Soil Fertility Investigations and Effects of Commercial Fertilizers on Reseeded Vegetation in West-Central Kansas[1]

J. L. LAUNCHBAUGH

Pasture Management Specialist, Fort Hays Branch, Kansas Agricultural Experiment Station, Hays, Knsas.

Much of the native grass reseeding in western Kansas is done on eroded cropland of low fertility. When moisture conditions are favorable, most sites may be revegetated successfully with native grasses, but subsequent forage production often is low, especially where most of the topsoil has eroded away. Evaluation of soil fertility needs and the responses of vegetation to fertilization are problems associated with management of many reseeded areas.

This experiment was conducted to investigate the relationships between a rapid soil-test method and a greenhouse pot-test method to determine major element deficiencies in soils, and to study yield responses of reseeded grasses fertilized with nitrogen and phosphorus on two soils exhibiting nutrient deficiencies typical of many reseeded areas in west-central Kansas.

Review of Literature

Rapid soil-tests designed to measure available plant-nutrient supplies are used in many areas in an attempt to determine the fertilizer requirements of soils for various crops. Generally such tests are not considered entirely reliable in estimating fertilizer needs (Millar and Turk, 1943). To overcome the shortcomings of rapid soil-tests biological methods have been developed using indicator plants in potted top soil under greenhouse conditions. Nutrients are added in various combinations, and yields relative to a standard full treatment of nitrogen, phosphorus, and potassium are interpreted as a measure of the soil's ability to supply a given element under the experimental conditions that exist (Jenny, Vlamis, and Martin, 1950). They showed that the lower the relative pot-test yield, the greater was the chance of securing a field crop response to added plant nutrients.

Numerous field applications of fertilizers in various forms and combinations have been tested. In the drier areas much of the emphasis has been placed on increasing cultivated grain yields. During years when moisture conditions were favorable, grain crop yields generally were increased by adding nitrates and phosphates in Kansas (Throckmorton and Duley, 1935); in Oklahoma (Eck and Stewart, 1954); in eastern Colorado (Greb and Whitney, 1953); in Nebraska (Lowry, Ehlers, and Pumphrey, 1954); and in the Texas Pan Handle region (Box and Jones, 1954).

A number of fertilizer trials have been conducted on native range vegetation throughout the Great Plains region. Immediate and residual responses have resulted from the application of 10 to 12 tons of cattle manure per acre in southern Saskatchewan (Clark, Tisdale, and Skoglund, 1943) and in northeastern Colorado (Klipple and Retzer, 1959). Other trials on native range involving commercial forms of nitrogen and phosphorus applied at rates up to 90 pounds of nitrogen and 100 pounds of phosphorus pentoxide per acre have shown that when nitrogen was included, yields generally were increased significantly, but not enough to make the fertilizer applications economical (Clark and Tisdale, 1945; Westin, Buntley, and Brage, 1955; Klipple and Retzer, 1959; and Rogler and Lorenz, 1957).

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Table 1. Survey mapping symbols and descriptions of soils selected for fertility studies.

		Soil Characteristics							
Soil No.	Survey Mapping Symbol[1]	Effective Depth, inches	Topsoil Texture[2]	Permeability of First significant zone	Permeability of Second significant zone	Parent Material	Percent Slope	Degree of Erosion	Range Site
1	1M34T / 2-1	60 or more	Silt loam	Moderately slow	Moderate	Loess and outwash	1 to 3	None apparent	Clay Upland
2	1M4T / 6-3	60 or more	Loam	Moderate	Moderate	Loess and outwash	5 to 7	Severe	Limy Upland
3	1M23D / 2-2	60 or more	Silt loam	Slow	Moderately slow	Loess	1 to 3	Moderate	Clay Upland
4	1F34T / 2-2	60 or more	Silt loam	Moderately slow	Moderate	Loess and outwash	1 to 3	Moderate	Clay Upland
5	1S5X / 2X-2	60 or more	Loamy sand	Moderately rapid	Moderately rapid	Recent alluvium	1 to 3 undulating	Moderate	Sandy
6	1M34T / 2-2	60 or more	Silt loan	Moderately slow	Moderate	Loess and outwash	1 to 3	Moderate	Clay Upland
7	XR / 8-3	10 or less	Loam	Moderate	Slow to very slow	Tertiary mortar beds	7 to 9	Severe	Breaks
8	XR / 8-3	10 or less	Clay loam	Moderate	Slow to very slow	Tertiary mortar beds	7 to 9	Severe	Breaks

[1] Standard mapping symbols for coding soil characteristics. U.S. Department of Agriculture Soil Conservation Service, 1951.
[2] From mechanical analyses by Lyle Linnell, former graduate student, Fort Hays Kansas State College, Hays.

Fertilizing reseeded cool-season grasses in pure stands with nitrogen at various rates up to 133 pounds per acre in the northern Great Plains generally produced significantly higher forage yields than those obtained from the untreated checks (Carter, 1955). In many cases, yields were such that nitrogen applications on cool-season species were economically feasible (Rogler and Lorenz, 1957). McIlvain and Savage (1950) reporting on the effects of fertilizing reseeded weeping lovegrass *(Eragrostis curvula* (Schrad.) Nees) in the southern Great Plains with 30 pounds of nitrogen per ace one year and 53 pounds the next showed that the grazing capacity was increased 33 percent and steers gained nine pounds per head more than those on unfertilized weeping lovegrass pasture. Gains were increased to the extent of 37 pounds per acre.

Procedure

During the fall of 1956, seven areas reseeded to native grasses near Hays, Kansas were selected to represent a wide range of soils and degrees of erosion[2]. The soil designations and descriptive characteristics appear in Table 1. The range seedings were made prior to 1950 and, except for one site (soil number 5) which supported a pure seeding of sand lovegrass *(Eragrostis trichodes* (Nutt.) Wood); native warm-season mixtures were planted on all sites. In addition, an upland site (soil number 1) of unbroken sod, representing large acreages of the type of land presently under cultivation, was included to indicate inherent soil fertility prior to cultivation and subsequent revegetation. Plots of at least one acre were located in each area and 50 randomly-collected soil cores four inches in diameter and six inches in depth were composited from each site to be used for rapid soil-test and pot-culture test analyses.

Rapid Soil-Tests

The soil samples from the various sites were given the following general soil fertility tests:[3] (1) limemeter test to determine pH as an indicator of lime requirements; (2) spectrophotometer test to determine percentage organic matter content (indicator of nitrogen requirement), available phosphorus in pounds per acre, and exchangeable potassium in pounds per acre.

Pot-Culture Tests

The pot-culture tests described by Jenny, Vlamis and Martin, 1950 were modified for use in this study. Six barley *(Hordeum vulgare* L.) plants of the early variety, Beecher, were grown to maturity in six-inch asphalt-coated clay pots and saucers filled with 1,500 grams of soil. The major elements were added in solution to the pots in the

[2] *Bert Soderblom, Edward E. Bookless, and Robert K. Glover, USDA, Soil Conservation Service, Hays, Kansas, assisted with the site selections and furnished the soils descriptions.*

[3] *Analyses were made by the Soil Testing Laboratory, Department of Agronomy, Kansas State University, Manhattan.*

[4] *Field plots were situated 11 miles east of Hays, Kansas.*

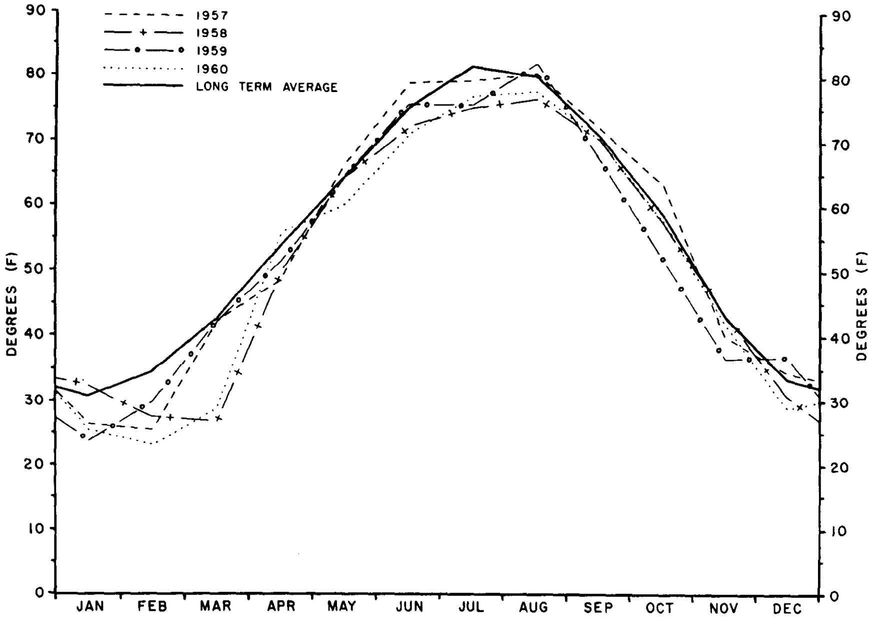

FIGURE 1. Monthly average temperatures for the four-year period in relation to the long-term average at the site of fertilizer applications.

combinations and rates shown in Table 2. The treatments were replicated four times and the pots were rerandomized on the greenhouse benches at two-day intervals to reduce location effects. The pots were watered as necessary to maintain optimum soil moisture conditions. Recorded information included total dry matter yields at maturity and crude protein analyses of the harvested material.

Field Application of Nitrogen and Phosphorus

Broadcast applications of nitrogen and phosphorus were made during April, 1957, at two adjacent field locations, soils 2 and 3[4], selected on the basis of barley performance in the pot-culture tests. The treatments consisted of 80 pounds of nitrogen per acre in the form of ammonium nitrate, 60 pounds of phosphorus pentoxide per acre in the form of treble superphosphate, a combination of the two fertilizers at the above rates, and an untreated check. Plot size was 15 by 45 feet in a randomized block design with four replications at each soil location. Carry-over effects of the various treatments were measured during 1958. The plots were given the original fertilizer treatments again in April, 1959. Carry-over effects were measured during 1960.

Dry weight yields were obtained from a 39-inch sample strip mowed two inches high along the longitudinal center of each plot. Additional plot sampling consisted of dominant species height measurements, species composition estimates, and crude protein content analyses of the dominant grasses during June and September. Plots were harvested annually during September, near the close of the growing season.

Weather Conditions During the Field Trials

The climate of west-central Kansas has been described by Flora, 1948. The experimental area weather is characterized by extremes in temperatures and wide variations in the annual precipitation pattern. Figure 1 shows the long term average monthly temperatures and monthly averages during the four years of study. Figure 2 illustrates the long term average precipitation and amounts received during the study period.

Temperatures were much lower than average during the late winter months each year and only occasionally above average the remaining months. Annual precipitation was one inch to over eight inches above average during the four-year period. Growing conditions were favorable during 1957 and 1958 when adequate moisture was received throughout the growing season. Although below-average April and June precipitation caused the 1959 season to be somewhat drier than the two previous years, the vegetation had sufficient moisture for growth during the summer months. Severe drought conditions from late June to early August reduced growth during the summer of 1960. The effects of this drought were moderated considerably by below-average temperatures during the dry period; thus there was significant recovery in late August and early September.

Results

Rapid Soil-Tests

These tests revealed large differences among the soils in terms of soil reaction, organic matter content, and usable amounts of phosphorus and potassium (Table 3). Soils with a high per-

Table 2. Combinations and equivalent amounts on a surface acre basis of major elements added to the 1,500 grams of soil in the pot-culture tests.

Treatment	Nitrogen	Phosphorus	Potassium
	— — (Equivalent Rates in Pounds Per Acre) — —		
$N_0P_0K_0$	0	0	0
$N_0P_3K_2$	0	300	200
$N_3P_0K_2$	300	0	200
$N_3P_3K_0$	300	300	0
$N_3P_3K_2$	300	300	200

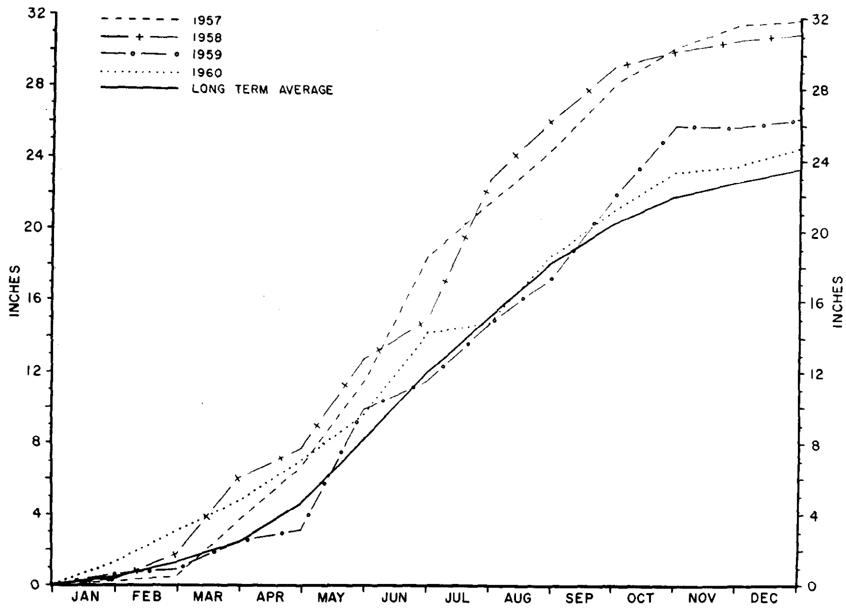

FIGURE 2. Accumulative monthly precipitation amounts compared with the long-term average during the four-year period at the sites of fertilizer applications. The slope of an annual curve in relation to the long-term average curve indicates plus or minus departures from average at monthly intervals.

centage of topsoil intact were slightly acid, while the severely eroded areas were definitely alkaline. Because of leaching, calcium carbonate accumulates in the B horizon and may occur as free lime on the surface of severely eroded areas. Organic matter content was highest in the unbroken sod and lowest in the lowland loamy sand site. The soil samples from reseeded upland sites contained percentages of organic matter nearly proportional to the amounts of remaining topsoil. Using the rapid soil-test as a guide, nitrogen fertilizer requirements for most dryland crops were about half as great on the native sod area as on the other sites. Available phosphorus ranged from a medium amount of 34 pounds per acre on the slightly eroded upland site 3 to nine pounds per acre on the eroded shallow slope on site 8; however, there was no direct relationship between degree of erosion and phosphorus content. Several of the most severely eroded sites contained more available phosphorus than the unbroken native grass area. The required phosphorus amendments recommended from these rapid soil-tests varied from none for grain crops and cool-season grasses on soils 3 and 4 to 30 or 40 pounds per acre on soil 8. The amount of exchangeable potassium was high to very high in all samples and as with percentage of organic matter, there was a positive relationship with the proportion of remaining topsoil.

Pot-Culture Tests

Plants on all eight soils responded to additions of nitrogen and phosphorus but not to potassium in the pot-culture tests (Table 4). Nitrogen was highly deficient in all the soils except number 1 which was benefited least. The soils were differentiated into two groups on the basis of the nitrogen-phosphorus interaction. On highly eroded soils 2, 7, and 8 and the loamy sand site 5 the responses to phosphorus or nitrogen were not significant unless the two elements were added in combination. The remaining soils were not benefited by the addition of phosphorus without nitrogen, but showed responses to nitrogen when phosphorus was absent. These reactions to fertilizer combinations are illustrated by barley dry matter yields in Figure 3. Soil 2 is representative of the group needing a combination of nitrogen and phosphorus, and soil 3 is typical of the group in which nitrogen without phosphorus gave a response intermediate between the check and full treatments. Soil number 1 is included to indicate the relative inherent fertility associated with unbroken native sod.

Crude protein content of the mature barley plant was not influenced significantly by pot-culture treatment except in the four soils requiring the addition of both nitrogen and phosphorus to obtain significant yield increases

Table 3. Data from rapid soil-tests and recommendations for plant nutrients to be added to the soil for small grains, sorghums, and cool-season grass pastures.[1]

		Organic Matter		Phosphorus		Potassium	
Soil	Reaction	Content	N Needed	Available	P_2O_5 Needed	Exchangeable	K_2O Needed
No.	pH	%	lb/A	lb/A	lb/A	lb/A	lb/A
1	6.6	2.5	30-40	18	20-30	550	0
2	7.9	0.5	40-80	20	20-30	275	0
3	6.4	1.3	40-80	34	0-20	550	0
4	6.8	1.5	40-80	28	0-20	550	0
5	8.5	0.3	40-80	13	20-30	314	0
6	7.4	1.5	40-80	15	20-30	550	0
7	8.0	1.0	40-80	22	20-30	440	0
8	7.8	0.7	40-80	9	30-40	480	0

[1]Fertilizer recommendations obtained from: Interpretation and Explanation of General Soil Fertility Tests. Form ST 4E 9-55. Departments of Agronomy and Extension Service, Kansas State University, Manhattan, cooperating.

(Table 5). Here the addition of nitrogen without phosphorus increased the percentage crude protein of the barley two to three times above the other treatments. The plants incorporated the nitrogen without making any measureable increase in growth over those on the unfertilized soil.

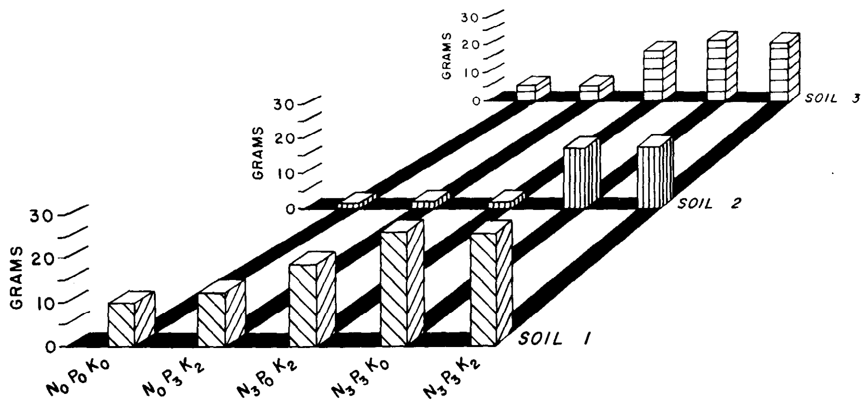

FIGURE 3. Barley dry matter yields in reponse to various fertilizer combinations in potted top soils. Soils 1 and 3 exhibited a significant response to nitgoren without the addition of phosphorus. Soil 2 required nitrogen and phosphorus in combination to obtain a response.

Field Application of Nitrogen and Phosphorus

Table 6 shows the average total dry matter yields of fall-harvested vegetation on soil site 3 during the four-year study. In 1957, treatments containing nitrogen produced yields significantly higher than the phosphorus alone or check treatments. The 1958 residual effects showed the same trend but differences were not significant. The treatments containing nitrogen produced significantly higher yields again in 1959, and 1960 yields from carry-over nitrogen were large enough to be significantly greater than the residual phosphorus or check yields. The addition of phosphorus in the presence of nitrogen gave no significant increases in yields over the nitrogen alone on this site. The progressive decrease in forage production from year to year, as reflected in the check and phosphorus treatments, was brought about by a combination of mowing effects and reduced precipitation during the last two years of the study.

Table 4. Dry weight yields per pot of six barley plants grown to maturity in the various soils and fertilizer combinations under greenhouse conditions.

Fertilizer Treatment		Soil Number 1	2	3	4	5	6	7	8
		(Grams)							
$N_0P_0K_0$		10.1	1.8	5.6	3.0	1.6	2.6	3.0	2.8
$N_0P_3K_2$		12.0	2.2	5.4	3.3	1.7	2.6	4.0	3.4
$N_3P_0K_2$		18.4	2.1	18.0	13.2	3.0	9.5	3.8	3.3
$N_3P_3K_0$		25.7	17.5	22.0	17.5	14.5	16.2	16.9	16.1
$N_3P_3K_2$		25.3	18.5	20.8	18.5	15.3	17.2	17.2	16.9
L.S.D.	.05	2.0	1.0	1.3	1.4	1.4	3.0	1.1	1.1
	.01	2.7	1.4	1.9	2.0	2.0	4.1	1.6	1.6

Annual bromes (*Bromus japonicus* Thunb., and *B. tectorum* L.) played an important role in the plots on soil site 3. Figure 4 illustrates production of the three major vegetation components, switchgrass (*Panicum virgatum* L.), annual bromes, and other species (blue grama (*Bouteloua gracilis* (H. B. K.) Lag. ex Steud.), buffalograss (*Buchloe dactyloides* (Nutt.) Engelm.), sideoats grama (*Bouteloua curtipendula* (Michx.) Torr.), little bluestem (*Andropogon scoparius* Michx.), red threeawn (*Aristida longiseta* Steud.), and a trace of native forbs) separately by years and fertilizer treatments. During 1957 and 1959, the years when fertilizers were applied, annual bromes responded more to nitrogen fertilization than did switchgrass and other species. Considering total vegetation minus annual bromes, the yield increases due to nitrogen fertilization were not significant in 1957; however, the yield of each component was increased significantly by nitrogen fertilization in 1959. Switchgrass and the annual bromes each responded significantly to carry-over nitrogen during 1960.

Yield increases due to nitrogen fertilization on low fertility site 2 were highly significant each year (Table 7). In addition there were significant nitrogen-phosphorus interactions in 1957 and 1959. During the years the fertilizers were applied, plots receiving both elements yielded more than those receiving only nitro-

Table 5. Crude protein content of barley plants in percentages grown to maturity in the pot-culture tests.

Fertilizer Treatment	Soil Number 1	2	3	4	5	6	7	8
	(Percent)							
$N_0P_0K_0$	6.7	8.2	6.4	6.2	7.5	6.9	7.2	6.7
$N_0P_3K_2$	5.9	7.8	6.6	5.8	7.0	8.0	6.2	6.5
$N_3P_0K_2$	7.7	19.0	7.0	7.2	13.3	7.2	13.6	12.3
$N_3P_3K_0$	7.3	5.9	6.2	5.9	5.9	5.4	5.4	5.8
$N_3P_3K_2$	7.3	6.1	6.4	6.1	5.9	5.3	5.6	5.8

Table 6. Yield responses of total forage to field applications of 80 pounds of nitrogen and 60 pounds of phosphorus pentoxide per acre alone and in combination on soil site 3. Plots were fertilized in April, 1957, and again in April, 1959.

Fertilizer Treatment		Yield Following: 1957 Application	1958 Carry-over	1959 Application	1960 Carry-over
		— — — — — (Pounds	per acre)	— — — — —	
NP		5,029	3,058	3,805	1,664
N		4,923	3,042	3,554	1,547
P		3,385	2,586	1,618	1,189
O		3,522	2,672	1,600	1,250
L.S.D.	.05	742	n.s.	374	218
	.01	1,067		538	313

gen. As on soil site 3, there was no response to the addition of phosphorus alone. No annual grasses were present on the low fertility site 2, and although over 90 percent of the production was sideoats grama, there was no differential response of species to fertilizer treatment. Other species on site 2 included blue grama, little bluestem, buffalograss, and a trace of native forbs.

Crude Protein Content of the Forage

The crude protein content of switchgrass on site 3 at two annual sampling dates during the four-year period is shown in Table 8. As expected, crude protein content decreased between June and September each year. Only the June, 1959, measurements were significantly different between treatments. At that time samples from the nitrogen and nitrogen-phosphorus plots contained higher percentages of crude protein than samples from the phosphorus and check plots. By September, 1959, the differences no longer existed. Similar analyses for crude protein in sideoats grama on site 2 resulted in findings nearly identical with those from switchgrass on site 3.

Discussion

The general soil-test and the pot-culture techniques agreed reasonably well in determining the relative nitrogen requirements for the various soils. The two methods did not agree in estimating the relative needs for phosphorus. In most instances when pot-tests indicated a low inherent phosphorus content, the rapid soil-test showed relatively high amounts of available phosphorus and vice versa. Because of the abundance of potassium in all soils tested, there were no apparent discrepancies in the two methods. Organic matter content found by the rapid soil-test was the most reliable indicator of soil potential in supplying both nitrogen and phosphorus for plant growth in the pot-culture tests.

Considering the limited number of locations where fertilizers were applied in the field, direct comparisons of the three methods for all of the soils are not possible; however, yield results from the two field sites differed from predictions based on pot-culture results. Soil number 3, a relatively high fertility site with a low but significant nitrogen-phosphorus interaction in the pot-culture tests, responded as well to field applications of nitrogen alone as to a combination of nitrogen and phosphorus. Soil number 2 which required nitrogen and phosphorus in combination to produce any increase in pot yields, responded significantly to field applications of nitrogen alone, although nitrogen in the presence of phosphorus produced the highest yields under field conditions.

Several factors may account for these inconsistencies in greenhouse and field results. First, only the upper six inches of soil was used in the pot-culture tests, while the perennial grasses in the field were extracting nutrients throughout the depth of their root systems. Second, barley as an indicator plant may have had different requirements for the various nutrients under greenhouse conditions than established vegetation in the field plots. The growing period, temperature, soil moisture, and nutrient availability relationships in the field were totally unlike those under greenhouse conditions, suggesting that growth time and nutrient avail-

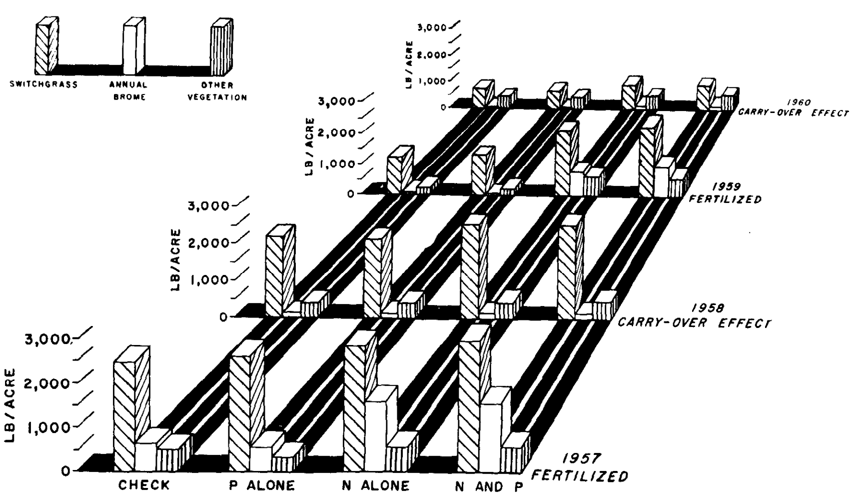

FIGURE 4. Dry matter yields of the major vegetation components on soil 3. Note the differential stimulation of annual brome to treatments containing nitrogen during years of fertilizer application.

Table 7. Yield responses of total forage to field applications of 80 pounds of nitrogen and 60 pounds of phosphorus pentoxide per acre alone and in combination on soil site 2. Plots were fertilized in April, 1957, and again in April, 1959.

Fertilizer Treatment		Yield Following: 1957 Application	1958 Carry-over	1959 Application	1960 Carry-over
		(Pounds per acre)			
NP		1,204	484	1,426	393
N		721	410	718	417
P		233	209	111	76
O		266	252	161	127
L.S.D.	.05	244	95	153	71
	.01	350	144	220	102

ability at various depths in the field may have played a large part in making more phosphorus available than the pot-culture tests indicated. The pot-culture technique, to be practical, must utilize quick-maturing indicator plants, but these greenhouse and field comparisons show that it might have been advantageous to composite a soil sample representative of the soil profile containing the established plant root systems. Identical yield responses to carry-over nitrogen and nitrogen plus phosphorus on soil 2 suggest that high levels of nitrogen were needed to produce a nitrogen-phosphorus interaction on this site.

The differential response of winter annual bromes to nitrogen fertilizer supports the conclusion that cool-season species are benefited more by nitrogen fertilization than are associated warm-season species (Rogler and Lorenz, 1957). Increases in forage production on both sites were not of sufficient magnitude to justify the expense of fertilization, considering forage yields alone. The economic value of such a practice should be measured by animal response which would integrate the factors of forage quantity and quality. Crude protein content was increased during the early growing period of 1959 by nitrogen fertilization in these trials, but similar increases were not detected during the other years. In related studies, forage protein content usually was increased by applications of nitrogen (Carter, 1955; McIlvain and Savage, 1950; Williams, 1953; and Westin, Buntley, and Brage, 1955); however, this was not always true (Clark and Tisdale, 1945).

Summary

1. The nitrogen, phosphorus, and potassium levels in the upper six inches of eight soils were compared by a rapid soil-test and a pot-culture technique.

2. Organic matter content used as an index to available nitrogen in the rapid soil-test was a good indicator of the ability of each soil to supply nitrogen in the pot-culture tests.

3. Organic matter content was better than soil-test phosphorus determinations in predicting the ability of a soil to supply phosphorus in the pot-culture tests.

4. The rapid soil-test showed a wide range, but high amounts of potassium in all soils. The pot-culture tests indicated no potassium deficiencies in any of the soils used in this experiment.

5. Pot-culture yields of barley were greatest for all soils when both nitrogen and phosphorus were added. Adding potassium was not necessary. Yields were not increased over those from untreated check pots by phosphorus without nitrogen. Nitrogen without the addition of phosphorus increased pot yields to an intermediate level between the check and full treatment in the four soils having the highest amounts of organic matter. Plants grown in the four soils containing the lowest amounts of organic matter did not respond to the addition of nitrogen without phosphorus in the pot-culture tests.

6. Field applications of 80 pounds of nitrogen per acre, 60 pounds of phosphorus pentoxide per acre, the two in combination, and no treatment were made on a high organic matter content site and a low organic matter content site in the spring of 1957,

Table 8. Average crude protein content of switchgrass on June 15, and September 15, annually from fertilizer plots on soil site 3. Fertilizers were applied at rates of 80 pounds of nitrogen and 60 pounds of phosphorus pentoxide per acre alone and in combination in April, 1957, and again in April, 1959.

Fertilizer		Crude Protein Content in: 1957		1958		1959		1960	
Treatment		June	Sept.	June	Sept.	June	Sept.	June	Sept.
		(Percent)							
NP		6.1	3.1	5.9	3.4	7.0	2.9	6.6	3.1
N		6.9	2.7	5.8	3.2	7.0	3.0	6.6	3.1
P		6.1	2.9	5.9	3.7	5.9	3.4	6.9	3.0
O		6.8	3.1	5.7	3.5	5.9	3.4	6.9	3.1
L.S.D.	.05	n.s.	n.s.	n.s.	n.s.	0.3	n.s.	n.s.	n.s.
	.01					0.4			

and the plots were retreated in the spring of 1959.

7. Forage yields on the high organic matter site were increased significantly by nitrogen. Nitrogen and phosphorus together did not increase yields over nitrogen alone. Phosphorus alone did not increase yields above those of the untreated check plots. Cool-season annual bromes growing with the reseeded grasses responded more to nitrogen fertilization than did the warm-season perennial grasses. Carry-over effects of nitrogen were small each year following fertilizer application.

8. Yields were greatly increased by nitrogen and phosphorus in combination on the low organic matter site over relatively low producing untreated check plots. Nitrogen alone gave an intermediate response. Phosphorus alone produced no increase in yields. Carry-over responses to nitrogen and phosphorus and nitrogen alone were the same and were relatively high.

9. Forage crude protein content was increased in plots receiving nitrogen on both soil sites during the early growing season of 1959. This was the only time when differences were found.

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