EFFECT OF MANURE APPLICATIONS COMPARED TO COMMERCIAL FERTILIZER FOR TOTAL NITROGEN IN DRYLAND WINTER WHEAT (TRITICUM AESTIVUM L.)

Ravinder Singh*, Daryl B. Arnall, Sharry Raedan
Oklahoma State University, Stillwater, OK
*ravinder.singh@okstate.edu 405-762-8430

ABSTRACT

The Magruder plots are one of the staples in research agriculture not only in Oklahoma but across the country. The historic data gathered from the Magruder Plots allows for the analysis of long term data sets in excess of 124 years of data. The Magruder treatment structure allows for the comparison of the added benefits of manure applications as compared to inorganic sources of fertilizers. Manure applications were made once every four years as a total nitrogen source compared to annual applications of commercial based Nitrogen (N), Phosphorous (P) and Potassium (K) fertilizers as well as lime (Ca) on winter wheat. Response to N, P, K, yield and organic matter have been measured in the Magruder plots since 1931, yield and organic matter response has been tracked since the implementation of the plots in 1892. Having access to 124 years of yield history has showed that moving to bi or tri annual applications will increase the efficiency of N utilization from mineralization in dryland winter wheat. Oklahoma State University suggest that first year mineralization occurring at a rate of 50 to 70% is highly over estimated according to the results of the study, although the OSU expected future mineralization rate of 10-20% is more accurate. The data suggest that growers could make tri-annual applications of the 269 kg N ha^{-1}rate to stabilize yield in their system. Utilizing a tri-annual application will allow growers to maximize N mineralization as well as N from the inorganic form when producing winter wheat. Further analysis of nitrogen mineralization rates in beef feedlot manure should considered by Oklahoma State University moving forward. Soil test should be conducted regularly to ensure phosphorous levels are maintained below critical threshold for losses

INTRODUCTION

Farmers use manure as a long-term investment in arable land because it decomposes slowly and provides nutrients to crops for many years. Manure is a vital source of organic matter as well as a source of many nutrients for crop cultivation. Increased soil organic matter improves soil structure or tilth, improves drainage in fine-textured clay soils, offers a source of slow-release nutrients, minimizes wind and water erosion, and stimulates the growth of earthworms and other beneficial soil organisms (Rosen and Bierman, 2017).

Winter wheat (*Triticum aestivum* L.) is a major crop in the state of Oklahoma even prior to its statehood in 1907 with approximately 1.78 million hectares planted per year (NASS, 2020). Wheat has always played a significant role in Oklahoma's agricultural economy, with harvested grains providing $474 million in income in 2019. Weather patterns for producing crops in Oklahoma are anything but consistent, with year-to-year changes in environmental circumstances, as well as dropping grain prices, leaving growers looking for new ways to enhance yield while lowering operational costs. Winter wheat growers are seeking for strategies to reduce production costs without making drastic modifications to their production practices that might reduce yields in this era of high production costs and low commodity prices. Producers are questioning the effectiveness and advantages of fertilizer sources such as dung due to their availability. Researchers at Oklahoma State University are looking at solutions for a more effective approach to use manures due to increased demand.

The Magruder experiment (also known as Magruder plots) is one of the country's oldest experiments. It was founded in 1892 by A.C. Magruder to examine the productivity of native prairie soils without fertilizer. It began with a control treatment and was later divided after 6 years to apply manure in half of the experiment. It was modified again to include ten different treatments in 1930. Since 1947, there are six treatments available: manure, control, P, NP, NPK, and NPKL, with manure applied every four years, chemical fertilizers applied annually, and lime applied only when the pH went below 5.5.

The objective of this study is to evaluate the effect of manure application on grain yield and nitrogen contribution. To accomplish the objectives of this study, we used only manure, control, and NPKL treatments.

MATERIAL AND METHOD

For this study, historical data from a long-term continuous winter wheat experiment (Magruder plots) were analyzed. These plots have been managed under conventional tillage since 1892 at the Agronomy Experiment Station in Stillwater, Oklahoma (36°, 7'11.1" N, 97° 5'18.9" W). Magruder plots are situated on Kirkland silt loam (fine, mixed, thermic Udertic Paleustolls), with an average annual rainfall of 33 inches and a mean annual temperature of 15.5 degrees Celsius.

There are currently six non-replicated plots, including an unfertilized plot (control), manure, P, NP, NPK, and NPK-Lime (lime applied when soil pH 5.5). For this study, only three treatments were used. There was no robust use of statistical methods in agricultural experiments at the time of the establishment of this long-term experiment. As a result, replications were omitted from the experimental plan. Manure treatment began in 1899, and inorganic fertilizer was introduced in 1929. Prior to 1968, manure was used to deliver 134 kg N ha^{-1}. Following that, manure plots received 269 kg N ha^{-1} of cattle manure every four years beginning in 1968. While inorganic fertilizers are applied before planting on an annual basis. We only used manure, control, and NPK-lime treatments in this study (Table 1). Between 1930 and 1967, nitrogen was applied as sodium nitrate at 37 kg N ha^{-1}, ammonium nitrate at 67 kg N ha^{-1} from 1968 to 2014, and urea at 67 kg N ha^{-1} since 2005. Between 1931 and 1967, phosphate was applied as ordinary superphosphate (osp) (20 percent P) at a rate of 15 kg P ha^{-1}, and in 1968, it was changed to triple superphosphate (46 percent P2O5). Since 1931, potassium has been used as a muriate of potash at a rate of 29 kg K2O ha^{-1}. Lime was given to the NPK-lime plot just twice over the life of the Magruder Plots (1929 and 1954) when the pH fell below 5.5. Each plot is 30.5 m long and 5.3 m wide, with a 1.2 m alley between them.

All plots were kept in accordance with the recommendations of the Oklahoma State University Extension Service. Using a Massey Ferguson 8XP plot harvester, the center of each plot (about 5 m) was harvested for grain yield each year of the study period, and wheat straw was uniformly redistributed within each plot each year. For the study period, simple statistics with a mean yield were produced. SAS 9.4 was used for the analysis of variance, with an alpha of 0.05.

Table 1. Treatment structure

	1932-1967			1968- Present		
	N	P	K	N	P	K
		Kg ha-1			Kg ha-1	
Manure	134 Kg N/ac, every 4th year			269 Kg N/ac, every 4th year		
Check	0	0	0	0	0	0
NPKL *	37	15	30	67	15	30

*, pH <5.5, 3T/ac
N source- Sodium Nitrate (16-0-0) (1932-1967); Ammonium Nitrate (34-0-0) (1946-2003); Urea (46-0-0) (2004-Present)
P- Ordinary superphosphate (0-20-0-12) (1932-1967); Triple superphosphate (0-46-0) (1968- Present)
K- Muriate of Potash (0-0-60) (1932-Present)

RESULTS AND DISCUSSION

Effect of Manure Application on Grain Yield

The data is grouped according to the amount of Nitrogen applied. Average grain yields for the check, manure, and NPKL treated plots are presented in Table 2 (1932-1967 period) and Table 3 (1968-2015 period).

During the period 1932-1967, manure applied plots averaged 1.38, 1.55, 1.50, and 1.65 Mg ha^{-1} one, two, three, and four years after application (YAA), respectively, while unfertilized check averaged 1.00, 0.87, 1.01, and 1.04 Mg ha^{-1}. However, the manure treatment yielded 0.13 Mg ha^{-1} (8%) less than the NPKL treatment, even though no significant difference was identified between the two treatments in this study.

After 1968, manure application rate was raised to 269 kg N ha^{-1} to satisfy the needs of high yielding dwarf wheat varieties. Over the study period of 1968-2015, grain yield in the unfertilized plot ranged from 1.04 to 1.28 Mg ha^{-1}, while that for the manure and NPKL treatments ranged from 1.84 to 2.49 and 2.21 to 2.62 Mg ha^{-1}, respectively. There was a significant difference ($p = < 0.0001$) in grain yield between the unfertilized check and fertilized treatments, but no differences were observed between the manure and the NPKL applied plots expect 4th year after manure application. This shows that applying manure instead of inorganic fertilizers could result in a similar yield. Ghosh et al., 2004 and Tayebeh et al., 2010 discovered similar results. However, the quality and kind of organic fertilizer used are critical to achieve comparable yields to chemical fertilizers

(Tayebeh et al., 2010). Farmers should consider using animal manure because fertilizer prices have nearly doubled since last year. Furthermore, soil organic carbon has decreased significantly in the Magruder plots since 1893, with the manure plot showing the least reduction when compared to the others. This suggests that manure helps in the improvement of soil health.

Table 2. Mean, minimum, and maximum wheat grain yield values for manure, NPKL, and unfertilized (check) plots at Stillwater, OK. 1932-1967.

	1 YAA			2 YAA			3 YAA			4 YAA		
Treatment	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
						Mg ha^{-1}						
Manure	1.38	0.81	2.03	1.55	0.43	2.70	1.50	0.69	2.52	1.65	0.22	2.99
NPKL	1.77	1.03	2.27	1.57	0.57	2.59	1.48	0.73	2.56	1.77	0.44	2.96
Check	1.00	0.40	1.32	0.87	0.06	1.73	1.01	0.17	2.00	1.04	0.29	1.89

Table 3. Mean, minimum, and maximum wheat grain yield values for manure, NPKL, and unfertilized (check) plots at Stillwater, OK. 1968-2015.

	1 YAA			2 YAA			3 YAA			4 YAA		
Treatment	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max	Mean	Min	Max
							Mg ha^{-1}					
Manure	2.49 a	1.08	4.07	2.17 ab	0.17	3.45	2.09 ab	1.22	3.07	1.84 bc	0.20	3.31
NPKL	2.62 a	1.69	4.39	2.48 a	0.36	4.19	2.35 ab	1.63	2.90	2.21 a	0.46	4.10
Check	1.28 c	0.90	1.82	1.04 d	0.33	1.42	1.18 c	0.63	1.90	1.06 d	0.12	1.82

Relative Yield

It is defined as the ratio of the yields between two treatments. Crop yield is affected by number of environment factors, so to remove the environment factor relative yield is a good option to examine effect of manure on wheat grain yield. Looking at the yield ratios of the manure-applied plots versus the unfertilized control, the addition of manure at 134 and 269 kg N ha-1 enhanced wheat production by 44 to 142 percent and 77 to 100 percent, respectively (Table 4). In both periods, the relative yield of wheat was highest at two years after planting. The high relative yield in the second year following treatment may be related to the rate and dynamics of feedlot manure mineralization. It is possible that the first year following application saw an initial immobilization with slow net mineralization, followed by increased mineralization in the second year, resulting in maximum wheat yield, and then a steady drop in the third and fourth years. Yield ratio between the manure applied plots and the NPKL treatments were below one, regardless of the study period except at three YAA with manure applied at 134 kg N ha^{-1} (Table 4). A relative yield value less than one shows that the NPKL plots outperformed the manure plots. However, the values (0.80 to 0.99) found in both times were close to one, implying that manure applied plot yields were comparable to NPKL treatments.

Table 4. Relative yield of winter wheat applied with cattle feedlot manure at 134 and 269 kg ha^{-1} in relation to the unfertilized check and the NPKL applied treatment

Year after manure application	Unfertilized Check		NPKL Treatment	
	134 kg ha^{-1}	269 kg ha^{-1}	134 kg ha^{-1}	269 kg ha^{-1}
1	1.44	1.95	0.80	0.94
2	2.42	2.01	0.99	0.90
3	1.99	1.77	1.09	0.87
4	1.73	1.83	0.90	0.85

Total Nitrogen Contributed by Manure

The results showed that manure applied at 134 kg N ha^{-1} contributed roughly 77 kg ha^{-1} of N across the four-year cycle, equating to a nitrogen usage efficiency (NUE) of 64%. On a yearly basis, N contribution was 15.06, 26.19, 19.38, and 24.23 kg N ha^{-1} one, two, three, and four years after application, respectively. Manure applied at a rate of 269 kg N ha^{-1} contributed about 140 kg N ha^{-1}, or to 58 percent NUE. N contribution per year was 48.11, 44.74, 34.56, and 29.05 kg N ha^{-1} for one, two, three, and four YAA, respectively. According to Kansas State University (KSU), the current estimate for the first-year manure treatment is 25%, half (12%) the following year, and even less (approximately 6%) the third growing season. In Oklahoma, the estimated range of N availability in feedlot manure is 50-70 percent in the first year and 10-20 percent in the subsequent years (Zhang, 2017). However, according to the study's findings (269 kg N ha-1 rate), feedlot manure N availability is 18, 17, 13, and 11 percent for one, two, three, and four YAA (Table 5). Overall, the mineralization rate at one YAA was 25-30% for five of the twelve years, 20% or higher for six of the twelve years (50 percent of the observations), and 15% or higher for nine of the twelve years (75 percent of the observations). At two YAA, minimum mineralization was always less than 20%. Nitrogen availability of feedlot manure for the first year of application is essentially lower compared to the current estimates. In the second year, N availability was comparable to the estimates of Oklahoma and KSU. According to the results from this data Kansas State Nitrogen availability for the first two years of application is essentially lower compared to the current estimates. Knowledge of availability of nitrogen is important because it influences the timing of manure application. Furthermore, inaccurate prediction of N availability may lead to the excess or under application of required nutrients for optimum growth and yield. The data suggest that growers could make tri-annual applications of the 269 kg N ha^{-1} rate to stabilize yield in their system. Utilizing a tri-annual application will allow growers to maximize N mineralization as well as N from the inorganic form when producing winter wheat. Further analysis of nitrogen mineralization rates in beef feedlot manure should considered by Oklahoma State University moving forward.

Table 5. Nitrogen contribution and availability of applied cattle feedlot manure to wheat in a four-year cycle at 134 (1932-1967) and 269 kg N ha^{-1} (1968-2015).

Years after application	134 kg ha^{-1}		269 kg ha^{-1}	
	N contribution	N availability	N contribution	N availability
	kg ha-1	%	kg ha-1	%
1	15.06	11	48.11	18
2	27.19	20	44.74	17
3	19.38	14	34.56	13
4	24.23	18	29.05	11
Total	85.86		156.46	
NUE	64		58	

REFERENCES

Kansas State University. 2003. Estimating manure nutrient availability. Kansas State University Agricultural Experiment Station and Cooperative Extension Service. MF-2562. Manhattan KS

Tayebeh, A., A. Abass, and A.K. Seyed. 2010. Effect of organic and inorganic fertilizers on grain yield and protein banding pattern of wheat. Australian Journal of Crop Science 4:384-389.

Rosen, C. J. and P. M. Bierman. 2017. Commercial fruit and vegetable production: Using manure and compost as nutrient sources for fruit and vegetable crops. University of Minnesota Extension. Twin Cities, MN.

Zhang, H. 2017. Fertilizer nutrients in animal manure. Oklahoma Cooperative Extension Factsheet: F-2228. Oklahoma State University, Stillwater, OK. http://pods.dasnr.okstate.edu/docushare/dsweb/Get/Rendition-2759/unknown