

Phosphorus Removal by Different Wheat-Stocker Cattle Production Systems

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Story in Brief

Grazing studies were conducted at two locations to measure phosphorus accretion in growing cattle grazing wheat pasture and total phosphorus removal in biomass from five winter wheat production systems. The production systems were 1) fall/winter grazing by growing beef cattle followed by grazeout, 2) fall/winter grazing followed by hay harvest, 3) fall/winter grazing followed by grain harvest, 4) no grazing followed by hay harvest, and 5) no grazing followed by grain harvest. Phosphorus accretion (g/kg) of carcass, empty body, and live weight gain of cattle was 7.5, 6.4, and 7.1, respectively. Removal of phosphorus from cattle-wheat production system is a function of concentration of P biomass and total biomass removed. Production systems that removed wheat biomass as hay resulted in the greatest removal of phosphorus. The least amount of phosphorus was removed in the grazing only system where biomass was only removed as cattle weight gain. There was no significant difference in the levels of soil test phosphorus during the duration of this experiment. This is consistent with previous information where as much as 20 lb of P_2O_5 must be removed to lower the soil test P level by one unit. In systems where manure is repeatedly applied to the same fields, soil phosphorus levels will increase when phosphorus application exceeds phosphorus removal. Cattle-wheat systems that incorporate biomass removal as hay will result in the slowest rate of increase in soil phosphorus.

Key Words: Wheat Production Systems, Phosphorus Removal, Soil Phosphorus

Introduction

Land applications of manures and effluent from cattle feedyards have caused concern for surface water contamination in recent years (U.S. Environmental Protection Agency, 1996). Repeated application on the same land area has increased levels of soil phosphorus (P) in such a manner that states are now adopting livestock waste management recommendations that evaluate agronomic and environmental benefits (McFarland and Hauck, 1995; Natural Resource Conservation Service, 1995; Sharpley and Sisak, 1996). These regulations could limit P application in a sensitive watershed to the amount of P removed from the site during a growing season. To determine best management practices for a given site, it will be necessary to quantify P removed in the biomass. For sites with limited land resources for effluent application, it will be critical to determine the biomass P removal for a proper nutrient management plan. In a winter wheat-stocker operation, there are several forms of biomass in which P can be removed. These include cattle weight gain, forage as hay or silage, and grain. The objective of this

study was to measure phosphorus accretion in growing cattle grazing wheat pasture and total phosphorus removal in biomass from five cattle-winter wheat production systems.

Materials and Methods

Five (5) treatments (Table 1) were used to determine the amount of phosphorus removed by selected production systems for winter wheat in the southern Great Plains. These represent common production systems for wheat-stocker production where the GZ-GZ treatment represents wheat used for grazing during the entire growing season. The GZ-H and GZ-GN treatments represent dual-purpose use of wheat for cattle grazing followed by hay or grain harvest, respectively. The final two treatments represent single purpose use of wheat for hay or grain production.

Table 1. Treatment structure for biomass removal from winter wheat production in the southern Great Plains

| Treatment | Wheat Biomass Management | |
|-----------|--------------------------|--------|
| | Winter | Spring |
| GZ-GZ | Graze | Graze |
| GZ-H | Graze | Hay |
| GZ-GN | Graze | Grain |
| N-H | None | Hay |
| N-GN | None | Grain |

These production systems were established in fields used for wheat grazing. Within these fields the N-H and N-GN treatments were established by constructing exclosures from wire panels (16 ft x 16 ft) in grazed pastures to prevent livestock from foraging inside the exclosures (Fig. 1). When cattle were removed during the late winter, exclosures were constructed to identify plots that were subsequently harvested for the GZ-H and GZ-GN treatments.

Four (4) replications of each treatment, within a completely random experimental design, were established at each of two locations (OSU Wheat Pasture Research Unit; Marshall, OK and Hartley Feeders; Hartley, TX) for the 2000-2001 growing season, and only at the Marshall location for the 2001-2002 growing season. The Hartley location utilized a modified grazeout period due to corn planting occurring in the spring of 2001; whereas, the Marshall location used a continuous wheat system throughout the grazing treatments. The modified grazeout period at Hartley utilized a small plot harvester to remove forage from the plot following cattle removal to allow for corn planting in early April, 2001. All other treatments remained the same at both locations. Wheat hay and grain samples were collected for both growing seasons at the Marshall location and for the 2000-2001 growing season at Hartley.

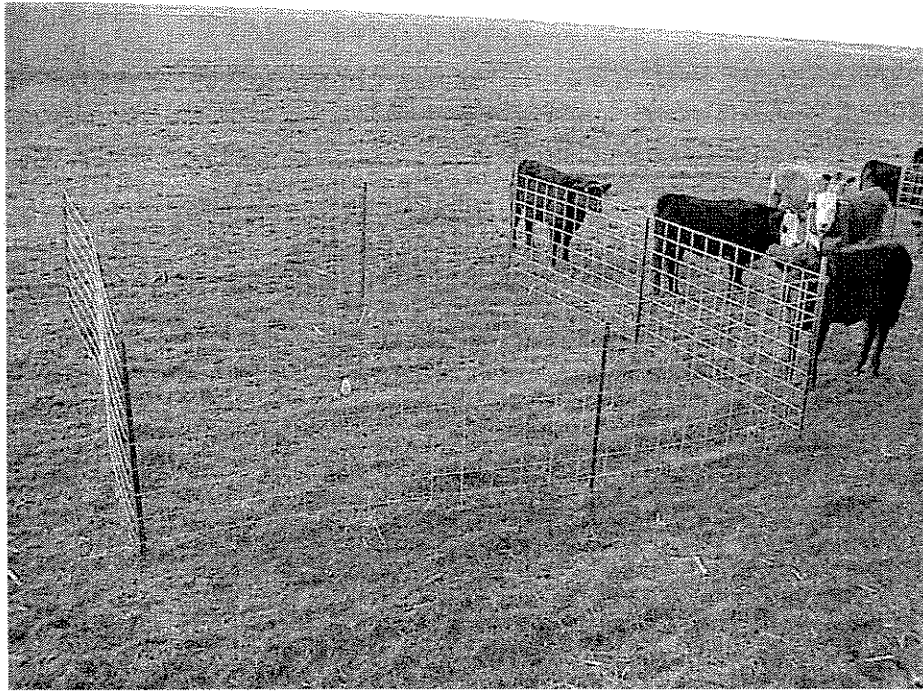


Figure 1. Enclosures in a wheat-stocker grazing system for the southern Great Plains at the Hartley, TX location during the 2000-2001 growing season.

Marshall (Year 1; 2000-2001). Three 24-acre and one 18-acre clean-tilled wheat pastures and 42 fall-weaned Santa Cruz steer calves from a single ranch were used. The steers were randomly allotted within weight groups to the four pastures on January 10, 2001 (mean initial weight of 560 lb) at a stocking rate of 0.465 steers/acre (2.15 acres/steer). The steers were not fed any mineral or any other type of supplement while grazing wheat pasture. Stocking rate during the grazeout period (March 21 to April 11, 21 days) was increased to 1.43 steers/acre by decreasing the area of each of the four pastures.

Marshall (Year 2, 2001-2002). Because of the very poor weather for production of wheat pasture in Year 1 at Marshall (see first part of “Results” section), this study was repeated, **at no cost to the Texas Cattle Feeders Association**, during the 2001/2002 wheat pasture year. The same four clean-tilled wheat pastures were used as in Year 1, and 52 fall-weaned Red Angus steer calves (mean initial weight of 500 lb) from Montana were placed on the pastures at a stocking rate of 0.58 steers/acre for the fall/winter grazing period of November 15 to March 13, 2002 (118 days). Because cattle were shipped at the end of the fall/winter grazing period, a grazeout period was not included.

Data Collection. Phosphorus removal from the sites was determined from the quantities of biomass (i.e., cattle, wheat hay, and grain) produced and the P concentration in each of the biomass products. Wheat hay and grain samples were collected at harvest, and cattle were weighed at the time of each management change.

Soil Sampling. Soil samples from 0-15 cm and 15-30 cm were taken prior to wheat planting at both locations to determine the level of P in the plot areas. Sampling sites

were clearly marked for future reference. Procedures for soil analysis consisted of 1) drying the soil at 100°C for 6 to 12 hours; 2) grinding the soil samples to pass through a 2-mm screen; 3) extracting the soil with Mehlich III extract (Mehlich, 1984) for soil testing of P level and other nutrients of interest (Fe, Zn, Cu, and K). The samples were used as a baseline for P uptake. Post-treatment samples were collected following the grazeout period at each site.

Crop Production. The seeding rate for the Hartley location was 90 lb/acre, while at Marshall it was 110 lb/acre with 50 lb/acre of 18-46-0 applied in the row at planting. Typical winter wheat crop production practices were utilized at both locations. These practices include fertilization based on yield goals, weed control, and insecticide applications.

Forage Sampling. Forages were harvested from the exclosures once in the spring by hand-clipping from a 0.203 m² area of the plot to determine biomass production following the restriction from grazing. Sub-samples from the plot were collected, dried for 48 hr at 60°C in a forced air oven, and were then ground to pass a 0.5-mm screen. The sub-samples were used to determine dry matter content and P concentration in the plant tissue. Phosphorus concentration and other nutrients of interest were determined following digestion of the plant tissue in HNO₃-H₂O₂. At the Hartley location forage quantity was decreased due to cattle collapsing the exclosure panels thus reducing biomass yields.

Grain Sampling. Grain was harvested from a 11.14 m² area within the exclosures with a Hege plot combine to determine grain production after grazing. Sub-samples were collected, dried for 48 hr at 60°C in a forced air oven then ground to pass a 0.5-mm screen. Grain sub-samples were analyzed for nutrient concentration in the same manner as forage samples.

Phosphorus Accretion (removal) by Growing Cattle. Six of the 42 Santa Cruz steers that grazed wheat pasture at Marshall were harvested during the 2000/2001 wheat pasture season to determine phosphorus accretion in stocker cattle grazing winter wheat pasture. Three steers were harvested at the Oklahoma Food and Agricultural Products Research and Technology Center (FAPC) on January 15, 2001 (i.e., initial harvest group) to determine initial phosphorus concentration in the whole body. Live weights of these steers were measured on January 10, when the steers were being withheld from feed and water. Steers that remained were introduced to pastures on January 10 until March 21, 2001 (winter grazing period, 70 d), and from March 21 to April 11 (grazeout period, 21 d). Three steers were harvested following completion of the grazeout period on April 16, to determine final phosphorus concentration in the whole body. Live weights of this group were measured on April 11 following an overnight shrink (approximately 16 hours) without feed or water.

Steers were harvested following normal operating procedures for FAPC. Once the steers were eviscerated, the visceral organs were removed, cleaned of their contents, and weighed individually. In addition to organs, head, hide, blood, mesenteric fat, and feet

and ears were weighed. These weights were combined to determine total offal weight for each steer.

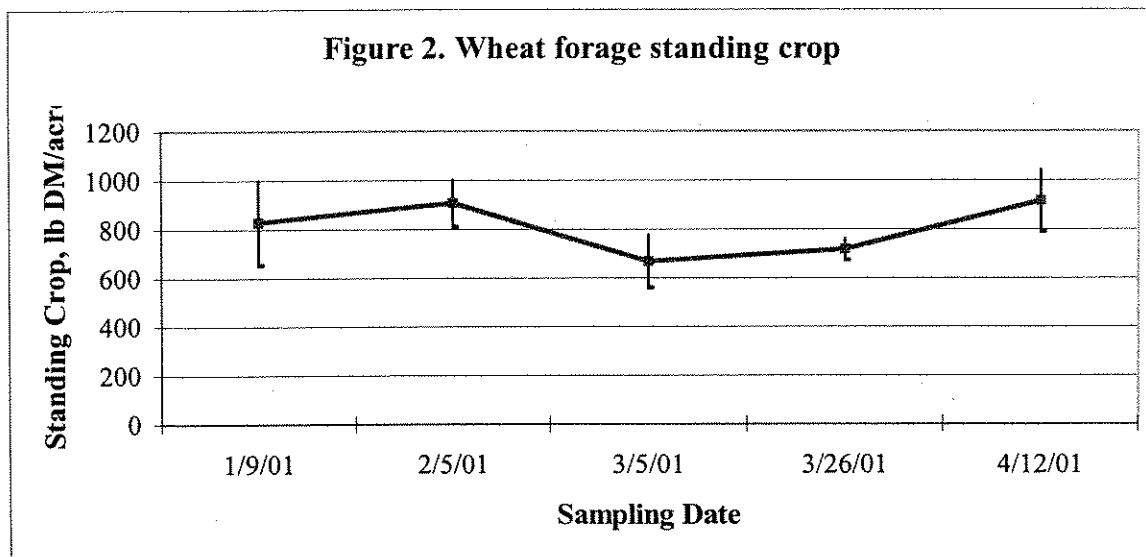
Offal was ground in a whole body grinder on the day of harvest. The right side of each carcass was ground in the same grinder following a 24-h chill. Triplicate samples, about 10 lb each, were collected from carcass and offal. Sub samples were collected to be lyophilized, and finely ground for subsequent laboratory analysis to determine nitrogen and phosphorus concentration. Samples were digested in 25% HCl, and analyzed spectrophotometrically to determine phosphorus concentration. Phosphorus concentration was then used to determine total phosphorus (g DM) in carcass and offal. Total phosphorus gain (g/kg) in carcass, empty body, and live weight was determined by linear regression as previously reported by Gibson et al. (2002). using simple linear regression analysis. These data were also used to calculate P removal in cattle weight gain at the Hartley location.

Statistical Analysis of Data. Data were analyzed by analysis of variance for a completely randomized design with four (4) replications per treatment. Mean separation was conducted using the least significant difference method for total P removal for each production system within location and year.

Results

Weather/Type of Wheat Pasture Year, and Weight Gain of Cattle.

Marshall, Year 1. The wheat pasture year of 2000/2001 was a very poor year for growth of cattle, and was characterized by a very dry late summer and early fall. From August through October a total of 4.83 inches of rainfall was received which compares to long-term precipitation data of 9.0 inches. However, for the period of August 1 to October 14 total rainfall was only 0.40 inches. Following wheat seedling emergence, record low temperatures in November and December resulted in very little growth of wheat. January and February remained consistently cold and wet. Therefore, the fall/winter grazing period was only 70 d (January 10 to March 21), and was followed by a short grazeout from March 21 to April 11 (21 d). Because of the weather and poor conditions for growth of wheat pasture, weight gain of steers was much less than usual. Wheat forage standing crop (Figure 2) was only 800 lb DM/acre at the start of grazing in January. We normally have standing crops of 1400 lb DM/acre at the start of grazing in late October or early November. Steers gained only 43 lb of live weight (0.62 lb/day) during the 70-day fall/winter grazing period. However, weight gains were excellent (3.16 lb/day or 66 lb/steer) during the short grazeout period.



Marshall, Year 2. With the exception of a severe ice storm on January 29 and 30, the 2001/2002 wheat pasture year was excellent for growth of cattle. The fall/winter grazing period was from November 15 to March 13, 2002 (118 days), and the steers gained 2.29 lb/day or 271 lb/steer. Because cattle were shipped at the end of the fall/winter grazing period, a grazeout period was not included.

Biomass Production. Cattle biomass removed from the continuous grazing treatment for 2000-2001 was 128 and 115 lb/acre at the Hartley and Marshall locations, respectively (Table 2). Wheat biomass from the Hartley location was greater than the Marshall location for hay and grain production. In addition biomass removal was greater for hay than grain at both sites for both years. At the Marshall location for 2001-2002 season, cattle biomass was 160 lb/acre and wheat biomass was greatest where hay was harvested.

Phosphorus Concentration. Phosphorus concentrations of wheat hay and grain were 1.7 and 2.7 mg/kg, respectively. These concentrations are consistent with other studies related to plant P uptake. Phosphorus accretion (removal) by steers grazing wheat pasture was 7.5, 6.4, and 7.1 grams per kilogram of carcass, empty body, and live weight gain, respectively, as previously reported by Gibson et al. (2002).

The concentration of P in plant biomass was similar for grain and hay at both locations, however P concentration in grain was greater than hay. At Marshall, P concentrations were similar for the hay for both years, however there was an 18% increase in grain P concentration for the 2002 harvest.

| Location | Treatment | Cattle Biomass Removal (lb/acre) | Cattle P Concentration (g/kg) | Wheat Biomass Removal (lb/acre) | Wheat P Concentration (g/kg) | Total Biomass P Removal (lb/acre) ^e |
|-----------|--------------------|----------------------------------|-------------------------------|---------------------------------|------------------------------|--|
| 2000-2001 | | | | | | |
| Hartley | GZ-GZ | 128 | 7.1 ^a | 0 | 0 | 0.9 c |
| Hartley | GZ-H | 128 | 7.1 | 11,113 | 1.5 ^b | 16.8 a |
| Hartley | GZ-GN | 128 | 7.1 | 4,485 | 2.7 ^c | 13.1 b |
| Hartley | N-H | 0 | 0 | 11,990 | 1.7 | 18.1 a |
| Hartley | N-GN | 0 | 0 | 6,354 | 2.6 | 14.5 ab |
| 2000-2001 | | | | | | |
| Marshall | GZ-GZ | 115 | 7.1 | 0 | 0 | 0.8 c |
| Marshall | GZ-H | 21 | 7.1 | 5,696 | 1.8 | 10.8 b |
| Marshall | GZ-GN | 21 | 7.1 | 3,383 | 2.7 | 10.2 b |
| Marshall | N-H | 0 | 0 | 9,196 | 1.7 | 16.2 a |
| Marshall | N-GN | 0 | 0 | 3,707 | 2.7 | 10.2 b |
| 2001-2002 | | | | | | |
| Marshall | GZ-GZ ^d | 160 | 7.1 | 0 | 0 | 1.13 c |
| Marshall | GZ-H | 160 | 7.1 | 2,465 | 1.9 | 5.92 ab |
| Marshall | GZ-GN | 160 | 7.1 | 964 | 3.1 | 4.11 b |
| Marshall | N-H | 0 | 0 | 4,069 | 1.7 | 6.92 a |
| Marshall | N-GN | 0 | 0 | 1,230 | 3.3 | 4.13 b |

^aThis represents the P concentration in g/kg of live weight gain for the cattle

^bThis represents the P concentration of the hay only

^cThis represents the P concentration of the grain only

^dFall/winter grazing only

^eTreatment means within the same site and year with common-letters are not significantly different ($P > 0.05$).

Phosphorus Removal. There was a significant difference in total phosphorus removal at the Hartley location with the greatest in the NG-H system (18 lb/acre) and least in the grazeout system (0.89 lb/acre). Total P removal is a function of total biomass and production and concentration of P in the biomass. Hay has a lower concentration of biomass P however a greater quantity of biomass can be removed from the site in this form than in grain or cattle. Similar results were observed at the Marshall location where N-H production offers the greatest potential to remove P from the production system. At the Marshall location, there was no difference regardless of year, for the grain production system and the GZ-H system. In both years these three systems removed the same quantity of biomass P. Again illustrating the relationship between biomass P concentration and biomass produced. Less grain biomass was removed but the P was more concentrated in the grain relative to the hay removed.

The quantity of P removed from the no graze-wheat hay system at Hartley would be equivalent to the amount applied from 2 tons of feedlot manure (assuming 21 lb P₂O₅ per ton) or approximately 1.75 acre-inch of lagoon effluent (assuming 1 lb P₂O₅/1000 gal). Many production systems apply more than 2 tons of manure or 2 acre-inch of effluent per year. Thus, soil build-up is an issue. At the measured levels of P removal, there will ultimately be a build-up of soil P where P additions are greater than P removal. If phosphorus applications continue at levels greater than plant removal, additional land will be required for manure application in systems where sensitive water bodies exist.

Soil Test Phosphorus (STP) Levels. Soil test P values did not change significantly during the 2000-2001 growing season at the Marshall site (Table 3). Net changes in soil test P values ranged from -3 to 38 for the graze/graze and no- graze/hay treatments. At the Hartley site, there were differences in between initial and final with the graze/grain and no graze/grain. These changes are more likely a result of sampling variability than the production systems.. Soil test P values will fluctuate with sampling time and these errors are within the sampling error. Removal of P in the biomass, in the form of forage, grain or cattle, will not necessarily be measurable in soil test values of the current growing season. As a general rule for Oklahoma conditions, approximately 15-20 lb of P₂O₅ must be added or removed from the soil for the soil test index to change one soil test unit. With this in mind, it would take several growing seasons of biomass removal to observe measurable changes in the soil test values at the biomass production levels experienced at this site. This is not inconsistent with the P removal data in figure 3 where the greatest amount of P removed in the biomass was with the hay production. If no additional phosphorus was added to the hay or grain systems the soil test P levels would decrease however, this could take many years to accomplish at soil test levels greater than 120 STP.

Table 3. Initial and final soil test P index for Hartley, TX and Marshall, OK locations for the 2000-2001 growing season

| | | Pre-experiment Soil Test Phosphorus | Post-experiment Soil Test Phosphorus | Net Change |
|--------------------|----------------|--|---|------------|
| Hartley 2000-2001 | Graze/graze | 201 | 154 | -47 ab |
| | Graze/hay | 274 | 229 | -45 ab |
| | Graze/grain | 227 | 266 | 40 a |
| | No-graze/hay | 265 | 244 | -20 ab |
| | No-graze/grain | 191 | 131 | -60 b |
| Marshall 2000-2001 | Graze/graze | 91 | 88 | -3 a |
| | Graze/hay | 90 | 109 | 19. a |
| | Graze/grain | 67 | 107 | 20 a |
| | No-graze/hay | 80 | 111 | 31 a |
| | No-graze/grain | 59 | 98 | 38 a |

Treatment means within the same site and year with common-letters are not significantly different ($P > 0.05$).

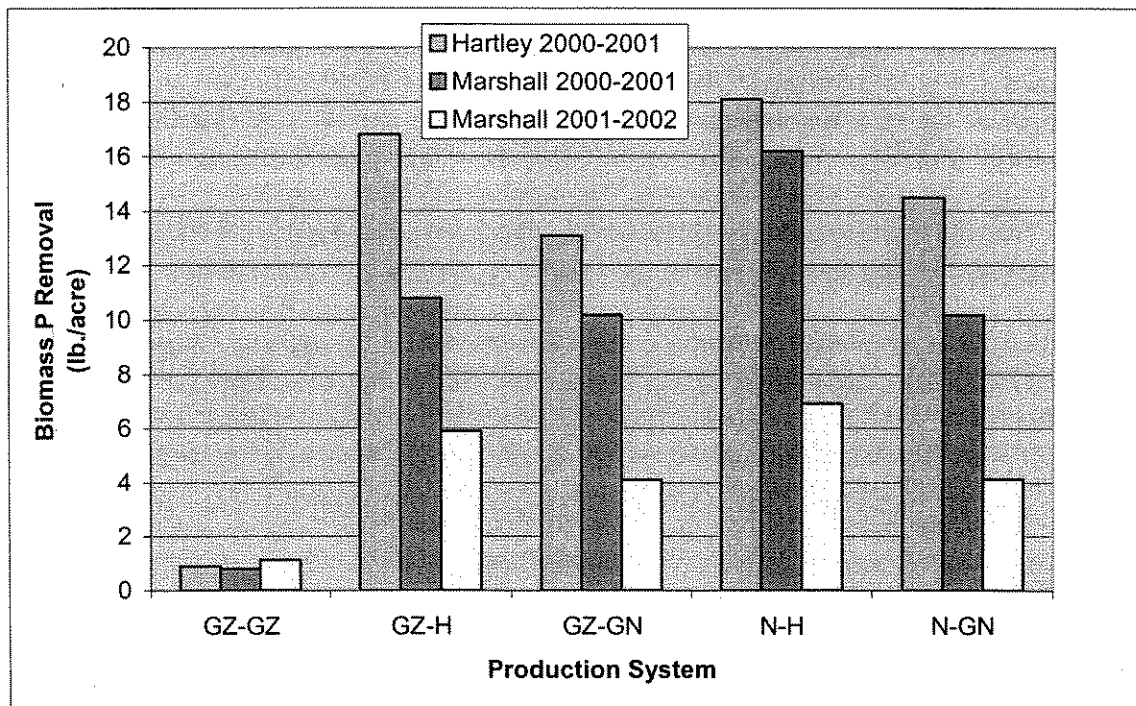


Figure 3. Steer and wheat biomass P removal from a wheat-stocker production systems at Hartley, TX and Marshall, OK from 2000-2002.

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