recovered
Cal Nitro	43.5
Sulphate of ammonia	34.5
Nitrate of soda	32.5
Calcium nitrate	32.5
Cyanamid	27.5
Home mixed 8-6-6	74.0
Commercial 8-6-6	60.0
10-20-20	63.5

The average recovery of nitrogen in the hay where nitrogen carriers alone were used was 34.1%, while 65.8% of the nitrogen of the complete fertilizers was returned in the hay. This is a matter of much importance to farmers. Unless complete fertilizers are used frequently in the rotation, it is quite possible that the top-dressing fertilizer for grass hayland should carry the three important plant food elements. The need for a complete fertilizer is a matter that a rapid soil test should help to determine.

Protein Percentage

The average percentages of protein in the forage of the different treatments for the period studied are given here:

TABLE V.

Protein Percentage of Hay—Mathes Farm

Treatment	Nitrogen Carriers	Treatment	Complete Fertilizers
Calcium nitrate	10.42	8-6-6 commercial	9.70
Cal Nitro	10.31	8-6-6 home mixed	9.36
Nitrate of soda	10.23	10-20-20	8.85
Sulphate of ammonia	9.94		
Cyanamid	9.79		
Untreated	9.63		

These data indicate that all the nitrogen carriers increased the protein percentages of the forage but that the tendency of the complete fertilizers was to decrease the percentage of protein, although they stimulated dry matter production to a greater degree. This appears to suggest that phosphoric acid and potash are limiting factors to the development of the structure of the plants and that when nitrogen is balanced with them, growth is able to proceed on a normal basis.

This seems to be supported by rapid soil tests of untreated land (check plots) on this field which show a ''very low'' test for both phosphoric acid and potash, tests which are too low for maximum grass hay production.

Second Cutting, Mathes Field Plots

Second cuttings were taken on the Mathes field plots annually in September of each year. The soil of this field is well supplied with moisture and second cuttings are usually quite good.

Because of the narrow range in yield among the various treatments, the second cutting data are all presented in Table VI. The interesting thing about the data lies in the fact that the yield variations are so slight. With the exception of calcium nitrate, all the hay yields are above those of the check plots and the protein yields are all above those of the untreated or check plot series. Except in the case of the dry matter figure for the 10-20-20 series and the protein values for this and the 8-6-6 home-mixed series, it is doubtful if any of the differences are significant. With respect to percentage protein, all the values are higher than the untreated plots except that of the hay from the 10-20-20 series, which happens to have exactly the same protein content as the untreated plots.

TABLE VI. *Second Cuttings on Mathes Farm Plots.*

Treatment	Lbs. Hay /Acre	% Protein	Lbs. Protein / Acre
No treatment (check)	1103	9.43	104
200 lbs. nitrate of soda April 15	1210	9.50	115
160 lbs. sulphate of ammonia	1104	10.14	112
160 lbs. Cal Nitro	1128	10.02	113
210 lbs. Calcium nitrate	1103	10.15	112
160 lbs. Cyanamid	1106	9.76	108
400 lbs. 8-6-6 commercial	1156	9.60	111
400 lbs. 8-6-6 home-mixed	1211	10.16	123
320 lbs. 10-20-20	1326	9.43	125
100 lbs. nitrate of soda April 15	1117	10.03	112
400 lbs. nitrate of soda April 15	1137	10.38	118
200 lbs. nitrate of soda April 5	1153	9.89	114
200 lbs. nitrate of soda April 25	1221	9.58	117

It seems quite apparent, therefore, that the major stimulation from fertilizers applied at dates well ahead of the first crop harvest will be secured in the first cutting of hay. If it is desirable on the farm to secure any considerable increase in second crop yields, it will be necessary to apply the top-dressing fertilizers at a date somewhat nearer the time of harvesting the first crop or perhaps soon after the first crop is cut.

One trial is reported in this publication (Table XVI) in which the nitrogen was applied immediately after the first crop was cut and in this instance a significant increase in the second crop was noted.

Dr. H. B. Sprague and his co-workers at the New Jersey Station report using nitrogen ten and twenty days before the first crop of hay was harvested, with some carryover of stimulation into the second cutting. It appears, therefore, that in the work reported herein the fertilizer had largely spent itself by the time of first-crop harvest because of the early application of the material.

O'Kane Field Experiments

Another test was begun on the O'Kane farm field in 1933 to determine the relative effects of phosphoric acid and potash on grass hay production. Applications of nitrogen alone have there been contrasted with nitrogen and phosphoric acid in both Ammo Phos A, 11% N, 48% P_2O_5 and nitrogen and superphosphate, also with nitrate of potash, 13% N, 44% K_2O, with a mixture of Ammo Phos A and nitrate of potash, as well as with a superphosphate-potash mixture.

This field was formerly old hay land which had not been plowed for many years. The field was plowed in the fall of 1932, manured at the rate of 20 tons per acre, fertilized with 300 pounds of an 8-16-16 fertilizer per acre and seeded to a mixture of timothy and alsike clover in

1933. Hay was harvested in 1933 and 1934 without fertilizer treatment. Plots were laid out early in 1935 and top-dressed in the spring.

The soil of the O'Kane field probably falls in the Suffield series and is of the clay-loam type. The Suffield series, according to the soil-survey parties working in other parts of New Hampshire, is characterized by "nearly flat topography" since it was "developed from material deposited in still water." The series is also said to be an "excellent grass soil."

The surface soil of the O'Kane field plots is probably a clay loam, underlain by interbedded clays and silts.

The plots in this test were one five hundredth of an acre in extent, small enough so that the green material could all be transported to a drier and brought to a uniform moisture condition. A protein analysis was made on a sample from each plot.

A glance at the data (Table VII) is sufficient to indicate the need for elements other than nitrogen in grass hay stimulation. A critical study leads to the conclusion that plots treated with phosphoric acid and potash (No. 7) produced slightly more hay than nitrogen alone (No. 2), and that on this particular soil nitrogen and phosphoric acid (No. 3 and No. 4) proved more effective in increasing yields than nitrogen and potash (No. 5). The substitution of one-half of the potash in treatment 5 with 87.5 pounds of phosphoric acid (No. 6) resulted in a large increase of dry matter and protein, both of which are significant when the two treatments are compared.

TABLE VII.

3-Year Average O'Kane Farm Plots

No.	Treatment	Dry Matter Lbs./Acre		Protein Lbs./Acre	
		Yield	Diff. from Ch.	Yield	Diff. from Ch.
1	Check (no treatment)	1858		161	
2	Nitrate of soda (250 lbs./acre) 40 lbs. nitrogen	2581	723	236	75
3	Ammo Phos A (364 lbs./acre) 40 lbs. nitrogen, 175 lbs. P_2O_5 per acre	3524	1666	278	117
4	Nitrate of soda and superphos. Equal to Ammo Phos A	3793	1935	325	164
5	Nitrate of potash (308 lbs./acre) 40 lbs. nitrogen, 135 lbs. K_2O per acre	2806	948	252	91
6	Ammo Phos A (182 lbs./acre) Nitrate of potash (154 lbs./acre) 40 lbs. N; 87.5 lbs. P_2O_5; 67.5 lbs. K_2O	3847	1989	318	157
7	Superphos. (400 lbs. 20%/acre) Mur. of potash (117 lbs. 60%/acre) 80 lbs. P_2O_5; 70 lbs. K_2O	2713	855	262	101

Rapid soil tests were carried out on some of the treated series at the close of the experiment with the following results:

Rapid soil tests on O'Kane plots.

Treatment	pH	NO_3	NH_3	P_2O_5	K_2O
Complete fertilizer	5.33	trace	very low	low +	very high +
Nitrogen only	5.74	trace	very low	very low	low-medium
No treatment	5.42	trace	very low	very low	medium

The soil is acid, but not excessively so. The higher pH test on the nitrogen plots may be due to lower acidity from the applications of nitrate of soda. The test for nitrogen is identical for all three series. This may be explained, however, by the fact that the test was not made until after the growing season, which indicates no residue of nitrogen remaining at this date.

The interesting facts about the tests have to do with phosphoric acid and potash. Applications of complete fertilizer have raised the test for phosphoric acid from "very low" to "low plus," a level which is apparently satisfactory for the grass hay crop. The potash test at medium for the untreated plots is high enough for good crops of grass hay. Continued treatment with nitrogen alone reduced this test to "low-medium," while the "very high plus" test for potash on the complete fertilizer plots is, of course, above the level at which grass hay will give additional response to this nutrient.

The recovery of nitrogen in this test follows the same general pattern as in the one previously discussed, running 30% for nitrogen alone, 36.4% for nitrate of potash, 46.8% for Ammo Phos A, 65.6% for nitrate of soda and superphosphate, and 62.8% for the complete fertilizer.

On another section of the O'Kane field previously described, a test was run to determine the relative response of fall and spring applications of top-dressing fertilizers.

One such test was with nitrate of soda applied in mid-September, too late to get much growth stimulation in the fall but early enough for nitrate absorption and root storage. This was compared with the same amount of nitrate of soda applied April 15-20, depending upon weather conditions. Two hundred and fifty pounds of nitrate of soda per acre was the application rate.

Table VIII. *Spring and fall applications of nitrate of soda on O'Kane farm plots.*

Treatment	3-Year Average			
	Dry Matter		Protein	
	Lbs. Hay Acre	Diff. from Ch.	Lbs. Acre	Diff. from Ch.
Check (no treatment)	1939		171	
Nitrate of soda in fall	3022	1083	264	93
Nitrate of soda in spring	3014	1075	275	104

These data are rather surprising in that they indicate practically no difference between the stimulation from fall and spring applications of nitrogen applied at the dates studied. The results are somewhat at variance with commonly accepted views on the subject and are probably accounted for to some extent by root absorption of the fall-applied nitrogen which was stored during the winter and translated into growth during the spring months.

Cyanamid, too, was applied both fall and spring in this test. The fall application was made in November, just before the ground froze. and the spring treatment was made usually around April first, after the frost was out of the soil but before growth started to any extent. Two hundred pounds of cyanamid per acre were used in both tests.

TABLE IX. *Spring and fall applications of cyanamid on O'Kane farm plots.*

Treatment	Three-Year Average			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	1939		171	
Cyanamid in fall	2689	750	230	59
Cyanamid in spring	2779	840	249	78

Both treatments gave significant increases over the check plots but the difference between the two treated series is very slight, and not significant.

This appears to indicate that cyanamid may be safely applied as a top-dressing in late fall, a factor which might be advantageous to avoid the rush of spring work, or on land that is normally too wet to get over with a team and spreader in the spring at a time when cyanamid should be applied.

A similar comparison was made with a complete fertilizer. In this case a heavy application of a 4-8-7 formula, 1,000 pounds per acre, was made. The 40-pound nitrogen application was thus constant for all these trials. Applications were made in September and April, at the same time as nitrate of soda.

TABLE X. *Spring and fall applications of a complete fertilizer on the O'Kane farm plots.*

Treatment	3-Year Average			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	1939		171	
Complete fert. in fall	2863	924	238	67
Complete fert. in spring	3666	1727	316	145

The treatments both exhibit significant differences when compared with the checkplot series; likewise the differences between the spring and fall treatments are significantly higher for the spring application.

It is difficult from the facts at hand to harmonize the results secured with fall and spring applications of complete fertilizers with those for nitrogen (Table VIII). Slightly greater growth was made by the grass with complete fertilizer in the weeks after its application in the fall than with nitrogen, but this difference would not be sufficient to account for the use of a great deal of the fall fertilizer. It is more likely that the explanation lies in the soil itself and in its power to fix phosphoric acid and potash in insoluble compounds and perhaps in varying bacterial relationships caused by the fertilizers. Neither of these problems were studied in this experiment.

Fall Applications Further Compared

The series of plots treated in September with nitrogen and complete fertilizers were harvested along with certain check plots for comparison. These harvests were taken about one month after the fertilizers were applied.

TABLE XI. *Comparison of harvests after the use of nitrogen and a complete fertilizer in fall applications on the O'Kane farm plots.*

Treatment	3-Year Average			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	301		37	
Nitrogen in fall	554	253	87	50
Complete fert. in fall	601	300	94	57

Both treatments exhibit an increase in dry matter when compared with untreated plots, and the difference is greater when considering the protein content of the hay. This is due to the higher protein percentage of the hay from treated areas, the percentages being 15.7% and 15.6% respectively for the nitrogen and complete fertilizer plots and but 12.3% for the check series.

Nitrogen in Different Amounts

A series of plots which received nitrate of soda in different amounts were included among the Mathes farm plots. Actual quantities used were 100, 200, and 400 pounds per acre, containing 16, 32, and 64 pounds of nitrogen respectively.

TABLE XII. *Results of applications of nitrate of soda in different amounts on Mathes farm plots.*

Treatment	4-Year Average			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	1703		164	
100 lbs. nitrate of soda	2144	441	209	45
200 lbs. nitrate of soda	2239	536	229	65
400 lbs. nitrate of soda	2772	1069	301	137

The data in Table XII show slightly better utilization of the nitrogen in the small application. Nitrogen recovery and protein percentage for these plots are given in Table XIII.

TABLE XIII. *Nitrogen recoveries and protein percentages resulting from the use of different amounts of nitrate of soda on the Mathes farm plots.*

Treatment	Nitrogen Recovery Above Check—%	Protein % of Hay
Check (no treatment)		9.63
100 lbs. nitrate of soda	45.00	9.75
200 lbs. nitrate of soda	32.50	10.23
400 lbs. nitrate of soda	34.25	10.86

Nitrogen at Different Dates

Nitrogen has been applied at different dates in April to determine whether there is any appreciable variation in response. Nitrate of soda was used in this test and 200-pound applications were made April 5, April 15, and April 25. The data (Table XIV) do not indicate any significant differences in yield for the different dates but they do indicate progressively greater recovery of nitrogen for the later applications.

TABLE XIV. *Nitrate of soda applied to Mathes farm plots on different dates.*

Treatment	4-Year Average Mathes Farm			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	1703		164	
April 5: 200 lbs. nitrate of soda	2278	575	224	60
April 15: 200 lbs. nitrate of soda	2239	536	229	65
April 25: 200 lbs. nitrate of soda	2385	682	245	81

In another test on the Weld farm, plots which had uniform nitrogen applications at different dates have been harvested for a six-year period. The data in Table XV support that which is presented in Table XIV, indicating slightly greater growth stimulation and nitrogen recovery at the later date. These tests have both been conducted with readily soluble nitrate of soda, a substance that is easily leached, and for this reason its application before the roots are in an active condition is not to be recommended.

In another series of plots adjoining those presented in Table XV, the nitrogen application was delayed until after the first harvest which was made annually on June 10. All plots were thus harvested in June and again in September, the idea being to determine whether the June application of nitrogen would greatly stimulate the second cutting.

TABLE XV. *Nitrogen of soda applied on various dates on Weld farm plots.*

Treatment	6-Year Average Weld Farm			
	Dry Matter		Protein	
	Lbs. Hay /Acre	Diff. from Ch.	Lbs. /Acre	Diff. from Ch.
Check (no treatment)	1490		169	
April 5: Nitrogen	2082	592	208	39
April 25: Nitrogen	2117	627	241	72

Table XVI lists the second cuttings from the plots in Table XV and includes the series which was top-dressed June 10. The relatively close yields of the untreated and April top-dressed series indicates no carry-over of stimulation into the second cutting, while the plots top-dressed June 10 responded with an increase in both dry matter and protein. When the first and second cuttings are combined (Table XVII), the data do not indicate much difference in yield no matter when the top-dressing fertilizer was applied. The slight differences noted in yields of dry matter and protein between the treated series are not significant, while the treated series are all significantly higher than the untreated plots.

TABLE XVI

6-Year Average Second Harvest Weld Farm Plots		
Treatment	Dry Matter Lbs. Per Acre	Protein Lbs. Per Acre
Check (no treatment)	548	69
April 5: Nitrogen	547	66
April 25: Nitrogen	527	63
June 10: Nitrogen	911	112

TABLE XVII

6-Year Average of 1st and 2nd Cuttings Combined from Weld Farm Plots			
Treatment	Dry Matter Lbs. /A.	Ave. % Protein	Protein Lbs. /A.
Check (no treatment)	2038	11.7	238
April 5: Nitrogen	2629	10.4	274
April 25: Nitrogen	2644	11.5	304
June 10: Nitrogen	2520	11.3	284

Hay Yields

Hay yields reported in Tables II to XVII are not high, but it must be remembered that the plots were harvested on June 10, at the time timothy plants are coming into head and before maximum growth had been obtained. Had this hay been allowed to grow until it had more nearly approached maturity, the yields would have been considerably higher.

Financial Returns

In the discussion following Table I, it was pointed out that the fertilizer cost for the hay increase ranged from $5.48 to $7.88 per ton, depending upon the treatment. Valuing hay at $12.00 per ton, this increase would mean, roughly, that each dollar invested in fertilizer brought in two dollars in increased hay.

On the face of it, $12.00 per ton may seem a high valuation for hay in the field. But if hay is to be cut anyway, mowing, raking, etc., cost no more with fertilizer than without. Furthermore, the slightly better feeding value from the standpoint of protein or minerals affects all the hay that is produced and not the increase alone. No attempt has been made to evaluate this factor; neither has any cost been ascribed to spreading the fertilizer, an item that would vary from farm to farm but which is usually a minor charge, since men and teams are not very busy at the time of year when this must be done.

This explanation may serve to help understand the calculations that follow with respect to the economy of fertilizer usage. No attempt has been made to calculate all the treatments reported where top-dressing fertilizers were applied, for some of these were made to determine if possible the upper limits of response to phosphoric acid and potash as well as nitrogen, regardless of economy of treatment.

A study of Table XVIII indicates that under the conditions stated no severe losses were sustained from using any of the fertilizers and that the returns from the best nitrogen carrier (Cal-Nitro) were $1.30 for each dollar spent, the increase in hay costing $9.19 per ton, while the best complete fertilizer paid back $1.78 for each dollar spent, the increased hay costing but $6.84 per ton. It will be noted that the returns per dollar invested and the cost for the hay increase for the "average" nitrogen carrier do not show a profit and that the figures for the "average" of the three complete fertilizers are not so encouraging as for the best one. This is due largely to the increased cost of the

TABLE XVIII. *Cost and efficiency comparisons of fertilizers used on Mathes farm.*

Treatment	Mathes Farm				
	Table No.	Cost of Fertilizer per A.	Val. of Increased Hay Produced	Returns /$ Invested	Cost /Ton of Increase
Best nitrogen carrier	II	$3.36	$4.39	$1.30	$9.19
Ave. nitrogen carrier	II	3.61	3.52	.975	12.30
Best complete fert.	III	5.50	9.79	1.78	6.84
Ave. complete fert.	III	7.30	8.89	1.22	9.86

10-20-20 fertilizer, which apparently carries more phosphoric acid and potash than grass hay needs.

The same may be said of the O'Kane farm work where one of the principal objects of the study was to determine whether grass hay responded more to phosphoric acid or to potash. Hence an excess of each of these elements was applied.

TABLE XIX. *Cost and efficiency comparisons of fertilizers used on O'Kane farm.*

Treatment	O'Kane Farm				
	Table No.	Cost of Fertilizer per A.	Val. of Increased Hay Produced	Returns /$ Invested	Cost /Ton of Increase
Nitrate of soda	VII	$5.00	$4.33	$ .87	$13.80
Ammo Phos	VII	12.34	10.00	.81	14.40
Nitrate of potash	VII	10.28	5.68	.55	21.69
Complete fertilizer (Ammo Phos and nitrate of potash)	VII	11.31	11.93	1.06	11.38

In the test in which Ammo Phos and nitrate of potash were compared with a mixture of the two substances and with nitrogen alone, the only treatment in which the returns were commensurate with the expense was that for the Ammo Phos-nitrate of potash combination, in which case each dollar invested returned $1.06 and the hay increase cost $11.38 for fertilizer alone. This was doubtless due to the balance of phosphoric acid and potash in the mixture as well as to the balance between the two nitrogen carriers.

Both nitrate of soda and cyanamid in the fall and spring applications were used at a profit based on these calculations, the nitrate of soda returning $1.30 for each dollar spent, the cyanamid $1.10. The heavy application of complete fertilizer, although it produced a nice increase in hay, failed to return a dollar for each one spent for fertilizer.

It thus becomes apparent that in top-dressing work the margin of profit is likely to be quite narrow when considered from the standpoint of yields alone; and in order to profit by the operation, a farmer needs to have as much prior information as he can get relative to the needs of his soil as revealed by a soil test, as well as information regarding the crop itself, and the past history of the soil in question.

Cutting Grass Hay at Different Dates

A preliminary report on yields and protein analyses of hay cut at ten-day intervals from June 10 to July 30 was published in May 1933 under the title of "Studies of Feed Value of Early Cut Hay" (N. H. Sta. Circ. 41). This publication contained data covering three years' work on the plots that will now be discussed.

The summary presented in Circular 41 is supported in general by this subsequent work. Briefly, this summary states, "Early cut grass hay carries a greater percentage of protein and more protein per acre than later cuttings.

"Second crop yields are larger when the first crop is cut early.

"A difference of one month in time of cutting, as between June 20 and July 20 under the conditions here reported, means a difference of at least 50 per cent in digestible protein per acre in favor of the early cut hay." (This latter statement was made as a result of feeding trials in the nutrition laboratory of the N. H. Agricultural Experiment Station by Prof. E. G. Ritzman and his associates.)

The same plots were harvested in this test over a period of eight years. Except for 1930 they were all top-dressed alike with a nitrogen carrier containing 36 pounds of elemental nitrogen per acre, and in 1937 phosphoric acid and potash were added to the nitrogen application.

Average yields declined to some extent during the eight-year period and certain weeds, notably devil's paint brush, secured a foothold during this time. This was due to the age of the stand and continued harvesting, but weeds appeared to be somewhat more noticeable on the series cut June 20 and June 30 than on the plots cut at other dates. No appreciable difference in this respect was noticed, however, until the sixth year of the test so it seems to be of little practical import as most farmers have or should have plowed their fields by this time in the rotation.

The difference is reflected, however, in yield data presented in Table XX, where the first cuttings are grouped into two four-year periods, 1930-33 and 1934-37 inclusive. According to these data, the yield was more nearly maintained on the June 10 plots than on any other series, while the June 30 plots show the greatest decrease when compared with the average for the first four-year period. (The percentage reported in Column 3, Table XX, was obtained by dividing the yield for the second four-year period by the yield of the first four-year period for the same date.)

TABLE XX. *Comparison of cutting dates at Weld farm.*

Date Cut	Yield Dry Matter Per A. 1st 4 Years (Lbs.)	Yield Dry Matter Per A. 2nd 4 Years (Lbs.)	% of 1st 4 Years
June 10	1973	1762	89.3
June 20	2334	1818	77.9
June 30	2604	1886	72.4
July 10	3046	2285	75.0
July 20	2998	2355	78.6
July 30	3065	2507	81.8

Table XXI gives the average yield of dry matter and protein per acre and the percentage of protein in the hay cut at different dates for the entire eight-year period. From the data it appears that the dry matter per acre increases from the time timothy plants begin to head (June 10) until they are almost ripe (July 30). Conversely there is a fairly steady reduction in the amount of protein per acre, at least in that portion of the hay which is normally harvested, and a steady and consistent decrease in percentage of protein in the dry matter.

From the practical viewpoint these facts have much significance since New Hampshire and New England are in a protein deficient region, high protein feeds representing the dairyman's biggest cash expense.

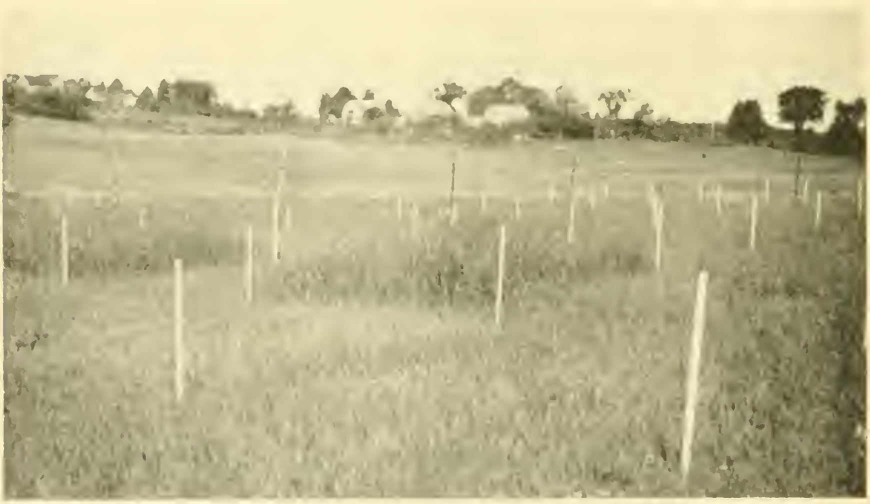
TABLE XXI. *Comparison of protein yields from different cutting dates on Weld farm. Eight-year average first cutting.*

Date Cut	Yield Dry Matter Lbs. Per Acre	% Protein	Yield Protein Lbs. Per Acre
June 10	1867	10.93	204
June 20	2076	8.96	186
June 30	2245	7.44	167
July 10	2666	6.64	177
July 20	2676	6.13	164
July 30	2786	5.56	155

It should be the aim of every dairyman to try to harvest as much protein in his home-grown roughage as possible so that its purchase in grain will not consume such a large proportion of the milk check.

Grass hay can be secured with a high protein content. The average of the June 10 cutting over the eight-year period was 10.93% protein, a figure that closely approaches the analysis of clover. Fifty days later (July 30) this percentage was but 5.56, a drop of almost one-half, while in the same period the total protein per acre varied from 204 pounds in the June 10 cutting to 155 pounds in the July 30 harvest, a reduction of 24 per cent.

The difference in digestible protein would, of course, be even greater for the two harvests. Digestibility trials of June 20 and July 20 hay (Circ. 41) indicated a digestibility factor of 62% for the June-cut hay and but 47% for that harvested on the corresponding date in July. Applying these percentages to the June 10 and July 30 harvests it will be observed that the digestible protein harvested on the two dates in question would be 126.5 and 72.8 pounds per acre respectively, result-



Weld farm plots showing cuttings done at different dates.

ing in a difference of 43.7 pounds per acre. This is equal to protein that would be assimilated by cows from approximately 300 pounds of a 20% dairy ration.

Second cuttings were made on these plots in seven of the eight years of the test. No harvest was taken in 1936 as the growth was deemed too short to be satisfactorily harvested. Second cuttings were made on the same date on all plots during the first week in September, about the time a farmer would normally take his second cutting or start to pasture off the rowen crop.

TABLE XXII.

7-Year Average of Second Cuttings on Weld Farm

Fall Cuttings from Plots Harvested First Time on	Series	Yield Lbs. /A. Dry Matter	% Protein	Yield Lbs. /A. Protein
June 10	A	577	11.61	67
June 20	B	425	12.94	55
June 30	C	327	12.84	42
July 10	D	302	14.24	43
July 20	E	247	14.56	36
July 30	F	252	15.48	39

The heaviest second cutting from these plots was obtained in 1931, when the yields varied from 922 pounds in the A series to 239 in Series F. The lightest yield (aside from 1936) was recorded in 1934 when the average for all the plots was but 152 pounds of dry matter per acre. The rainfall in 1931 was fairly evenly distributed through the spring and summer months, totaling 20.89 inches from March through August, whereas the 1934 rainfall totalled 17.39 inches, although in June, July and August but 7.1 inches of rain fell as against 11.42 inches during the same months of 1931.

The data in Table XXII indicate slightly heavier harvests and a greater protein yield in the second harvests from the plots which were first cut June 10 and 20 with very little difference among the remaining plots.

Rainfall data covering the six months from March to August for the years 1930-37 are presented in Table XXIII. During these years the driest six months were those of 1932 and the wettest in 1933. This latter year was not the most favorable hay year since the 12-inch rainfall recorded in April 1933 appeared to come too early to be of much benefit to hay growth and 1931 with its evenly distributed rainfall proved to be the best hay year for both first and second cuttings during the period studied. It must be kept in mind, however, that the 1931 crop was favored by the rainfall occurring much earlier in the life of the stand.

This experiment was conducted for a longer period of years than was necessary to establish comparative values of hay harvested at different dates for the reason that it seemed desirable to determine the effect of

TABLE XXIII.

Rainfall Data 1930-1937								
Month	1930	1931	1932	1933	1934	1935	1936	1937
March	4.57	3.95	2.06	5.06	2.21	1.59	8.87	3.73
April	1.56	2.49	2.20	12.49	4.71	2.86	4.23	4.87
May	2.93	3.03	1.25	2.41	3.37	1.35	2.08	3.29
June	3.20	5.52	2.33	1.85	3.57	6.36	1.58	4.42
July	3.71	2.20	1.89	4.61	2.32	2.13	2.58	.67
August	2.21	3.70	3.11	4.24	1.21	1.55	2.95	5.48
TOTAL	18.18	20.89	12.84	30.66	17.39	15.84	22.29	22.46

different cutting dates upon the life of the stand. Yields obtained were therefore somewhat lower than those which would be secured by farmers who practice a shorter rotation, but it is believed that with a shorter rotation span the yields secured would be proportionally similar to those found here if cutting were practiced at identical dates. Further, it seems certain that the percentage of protein and total protein per acre would vary in essentially the same proportion as far as the grass hay crop is concerned.

These facts apparently leave little room for doubt that for cows grass hay should be cut early, at least before the period of bloom. If cut between the dates when heads begin to appear and before bloom, the yield will be somewhat less and total carbohydrates will doubtless run somewhat lower than if cutting is practiced at a later date, but both the percentage protein and total protein will be significantly higher than if cutting is delayed.

Furthermore, hay cut before bloom will be somewhat harder to cure because it carries more moisture in its tissues[5] than it does at a later date. Farmers who wish to utilize this knowledge of grass hay composition to fullest advantage should use hay-making methods that require a minimum of hand and a maximum of machine labor to cut the cost of the curing process.

Farmers who are normally short of hay may not wish to sacrifice on yields to secure the better feeding value that can be obtained by early cutting. If early cutting would result in a reduction in yield sufficient to cause the purchase of hay during the following winter there might be some question as to the wisdom of the practice on those farms. There are so many ways of augmenting the hay supply, such as top-dressing, cutting hay on other nearby farms, practicing shorter rotations to increase yields, etc., that this does not seem a reasonable argument against early cutting on very many farms.

A very serious problem on farms where early haying is well established is to get all the hay cut while the feeding value is still fairly high. To do this requires starting well before the period of bloom, probably at the time when the plants come into head or certainly not long after this period.

[5] Circ. 41, N. H. Exp. Sta.

Under growing conditions at Durham, the hay in this test was cut at approximately the following stages of maturity:

June 10: Heads appearing
June 20: Headed
June 30: Bloom appearing
July 10: Past bloom
July 20: Seed dough
July 30: Seed nearly ripe

SUMMARY

Experimental data indicating how grass hay yields and feeding value may be improved are discussed in this bulletin.

In a test at Greenland covering three years' work, 32 pounds of nitrogen from 200 pounds of nitrate of soda increased the hay yield 1,462 pounds per acre. Thirty-two pounds each of phosphoric acid and potash coming from superphosphate and muriate of potash increased the yield 728 pounds per acre, while a complete fertilizer equal to the two treatments caused an increase of 2,159 pounds of cured hay per acre. These increases were produced at a cost of $5.48, $7.88 and $6.36 per ton respectively.

Rapid soil tests of the plots on this field indicated moderate amounts of available phosphoric acid and potash, due no doubt to uniform applications of complete fertilizers in each of three years preceding the seeding of the land.

On a heavy soil which had been in hay for a long time and which had not been generously treated with phosphoric acid and potash, complete fertilizers gave better returns comparatively than nitrogen alone. Whereas in the Greenland soil a complete fertilizer increased the yield over nitrogen alone approximately 50 per cent, on this heavy soil complete fertilizers gave approximately 200 to 300 per cent greater increase in production than the nitrogen carriers used. (Tables II and III.)

An 8-6-6 fertilizer mixed from highly soluble materials proved slightly more effective in increasing yields than a commercial 8-6-6 mixture.

Nitrogen recovery was greatly increased on this soil by the use of phosphoric acid and potash in mixed fertilizers. (Table IV.)

Nitrogen alone applied about the time growth starts increased slightly the percentage of protein in the forage, but the use of complete fertilizers had little effect or slightly decreased the protein percentage in the hay (Table V), although both nitrogen and complete fertilizers markedly increased the total amount of protein per acre.

None of the fertilizers stimulated the second crop yields to a significant extent. One application of fertilizer only was made, and this was applied at about the time growth starts in the spring (Table VI).

In another test (Table VII), nitrogen and phosphoric acid stimulated grass hay production more than nitrogen and potash. Rapid soil tests indicated, however, that there was probably enough potash for maximum grass hay crops whereas the level of available phosphorus was very low except on the plots where phosphoric acid was used.

Nitrate of soda applied in mid-September was practically as effective in stimulating yields the following season as when the same amount of

fertilizer was applied the middle of April. (Table VII.) Likewise, a late fall application of cyanamid was about equal to a March application (Table IX). Complete fertilizer applied in September proved not to be equal to a similar amount applied in April. (Table X.)

An application of 100 pounds of nitrate of soda increased yields in greater proportion than either a 200- or 400-pound application and a greater percentage of the nitrogen was recovered in the protein of the hay from the small application. (Tables XII and XIII.)

Nitrate of soda applied April 25 gave slightly better yields than when spread April 15 or April 5 and a greater percentage of the nitrogen from the late application was recovered in the forage. (Tables XIV and XV.) A delayed application of nitrogen on June 10, just after the first crop was cut, significantly increased the second crop and produced, at the two cuttings, almost as much hay as when the fertilizer was applied April 5 or 25. (Tables XVI and XVII.)

The conclusion seems to be warranted after studying the data that a 1-1-1 ratio of fertilizer nutrients is more satisfactory than a 1-2-2 ratio for grass hay production, assuming that fertilizers are applied annually as they were in the experiments which are described.

When the financial returns for this top-dressing work are considered, it seems that the returns per dollar invested are quite small, with hay values calculated at $12.00 per ton and using only the cash outlay for fertilizer as a basis for figuring. To make a profit from the operation, then, a farmer must know something about the needs of his soil, either from the past history of the fields in question or from a soil test or both. In fact, a rapid soil test will likely prove of considerable value in determining the needs for fertilization as well, perhaps, as amounts and elements to use.

Under some conditions greatest net profit may come from the use of nitrogenous fertilizers only, while under many others a complete fertilizer is certainly desirable and advisable. To profit most from top-dressing grass lands a farmer must realize these conditions and marshal as many facts as he can to help him determine the best procedure.

Experiments in cutting hay at different dates from June 10 to July 30, clearly indicate that a greater amount of protein and a higher protein forage will be harvested from the earlier cuttings. While early cut hay is somewhat more difficult to cure, it seems advisable if the hay is to be used for cow feed to harvest grass hay before the period of bloom.

Second cuttings from June 10 and June 20 harvests have been slightly heavier than if the first cutting is made at a later date and the second crop from plots cut early carried somewhat more protein per acre.

Over a period of years the stand of hay suffered somewhat more on the plots cut in mid season than on those cut early or late. Because this reduction was slight it does not appear to be a determining factor in hayland management.