OKLAHOMA

The Magruder Plots – Long-Term Wheat Fertility Research

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In 1891, A.C. Magruder established a continuous winter wheat fertility study at Oklahoma State University that remains ongoing today. The experiment was initially established to evaluate the effect of manure application on wheat yield and determine how long the soil could sustain continuous wheat production. In 1930, treatments evaluating inorganic sources of N, P and K were added. The data set collected over the last 110 years has been a valuable source of information for long-term monoculture wheat fertility and sustainable agriculture.

During the early decades of the trial, manure application resulted in a marked increase in yield when compared to the unfertilized check plot (**Figure 1**). Even then, the realization that there was not enough manure to cover all of Oklahoma's wheat ground was noted. As the ability to synthesize inorganic fertilizers increased, treatments evaluating inorganic forms of N, P and K were added to the trial. From the time inorganic fertilizers were first added (1929), yields due to these materials have matched or exceeded those of the manure treatment.

> This 110-year-old wheat fertility study is a convincing example of the importance of recognizing a soil's nutrient supplying capability in nutrient management. Phosphorus (P) was the first limiting nutrient, then nitrogen (N), and finally potassium (K).

Another important aspect of the Magruder Plots is identifying the onset of macronutrient deficiencies. Comparison of the P only and the NP treat-

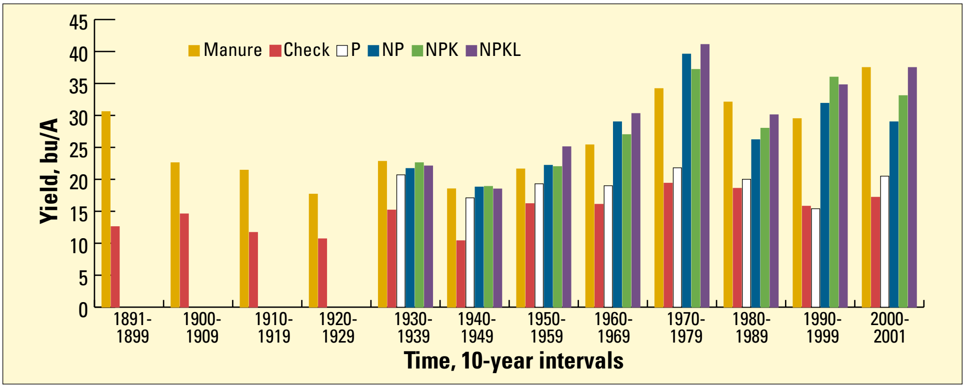

Figure 1. Ten-year average yields for the Magruder Plot treatments, Stillwater, OK, 1890 to 2000.

Manure:	1891-1967, applied at a rate of 120 lb N/A every four years; 1968-present, applied at a rate of 240 lb N/A every four years
Check:	no soil amendments added
P:	1930-1967, P applied as ordinary superphosphate at a rate of 30 lb P_2O_5; 1968-present, applied as triple superphosphate
NP:	1930-1945, N applied as sodium nitrate at a rate of 33 lb N/A; 1946-1967, N applied as ammonium nitrate at a rate of 33 lb N/A; 1968-present, N applied as ammonium nitrate at a rate of 60 lb N/A; P application same as P only treatment
NPK:	N and P treatment same as NP treatment; 1930-present, K applied as potassium chloride at a rate of 30 lb K_2O/A
NPKL:	N, P and K applied the same as NPK treatment; lime (L) applied when soil pH < 5.5

Dr. Bill Webb, Dr. Robert Westerman, and Dr. Billy Tucker (left to right) each served as Manager of the Magruder Plots in past years. Dr. W.R. Raun has handled the responsibility since 1992.

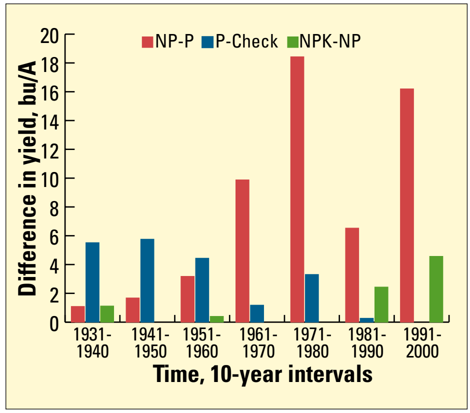

Figure 2. Differences among selected treatments of the Magruder Plots, 1930-2000.

NP-P: difference in winter wheat yield between NP treatment and P only treatment

P-Check: difference in winter wheat yield between P only treatment and check

NPK-NP: difference in winter wheat yield between NPK treatment and NP treatment

ments shows that a considerable difference in yield due to N fertilization was not noted until the 1960s (**Figure 2**). Thus, early in the study, N in rainfall and that mineralized from soil organic matter were sufficient to meet plant needs at these dryland yield levels. A response to applied K was not observed until the 1980s when the yield of the NPK fertilized plots minus that of the NP fertilized plots began to show a difference (**Figure 2**). This coincides with the disappearance of a P response in the P only treatment resulting primarily from the development of N deficiency. However, K was likely a contributing factor since it was also becoming yield limiting. It is interesting to note that when N, P, K, and lime are adequately supplied, there has been little if any benefit from the addition of secondary and micronutrients supplied by the manure treatment.

Soil N has decreased notably over the last 100 years, as has the soil organic matter level. In 1893, N and organic matter in the surface soil were 0.16 and 3.58 percent, respectively. After 108 years of monoculture, winter wheat under conventional tillage, soil N and organic matter levels have dropped below 0.06 and 1.50 percent, respectively (**Figures 3** and **4**). The decrease is most notable in the 0 N treatments, resulting from depletion of native N for crop needs. Soil P

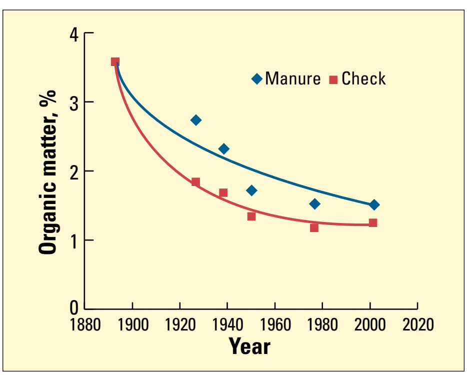

Figure 3. Change in soil organic matter over the last 100 years of the Magruder Plots.

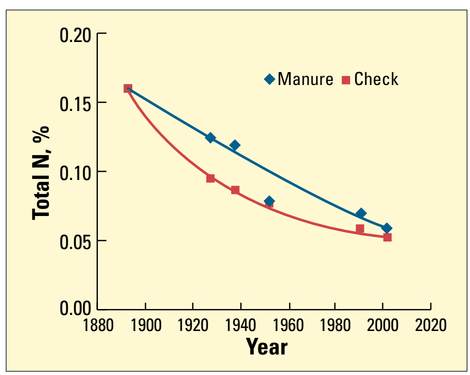

Figure 4. Change in total soil N over the last 100 years of the Magruder Plots.

and K levels have changed considerably over the last 34 years (**Table 1**). Soil test P has decreased in the check, and P levels of the P only treatment are higher than other treatments because N has been limiting, thus reducing yields and P removal.

The data collected from 110 years of monoculture winter wheat on the Magruder Plots have been invaluable. Identifying that in the 1980s soil K was depleted to levels where yield was adversely affected emphasizes the need for soil testing and proper nutrient management. The lack of a considerable response to inorganic N fertilization prior to the 1960s also illustrates that the original source of N in the soil is organic matter. Its contribution of N via mineralization was and continues to be quite significant. On these prairie soils, first tilled in 1892 and in continuous winter wheat since, it took 70 and 90 years to observe N and K responses, respectively. BC

TABLE 1. Soil P and K levels measured in 1967 and 1997.

Treatment	P	K
	parts per million (ppm)	
	1967[1]	
Check	17.7	316
Manure	27.3	371
P only	50.6	259
NP	35.2	311
NPK	37.5	383
NPKL	30.6	350
	1997[1]	
Check	6.7	231
Manure	41.3	230
P only	55.7	219
NP	46.3	257
NPK	43.2	282
NPKL	38.3	262

[1]In 1967, Bray-Kurtz P-1 for P and ammonium acetate for K; in 1997, both P and K by Mehlich 3.

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weather conditions and a greater demand for Mg may be the cause for the decrease in blood serum Mg observed on March 20, 2001.

Calf performance. Calves had higher rates of gain in both years when their mothers grazed tall fescue fertilized with P (**Table 1**). We thought that milk quality might have been affected by P fertilization. However, when milk samples were analyzed for protein, no differences were found among treatments. Therefore, it seems that the volume of milk produced may have been greater for the P fertilized group compared to the Mg supplement and control animals. As a result, the calves grew faster. If forage availability is greater, cows can produce more milk for their calves. However, we attempted to keep the amount of available forage equal among pastures. Therefore, the greater milk production may have been the result of increased forage quality, although we do not have those data at this time.

Summary

These results agree with previous research indicating the importance of soil P in increasing Mg uptake by tall fescue. Fertilizing pastures with P compares favorably to use of Mg supplements to protect against grass tetany. Further, P fertilization provides additional benefits to cattlemen, including greater calf gains. BC

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