THE EFFECTS OF STEER MANURE LOADING RATE AND CROPPING PATTERN UPON SOIL FERTILITY STATUS

by

Scott Hathorn III

A Thesis Submitted to the Faculty of the

DEPARTMENT OF SOILS, WATER AND ENGINEERING

In Partial Fulfillment of the Requirements
For the Degree of

MASTER OF SCIENCE
WITH A MAJOR IN SOILS AND WATER SCIENCE

In the Graduate College

THE UNIVERSITY OF ARIZONA

1 9 7 8

STATEMENT BY AUTHOR

This thesis has been submitted in partial fulfillment of requirements for an advanced degree at The University of Arizona and is deposited in the University Library to be made available to borrowers under rules of the Library.

Brief quotations from this thesis are allowable without special permission, provided that accurate acknowledgment of source is made. Requests for permission for extended quotation from or reproduction of this manuscript in whole or in part may be granted by the head of the major department or the Dean of the Graduate College when in his judgment the proposed use of the material is in the interests of scholarship. In all other instances, however, permission must be obtained from the author.

SIGNED: Scott Hudson III

APPROVAL BY THESIS DIRECTOR

This thesis has been approved on the date shown below:

Maccare H. Fuller
W. H. FULLER
Professor of Soil Microbiology

May 3, 1978
Date

ACKNOWLEDGMENTS

The author wishes to acknowledge, at the outset of this manuscript, that he was not involved with the conception, initiation, implementation or management decisions of this experimental manuring project and was not associated with the project until the first sampling of the Sudangrass indicator crop. Although the previous cropping history and management practices are not absolutely essential to the soil fertility evaluation, the author believes that this information is pertinent for thoroughness and for practical, economical application of the soil fertility evaluation. In this light, the author wishes to acknowledge and thank all those that have been associated with this experimental manuring project since its conception.

The author wishes to thank the members of his graduate committee, Dr. Wallace H. Fuller, Dr. David M. Hendricks and Dr. Ian L. Pepper, for their ready and timely assistance, advice and constructive criticism in the preparation of this manuscript. In addition, the author wishes to thank Ted W. McCreary and Dr. Thomas C. Tucker for their contributions in the preparation and analysis of the Sudangrass plant samples. Finally, special heartfelt thanks are due Dr. Wallace H. Fuller, major professor, for his patience, frankness and personal interest and for the opportunities extended to the author.

TABLE OF CONTENTS

LIST OF ILLUSTRATIONS

LIST OF ILLUSTRATIONS--Continued

LIST OF TABLES

ABSTRACT

Soil fertility status was evaluated for six application rates of steer manure after two years of fallowing or double-cropping. The steer manure loading rates were 0, 44.8, 134.4, 178.2, 224.0 and 448.0 metric tons per hectare (dry weight). The fallowed section was uncultivated and unirrigated. The two year double-cropping system included four small-grain crops produced under standard, commercial-production practices used in the irrigated desert Southwest. One hundred pounds HN_4NO_3 was applied broadcast to all fallowed and cropped plots before seeding the Sudangrass indicator crop. The grass was sampled twice, just prior to booting. The soil fertility analysis utilized field-green and dry weight, plant nitrogen and phosphorus content and total nitrogen and phosphorus uptake plant parameters and two soil parameters, total organic carbon and CO_2-soluble phosphorus.

The soil fertility analysis revealed that any manure loading rate may pose a potential salinity hazard. Manure loading rates up to about 180 mt/ha appeared to increase soil fertility benefit or while manure loading rates of at least 180 mt/ha appeared to maintain soil fertility status near or above native fertility levels after two years of double-cropping. Two years of double-cropping reduced soil fertility status to levels less than those of the fallowed treatment for any given manure loading rate, with low soil nitrogen fertility status appearing to be the principle yield-limiting factor.

CHAPTER 1

INTRODUCTION

Rapid human and food animal population growth increases the demands upon a finite amount of space. One of the major problems associated with population growth is waste and manure production and accumulation. Livestock and poultry manure production and accumulation has reached magnitudes that require management and disposal solutions to minimize the environmental pollution potential. Loehr (1968) estimates American farms produce approximately two billion tons of manure annually. An estimate of the scope of the problem facing the Arizona beef-cattle industry is as much as ten million tons of steer manure produced per year. Similar estimates of manure production by livestock or poultry operations may utilize livestock census information from the U. S. Census Bureau in conjunction with per capita daily manure production data such as that in Table 1 (Taiganedes 1964).

Even though some manure is distributed over pasture and range naturally, the enormous bulk of manure has accumulated and stockpiled at the production site. Proximity of livestock and poultry industries to human populations, cultural practices and economic factors have resulted in the redistribution from small, low-density-population operations to large, high-density-population operations. Some consolidated beef-cattle feedlots have up to five hundred thousand (500,000) head capacities. Thus, manure production has not only increased but has also

Table 1. Some livestock and poultry manure production and analyses[1]

Animal	Pounds per Day	Analysis in Percent		
		Nitrogen (N)	Phosphate (P)	Potash (K)
Dairy Cows	70.0	5.6	0.44	4.2
Beef Cattle	64.0	3.7	0.48	2.5
Hogs	7.0	4.5	1.19	3.5
Hens (1000)	250.0	5.6	1.89	1.7

[1]Taiganedes 1964

been concentrated at fewer sites, accelerating accumulation rates. Rapid manure accumulation under similar feedlot conditions has accentuated the pollution potential.

Manure pollutants involve both chemical and biological components. The chemical component includes, in order of decreasing pollution potential, nitrogen and phosphorus containing compounds, salts, trace elements and heavy metals. The biological component includes organic substances, pathological agents, insects and vermin, weed seed and obnoxious odors. The amount of these constituents is dependent upon the animal ration, method of housing and method of collection (Fuller 1976).

The manner in which the manure is handled, stored and utilized affects the pollution hazard and impact upon the surrounding environment (McCalla et al. 1972). The erosional runoff problem associated with feedlots or other manure accumulating operations is a serious contributor to water pollution. During periods of heavy rainfall or rapid snow melt, manure-laden runoff water collects wherever surface water accumulates in natural drainage systems. The runoff problem is not strictly a humid climate phenomenon but may occur in arid climates as well.

When nitrogen and phosphorus become concentrated in standing or slow-moving surface waters, excessive growth of aquatic plants often results, which may clog waterways, limit the oxygen supply, restrict fish populations and generally upset the environmental balance. In extreme cases, high nitrogen concentrations may produce nitrate toxicities. Miner and Willrich (1970) studied oxygen-demanding organic matter decomposition. Organic matter from livestock wastes, another manure runoff pollutant of surface waters, is a suitable substrate for aerobic

bacteria. Once manure organic matter enters surface waters, bacteria utilize any available dissolved oxygen for decomposition. The decomposing organic matter not only depletes the aquatic habitat of oxygen but also contributes disagreeable color, taste and odor to public waters.

Even when precipitation is not heavy enough to cause runoff conditions, leaching of soluble manure pollutants, principally nitrate-nitrogen and salts, from accumulated stockpiles remains a serious consideration. Movement through soils by nitrate, sodium and potassium salts is a function of applied water, either rainfall or irrigation. Given sufficient drainage and time, these soluble ions move freely to the water table (Adriano, Pratt, and Bishop 1971). Gilham and Webber (1968) and Stewart et al. (1967) report similar findings and conclusions. While ground water pollution is primarily a nitrate contamination problem, salts are also contributors. In semi-humid and semi-arid regions where irrigated agriculture is practiced, ground water may be the major water source. Irrigation water quality is critical to favorable soil solution salt concentrations and distributions for soil structure maintenance (Cross, Mazurak, and Chesnin 1973) and successful plant germination and growth (Adriano et al. 1973).

Accumulation of feedlot manures and the subsequent pollution hazard created pose a serious management concern, particularly when livestock and poultry producers are held legally responsible. Feedlot waste management must deal with the economics of manure utilization or disposal. The value per unit weight of manure is relatively low for any utilization option. Because manure is bulky and often high in moisture, transportation costs increase rapidly with distance. More

often than not, the transportation costs exceed manure utilization or recycling value (Stubblefield and Smith 1964). Economics essentially limits manure utilization or disposal to the immediate vicinity of the production site.

Manure may be recycled at the production site as bedding or litter or processed and recycled through animal ration to recover nutritive food energy (Animal Science Research Division 1971). However, manure from pathogenically infected animals may contain pathogens and direct refeeding of these manures may expose recipient animals to disease. Another alternative may be utilization as an energy source by burning or methane generation (Dale 1971). Although economic and technological aspects presently limit use of manure as an energy source, manuring may be more attractive in the future.

Manure utilization as a soil conditioner and fertilizer, when spread and incorporated into the soil, is probably the most versatile solution. Manuring not only builds soil organic matter and tilth but also furnishes all inorganic nutrients essential for plant growth (Peterson, McCalla, and Smith 1971). However, manures are not usually completely balanced plant nutrient sources but may require supplemental nutrient additions or may supply certain nutrients in toxic levels (Meek et al. 1974).

Because manures are variable, physical and chemical properties should be known before application to agricultural lands for most effective management. Feedlot manure is usually collected with a blade or scoop loader. If collected from concrete floors, manure may be relatively free of dilutents. However, when collected from natural

floors, as much as 50% of the material collected may be underlying bedding, litter, soil, sand and gravel. Manures reflect these dilutents in particle size distribution, moisture content and density characteristics.

Manure chemical composition varies not only with the type of livestock or poultry operation (Table 1) but also from feedlot to feedlot for a given type of operation within a specified climatic region. Comparison of manure chemical constituents (Tables 2, 3, 4, and 6, see p. 15) from four desert Southwest beef cattle feedlots is evidence of this variability.

Wherever dry-land or irrigated agriculture is practiced, soil salt balances are critical for soil structure maintenance and plant growth. Steer manures of the desert Southwest tend to be high in soluble salts, ranging from 5.30 to 12.10%. The total salt content may vary with the quantity of urine incorporated into the manure. Potassium may dominate and exceed sodium in the soluble salt fraction, particularly in manure from unpaved, out-of-doors feedlots where collection may incorporate underlying materials. Elimination of "free-choice" salt (NaCl) feeding may reduce manure sodium content (Meek et al. 1975).

Nitrogen and phosphorus in manures are of fertilizer value, as these primary nutrients are required in relatively large amounts by plants. Total nitrogen and total phosphorus values reported in Tables 2, 3, 4 and 6 (p. 15) range from 1.625 to 2.390% and 0.27 to 1.30%, respectively. Meek et al. (1975) state that total feedlot manure nitrogen content varies with animal diet management and that approximately 82-90% of that nitrogen may exist as organic forms. Microbiological degradation gradually mineralizes organic nitrogen to

Table 2. Some chemical characteristics of feedlot steer manure from Tucson, Arizona in 1975 (oven-dry)[1]

Constituent	%
Organic carbon	25.00
Ash	37.00
Soluble ions	12.10
Na	1.26
K	1.50
Ca	1.72
Mg	0.56
Total N	2.39
Total P	0.80
Trace elements	
Fe	0.5660
Mn	0.0159
Zn	0.0067
Cu	0.0032
Pb	0.0015
Co	0.0008
Cr	0.0070
Ni	0.0042

[1] Amoozegar-Fard, Fuller, and Warrick 1975

Table 3. Some chemical characteristics of feedlot steer manure from Phoenix, Arizona in 1964 (oven-dry)[1]

Constituent	%
Ash	20.00
Soluble ions	6.10
Na	0.50
K	1.93
Ca	0.12
Mg	0.08
Total N	1.77
Total P	1.30

[1]Stubblefield and Smith 1964

Table 4. Some chemical characteristics of feedlot steer manure from Brawley, California in 1972 (oven-dry)[1]

Constituent	%
Organic carbon	63.70
Soluble ions	10.00
Na	2.84
K	1.12
Ca	2.80
Mg	1.53
Total N	1.98
Total P	0.27
Trace elements	
Fe	0.4800
Mn	0.0153
Zn	0.0099
Cn	0.0030
B	0.0137
Li	0.0009

[1]Meek et al. 1974

leachable, plant-available forms. Biological reactions do not influence phosphorus or other mineral constituent losses appreciably. Precipitation reactions tend to keep phosphorus in decomposing manures or within the soil volume of incorporation.

Manure trace element content may be small but not insignificant. Although manure may supply many micronutrients at beneficial levels, manure may supply lithium or boron at toxic levels for certain sensitive plants.

Proper management is essential for manure application to soils under crop production. Salinity hazard due to the addition of high amounts of sodium and potassium in manure is always present and particularly acute in semi-arid and arid climates. Ammonia toxicity to plant life is another problem (Murphy et al. 1972), as are lithium and boron toxicities. Even so, all of these problems may be overcome with proper manure application rate, irrigation, soil management and tolerant crop selection.

CHAPTER 2

THE EXPERIMENTAL PROCEDURE

The literature is fraught with manuring experiments to determine fertility benefits and waste utilization or disposal guidelines. The experimentation reported here, however, is unique in that the manure loading rate range extends to rates far in excess of those used in previous studies.

Objective

The specific objective of this research is to determine the effects of steer manure loading rate and cropping pattern upon soil fertility status. Evaluation of the soil fertility analysis is two-fold--to evaluate manure loading rate application to the soil (1) for optimal fertility benefit and (2) for maximum manure utilization or disposal as a waste management alternative.

Materials and Methods

Soil

The field experiment site is located on the eastern half of Field A-1 at the University of Arizona Agricultural Experiment Station at Marana, Arizona (Figure 1). Grabe loam, a deep, well drained, flood-plain soil, predominates the field site. Post, Hendricks, and Pereira (1978) classified the Grabe soil series in the course-loamy, mixed, calcareous, thermic family of the Typic Torrifluvent subgroup.

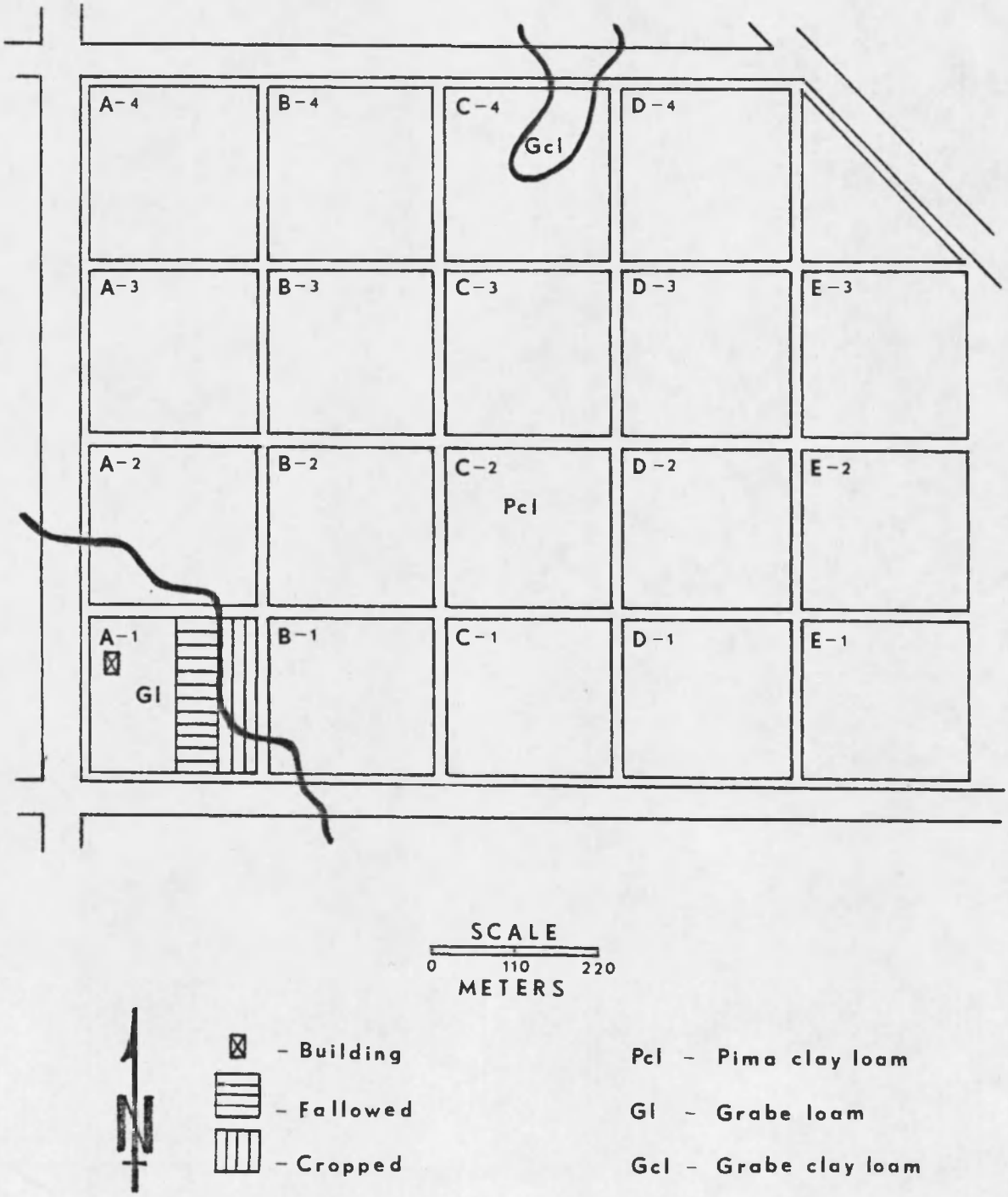

Figure 1. Field experiment site and soil map of the University of Arizona Agricultural Experiment Station at Marana

The surface texture of the field site soil is clay loam, composed of 37.4% sand, 33.6% silt and 29.0% clay and averages 46-50 cm in depth (Pereira 1971). The brown, clay loam, surface soil is underlain by stratified loam, silt loam or fine silt loam subsoils. The profile is moderately alkaline, pH 7.78-7.83, and generally calcareous but free of a lime accumulation layer or caliche.

Soil characteristics of the composite Ap horizon (0-30 cm) from field A-1 are presented in Table 5. The native organic carbon and CO_2-soluble phosphorus values for the surface 30 cm of soil were fairly uniform throughout the site averaging 0.387% and 1.75 ppm, respectively.

Manure

The feedlot steer manure used in the field experiment came from a large, high-density-population, commercial operation in Red Rock, Arizona. Comparison of chemical characterizations (Tables 2, 3, 4 and 6) indicated that the constituent composition and nutrient value were fairly representative of desert Southwestern feedlot steer manures. The soluble ions value, 5.30%, however, fell at the lower end of the range. Of the trace elements determined, iron and manganese were preponderant with values of 0.6700 and 0.0219%, respectively.

Indicator Crop

Sudangrass, an annual grass well-adapted to the desert Southwest, was chosen as the soil-nutrient-indicator crop. Because a vigorous, solid stand of Sudangrass exhibits a sponge-like ability to absorb virtually all available nutrients, this grass is considered a reliable indicator of soil fertility status.

Table 5. Some characteristics of the composite Ap horizon (0-30 cm) clay loam soil from the field site (A-1) at the University of Arizona Agricultural Experiment Station at Marana, Arizona

Characteristic		% (oven-dry)	ppm
Soil paste pH	range:	7.64 - 7.83	
	mean:	7.78	
Total organic carbon (C)	range:	0.317 - 0.486	
	mean:	0.387	
Total dissolved salts	range:		693 - 861
	mean:		807
CO_2-soluble phosphorus (P)	range:		1.10 - 2.10
	mean:		1.70

Table 6. Some chemical characteristics of feedlot steer manure from Red Rock, Arizona applied in June 1974 to the loading-rate field experiment (oven-dry)[1]

Constituent	%
Organic carbon	49.99
Soluble ions	5.30
Na	0.45
K	1.52
Ca	2.24
Mg	0.30
Total N	1.63
Total P	0.47
Trace elements	
Fe	0.6700
Mn	0.0219
Zn	0.0106
Cu	0.0027
Pb	0.0025
Ca	0.0042
Cr	0.0171
Ni	0.0092

[1] Artiola-Fortuny 1976

Experimental Design

The experimental design included the following parameters:

1. Fallowed or cropped,
2. 0, 44.8, 134.4, 178.2, 224 and 448 metric tons per hectare (mt/ha) steer manure loading rates (on a dry-weight basis),
3. Four replications per loading rate.

The individual plots within each replication as well as the replications within the fallowed or cropped sections were laid out in a modified randomized block design to minimize the effects of natural soil fertility or textural variations upon yield. The 48 plot (2 x 6 x 4) experimental layout is illustrated in Figure 2. There was a four-row buffer between fallowed and cropped sections. Each of the 48 individual plots was eight rows or 8.12 meters wide by 21.34 meters long. Soil and plant samples were taken from subplots centered within each individual plot. In effect, then, each sampling plot was buffered from the rest in an attempt to minimize sampling error due to soil fertility gradations from border overlap effects caused by manure rate application overlap or tillage operations. The sampling plots were three rows or 3.04 meters wide and 13.41 meters long.

Cropping History

The field experiment was begun in July, 1974, when commercial steer manure from a Red Rock, Arizona feedlot was applied to the randomized plots at the prescribed rates. The manure was applied during the period July 4 through July 12, 1974 and incorporated into the soil to a depth of 15 cm.

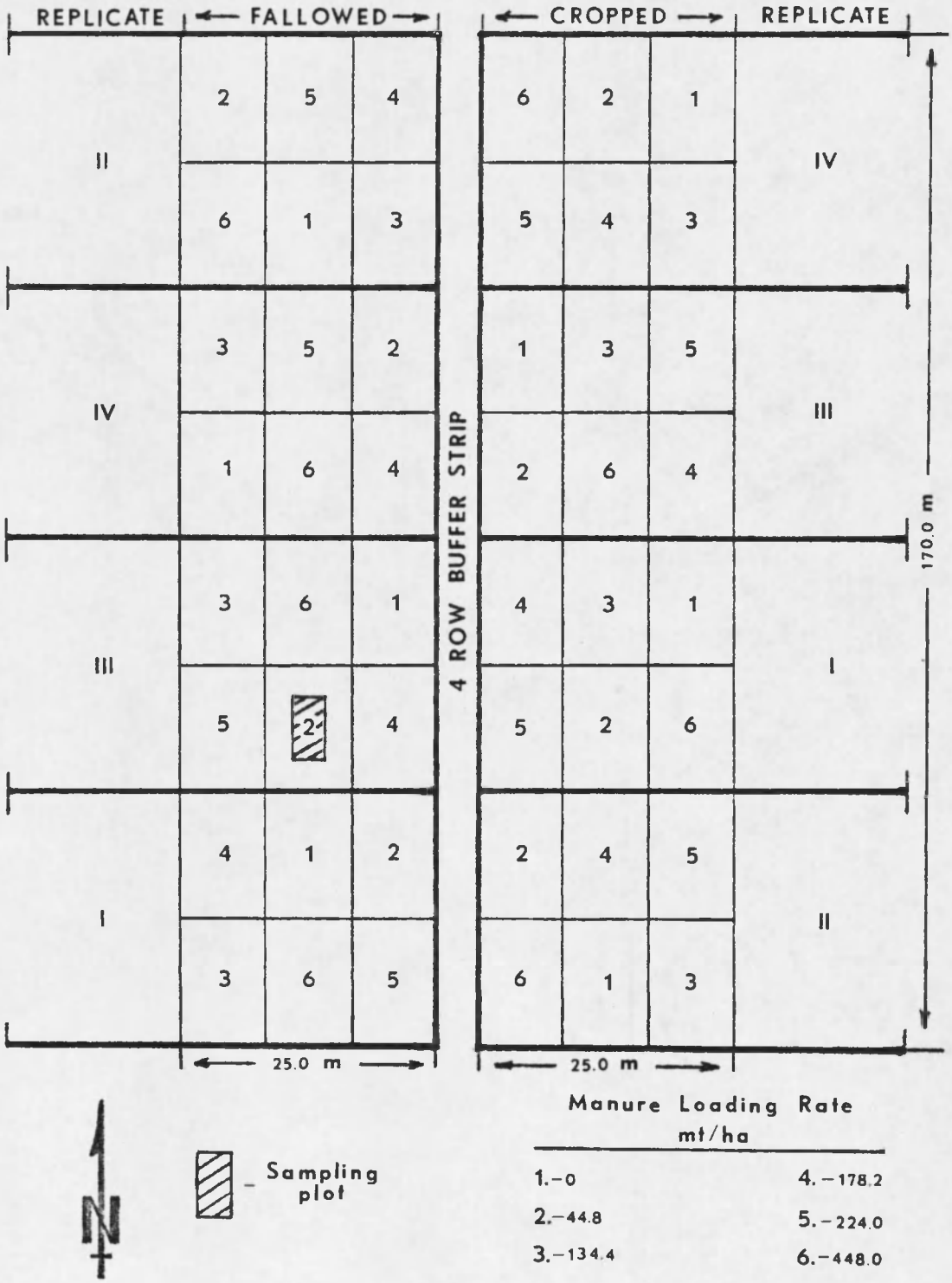

Figure 2. Field experiment plot design showing fallowed and cropped sections, replications, and manure loading rates

Half of the plots were left fallowed, that is, uncultivated and unirrigated, for two years. The cropped plots were planted with grain sorghum (Sorghum vulgare) on July 17, 1974. Henceforth, the cropped plots were double-cropped alternately with grain sorghum and barley (Hordeum vulgare) for two years. Cultural practices were standard, commercial-production techniques used in the irrigated desert Southwest for grain sorghum and barley. The grain yields were harvested by combine and removed at maturity. Crop residues were reincorporated into the soil.

The first crop, sorghum, was severely stunted and did not produce grain. The successive crops produced grain dry-weight yields as reported in Table 7. Analysis of these yield data indicated that, after four croppings, soil nitrogen may have been deficient for the production of a vigorous grass stand on the cropped plots. Therefore, 100 lbs of NH_4NO_3 fertilizer was applied broadcast to all fallowed and cropped plots prior to planting the soil-nutrient-indicator crop.

Prior to seeding the Sudangrass in July, 1976, soil samples of the composite Ap horizon (0-30 cm) were collected from all subplots in both fallowed and cropped sections. The soil samples were analyzed for total organic carbon (C) (Black 1965). CO_2-soluble phosphorus (P) was extracted from soil samples as described by McGeorge, Beuhrer, and Breazeale (1935). The Murphy and Riley method according to Watanabe and Olsen (1965) was used for colorimetric measurement of the CO_2-extract. The chemical analysis data of the soil parameters are presented in tabular form in Appendix A.

Table 7. Grain sorghum and barley dry weight yields from four crops grown on clay loam soil of the cropped section after receiving steer manure at various loading rates[1]

Harvest Date	Steer Manure Loading Rate mt/ha					
	0	44.8	134.4	178.2	224	448
	kg/ha					
12/1974	--	--	--No Grain Yield --		--	--
6/1975	2815	4152	5520	5466	5621	4385
12/1975	4131	4536	4905	5484	5529	4740
6/1976	218	381	1065	1392	1687	3584

[1] Fuller 1977

The Sudangrass was planted broadcast on all fallowed and cropped plots over 100 cm beds. The planting technique produced a solid, non-cultivated stand of grass. The grass was grown to the booting stage and sampled August 2, 1976. After sampling, the grass was cut and removed. A second sample was taken September 14, 1976 at the same growth stage. In both instances, the Sudangrass was sampled just prior to booting when growth, nutrient uptake utilization are maximized.

Field-green and dry weights were recorded for both samplings from fallowed and cropped sections. Moisture content data for all samples was determined from field-green and dry weight data. In addition, all samples were analyzed for plant nitrogen (N) content using the Kjeldahl method (Black 1965) and for plant phosphorus (P) content using the spectrophotometric molybdovanadophosphate method (Kitson and Mellon 1944). Total nitrogen (N) uptake and total phosphorus (P) uptake data were calculated from dry weight data and respective plant nutrient content data. The tabular data of the various plant tissue analyses and plant parameters are displayed in Appendix B.

Results and Discussion

This section presents the data graphically as histograms and the discussion of the relationships of the various soil and plant parameters to one another and to soil fertility as influenced by steer manure loading rate. Statistical treatment of the data includes analysis of variance at the 95% confidence level to test for significant differences between rates, harvests and cropping pattern. Separate correlation analyses, also at the 95% confidence level, for the two harvests show

a difference in the number of significant correlations between the various parameters from one harvest to the next, supporting the intuitive feeling that the correlations of the first harvest may be different from those of the second harvest.

Soil Parameters

The soil analysis data for both total organic carbon (C) and CO_2-soluble phosphorus (P) content of the composite Ap horizon are significantly different by manure loading rate as well as by cropping pattern. General differences and trends from rate to rate and between fallowed and cropped sections for the soil parameters are readily discernible from Figures 3 and 4.

Total Organic Carbon. The mean total organic carbon content, 0.387%, of the experimental field soil prior to manure application is lower than that of the non-manured, fallowed, control plots sampled two years later. Since no organic matter was added to the control plots, the difference presumably is due to residual weed growth and wind-transported crop residues from neighboring fields. Even so, from the reported range of native organic carbon levels from the experimental field soil (see Table 5), 0.49% is not unreasonable and seems representative enough to be assumed to be the base or native level for further discussions. That other mean data values are larger than the control value, 0.49%, for all rates of fallowed and cropped sections, further supports this assumption.

The organic carbon levels reflect manure loading rates in both fallowed and cropped sections, even after two years. In both sections,

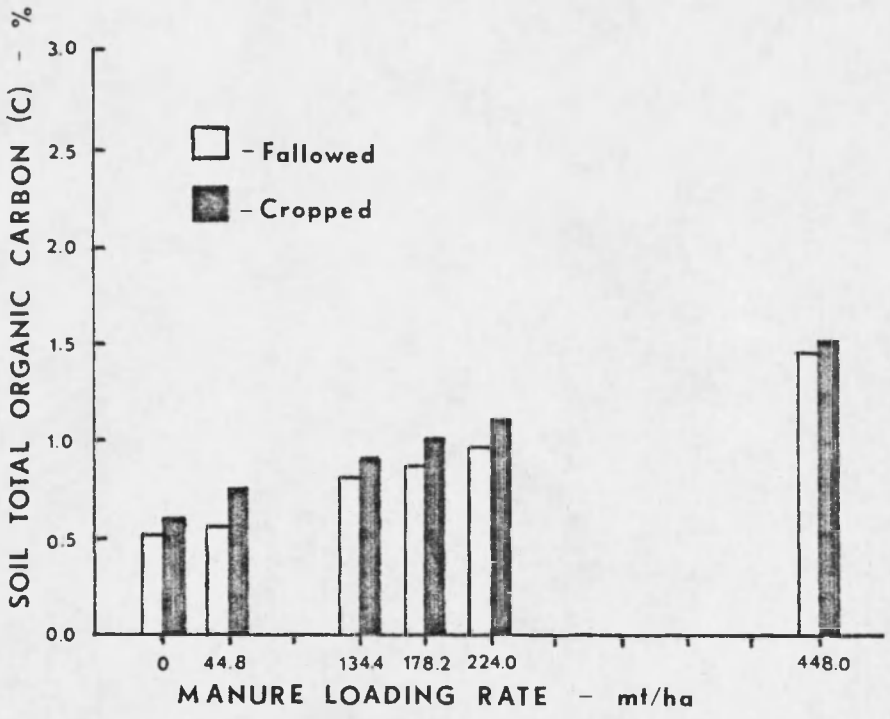

Figure 3. The effects of steer manure loading rate upon soil total organic carbon content as influenced by cropping pattern

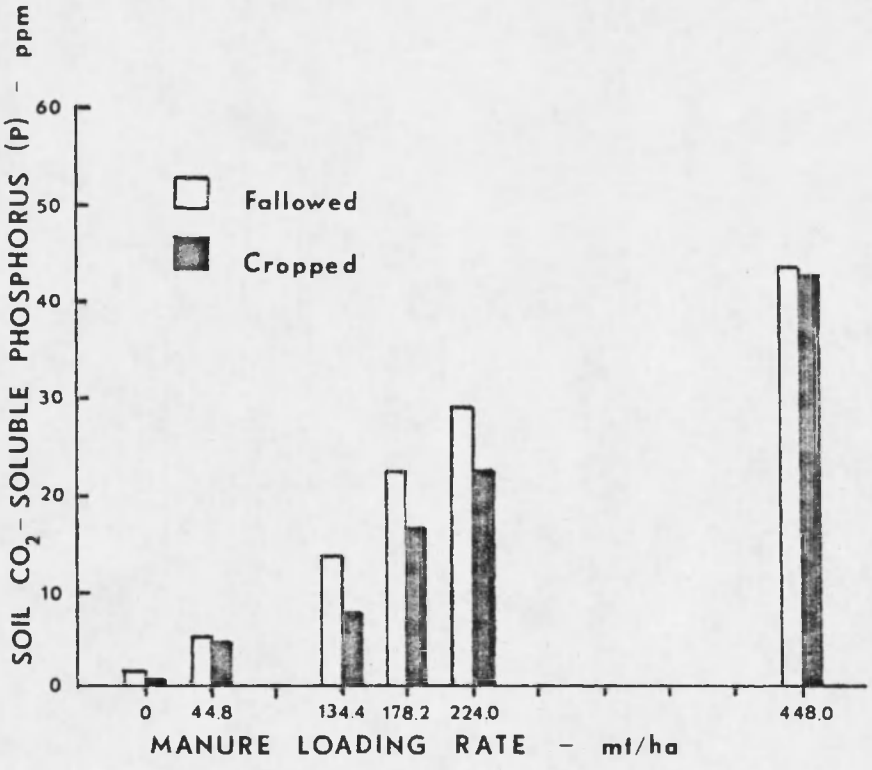

Figure 4. The effects of steer manure loading rate upon soil CO_2-soluble phosphorus content as influenced by cropping pattern

the organic carbon content for the 448 mt/ha-rate is about three times that of the 0 mt/ha-rate. The total organic carbon content of the surface 30 cm of soil is statistically greater for the cropped section than for the fallowed section, at all rates. One may surmise that this effect is due to reincorporation of crop residues from the four grain crops produced on the cropped section.

CO_2-soluble Phosphorus (P). Even though the mean soil CO_2-soluble phosphorus content, 1.17 ppm, of the non-manured, fallowed, control plots is lower after two years than the mean native level of the experimental field prior to beginning the experiment, one must assume that 1.17 pm represents the native level for subsequent discussions. Soil CO_2-soluble phosphorus data for both fallowed and cropped sections follows the same trend as the organic carbon data, increasing significantly with increasing manuring rate. The highest rate shows substantially more CO_2-soluble phosphorus, about forty times as much for both cropping patterns, than the no manure rate. The apparent relationship of soil CO_2-soluble phosphorus to manuring rate indicates that phosphorus seems to remain in the decomposing manure with very little, if any, leaching.

Grain crops, such as grain sorghum and barley, generally require larger quantities of phosphorus for grain production than non-grain producing crops. Therefore, since crop residues were reincorporated after grain harvesting, one may expect the soil CO_2-soluble phosphorus levels to be lower in the cropped section than in the fallowed section, at any given rate, by the phosphorus content

of the harvested grain crops. The data support this proposition at all rates.

Although statistical analysis does not correlate total organic carbon with soil CO_2-soluble phosphorus, the relationship between these parameters seems undeniable.

Plant Parameters

The data include field-green and dry weight yield, moisture content, plant tissue content of nitrogen and phosphorus and total uptake of nitrogen and phosphorus parameters for two samplings of the Sudangrass indicator crop for both cropping patterns. The field-green and dry weight yields are measures of annual-plant growth and reflect all environmental factors. Initially, annual-plant growth or yield proceeds rapidly to a certain level and then, as the plant approaches maturity, increases by successively smaller increments, characterizing the "growth curve." Assuming all other factors are favorable, soil-solution nutrient concentrations as well as the soil's ability to sustain component nutrient levels during cropping strongly influences yield parameters. Plant tissue nutrient content (nitrogen and phosphorus) parameters are an expression of nutrient availability or relative soil-solution concentration of those nutrients at the time of sampling. Plant tissue nutrient content, depending on many factors, such as nutrient requirement or accumulation, is a relative parameter not always well-related to yield. Dry weight data and plant tissue nutrient content data combine to generate total nutrient uptake data, which may best represent the soil's ability to supply a nutrient during

a given growth period. Together, the relationships among field-green and dry weight yield parameters and total uptake parameters provide a "handle" for soil fertility evaluation and may serve as the major plant parameter criteria for further discussion.

The numerous plant parameters ought to be extensive enough to furnish considerable information about soil nitrogen and phosphorus fertility and furthermore, a general indication of overall soil fertility status. However, because the data are somewhat cumbersome to analyze, discussions and analyses by rate, harvest and cropping pattern may facilitate the evaluation of the data. In addition, presenting the data in histograms, Figures 5 through 18, may elucidate the underlying trends and relationships among the various parameters.

Analysis by Rate. Analysis of variance, by rate, indicates significant differences for all fallowed and cropped-section plant parameters except fallowed-section plant phosphorus content. One may expect yield and total uptake parameters (Figures 5, 6, 9 and 11) and overall soil fertility of both cropping pattern sections to reflect manure loading rate or total organic carbon content, as an index of substrate from which many nutrients may become plant-available via organic matter decomposition over an extended number of croppings. The yield and total uptake parameters of the first harvest of the fallowed section do not seem to follow manuring rate but appear to be governed by some growth depressing factor. Increasing plant nitrogen content as rate increases in the first-harvest, fallowed-section data (Figure 8) may indicate increasing soil-solution nitrogen concentration or, but

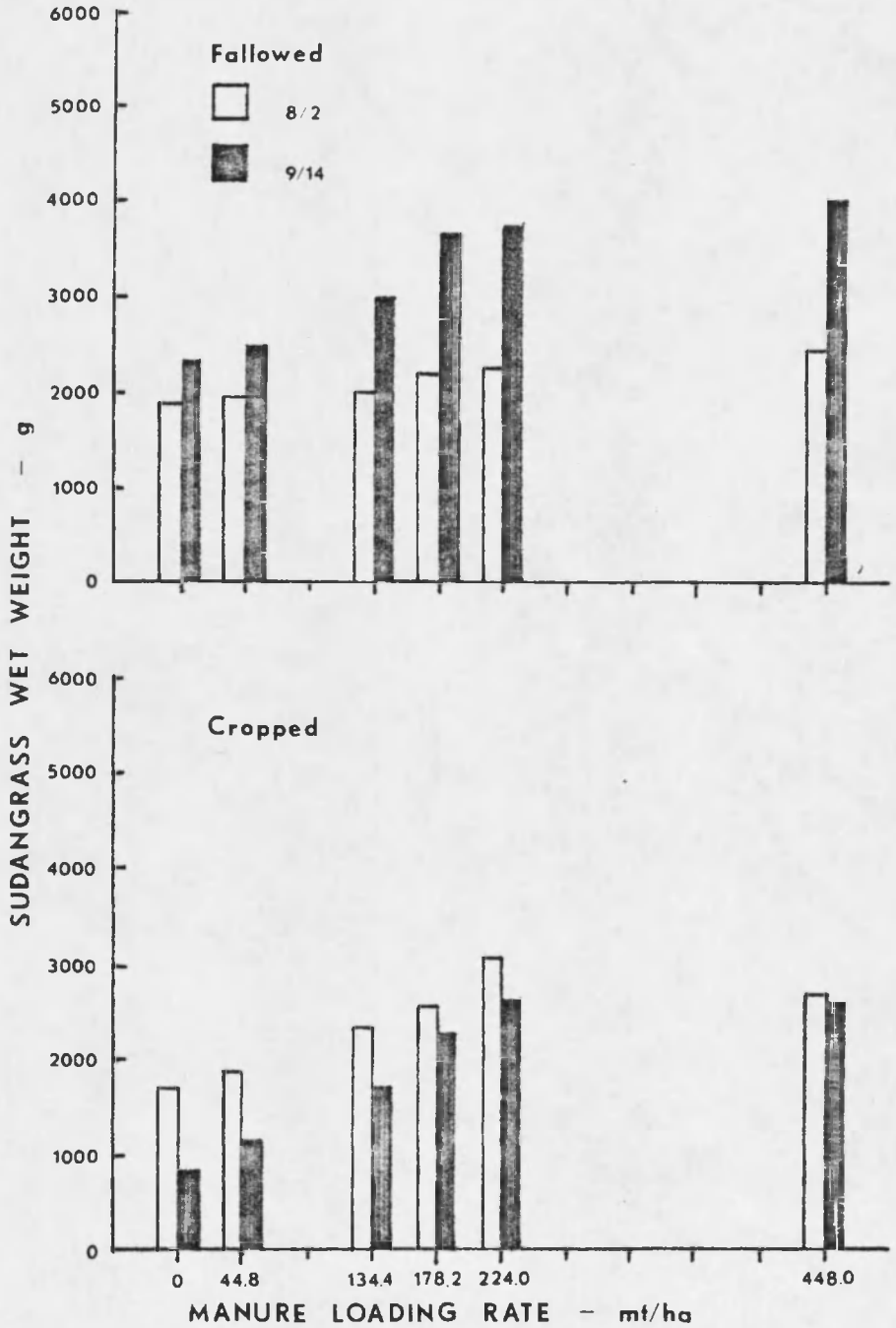

Figure 5. The effects of steer manure loading rate and cropping pattern upon wet weight of two consecutive harvests of Sudangrass

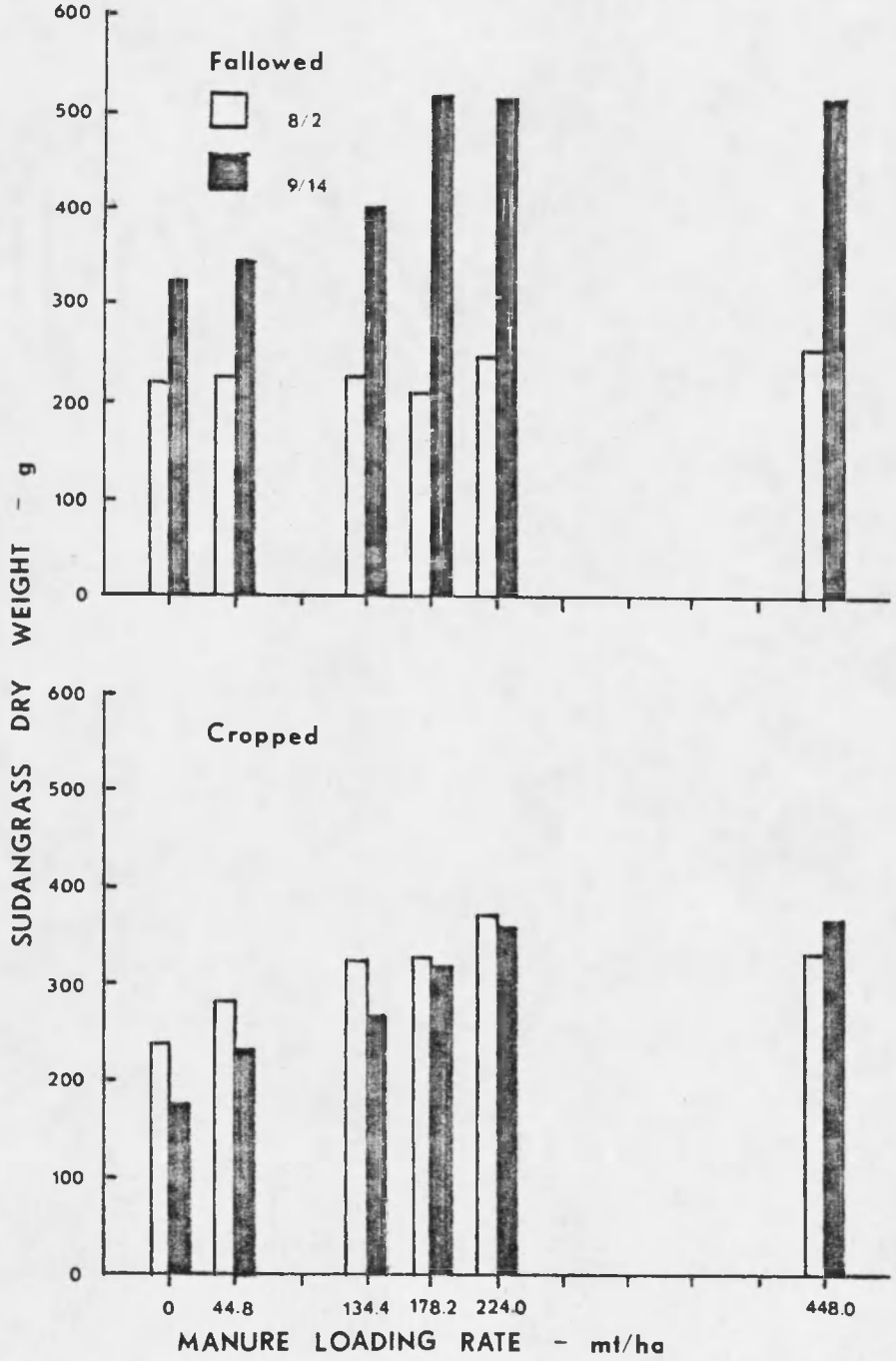

Figure 6. The effects of steer manure loading rate and cropping pattern upon dry weight of two consecutive harvests of Sudangrass

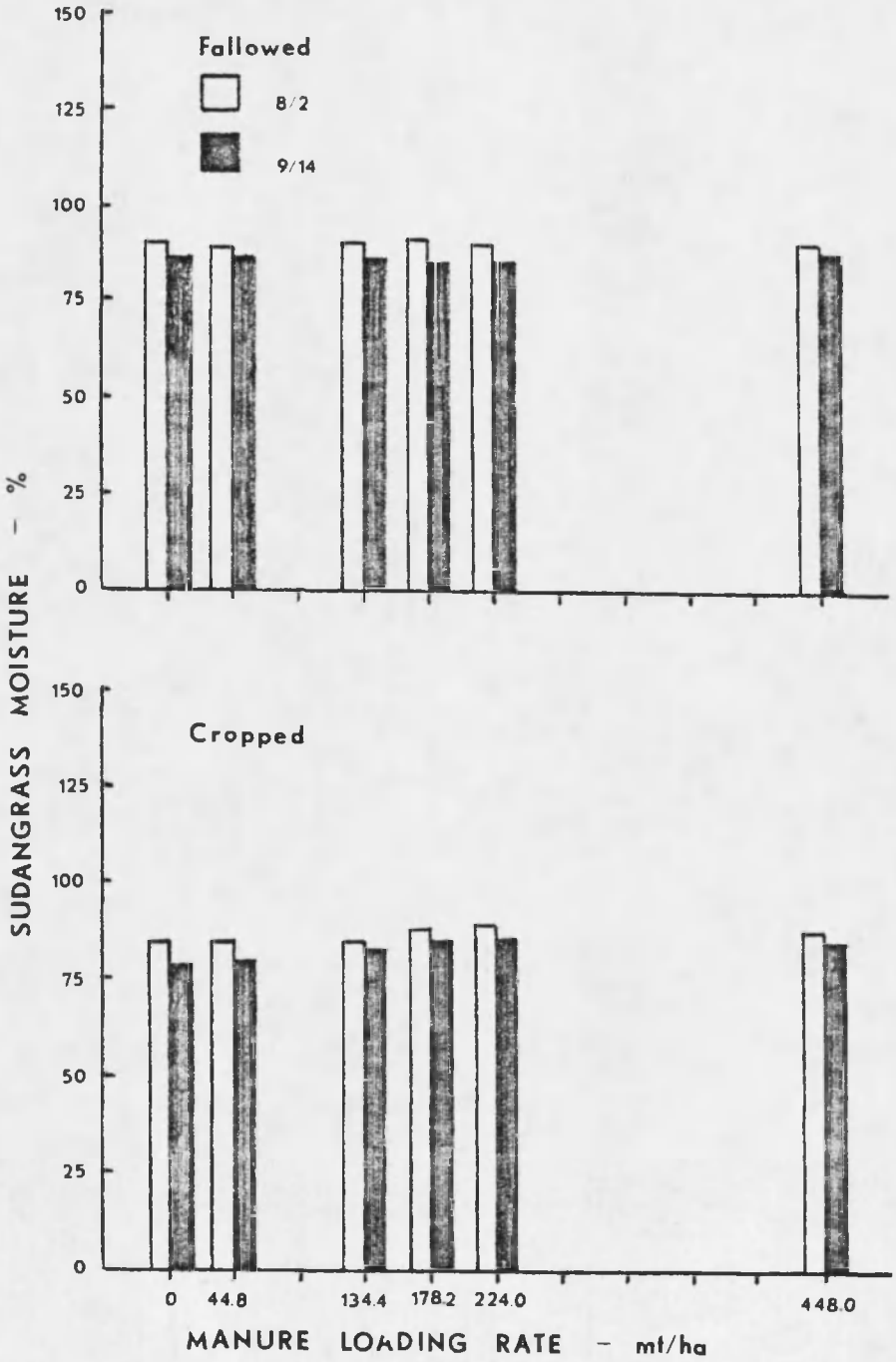

Figure 7. The effects of steer manure loading rate and cropping pattern upon moisture content of two consecutive harvests of Sudangrass

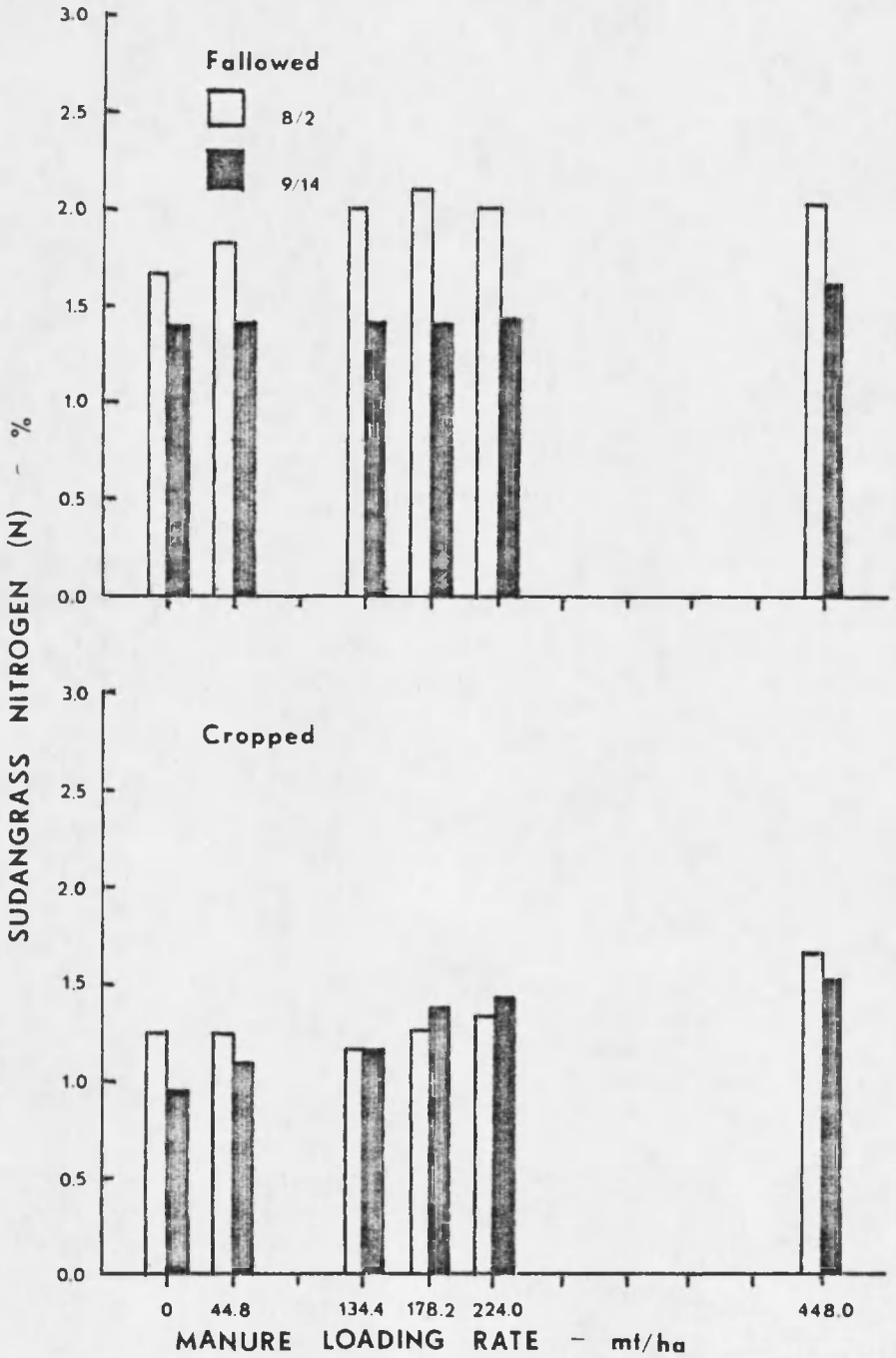

Figure 8. The effects of steer manure loading rate and cropping pattern upon nitrogen content of two consecutive harvests of Sudangrass

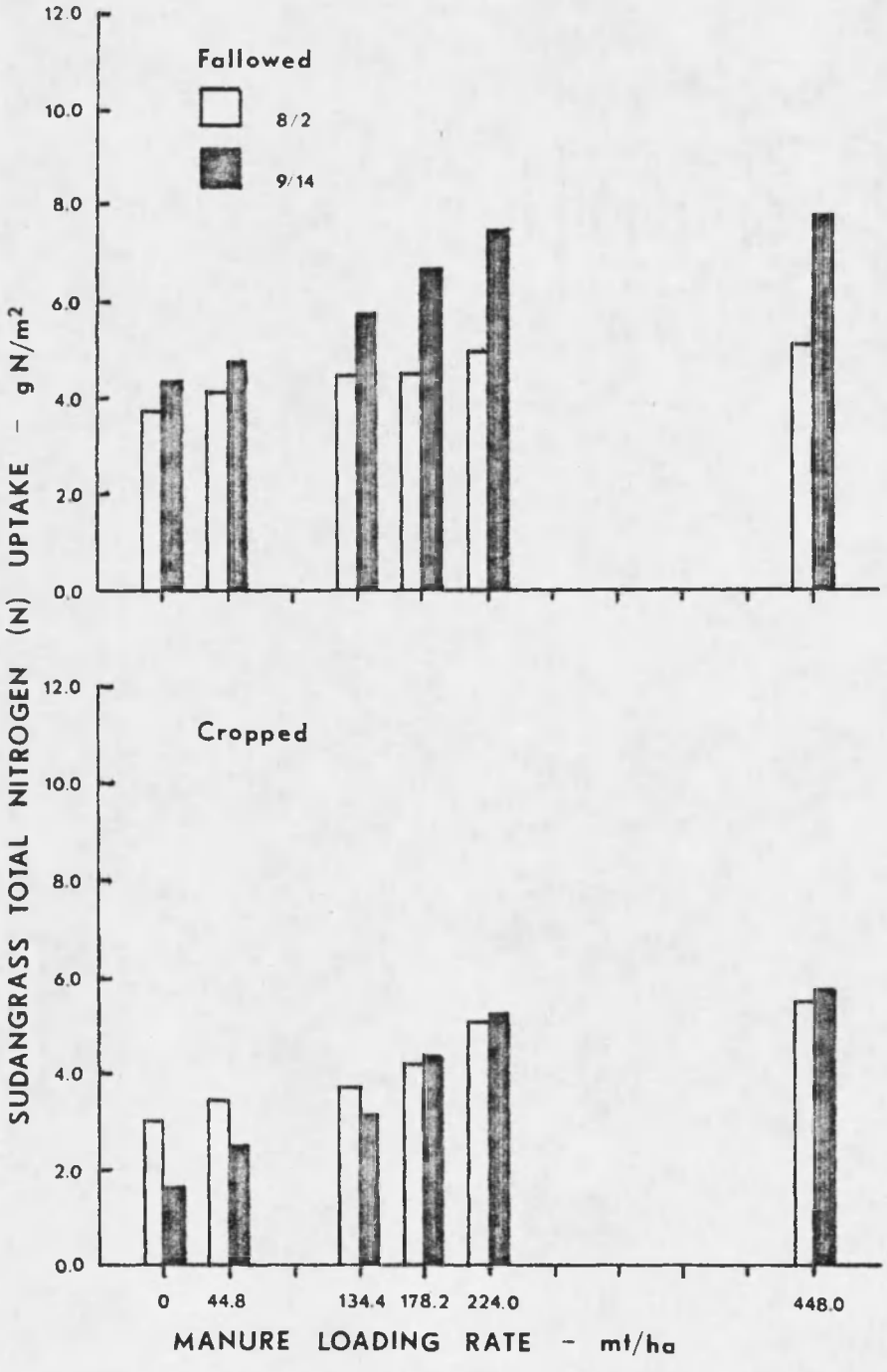

Figure 9. The effects of steer manure loading rate and cropping pattern upon total nitrogen uptake of two consecutive harvests of Sudangrass

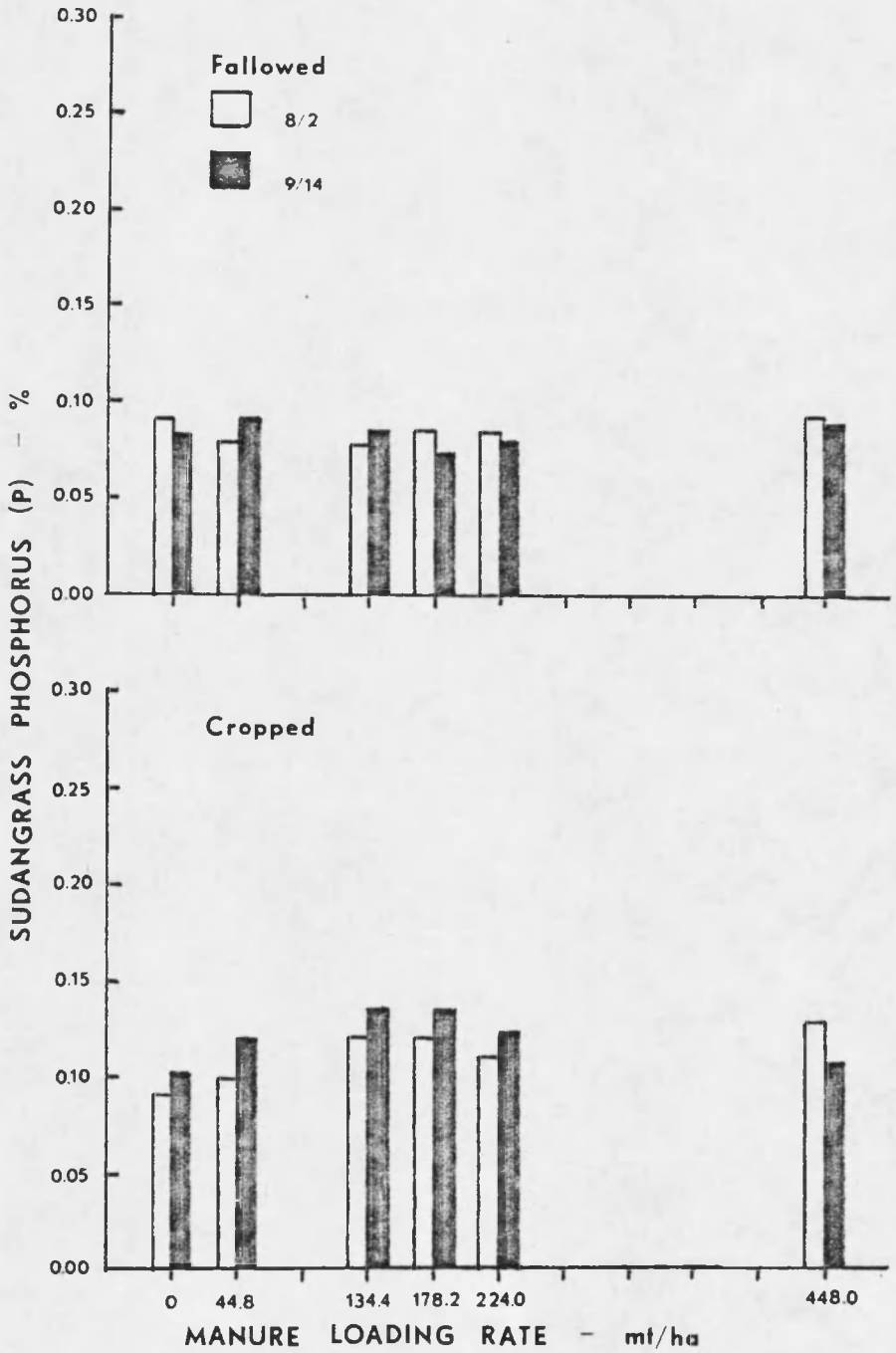

Figure 10. The effects of steer manure loading rate and cropping pattern upon phosphorus content of two consecutive harvests of Sudangrass

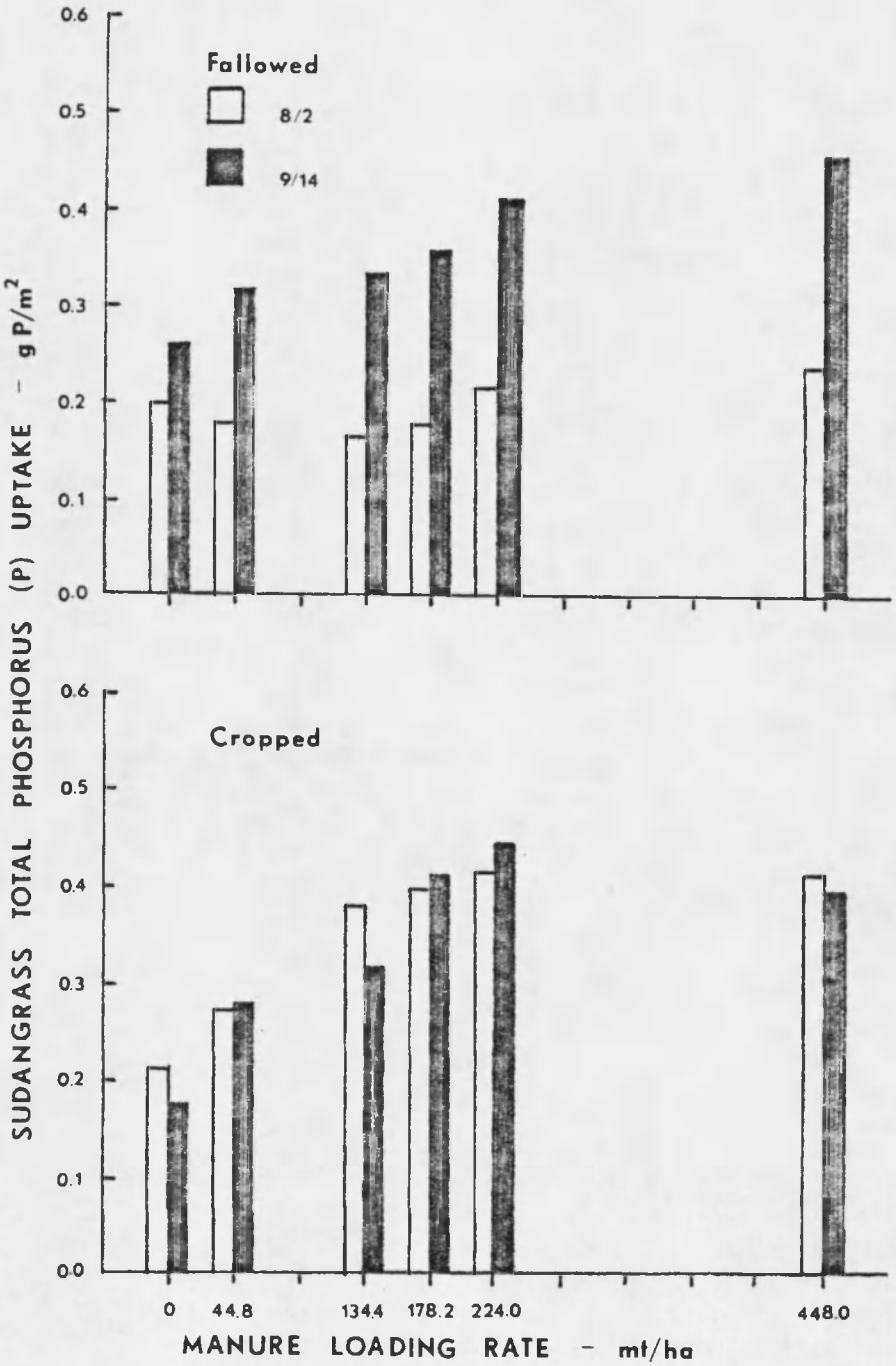

Figure 11. The effects of steer manure loading rate and cropping pattern upon total phosphorus uptake of two consecutive harvests of Sudangrass

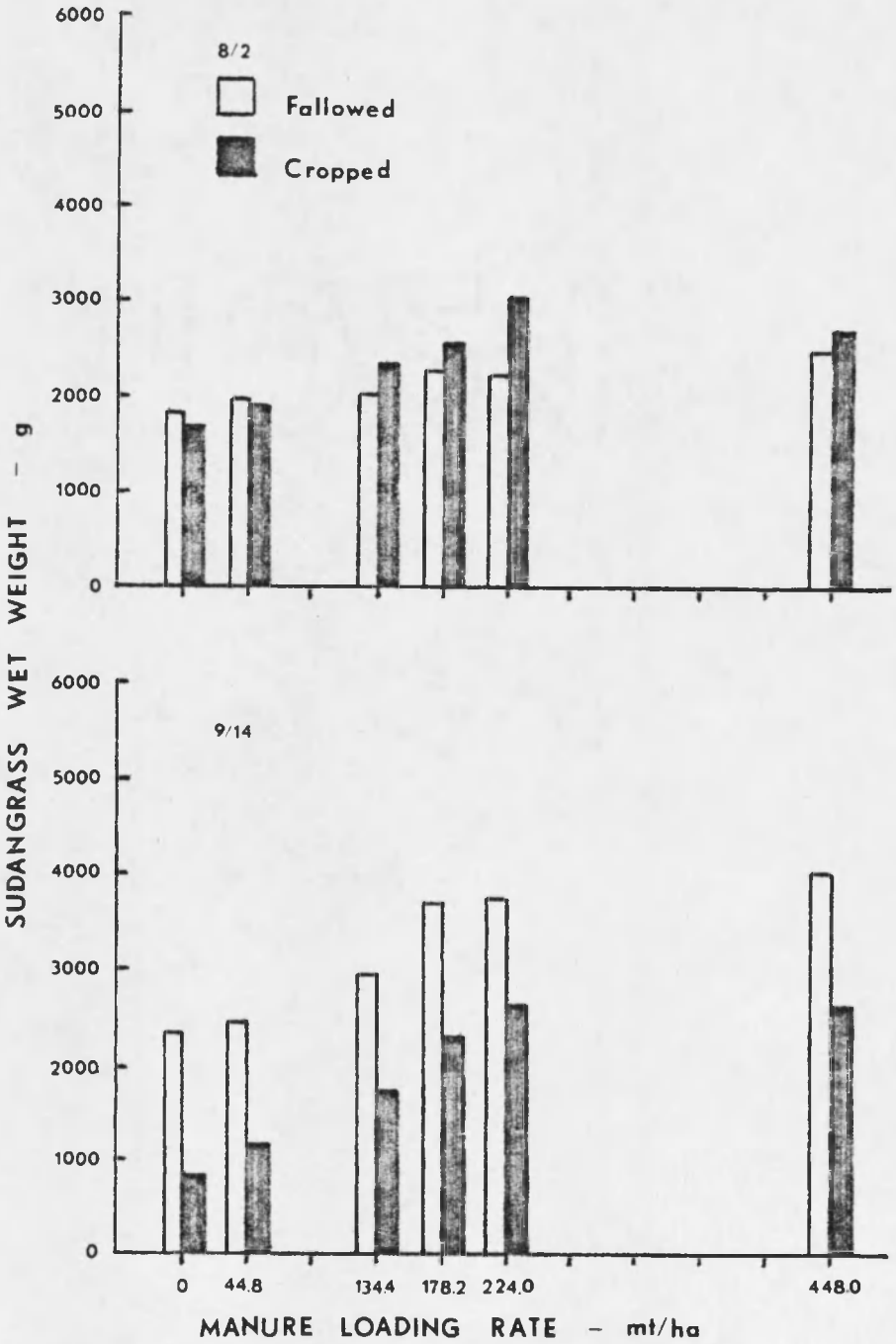

Figure 12. The effects of steer manure loading rate and harvesting sequence upon Sudangrass wet weight as influenced by cropping pattern

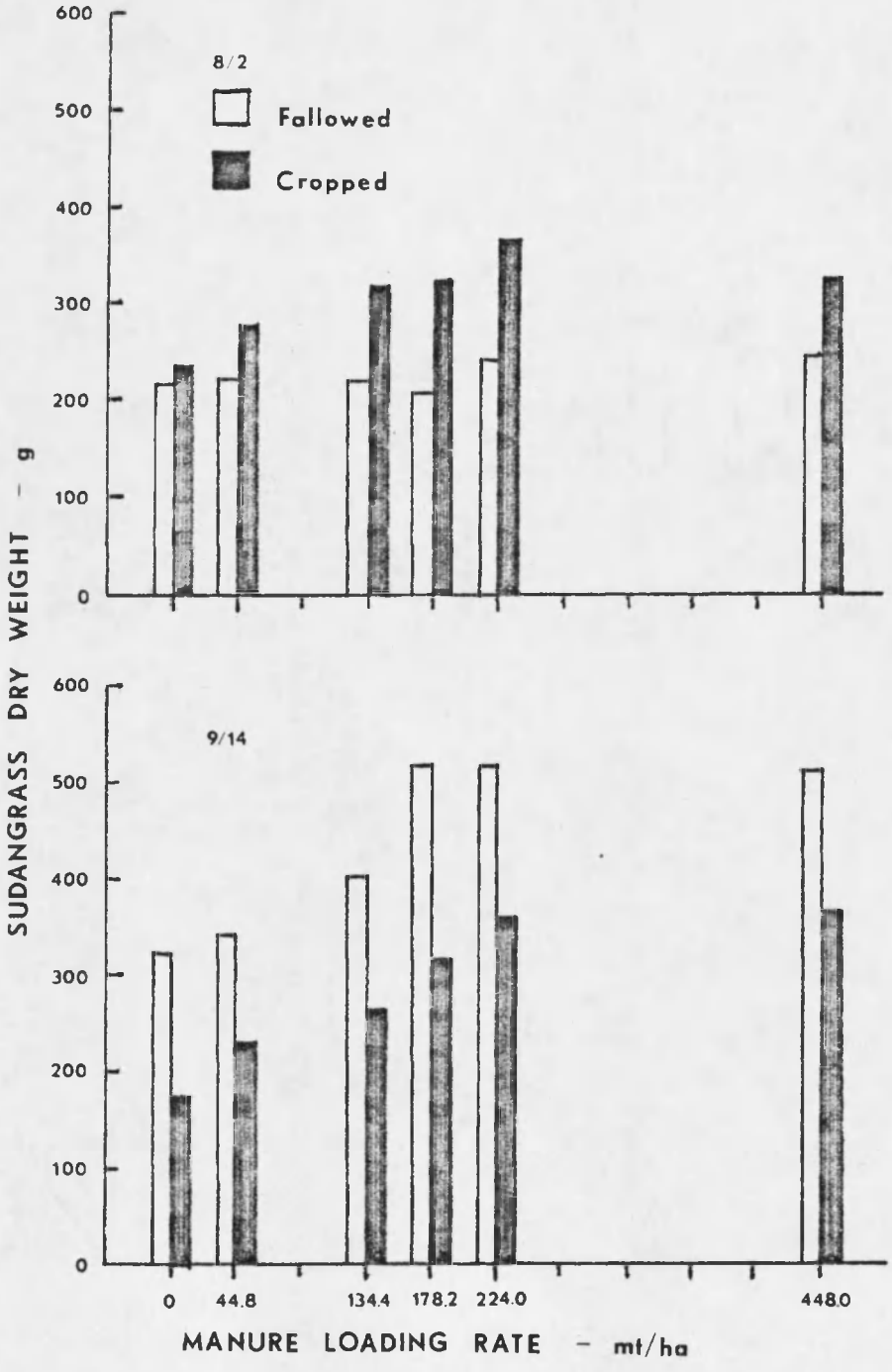

Figure 13. The effects of steer manure loading rate and harvesting sequence upon Sudangrass dry weight as influenced by cropping pattern

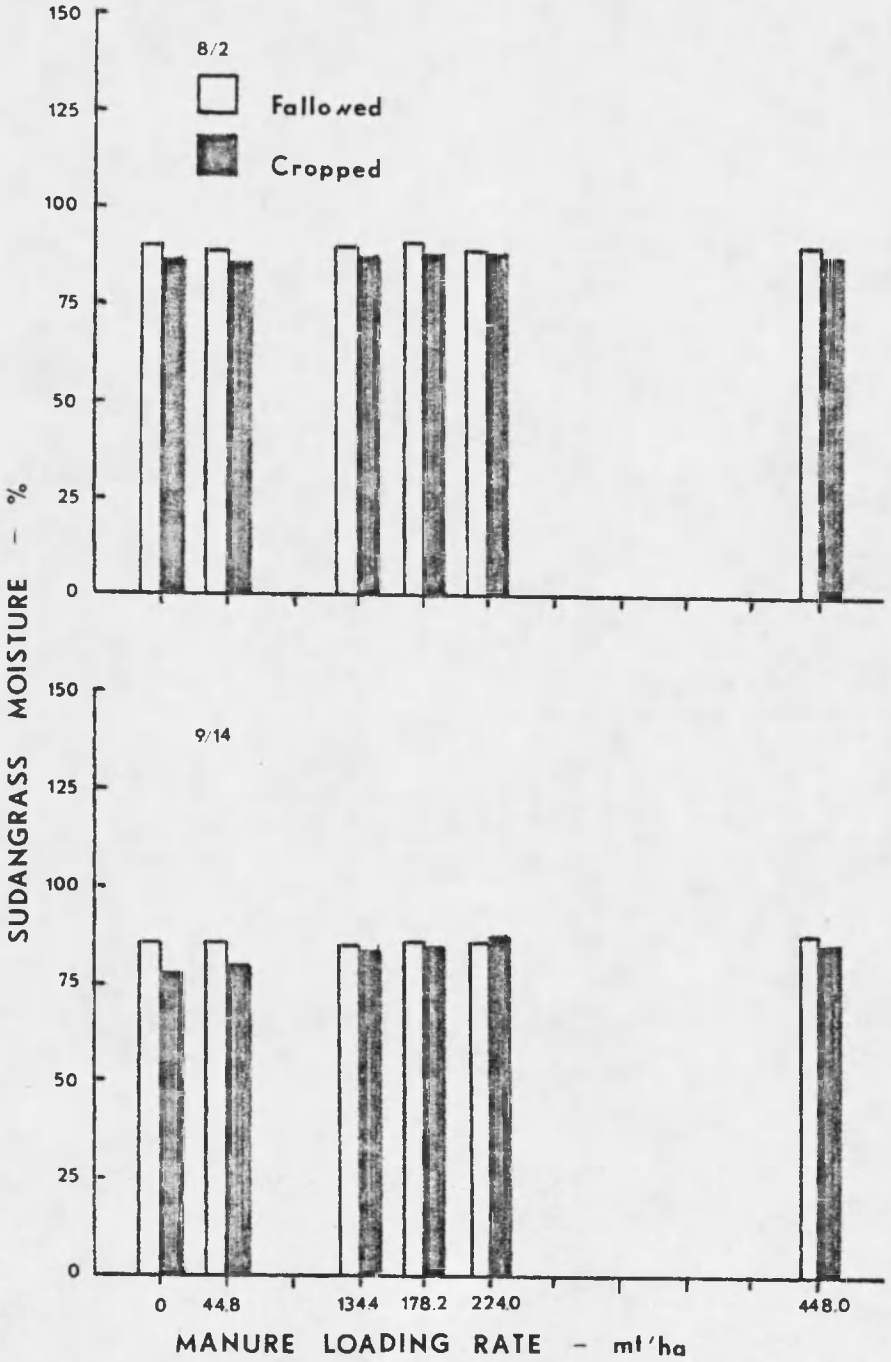

Figure 14. The effects of steer manure loading rate and harvesting sequence upon Sudangrass moisture content as influenced by cropping pattern

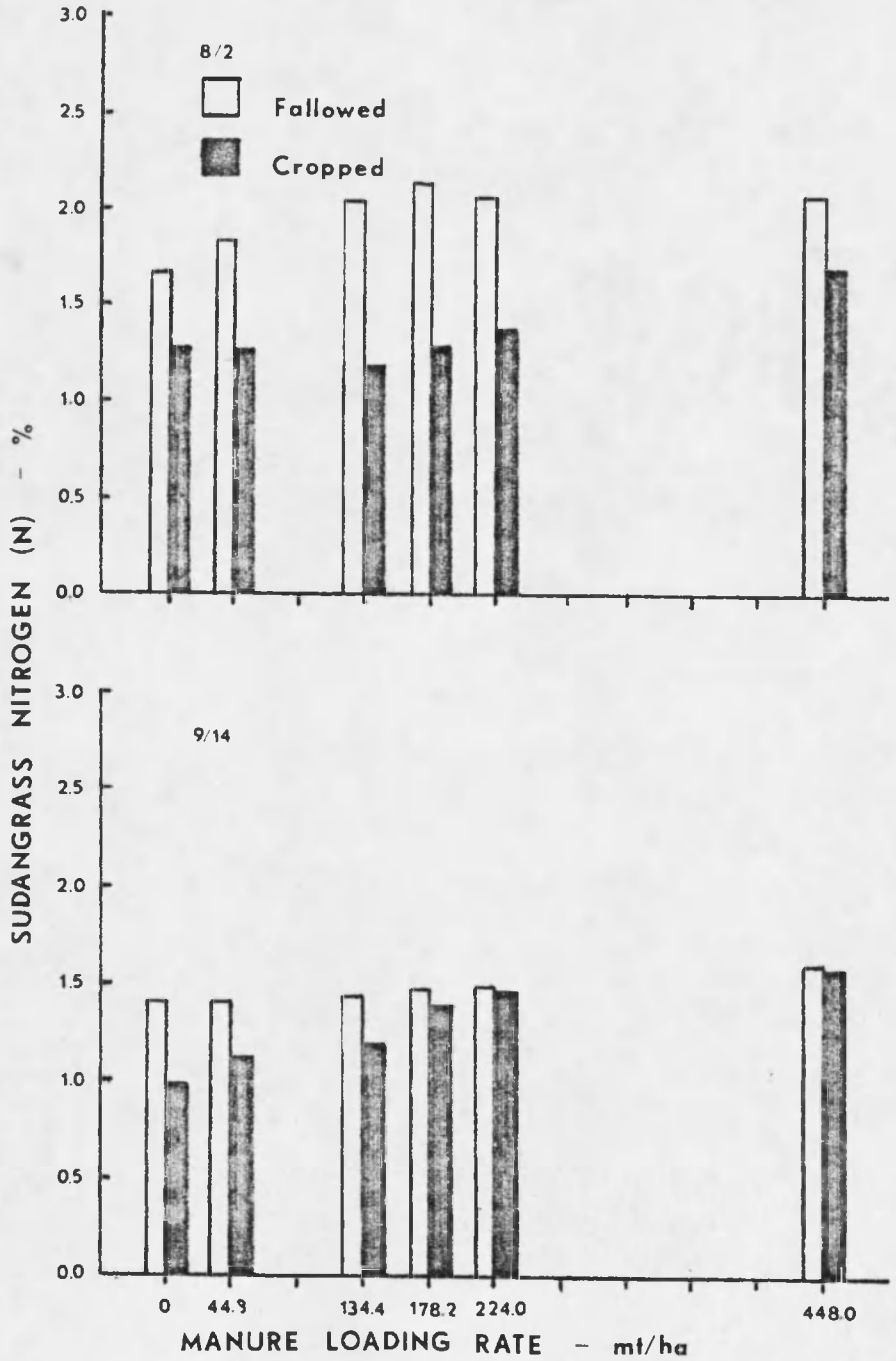

Figure 15. The effects of steer manure loading rate and harvesting sequence upon Sudangrass nitrogen content as influenced by cropping pattern

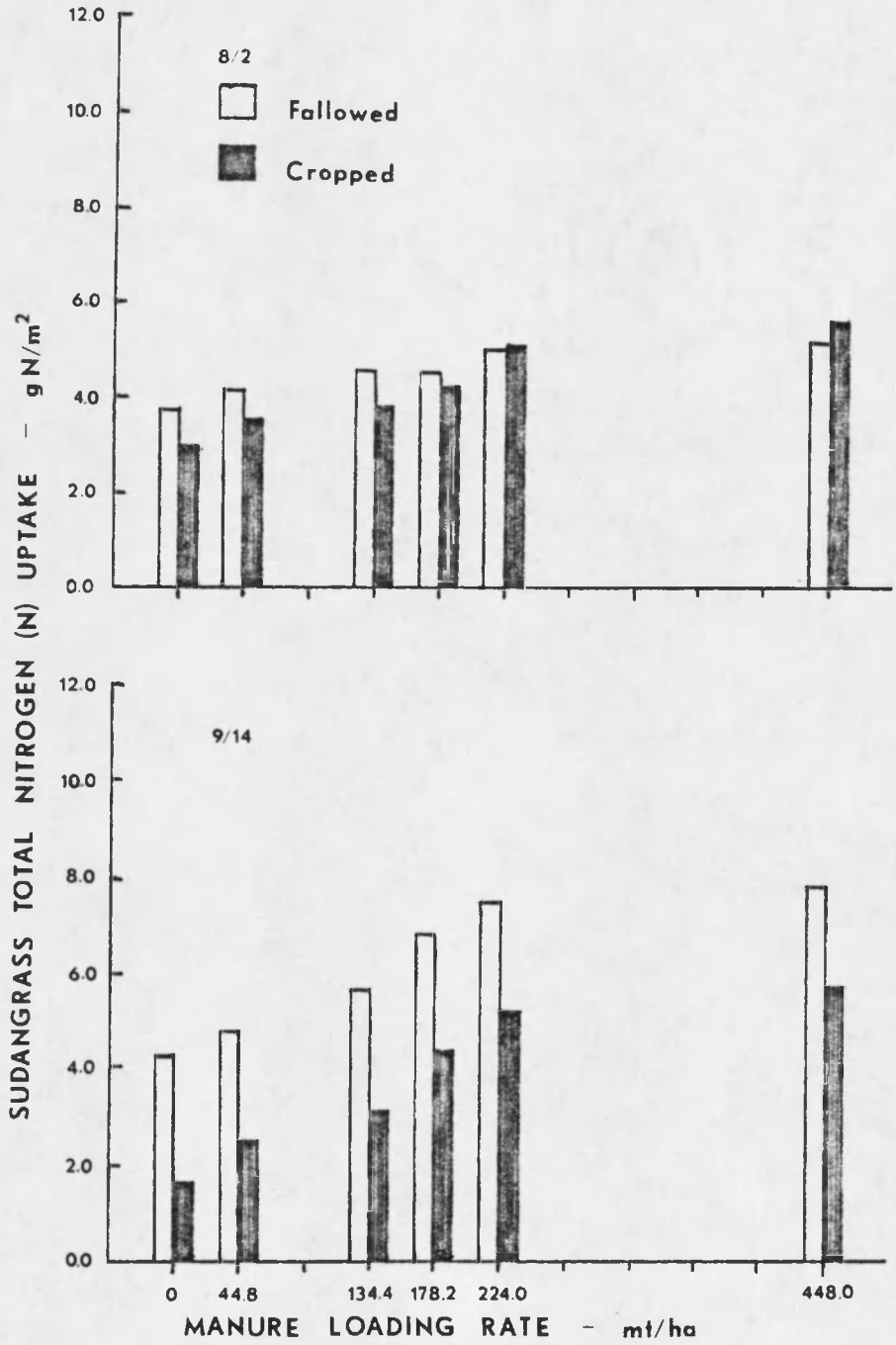

Figure 16. The effects of steer manure loading rate and harvesting sequence upon Sudangrass total nitrogen uptake as influenced by cropping pattern

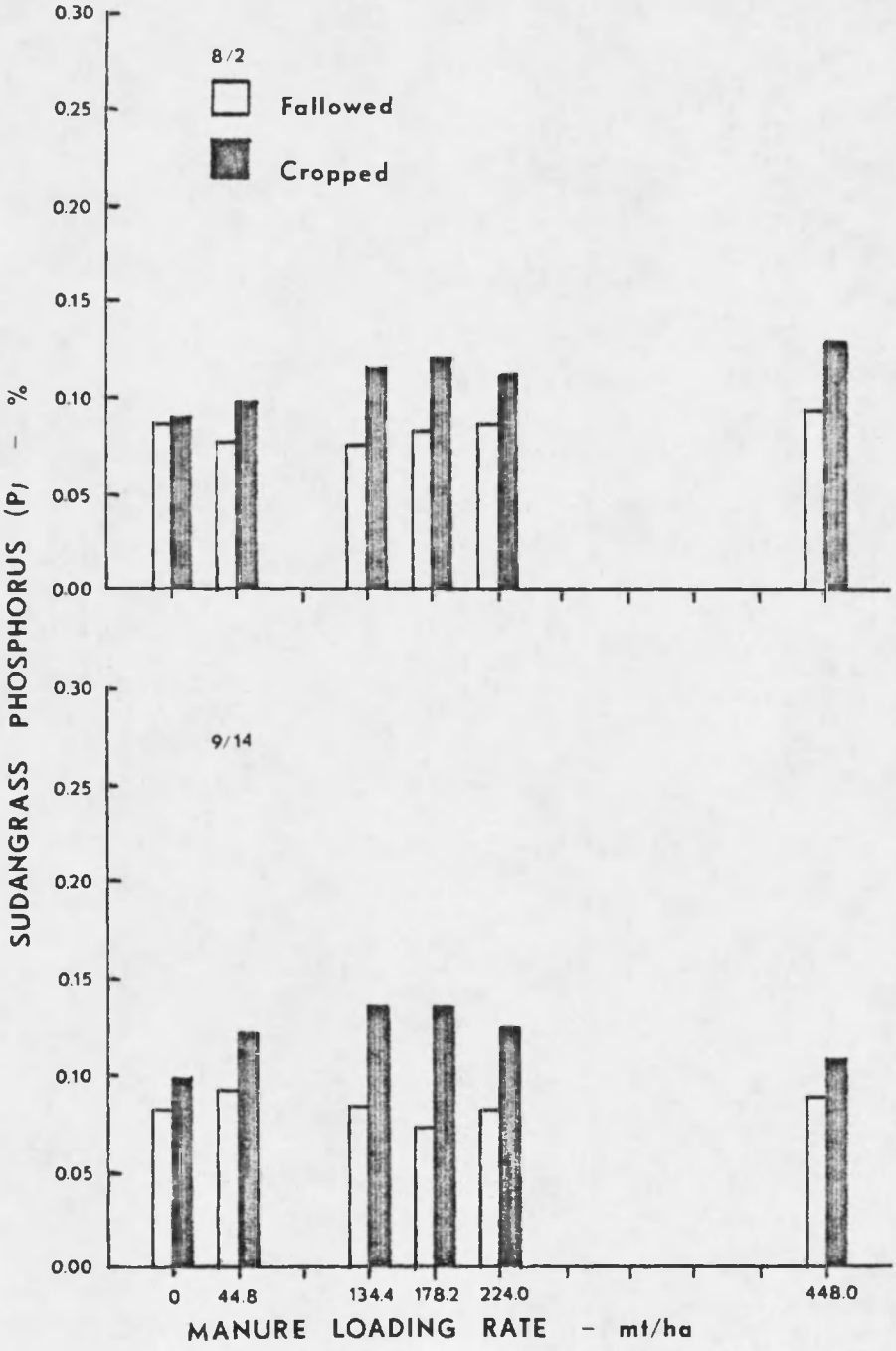

Figure 17. The effects of steer manure loading rate and harvesting sequence upon Sudangrass phosphorus content as influenced by cropping pattern

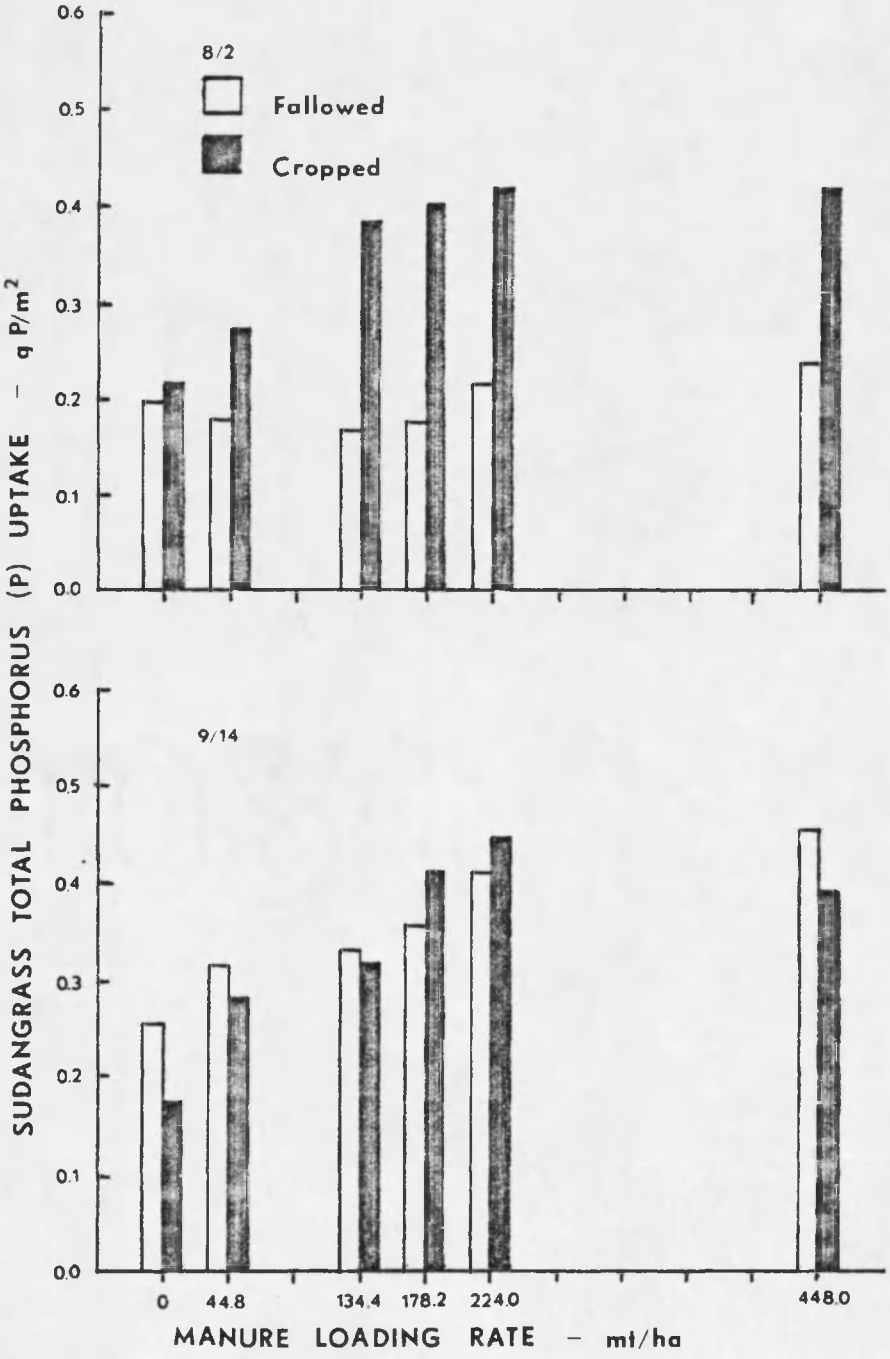

Figure 18. The effects of steer manure loading rate and harvesting sequence upon Sudangrass total phosphorus uptake as influenced by cropping pattern

not necessarily, nitrogen accumulation by the crop. Irregardless, plant nitrogen content during the first growth of the fallowed section is undoubtedly a function of both manure loading rate and pre-plant nitrogen fertilization. Plant nitrogen levels of the second-harvest, fallowed section remain fairly constant despite manure loading rate increases, reflecting nitrogen fertilization effects. In both harvests of the cropped section, plant nitrogen content appears to follow loading rate. The 100 lb NH_4NO_3 fertilizer application seems to influence the first-harvest, cropped-section, plant nitrogen content levels more at the lower manure loading rates than at the higher rates. At the higher manure loading rates, rate seems to be the predominant influence upon soil nitrogen fertility levels. In spite of the significant difference by rate for the plant phosphorus content (Figure 10), this parameter seems to vary little or even decrease with increasing rate in the fallowed section but increase with increasing rate in the cropped section. That plant phosphorus content does not appear to be considerably different as rate varies while total phosphorus uptake and yield increase with rate seems to indicate that even the lowest plant phosphorus content level may be sufficient for crop nutritional requirements and maximum yields. Analagous reasoning may be an alternative explanation to similar nitrogen and yield parameter relationships of the second-harvest, fallowed-section data. Notwithstanding total phosphorus uptake and soil CO_2-soluble phosphorus content may both be indicators of phosphorus availability and appear to be significantly correlated with one another, statistical analysis does not significantly correlate these parameters. Although overall soil

fertility seems to follow manuring rate or soil total organic carbon content, there are no significant correlations of any plant parameters with total organic carbon content of the soil.

The fertility benefit or apparent fertility increase as manure loading rate increases, as evidenced by increasing yield and total uptake parameters (Figures 5, 6, 9 and 11), appears to be optimum near the 180 mt/ha rate for both cropping patterns. Manuring rates above 180 mt/ha do not appear to be of any additional benefit; that is, yield and total uptake parameters do not increase at manuring rates in excess of 180 mt/ha.

Analysis by Harvest. A comparison by harvest of the various plant parameters for both cropping patterns indicates similarities or differences between the harvests. Plant parameter differences by harvest may reflect changes in plant growth character or in soil fertility status. An example of the former may be the change in plant moisture content from first to second harvest (Figure 7). The calculated, mean, moisture content differences of the Sudangrass are 3.15 and 3.98% greater in the first growth than in the second growth for the fallowed and cropped treatments, respectively. Higher moisture content and higher plant nitrogen content during the first growth may be manifestations of plant succulence, associated with juvenile growth. Plant parameter differences between harvests may, but not always, reflect changes in soil fertility as nutrients are removed by cropping or soil equilibrium is changed over a period of time. Under cropping conditions, soil fertility levels often change, usually decreasing as the season progresses

and nutrients are utilized or removed from the root zone. All plant parameters reported except plant phosphorus content, for either cropping pattern, are significantly different by harvest, probably indicating some change in soil fertility status. However, statistical treatment does not reveal the nature of the difference; that is, whether a parameter increases or decreases from first to second harvest. Figures 5 through 11 illustrate that differences by harvest may be better related by cropping pattern. Therefore, analysis of the nature of the plant parameter differences by harvest may be more relevant if presented according to cropping pattern; that is, fallowed versus cropped

Fallowed Section. The upper histograms of Figures 5 through 11 show the parameter trends by harvest for the fallowed section. One may expect yield, plant nitrogen content and total uptake parameter values of the first harvest to be similar to or greater than those of the second harvest in response to the more immediate effect of the preplant nitrogen application and the slower nutrient contribution effects as organic matter decomposes. Only plant nitrogen content follows this pattern, probably indicating declining soil nitrogen availability as the cropping season progresses. The yield and total uptake parameters do not support the expected nitrogen-fertilization growth response, greater yield and consequent greater nitrogen and phosphorus uptake, by the first growth. The yield and total uptake parameters (the upper graphs of Figures 5, 6, 9 and 11) increase significantly during the second growth indicating either a rather sudden increase in soil fertility during the second growth or plant growth

inhibition by a transient soil factor during the first growth. A sudden increase in soil fertility levels seems unlikely since no fertilizers or amendments were applied between harvests, nor were any cultural practices changed. If the second-harvest data may be considered a truer representation of soil fertility or potential yield and total uptake values for a soil under Southwestern, irrigated, production practices than the first-harvest data; then, some soil factor is suppressing these data parameters in the first harvest.

The most likely soil factor that seems to fit the data may be salinity effects due to salt accumulation. The overall effects of high salinity are germination reduction and growth inhibition. When salts are added to soil as a constituent of manure, one expects salt accumulation and salinity effects to increase in proportion to manuring rate. If the second-harvest data may be assumed to be an accurate indication of yield potential, the detrimental salinity effects apparently offset the expected beneficial effects of manuring; that is, higher yields in the first harvest. In fallowed lands soluble salts do not tend to move downward without precipitation or irrigation. Under high evaporation conditions of arid climates, salts tend to concentrate near the soil surface. The cultural practice of "bedding up" for furrow irrigation further accentuates salt accumulation near the soil surface of the beds. With proper irrigation management, salinity effects are transient and diminish as salts leach downward with irrigation and crop roots grow out of the surface salt accumulation zone.

Of the two harvests, the second-harvest data seems to be the better indicator of soil fertility status under crop production

conditions for the fallowed cropping pattern. By the second harvest, the data shows minimal, if any, growth-inhibiting of yield-depressing effects of salt accumulation. Also, the nitrogen fertilization prior to seeding does not appear to exert any discernable influence upon yield or total uptake data during the second growth.

Cropped Section. Statistically significant differences exist between harvests of the cropped section for all plant parameters. The lower histograms of Figures 5, 6, 8, 9 and 11 show that the differences between harvests for yield, plant nitrogen content and total uptake parameters result from decreased parameter levels of the second harvest. After two years of double-cropping without fertilization other than manuring, one anticipates low soil nitrogen fertility due to crop removal, leaching and denitrification, especially for the lower manure loading rates, which may be depleted sooner. The data trends support the prediction that the 100 lbs NH_4NO_3 per plot application prior to planting would produce a greater growth response, as evidenced by significantly higher yield and total uptake parameter values in the first growth than in the second growth. Although plant phosphorus content (lower graph, Figure 10) appears higher in the second harvest, the difference between harvests for this parameter is not statistically significant. Irregardless, the crop appears to be well enough supplied with phosphorus to satisfy crop demand and maintain plant nutritional balances.

By the time of the second sampling, nitrogen fertilization effects are not discernible. Indeed, of the two harvests, the

second-harvest, cropped-section date seems to be a truer indication of soil fertility status for a soil under crop production.

Analysis by Cropping Pattern. In this section a comparison of the fallowed-section plant parameters to the cropped-section plant parameters may elucidate the effects of cropping pattern, either double-cropped or fallowed for two years, upon soil fertility status. The previous discussion suggests that, for both fallowed and cropped sections, the first-harvest data may not be as representative as the second-harvest data for soil fertility evaluation under production conditions. During the first growth, the fallowed-section parameters appear to be influenced by salt accumulation effects. Nitrogen fertilization effects or higher nitrogen fertility undoubtedly influence first-growth parameters of both cropping patterns. Furthermore, there are more significant correlations between the various plant parameters of the second harvest than of the first harvest. Positive correlations at the 95% confidence level include field-green with dry weight yields, dry weight yield with total nitrogen uptake, plant nitrogen content with total nitrogen uptake, plant phosphorus content with total phosphorus uptake and total nitrogen uptake with total phosphorus uptake. The correlations seem to indicate that the trends of the various plant parameter data of both cropping patterns are more similar in the second harvest, as may be apparent from the lower graphs of Figures 12 through 18. If so, the correlations support the proposition that, of the two harvests, the second harvest data for both fallowed and cropped treatments may be the better indicator of soil fertility status of a soil under irrigated agricultural production. Ergo, the comparison of fallowed section to

cropped section to determine the effects of cropping pattern upon soil fertility status after two years principally utilizes the second-harvest data.

Analysis of variance of the second-harvest data estimates significant differences between fallowed and cropped sections for all plant parameters. The lower graphs of Figures 12, 13, 15 and 16 show that the cropped-section field-green and dry weight yields, plant nitrogen content and total nitrogen uptake values are lower over all rates than the corresponding fallowed-section values. That the cropped-section plant nitrogen content and total nitrogen uptake are lower over all rates seems to indicate less soil nitrogen availability in the cropped section. The mean moisture content (Figure 14) of the cropped-section Sudangrass is 3.35% lower than that of the fallowed-section, which may reflect lower cropped-section plant nitrogen content and succulence. Since areation and cultivation strongly influence the rate of organic matter biodegradation and subsequent oxidation of organic nitrogen forms to plant-available inorganic forms, one may expect more inorganic nitrogen to have been released from the organic matter during two years of cultivated double-cropping than during two years of non-cultivated, non-irrigated fallowing. Furthermore, if a crop cannot utilize all of the plant-available nitrate released from the organic matter degradation, this inorganic form of nitrogen is susceptible to leaching, denitrification and volatilization losses. Therefore, even if most of the crop-removed nitrogen is reincorporated into the soil, leached or volatilized nitrogen may account for apparent lower cropped-section soil nitrogen availability. Soil nitrogen depletion seems to be more

apparent for the lower manure loading rates. Plant phosphorus content, on the other hand, is generally higher over all rates in both harvests (Figure 17) for the cropped section than for the fallowed section, even though soil CO_2-soluble phosphorus levels are lower over all rates for the cropped section. The soil CO_2-soluble phosphorus content data of soil sampled after the previous crop does not include nor reflect the crop residue phosphorus content that may become available from subsequent crop residue biodegradation. Another explanation for higher plant phosphorus levels and possibly higher soil phosphorus availability for the cropped section may be better cropped-section tilth resulting from higher organic matter content over all rates. Better tilth usually promotes more extensive root development, which is important in plant acquisition of relatively immobile nutrients such as phosphorus. Finally, higher cropped-section plant phosphorus content may result from a better developed root system than the no doubt salinity inhibited or stunted fallowed section root system, as evidenced by the fact that the fallowed section is better supplied with the mobile nutrient, nitrogen, while being less well supplied with the immobile nutrient, phosphorus, than the cropped section. The probability that all of these effects exert a combined influence upon plant phosphorus content and soil phosphorus availability seems most likely. Therefore, although the plant phosphorus content data may be statistically different by cropping pattern, the differences may not be significantly important to the crop with respect to yield and total phosphorus uptake, especially if one considers that the maximum range of the differences by cropping pattern is only 0.07%. That the total phosphorus uptake is significantly

different between fallowed and cropped section is difficult to discern (lower histogram, Figure 18). Moreover, simultaneous comparison of the first-harvest cropped data and the second-harvest data for both fallowed and cropped sections affords the impression that the total phosphorus uptake levels and trends are fairly analagous for all three sets of data.

The lower cropped-section field-green and dry weight yield data, as a function of overall soil fertility status, indicates lower soil fertility for the cropped section than for the fallowed section at any given loading rate. Lower cropped-section yields may indicate that, despite statistical differences by cropping pattern, in plant phosphorus content by cropping pattern, while total phosphorus uptake levels and trends seem similar for both cropping patterns, soil phosphorus availability is sufficient for higher cropped-section yields than achieved and is not the cropped-section, yield-limiting, fertility factor. If total phosphorus uptake levels and trends are assumed to be analagous for both cropping patterns, the obviously lower cropped-section total nitrogen uptake and yield levels over all rates, as well as the strong positive correlations between total nitrogen uptake and yield trends, seem to indicate that the lower cropped-section yields are primarily a result of correspondingly lower soil nitrogen availability and fertility. Two years of cultivated, double-cropping could certainly affect a soil nitrogen fertility reduction of this nature.

The long-term fertility benefit of manuring may become apparent by comparing the fallowed-section, non-manured, control-rate yield and total nitrogen uptake levels with the corresponding parameter levels of the cropped-section manuring rates at or above 180 mt/ha. Even after

double-cropping for two years, the cropped-section rates near or above 180 mt/ha still maintain soil fertility to produce yields at about the same levels as the non-manured, fallowed plots, which represent the native soil fertility level.

Conclusions

1. All manure loading rates may pose a potential salinity hazard.
2. Manure loading rates up to about 180 mt/ha appear to increase soil fertility benefit or crop yields for both cropping patterns.
3. Manuring rates of or in excess of 180 mt/ha maintain soil fertility status near or above native soil fertility levels, even after two years of double-cropping.
4. After two years of double-cropping, soil fertility status is generally lower over all rates than after two years of fallowing.
5. Specifically, after two years of double-cropping, lower or depleted soil nitrogen fertility status seems to be the principle yield-limiting fertility factor, while soil phosphorus fertility status seems sufficient for both cropping patterns.

CHAPTER 3

RESEARCH APPLICATION

Economics essentially governs modern commercial agricultural production. Commercial farm management seeks to maximize economic profit by increasing yields while simultaneously minimizing production costs. Fertilization economics demands that fertilizers be chosen and applied on a minimal cost per unit nutrient or yield benefit basis since maximum profit is obtained when the added yield return just equals the cost of the last increment of fertilizer. Manure bulkiness, variability in moisture and nutrient content, generally low nutrient analysis and unbalanced nutrient levels result in comparatively high labor and handling costs per unit fertilizer benefit, reducing its competitive economic value. Recent farm budgeting information (Hathorn and Cluff 1978) for commercial agricultural production in southeastern Arizona illustrates the economic noncompetitiveness of manure as commercial fertilizer. The budget data enables direct cost comparison of steer manure versus inorganic fertilizer for the cropping system used in this research prior to the soil fertility evaluation.

The soil fertility analysis indicates that the 180 mt/ha steer manure loading rate may provide optimal long-term fertility benefit for two years of small grain double-cropping (two crops of grain sorghum and two crops of barley). Based on Hathorn and Cluff's 1978 budget data, the cost for the 180 mt/ha manure fertilization is about $830/ha, while

the combined cost of inorganic fertilizer fertilization for two crops of grain sorghum and two crops of barley is about $260/ha. Commercial farm management simply cannot justify more than tripling fertilization input cost by using manure instead of inorganic fertilizer, particularly when operating under present-day, marginal, economic profit conditions. Furthermore, potential hazards and management problems make manuring even less attractive to commercial agriculture.

By the same token, economics create a considerable waste disposal problem for commercial feedlot management. However, manure disposal and recycling as fertilizer in a cropping system on adjacent acreage may be more economically attractive to feedlot management than to commercial farm management. Manure utilization in this manner serves two purposes simultaneously--manure disposal and soil fertilization for maximum yield production of crops which can be used for animal consumption. The key factor is the transportation distance from the feedlot to the utilization site. If feedlot management allots acreage adjacent to the feedlot for manure recycling in a cropping system, transportation and spreading costs may be minimal while fertility benefits may be optimal.

Soil and cropping system management technology is available to deal with potential hazards that may arise from steer manure loading rates as high as 180 mt/ha. Under irrigated agricultural production, thorough manure incorporation into the soil, flat-bed planting, a heavy pre-plant irrigation and tolerant crop selection are management practices that may substantially reduce potential seed germination or seedling damage and losses due to salinity, ammonia, lithium, boron or

other micronutrient toxicities. Under dry-land agricultural production, however, such high steer manure loading rates may not be advisable since the quantity and timing of precipitation required to leach the potentially hazardous manure constituents are not predictable.

Finally, crops may accumulate nitrate when grown on soils containing nitrogen in excess of plant nutritional requirements, as may be the case with heavily manured soils. Although nitrate accumulation may not be injurious to the crop, high levels of plant tissue nitrate may cause nitrate poisoning when fed to livestock (Bradley, Eppson, and Beath 1940, and Davison 1966). Even though toxicity levels of plant material nitrate content resulting from high manuring rates are included in the literature, there is little agreement upon specific toxicity values, which seem to vary with animal species. Limiting soil sulfur supply may accentuate nitrate accumulation in plant tissues (Odelien 1963). Odelien (1963) concludes that the danger of animal nitrate poisoning may be minimized if the percent total nitrogen to percent total sulfur ratio (N:S) in the plant material is maintained between 10:1 and 20:1 by adequate sulfur fertilization. Another alternative for reducing the animal nitrate poisoning potential of feeds produced on heavily manured soils is dilution with other feeds that do not contain potentially toxic levels of nitrate.

APPENDIX A

SOIL PARAMETER DATA

Table A-1. Total organic carbon content of the surface 30 cm of clay loam after receiving steer manure at various loading rates and fallowing or double cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		C--%			
		Fallowed			
0	0.56	0.57	0.40	0.44	0.49
44.8	0.56	0.61	0.55	0.51	0.56
134.4	0.74	0.83	0.75	0.78	0.78
178.2	0.80	0.86	0.86	0.93	0.86
224.0	0.98	0.93	0.96	0.96	0.96
448.0	1.27	1.51	1.60	1.44	1.46
		Cropped			
0	0.66	0.56	0.51	0.57	0.58
44.8	0.76	0.77	0.65	0.79	0.74
134.4	0.92	0.84	0.85	0.91	0.88
178.2	0.93	1.00	1.07	1.00	1.00
224.0	1.08	1.10	1.16	1.06	1.10
448.0	1.56	1.56	1.50	1.42	1.51

Table A-2. Soil CO_2-soluble phosphorus content of the surface 30 cm of clay loam after receiving steer manure at various loading rates and fallowing or double cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
			P--ppm		
			Fallowed		
0	1.00	0.85	1.63	1.18	1.17
44.8	4.50	10.98	2.95	0.90	4.83
134.4	13.18	13.50	10.75	15.63	13.27
178.2	20.88	22.50	24.50	20.33	22.05
224.0	25.25	28.75	29.25	31.50	28.69
448.0	50.50	46.50	33.50	40.38	42.72
			Cropped		
0	0.93	0.50	0.95	--	0.79
44.8	5.00	3.00	6.00	3.20	4.30
134.4	9.75	5.83	7.88	6.00	7.37
178.2	13.00	14.83	19.70	16.75	16.07
224.0	20.13	23.25	25.25	19.88	22.13
448.0	41.00	49.63	36.88	40.13	41.91

APPENDIX B

PLANT PARAMETER DATA

Table B-1. Field-green weights of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		g/m^2			
		Sampled 8/2/1976			
0	1820	1970	--	1750	1847
44.8	2255	1680	1645	2070	1913
134.4	1550	1745	2390	2300	1996
178.2	2195	1840	2050	2500	2146
224.0	1875	2200	2140	2590	2201
448.0	2300	2525	2560	2570	2489
		Sampled 9/14/1976			
0	2460	2050	2620	2100	2308
44.8	2770	2510	2070	2430	2445
134.4	3110	2060	3260	3240	2918
178.2	4930	3190	3510	2900	3633
224.0	4115	3410	3780	3490	3699
448.0	4470	3955	3800	3685	3978

Table B-2. Field-green weights of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		g/m^2			
		Sampled 8/2/1976			
0	1490	1770	1808	1720	1697
44.8	1980	1770	1935	1860	1886
134.4	2520	1850	2675	2300	2336
178.2	2640	2510	2450	2670	2568
224.0	2800	3050	3200	3070	3030
448.0	2390	3290	2575	2430	2671
		Sampled 9/14/1976			
0	1300	590	740	680	828
44.8	1440	810	1330	940	1130
134.4	1770	1780	1400	--	1650
178.2	2470	1990	2850	1630	2235
224.0	2675	2330	2980	2380	2591
448.0	2330	2345	2700	2940	2579

Table B-3. Dry weights of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		g/m^2			
		Sampled 8/2/1976			
0	176	183	252	266	218
44.8	210	204	188	296	225
134.4	174	194	181	242	223
178.2	228	168	201	240	209
224.0	208	222	271	284	246
448.0	223	287	185	310	251
		Sampled 9/14/1976			
0	349	243	395	299	322
44.8	351	340	313	363	342
134.4	398	321	445	451	404
178.2	631	443	463	534	518
224.0	624	474	468	490	514
448.0	578	558	509	410	514

Table B-4. Dry weights of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		g/m^2			
		Sampled 8/2/1976			
0	241	269	208	237	239
44.8	281	240	349	256	282
134.4	368	272	320	326	322
178.2	387	316	245	362	328
224.0	313	401	343	428	371
448.0	315	404	312	288	330
		Sampled 9/14/1976			
0	180	136	174	212	176
44.8	267	188	227	241	231
134.4	319	261	246	229	264
178.2	288	198	420	362	317
224.0	370	367	443	251	358
448.0	415	280	350	414	365

Table B-5. Moisture content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		H_2O--%			
		Sampled 8/2/1976			
0	90.32	90.71	--	84.80	88.61
44.8	90.69	87.86	88.57	85.70	88.21
134.4	88.72	88.88	92.43	89.48	89.89
178.2	89.61	90.87	90.19	90.40	90.27
224.0	88.91	89.91	87.34	89.03	88.80
448.0	90.30	88.63	92.77	87.94	89.91
		Sampled 9/14/1976			
0	85.81	88.15	84.89	85.76	86.15
44.8	87.33	86.45	84.88	85.06	85.93
134.4	87.20	84.42	86.35	86.08	86.01
178.2	87.20	86.11	86.81	81.59	85.43
224.0	84.84	86.10	87.62	85.96	86.13
448.0	87.07	85.89	86.61	88.87	87.11

Table B-6. Moisture content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		H_2O--%			
		Sampled 8/2/1976			
0	83.82	84.80	88.50	86.22	85.84
44.8	85.81	86.44	81.96	86.24	85.11
134.4	85.40	85.30	88.04	85.83	86.14
178.2	85.34	87.41	90.00	87.72	87.62
224.0	88.82	86.85	89.28	87.92	88.23
448.0	86.82	87.72	87.88	88.15	87.64
		Sampled 9/14/1976			
0	86.15	76.95	76.49	68.82	77.10
44.8	81.46	76.79	82.93	74.36	78.89
134.4	81.98	85.34	82.43	--	83.25
178.2	88.34	90.05	85.26	77.79	85.36
224.0	86.17	84.25	85.13	89.45	86.25
448.0	82.19	88.06	87.04	85.92	85.80

Table B-7. Nitrogen content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		N--%			
		Sampled 8/2/1976			
0	1.82	1.31	1.82	1.80	1.69
44.8	2.09	2.10	1.34	1.81	1.84
134.4	1.84	2.20	2.08	1.98	2.02
178.2	2.35	2.23	1.92	2.03	2.13
224.0	2.32	1.90	2.01	1.95	2.05
448.0	2.31	1.88	2.13	1.91	2.06
		Sampled 9/14/1976			
0	1.43	1.53	1.39	1.23	1.39
44.8	1.49	1.46	1.30	1.34	1.40
134.4	1.56	1.48	1.37	1.27	1.42
178.2	--	1.36	1.53	1.33	1.41
224.0	1.41	1.45	1.49	1.47	1.46
448.0	1.59	1.50	1.39	1.62	1.58

Table B-8. Nitrogen content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		N--%			
		Sampled 8/2/1976			
0	1.45	0.99	1.23	1.39	1.27
44.8	1.29	1.29	1.13	1.29	1.25
134.4	1.20	1.20	1.33	0.96	1.17
178.2	1.35	1.19	1.34	1.23	1.28
224.0	1.13	1.55	1.38	1.34	1.35
448.0	1.75	1.73	1.71	1.50	1.67
		Sampled 9/14/1976			
0	1.26	0.92	0.87	0.76	0.95
44.8	1.16	0.99	1.14	1.10	1.10
134.4	1.28	1.07	1.13	1.20	1.17
178.2	1.33	1.42	1.34	1.39	1.37
224.0	1.61	1.34	1.44	1.45	1.46
448.0	1.66	1.57	1.51	1.49	1.56

Table B-9. Total nitrogen uptake per square meter of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		gN/m^2			
		Sampled 8/2/1976			
0	3.19	2.39	4.59	4.79	3.74
44.8	4.38	4.28	2.52	5.38	4.14
134.4	3.20	4.26	5.84	4.79	4.52
178.2	5.35	3.74	3.87	4.87	4.46
224.0	4.82	4.24	5.46	5.52	5.01
448.0	5.15	5.40	3.94	5.92	5.10
		Sampled 9/14/1976			
0	4.97	3.72	4.83	3.66	4.30
44.8	5.23	4.98	4.06	4.88	4.79
134.4	6.22	4.75	6.11	5.73	5.70
178.2	--	6.01	7.11	7.10	6.74
224.0	8.79	6.88	6.97	7.21	7.46
448.0	9.21	8.40	7.06	6.63	7.83

Table B-10. Total nitrogen uptake per square meter of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		gN/m^2			
		Sampled 8/2/1976			
0	3.51	2.67	2.57	3.29	3.01
44.8	3.62	3.11	3.92	3.30	3.49
134.4	4.41	3.26	4.27	3.14	3.77
178.2	5.21	3.78	3.28	4.44	4.18
224.0	3.53	6.20	4.74	5.75	5.06
448.0	5.51	7.01	5.34	4.32	5.55
		Sampled 9/14/1976			
0	2.26	1.25	1.52	1.61	1.66
44.8	3.09	1.86	2.58	2.65	2.55
134.4	4.10	2.78	2.79	2.75	3.11
178.2	3.84	2.81	5.61	5.04	4.33
224.0	5.97	4.92	6.36	3.64	5.22
448.0	6.88	4.40	5.30	6.16	5.69

Table B-11. Phosphorus content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		P--%			
		Sampled 8/2/1976			
0	0.08	0.09	0.10	0.08	0.09
44.8	0.07	0.08	0.07	0.08	0.08
134.4	0.07	0.08	0.08	0.07	0.08
178.2	0.08	0.08	0.08	0.09	0.08
224.0	0.08	0.09	0.09	0.09	0.09
448.0	0.10	0.09	0.09	0.09	0.09
		Sampled 9/14/1976			
0	0.08	0.09	0.08	0.07	0.08
44.8	0.10	0.07	0.10	0.09	0.09
134.4	0.08	0.10	0.07	0.08	0.08
178.2	--	0.07	0.07	0.08	0.07
224.0	0.08	0.09	0.08	0.07	0.08
448.0	0.11	0.08	0.07	0.09	0.09

Table B-12. Phosphorus content of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		P--%			
		Sampled 8/2/1976			
0	0.09	0.09	0.10	0.07	0.09
44.8	0.08	0.10	0.90	0.12	0.10
134.4	0.12	0.09	0.14	0.12	0.12
178.2	0.11	0.09	0.15	0.14	0.12
224.0	0.10	0.11	0.12	0.12	0.11
448.0	0.13	0.11	0.13	0.14	0.13
		Sampled 9/14/1976			
0	0.10	0.10	0.10	0.10	0.10
44.8	0.12	0.12	0.13	0.12	0.12
134.4	0.13	0.14	0.15	0.12	0.13
178.2	0.12	0.18	0.12	0.11	0.14
224.0	0.13	0.12	0.12	0.12	0.12
448.0	0.09	0.11	0.13	0.11	0.11

Table B-13. Total phosphorus uptake per square meter of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and fallowing for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		gP/m^2			
		Sampled 8/2/1976			
0	0.14	0.16	0.26	0.21	0.19
44.8	0.15	0.16	0.14	0.24	0.17
134.4	0.12	0.15	0.23	0.16	0.17
178.2	0.19	0.14	0.16	0.20	0.17
224.0	0.18	0.20	0.23	0.24	0.21
448.0	0.22	0.26	0.17	0.28	0.23
		Sampled 9/14/1976			
0	0.27	0.22	0.32	0.22	0.26
44.8	0.37	0.23	0.33	0.33	0.31
134.4	0.30	0.31	0.32	0.39	0.33
178.2	--	0.31	0.34	0.41	0.35
224.0	0.48	0.43	0.40	0.33	0.41
448.0	0.61	0.44	0.37	0.39	0.45

Table B-14. Total phosphorus uptake per square meter of two samplings of Sudangrass grown on clay loam after receiving steer manure at various loading rates and double-cropping for two years

Steer Manure Loading Rate mt/ha	Replications I	II	III	IV	Mean
		g P/m^2			
		Sampled 8/2/1976			
0	0.23	0.24	0.22	0.17	0.21
44.8	0.23	0.23	0.31	0.32	0.28
134.4	0.44	0.25	0.45	0.38	0.38
178.2	0.44	0.27	0.37	0.50	0.40
224.0	0.32	0.44	0.40	0.50	0.42
448.0	0.40	0.45	0.40	0.42	0.42
		Sampled 9/14/1976			
0	0.17	0.13	0.17	0.21	0.17
44.8	0.32	0.22	0.29	0.29	0.28
134.4	0.27	0.36	0.38	0.26	0.32
178.2	0.34	0.37	0.52	0.41	0.41
224.0	0.47	0.46	0.54	0.31	0.44
448.0	0.36	0.31	0.44	0.45	0.39

REFERENCES

Adriano, D. C., A. C. Chang, P. F. Pratt, and R. Sharpless, 1973. Effect of soil application of dairy manure on germination and emergence of some selected crops. J. Environ. Qual. 2:396-399.

Adriano, D. C., P. F. Pratt, and S. E. Bishop, 1971. Nitrate and salt in soils and ground waters from land disposal of dairy manure. Soil Sci. Soc. Amer. Proc. 35:759-762.

Amoozegar-Fard, A., W. H. Fuller, and A. W. Warrick, 1975. Migration of salt from feedlot waste as affected by moisture regime and aggregate size. J. of Environ. Qual. 4:468-472.

Animal Science Research Division, 1971. Animal waste reuse--infinitive value and potential problems from feed additives: A review. USDA-ARS, Pub. No. 44-224.

Artiola-Fortuny, J., 1976. Methods for total metal determination on organic residues containing soil material. Master's Thesis, University of Arizona.

Black, C. A. (Chief Editor), 1965. Methods of soil analysis. Agronomy, No. 9, Part 2. Madison, Wis.: Am. Soc. of Agronomy, Inc., p. 957.

Bradley, W. B., H. Eppson, and A. O. Beath, 1940. Livestock poisoning by oat, hay and other plants containing nitrate. Wyoming Agr. Exp. Sta. Bull. 241.

Cross, O. E., A. P. Mazurak, I. L. Chesnin, 1973. Animal waste utilization for pollution abatement. Am. Soc. Agric. Eng., Trans. 16: 160-163.

Dale, A. C., 1971. Status of dairy cattle waste treatment and management research. pp. 85-96. In Animal Waste Management, Proc. of Nat. Symp. on Animal Waste Management (Lib. Congr. Catalog No. 70-188504). Warenton, Virginia: The Airlie House.

Davison, K. L., 1966. Sublethal nitrate poisoning--is it really a problem? Feed Age, March.

Fuller, W. H. (Ed.), 1976. Residual Management by Land Disposal. Proc. of the Hazardous Waste Research Symposium, Feb. 2-4, 1976, Tucson, Ariz. EPH-600/9-76-015, U. S. Environmental Protection Agency, Cincinnati, Ohio.

Fuller, W. H., 1977. Professor of Soil and Water Science, University of Arizona, personal communication. (Information based on data from unpublished reports W-124 for 1974, 1975, 1976.)

Gilham, R. W. and L. R. Webber, 1968. Nitrogen contamination of ground water by barnyard leachates. Journal of Water Pollution Control Federation, 41:M52-1762.

Hathorn, Scott Jr. and Ron Cluff, 1978. Arizona Field Crop Budgets--Graham County. Tucson, Arizona: Cooperative Extension Service, University of Arizona.

Kitson, R. E. and M. G. Mellon, 1944. Colorimetric determination of phosphorus as molybdovanadophosphoric acid. Ind. Eng. Chem., Anal. Ed. 16:379-383.

Loehr, R. C., 1968. Pollution implications of animal waste--a forward oriented review. U. S. Dept. Int., Federal Water Pollution Control Adm. Ada, Okla.: Robert S. Kerr Water Research Center.

McCalla, T. M., J. R. Ellis, C. B. Gilbertson, and W. R. Woods, 1972. Chemical studies of solids, runoff, soil profile and ground water from beef cattle feedlots at Mead, Nebraska. In Waste Manage. Research, Proc. of 1972 Cornell Agr. Waste Manage. Conf., 211-223.

McGeorge, W. T., T. F. Beuhrer, and J. F. Breazeale, 1935. Phosphate Availability in Calcareous Soils: A function of Carbon Dioxide and pH. J. Amer. Soc. Agron. 27:330-335.

Meek, B. D., L. Chesnin, W. H. Fuller, R. Miller, and D. Turner, 1975. Guidelines for manure use and disposal in the western region, U.S.A. Washington State Univ. Agr. Res. Cent. Bul. 814.

Meek, B. D., A. J. MacKenzie, T. J. Donovan, and W. F. Spencer, 1974. The effect of large applications of manure on movement of nitrate and carbon in an irrigated desert soil. J. Environ. Qual. 3:253-258.

Miner, J. R. and T. L. Willrich, 1970. Livestock operations and field spread manure as sources of pollutants. In Agricultural Practices and Water Quality. Ames, Iowa: Iowa State Univ. Press, 231-240.

Murphy, L. S., G. W. Wallingford, W. L. Powers, and H. L. Marges, 1972. Effects of soild beef feedlot wastes on soil conditions and plant growth. Proc. 1972 Cornell Agr. Waste Manage. Conf. 449-464.

Odelien, M., 1963. The effect of sulfur supply on the quality of plant products. Tidskr. Norske Land bruk., 70:35, Translated by J. Platou, The sulfur Institute.

Pereira, O. J., 1971. Mapping and characterization of the soils on the University of Arizona Experimental Farm at Marana. Master's Thesis, University of Arizona.

Peterson, J. R., T. M. McCalla, and G. E. Smith, 1971. Human and animal wastes as fertilizers. In R. A. Olson (Ed.), Fertilizer Technology and Use, 2nd edition, 557-596. Madison, Wis.: Soil Sci. Soc. Am.

Post, D. F., D. M. Hendricks, and O. J. Pereira, 1978. Soils of the University of Arizona Experiment Station: Marana. In cooperation with the Soil Conservation Service, USDA, Washington, D. C.

Stewart, B. A., F. G. Viets, Jr., G. L. Hutchinson, W. D. Kemper, F. E. Clark, M. L. Fairborn, and F. Strauch, 1967. Distribution of nitrates and other water pollutants under fields and corrals in the middle-south Platte Valley of Colorado. USDA-ARS, Bull. 41-134.

Stubblefield, T. M. and A. H. Smith, 1964. A survey of the production and marketing of cattle manure in Arizona. The Univ. of Ariz. Agr. Expt. Sta. and Coop. Ext. Serv. Bul. A-36.

Taiganedes, E. P., 1964. Disposal of animal waste. Paper No. 64-416. Presented at The 1964 Annual Meeting of the Amer. Soc. of Agric. Engineers.

Watanabe, F. S. and S. R. Olsen, 1965. Test of an ascorbic acid method for determining phosphorus in water and $NaltCO_3$ extracts from soil. Soil Sci. Soc. of Amer. 29:677-678.