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COMPOSTED MANURE AS AN ECONOMICAL SOURCE OF PHOSPHORUS FOR IRRIGATED CORN PRODUCTION IN THE TEXAS HIGH PLAINS

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Summary: 100% of the phosphorus requirement for a full-season corn hybrid (as determined by pre-plant soil testing) was applied to experimental plots in five different combinations of composted feedyard manure and liquid phosphate (10-34-0). The five treatments ranged from 0 to 100% of the P requirement supplied by compost, with the balance supplied by 10-34-0 to bring each treatment to the same nominal level of applied P. Each treatment was replicated five times. Small yield differences were seen in treatment-by-treatment comparisons, but there was no discernable trend in yield as a function of compost application rate, indica-ting that composted feedyard manure may be a reasonable substitute for liquid phosphate if properly analyzed and applied. The economics of composted manure at 2 tons/acre are comparable to those of liquid P at 65 lbs/ac (expressed as P_2O_5). Evidence of water-limiting conditions during the growing season indicates that conclusions reached from the statistical analysis of yield data from this study need to be verified at multiple locations with more replications per treatment. We have begun a second-year study for 1998 in which we have arranged to use a precision topdresser for the compost application; a new electronic weigh wagon for yield determination; and differential GPS with a yield-mapping combine for precision harvesting. We have also increased the number of replications from six to eight. Current drought conditions in the southern High Plains threaten reduced yields for 1998.

Keywords: Manure, compost, feedyard, phosphorus, corn, land application

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Introduction

The accumulation of feed-borne nutrients is characteristic of areas densely populated with confined animal feeding operations (CAFOs), and the Texas High Plains is no exception. Fully 25% of the fed cattle in the United States is produced within a 120-mile radius of Amarillo, with an annual slaughter of more than 6 million head (SPS, 1997). Assuming an average liveweight of 800 lbs. while in confinement, dry manure production from cattle feedyards in the Panhandle region is approximately 3.1 million tons (wet basis) per year, and that manure contains approximately 33,300 tons per year of elemental phosphorus (ASAE, 1997). The benefits of land-applying that manure on cropland are widely accepted, but the market value of manure and manure products does not justify transporting it over large distances due to:

(1) the relatively lower cost of synthetic, inorganic fertilizers,

(2) the uncertainty with respect to manure's actual agronomic value, and

(3) poor perceptions resulting from farmers' negative experiences with manure.

Nutrient-laden manure, therefore, tends to concentrate in areas of high CAFO density, increasing environmental stress on surface and ground water resources. The problem is even more pronounced where manure quality is low relative to the requirements of the end user, the farmer.

Because hauling contractors set their prices based only on weight and mileage, *not quality*, hauling costs often limit the wide distribution of feedyard manure. Increasing the quality of manure and manure products increases the so-called "break-even" distance by increasing farmer demand for those products.

Among the available strategies to relieve environmental stresses resulting from localized manure accumulation, the strategy with the best prospects for both short- and long-term success is the systematic addition of economic value to feed-yard manure. Thermophilic composting, the controlled, aerobic digestion of organic material (Epstein, 1997), is a viable method for adding economic value to manure as a fertilizer and as a soil amendment. Table 1 shows why, relating its value to the degree to which its characteristics are desirable to the end user.

The authors and the Texas Agricultural Experiment Station (TAES) wish to recognize the Texas Corn Producers Board for its financial commitment to the research; Mr. Dee Vaughn for his willingness to set aside land for the project; and Mr. Lee Gibson for providing the compost and land-application services.

TABLE 1. CHARACTERISTICS OF MANURE AND COMPOST WHICH ARE OF GREATEST IMPORTANCE TO THE FARMER AS AN END-USER.

Manure Characteristic	Desirable State	Fresh or Stockpiled Manure	Composted Manure	Comments
Water content	low	25-85%	15-25%	Heat generated in composting accelerates evaporation, reducing hauling costs per unit nutrient content
Ash content	low	variable	depends	Ash content in compost is directly related to ash content of manure feedstock
Nutrient content	high	moderate when fresh	lower than fresh manure	Highly variable, but averages 1-2% N (dry-weight basis) and 1-1.6% P_2O_5 in fresh manure; composting drives off N
$N:P_2O_5$ ratio	matched to crop needs	about 1.25	typically 1.0 or less	Ratio needed by grain crops can be 3.0 or higher. Composting drives off gaseous N but retains most of the P_2O_5
C:N ratio	~15	15-20	15-40	Products with a high C:N ratio compete with crops for nitrogen, reducing yields and/or crop quality
Weed seeds	low	variable	may be reduced	Extended thermophilic composting reduces viability of weed seeds deposited by wind on feedyard surface or in manure stockpiles (Pace, 1994)
Odor	low and inoffensive	sharp and ammonia-like	musty	Odors generally associated with compounds produced in the absence of oxygen. Composting, an aerobic process, produces less offensive odors
Pathogens	low	variable	may be reduced	Extended thermophilic composting can cause protein breakdown and subsequent microbe death; some microbes resistant to thermal destruction
Texture	friable	chunky	friable	Compost is much more easily and evenly spread than stockpiled manure

Justification

In a recent survey of dairy operators (Rynk, 1994) who began composting manure for use on their pastures and cropland, 51 of 98 respondents indicated that the decisive factors in their decision to use compost in their manure-management regime were:

(1) its overall quality for land application, and

(2) the relative ease with which it can be land-applied uniformly.

Although the fertilizer equivalence of compost is implicit in the concept of “overall quality,” the situation with these dairy operators was confounded by the facts that they were using the composted manure on their own cropland and that they knew the details of its production. The sale of compost to an unaffiliated farmer requires a greater degree of certainty as to its agronomic value. In other words, the compost’s fertilizer equivalence must be known in order to take advantage of the marketing opportunity presented by a drier, more uniform product.

Objective

The primary objective of this research was to develop and evaluate a scientific method for determining the phosphorus equivalence of composted feedyard manure for sprinkler-irrigated corn, with particular emphasis on its use as a phosphorus (P_2O_5) source.

Methods

This project was conducted on a private farm, one mile north of the North Plains Research Foundation at Etter, TX. The plots were located in the southwest quadrant of a sprinkler-irrigated field planted to corn for the 1997 summer season. The field was farmed in a circle.

The first-year experiment consisted of replicated (6x) yield comparisons among five fertilizer treatments. Thirty plots, each 12 rows (30 ft) wide x 400 ft long, were laid out within a full-season corn field under the 16th and 17th spans of a half-mile center-pivot. Experimental design was a randomized complete block (RCB). Composite soil samples (0-6” depth) were taken from within each of the plots and analyzed at the TAEX Soil, Water and Forage Testing Laboratory at College Station. 1X rates of N and P for 220-bushel corn were established based on laboratory recommendations. Composted feedyard manure produced in the local area was analyzed for total N and P. First-year availabilities of N and P in compost were arbitrarily set at 47% for this pilot study. The randomized plot layout is shown in Figure 1.

Each fertilizer treatment consisted of a combination of composted manure and commercial inorganic fertilizer (10-34-0) to meet 100% of the 1X rate of P for 220-bushel corn. Designating that rate as 1XP, the five phosphorus treatments were:

P1 = 100% of 1XP as composted manure
P2 = 75% of 1XP as composted manure; 25% of 1XP as liquid superphosphate
P3 = 50% of 1XP as composted manure; 50% of 1XP as liquid superphosphate
P4 = 25% of 1XP as composted manure; 75% of 1XP as liquid superphosphate
P5 = 100% of 1XP as liquid superphosphate

Target rates for compost application for the five treatments were 2.0, 1.5, 1.0, 0.5 and 0.0 tons/ac. Laboratory analysis data for the composted manure are shown in Table 2.

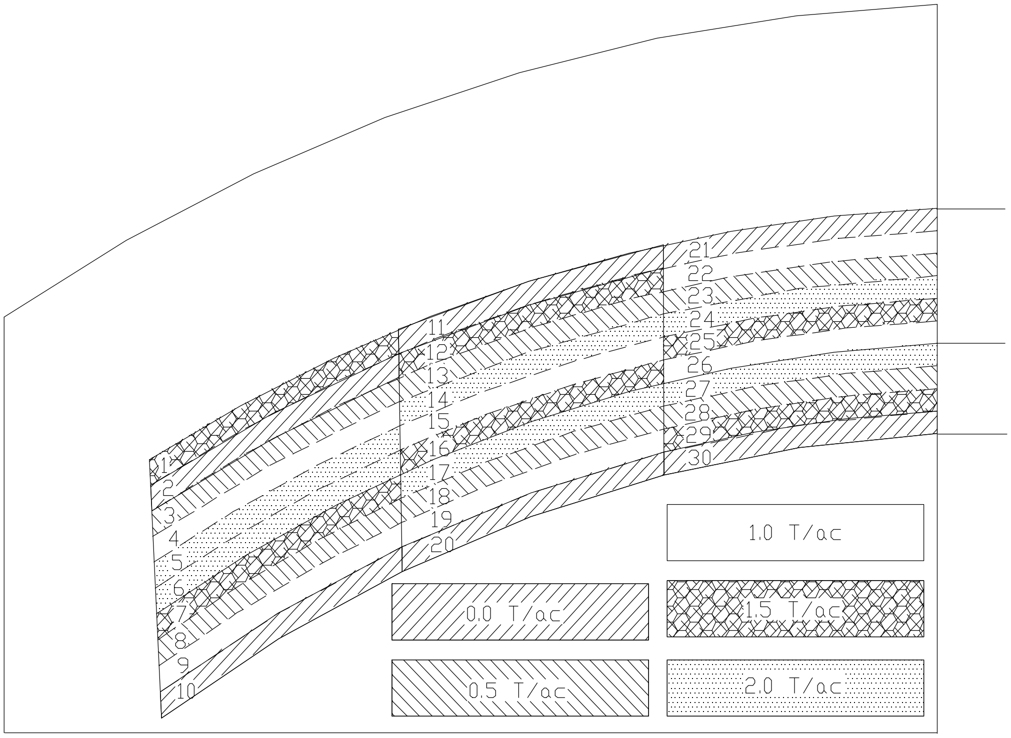

Figure 1. Plot layout and compost application rate.

Recognizing that both composted manure and liquid superphosphate contain N as well as P but in different ratios and availabilities, rates of fertilizer N were equalized for all five treatments based on the N analysis of the liquid superphosphate and composted manure (again, subject to a 47% estimated availability). Supplemental N was applied as liquid 28-0-0 to meet the recommended 1X rate of N for all five treatments. Target applications of each fertilizer source are summarized in Table 3.

TABLE 2. LABORATORY ANALYSIS OF COMPOSTED MANURE.

Sample #	Moisture % wb	Ash % db	Dry Matter % wb	N % db	P % db	K % db	Ca % db	Mg % db	Na ppm	Zn ppm	Fe ppm	Cu ppm	Mn ppm	Organic Matter % db
1	23.68	78.27	76.32	0.93	0.47	1.01	2.75	0.40	1005	163	5270	23	259	3.52
2	20.66	81.83	79.34	0.80	0.40	1.00	1.76	0.34	881	140	5848	20	250	3.52
3	20.68	81.17	79.32	0.85	0.37	0.88	1.42	0.32	767	179	3401	21	244	3.52
Mean	21.67	80.42	78.33	0.86	0.41	0.96	1.98	0.35	884.3	160.7	4839.7	21.3	251.0	3.52

TABLE 3. TARGET APPLICATION RATES OF COMPOSTED MANURE AND LIQUID INORGANIC FERTILIZERS.

Treatment #	%P2O5 as Compost	N Required lb/ac	P2O5 Required lb/ac	Compost T/ac	10-34-0 gal/ac	N supplied (Compost + 10-34-0) lb/ac	N needed (28-0-0) lb/ac	N needed (28-0-0) gal/ac
1	0	200	65.2	0.0	16.8	19.2	180.8	17.0
2	25	200	65.2	0.5	12.6	23.4	176.6	16.6
3	50	200	65.2	1.0	8.4	27.6	172.4	16.2
4	75	200	65.2	1.5	4.2	31.8	168.2	15.8
5	100	200	65.2	2.0	0.0	36.0	164.0	15.4

Compost Analysis		
N	P2O5	
45.2	69.7	total lb/T
0.4	0.47	Availability

Total Fertilizer Needs	
Compost	8.3 tons
10-34-0	69.4 gal
28-0-0	134 gal

Compost was applied pre-plant in increments of 0.5 tons/ac on March 17, 1997. All plots were subsequently disked to 4” to incorporate the compost. Supplemental liquid fertilizers were applied through a wheat drill on March 21-22, 1997. Injectors were calibrated each morning and for each fertilizer compound. All plots were then planted, tilled, chemigated and irrigated by the cooperator throughout the growing season according to his normal practices.

Grain harvest was conducted September 26-27, 1997. Each plot was harvested in two passes (east and west sides of each plot) using a six-row combine. Yield weights were measured for each pass. Plot totals were computed as the sum of the yield weights for each pass. Samples of corn from each half-plot were analyzed for moisture content. Harvested yield weights were corrected to 15.5% moisture and converted to standard bu/ac based on a bulk density of 56 lb/bu. Yields were also corrected for missing rows (based on combine-operator notes) and irregular plot geometry (determined by visual inspection during harvest by the Principal Investigators; see Figure 1).

Research Hypotheses

The apparent phosphorus equivalence of composted manure was assessed using (a) statistical separation of means across treatments and (b) linear regression of plot yields vs. compost application rate. The research hypothesis was twofold:

H_{O1}: Average total (east + west) standard grain yields were not significantly different across all possible pairs of fertility treatments.

H_{O2}: The slope of the linear regression model relating total standard yield to compost application rate is not significantly different from zero (i.e., there is no significant linear trend relating standard yield to compost application rate).

Results and Discussion

Standard yields from each plot are shown in Table 4. Data were analyzed using standard techniques for separation of means and linear regression (PC-SAS, Version 6.12 for Windows). Fisher's LSD test was applied separately to the total plot yield data and the individual data from the east and west combine passes on each plot. The results of the separations of means for the east, west and combined data sets are shown in Figure 2. Average standard yield for all thirty plots was 183.3 bu/ac.

Based on the reduced yields and on subsequent conversations with the cooperator, we surmised that there may have been significant yield differences between plots under span 16 and plots under span 17 of the center pivot due to nozzling and pump-capacity limitations. Yield data were combined across treatments and then blocked by span, and the block means were separated using Fisher's LSD test. Yield differences between spans were not significant at $\alpha=0.05$ for all three data sets (east, west, total). Yield differences between spans were significant at $\alpha=0.05$ for only the east and total data sets. Means and levels of significance are shown in Figure 3.

Pre-plant soil-analysis data (NPK) were then blocked by span, and the means were separated as usual. No significant differences were apparent between spans in the P and K analyses; differences in residual soil N (0-6") between spans were significant at $\alpha=0.01$. (These results are shown in Table 5.) However, the differences in residual soil N were of the order of 4 ppm elemental N, which is approximately equivalent to 8.7 lbs/ac N, or 4% of the N applied as inorganic fertilizer and compost. We conclude that differences in residual soil fertility (N only) did not contribute significantly to the yield differences between spans. (Significant differences in residual soil potassium were also discounted because of the high levels of soil K and the resulting laboratory interpretation that K was not expected to be yield-limiting. That interpretation is typical for a Sherm silty clay loam soil.)

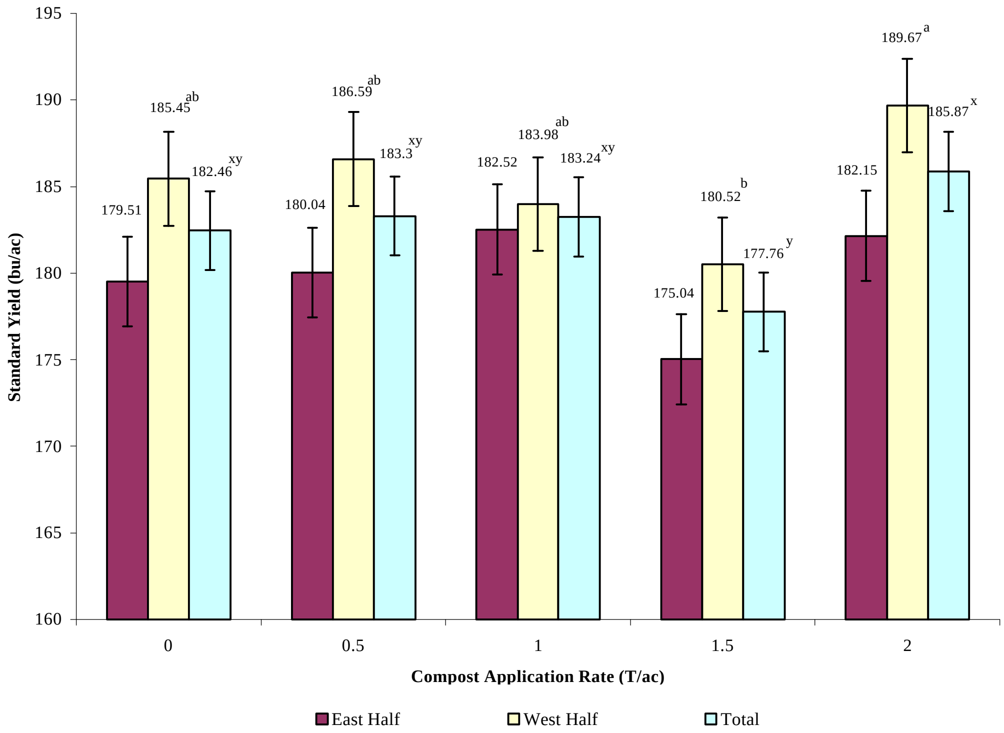

Figure 2. Mean standardized yields for the five phosphorus treatments.

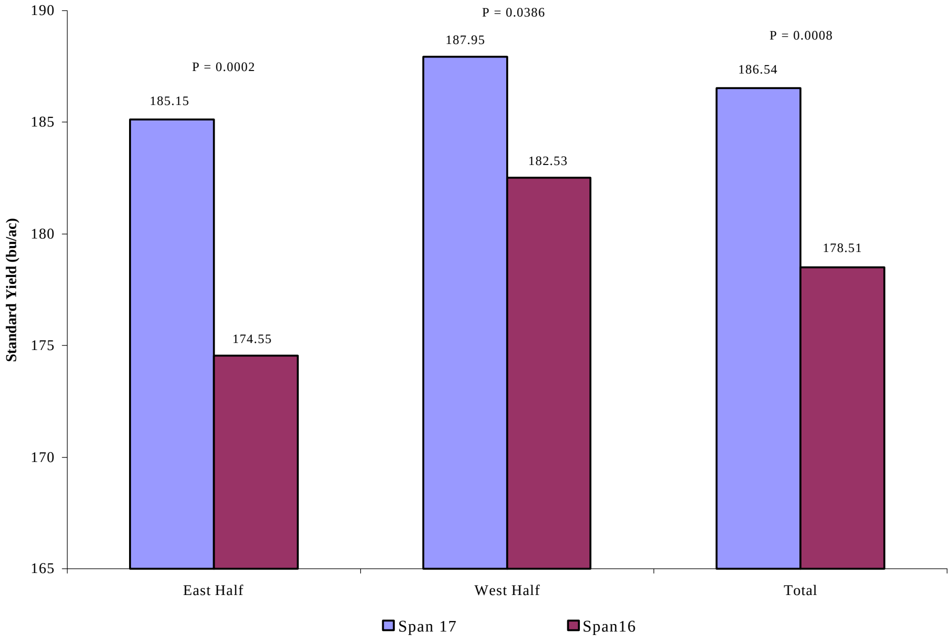

Figure 3. Yield comparisons between spans of the center pivot.

TABLE 4. HARVEST WEIGHTS, CORRECTED TO 15.5% MOISTURE, BASED ON 56 LB/BU BULK DENSITY.

	Harvest Weight (lbs)		Moisture	Corrected Harvest Weight (lbs)			Plot Area	Std. Yield @ 15.5%
Plot #	East Half	West Half	(%wb)	East Half	West Half	Plot Total	(ft2)	(bu/ac)
21	1435	1500	17.2	1406.1	1469.8	2876.0	11901.2	188
11	1445	1490	16.8	1422.8	1467.1	2889.8	11916.2	189
01	1335	1300	17.2	1308.1	1273.8	2582.0	11826.2	170
22	1515	1455	17.2	1484.5	1425.7	2910.2	11887.5	190
12	1515	1475	17	1488.1	1448.8	2936.9	11915	192
02	1360	1375	16.8	1339.1	1353.8	2692.9	11915	176
23	1495	1495	17.6	1457.8	1457.8	2915.7	11838.8	192
13	1450	1455	17.1	1422.5	1427.4	2850.0	11888.8	186
03	1410	1480	16.6	1391.6	1460.7	2852.4	11751.3	189
24	1490	1450	17.1	1461.8	1422.5	2884.3	11887.6	189
14	1470	1455	17.2	1440.4	1425.7	2866.2	11850.1	188
04	1520	1450	17.4	1485.8	1417.4	2903.2	11685.7	193
25	1440	1470	16.6	1421.3	1450.9	2872.1	11836.3	189
15	1420	1420	16.9	1396.5	1396.5	2792.9	11873.8	183
05	1480	1510	17	1453.7	1483.2	2936.9	11798.8	194
26	1425	1470	16.9	1401.4	1445.6	2847.0	11772.4	188
16	1305	1400	16.7	1286.5	1380.1	2666.6	11872.4	175
06	1420	1405	17	1394.8	1380.1	2774.9	11512.2	187
27	1335	1490	16.4	1320.8	1474.1	2794.9	11808.6	184
17	1355	1445	16.3	1342.2	1431.3	2773.5	11908.6	181
07	1355	1365	16.2	1343.8	1353.7	2697.5	11908.6	176
28	1345	1420	16.2	1333.9	1408.2	2742.1	11869.7	180
18	1310	1365	16.5	1294.5	1348.8	2643.3	11892.2	173
08	1310	1330	16.7	1291.4	1311.1	2602.5	11224.3	180
29	1285	1370	15.8	1280.4	1365.1	2645.6	11868.2	173
19	1310	1310	15.8	1305.3	1305.3	2610.7	11768.2	173
09	1225	1220	15.9	1219.2	1214.2	2433.4	10509.2	180
30	1315	1335	14.8	1325.9	1346.1	2672.0	11716.7	177
20	1350	1340	15.4	1351.6	1341.6	2693.2	11704.2	179
10	1265	1280	15.4	1266.5	1281.5	2548.0	10657.8	186
							Mean	183.3

A possible explanation for both (a) the unexpectedly low yields and (b) the yield differences between spans is that the area of the field in which the plots were placed was water-stressed for at least a portion of the growing season because of improper nozzle selection. Following the end of the harvest season, the cooperating farmer revealed that he had obtained low yields under the outer spans throughout the field. Because the plots were located on the topographically higher end of the field, poor sprinkler performance, underpressurization and even performance differences among nozzle sizes may all have been exacerbated. Post-harvest inspection of the nozzle packages for spans 16 and 17 has been conducted, but no analysis has been done to permit an assessment of the basis for yield and fertility differences between spans 16 and 17.

TABLE 5. SEPARATION OF MEANS FOR RESIDUAL (PRE-PLANT) SOIL FERTILITY, BLOCKED BY CENTER-PIVOT SPAN.

	Span			
Item	17	16	SE	P - value
N, ppm (0-3 in)	16.84	12.40	1.05	0.0033
N, ppm (3-6 in)	12.55	9.84	1.10	0.0701
N, ppm (0-6 in)	14.70	11.12	0.92	0.0062
P, ppm (0-3 in)	28.49	29.01	2.48	0.8723
P, ppm (3-6 in)	17.71	16.10	2.08	0.5538
P, ppm (0-6 in)	23.10	22.55	1.70	0.8061
K, ppm (0-3 in)	867.98	817.28	20.40	0.0677
K, ppm (3-6 in)	644.48	623.69	18.47	0.3946
K, ppm (0-6 in)	756.23	720.49	11.53	0.0252

Span 17 = plots 1-6, 11-16, 21-26.
Span 16 = plots 7-10, 17-20, 27-30

We conclude that although some significant differences existed between treatments, there was no statististically-significant trend relating yield to the percentage of supplemental phosphorus supplied as compost. We suspect that the harvest data have been confounded in part by the water-limited conditions.

Status of the Second-Season (1998) Study

For the 1998 season, we modified the 1997 protocol to increase the statistical power of the experimental design and to remove unforeseen sources of variability, error and yield limitations. We increased the number of replications from 6 to 8; replaced the wind-susceptible manure spreader with a low-altitude, precision topdresser (see Figure 4); changed the plot geometry to accommodate circular farming practices more conveniently; and blocked the experimental plots according to equivalent nozzle diameters. Soil-test recommendations were 240-95-0 (N-P_2O_5-K_2O), and application rates of compost and liquid inorganic fertilizer were determined in the same way as the 1997 study. Because of wet soil conditions from an excessively wet spring, liquid fertilizers were applied with a spray rig drawn by two tractors (see Figure 5). The spray rig was driven by the PTO of the rear tractor, whose only function was to maintain constant pressure and PTO speed on the delivery pump. The front tractor was used to pull the rear tractor and spray rig with a chain, and varying application rates were achieved by varying the ground speed of the front tractor.

In addition to the slight changes in experimental design, plot layout and land application equipment, we also obtained a new electronic weigh wagon to increase the accuracy of the yield measurements. We will also use a differential GPS system and yield-mapping combine to improve the geographical accuracy of the plot harvest.

Figure 4. Precision topdresser (typically used for golf courses and other urban turf). Left: the topdresser was calibrated upon delivery. Right: the topdresser in action during the April 1998 planting season.

Figure 5. Two perspectives on the tandem-tractor arrangement used to ensure precise application of liquid inorganic fertilizers through a spray rig. The rear tractor maintained pump pressure and PTO speed; the front tractor was responsible for maintaining the proper ground speeds for different application rates.

Acknowledgements

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