OPTIMUM SPACING OF PRE-PLANT BANDS OF N AND P FERTILIZER FOR WINTER WHEAT

by

THOMAS MARK MAXWELL

B.S., Kansas State University, 1978

A MASTER'S THESIS

submitted in partial fulfillment of the

requirement for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Approved by:

David E. Kissel

Major Professor

TABLE OF CONTENTS

Page

LIST OF FIGURES i

LIST OF TABLES ii

ACKNOWLEDGEMENTS iii

INTRODUCTION 1

LITERATURE REVIEW 3

- Introduction 3
- Placement of Fertilizer Phosphorus 4
- Effect of Nitrogen on P Uptake 10
- Polyphosphate as a P Source 18

MATERIALS AND METHODS 22

- Field Studies 22
  - Fertilizer Application Equipment 27
  - Leaf Tissue Sampling 32
  - Grain Head Sampling 36
  - Harvesting of Plots 37
- Greenhouse Studies 37
- Laboratory Analyses 42
  - Leaf Tissue 42
  - Grain Analysis 43
  - Assay of Radioactivity 44
- Statistical Analysis Procedures 45

RESULTS AND DISCUSSION 46

- Field Studies 46
  - 1979 Field Study Results 46
  - Leaf Tissue Sampling (1979 Studies) 51
  - Grain Head Sampling (Dickinson Co., 1979) 61
  - 1980 Field Study Results 61
  - Leaf Tissue Sampling (Labette Co., 1980) 76
  - Grain Head Sampling (Labette Co., 1980) 83
- Greenhouse Studies 96

SUMMARY AND CONCLUSIONS 117

LITERATURE CITED 120

VITA 124

APPENDIX 125

LIST OF FIGURES

Figure		Page
1.	Locations of 1979 and 1980 field studies	24
2.	Shank applicator used for 1979 and 1980 field studies	29
3.	Close up of ammonia shank used for dual knife N-P applications	31
4.	Diagram of leaf tissue and grain head sample position and sequence	35
5.	Diagram of ^{32}P Greenhouse Study treatments . . .	41
6.	Visual responses to knife spacing and P-rate on winter wheat (Dickinson Co., 1979)	48
7.	Visual responses to knife spacing and P-rate on winter wheat (Labette Co., 1980)	68
8.	Grain yield as affected by head number per sample (Labette Co., 1980)	93
9.	Visual appearance of winter wheat seedlings grown in mediums with different phosphorus levels (Greenhouse Study, 1980)	99
10.	Effect of phosphorus level on dry matter production by winter wheat seedlings (Greenhouse Study, 1980)	101
11.	Effect of phosphorus level on %P in the leaf tissue of winter wheat seedlings (Greenhouse Study, 1980)	103
12.	Effect of phosphorus level on P uptake by winter wheat seedlings (Greenhouse Study, 1980)	105
13.	Visual appearance of winter wheat seedlings grown at variable lateral distances from a pre-plant band of N and P (^{32}P Greenhouse Study, 1980)	112
14.	Effect of distance from row to fertilizer band on %P from fertilizer phosphorus in the leaf tissue of winter wheat seedlings (^{32}P Greenhouse Study, 1980)	115

LIST OF TABLES

Table		Page
1.	Soil test levels and general site information .	25
2.	Fertilizer application date, seeding rate and date, cultivar selection, tissue sampling date and grain harvest date information	26
3.	Effects of knife spacing and P-rate on winter wheat grain yield and grain composition (Dickinson Co., 1979)	50
4.	Effects of knife spacing and P-rate on winter wheat grain yield and grain composition (Osage Co., 1979)	52
5.	Effects of knife spacing and P-rate on winter wheat grain yield and grain composition (Riley Co., 1979)	53
6.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Dickinson Co., 1979)	54
7.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Osage Co., 1979)	57
8.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Riley Co., 1979)	59
9.	Effects of knife spacing and P-rate on winter wheat grain head number and grain composition at variable distances from a pre-plant band (Dickinson Co., 1979)	62
10.	Effects of knife spacing and P-rate on winter wheat grain yield and grain composition (Labette Co., 1980)	69
11.	Effects of knife spacing and P-rate on winter wheat grain yield, tissue composition, and grain composition (Harper Co., 1980)	71
12.	Effects of knife spacing and P-rate on winter wheat grain yield, tissue composition, and grain composition (Dickinson Co., 1980)	74
13.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition and dry matter production (Labette Co., 1980)	77
14.	Correlation of %N, %P, and dry matter of leaf tissue as affected by P-rate on samples centered between bands and centered over bands taken at the early sampling date (Labette Co., 1980)	84

LIST OF TABLES (Continued)

Table		Page
15.	Effects of knife spacing and P-rate on winter wheat grain heads/.127m, grain yield and grain composition (Labette Co., 1980)	86
16.	Correlation of sample grain yields with N uptake, P uptake, and dry matter of leaf tissue on samples centered between bands and centered over bands taken at the early sampling date (Labette Co., 1980)	95
17.	Effect of phosphorus level on N and P content, N and P uptake, and dry matter production by winter wheat seedlings (Greenhouse Study, 1980).	97
18.	Dry matter and N and P content of winter wheat seedlings grown on P deficient sand at 7 and 14 days after planting (Greenhouse Study,1980).	107
19.	Effect of distance from row to fertilizer band on P uptake and dry matter production of winter wheat seedlings (^{32}P Greenhouse Study, 1980)	109
I.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Dickinson Co., 1979)	126
II.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Osage Co., 1979)	132
III.	Effects of knife spacing and P-rate on winter wheat leaf tissue composition at variable distances from a pre-plant band (Riley Co., 1979)	138
IV.	Effects of knife spacing and P-rate on winter wheat grain head number and grain composition at variable distances from a pre-plant band (Dickinson Co., 1979)	144

THIS BOOK CONTAINS NUMEROUS PAGES THAT WERE BOUND WITHOUT PAGE NUMBERS.

THIS IS AS RECEIVED FROM CUSTOMER.

THIS BOOK CONTAINS NUMEROUS PAGES WITH THE ORIGINAL PRINTING BEING SKEWED DIFFERENTLY FROM THE TOP OF THE PAGE TO THE BOTTOM.

THIS IS AS RECEIVED FROM THE CUSTOMER.

ACKNOWLEDGEMENTS

Sincere appreciation is expressed to Dr. David Kissel, major professor, for his advice and counseling during the course of this study. Thanks are also extended to other members of the advisory committee, Dr. David Whitney and Dr. Roscoe Ellis, Jr. for their help throughout the graduate study program.

Appreciation is also expressed to the Tennessee Valley Authority - National Fertilizer Development Center - Test and Demonstration Branch, Farmland Industries, Inc., and Phillips Petroleum Company for providing the financial assistance needed for this research.

The author wishes to express appreciation to his fellow graduate students and laboratory technicians for their assistance with the plot work and chemical analysis.

Special thanks are extended to the author's wife, Jane, for her sacrifices, encouragement, and understanding during the course of this study. Gratitude is also expressed to the parents, Mr. and Mrs. Roscoe W. Wall and Mr. and Mrs. Thomas R. Maxwell for their guidance and assistance.

INTRODUCTION

With the increasing costs of crop production in recent years, the need for optimizing yields and minimizing input costs has become evident. Expenses could be reduced to some extent by combining fertilization and tillage operations. By combining the two operations, one trip over the field would be eliminated.

With the present fertilizer technology, anhydrous ammonia (NH_3) is the least expensive source of nitrogen available for use in crop production. As a result, tillage implement adaptation for the application of anhydrous ammonia is becoming more common in the midwest. The most common tillage implement used in the eastern half of Kansas for the incorporation of ammonia has been the chisel plow.

However, in addition to N, phosphorus must be included in many fertility programs to achieve maximum crop yields in the eastern half of Kansas. Research has shown that the simultaneous application of N and P pre-plant in bands is feasible and in many cases agronomically superior to conventional methods of application such as broadcast application and incorporation. A liquid P source such as ammonium polyphosphate (APP, 10-34-0) is ideal for this technique because of its high analysis and excellent handling characteristics. Thus, it is possible to apply an entire pre-plant fertilization program for wheat on high K soils with a tillage implement such as the chisel plow adapted for fertilizer application.

Under field conditions, a 46 cm spacing of pre-plant bands of N and P has caused uneven growth of wheat (a "wavy effect"). The uneven growth has led to speculation as to the effect of a narrower spacing on plant growth and subsequent grain production by winter wheat.

Thus, the need for agronomic evaluation prompted the establishment of studies with these objectives:

1. To evaluate the effect of various spacings of preplant bands of N and P fertilizer on the growth and grain yield of winter wheat.
2. To evaluate the effect of phosphorus rates in conjunction with various band spacings on the growth and grain yield of winter wheat.

LITERATURE REVIEW

Introduction

Phosphorus (P), along with nitrogen (N) and potassium (K) is classed as a major plant nutrient. Phosphorus occurs in most plants in quantities that are much smaller than those of nitrogen or potassium (Tisdale and Nelson, 1975).

Phosphorus is known to be associated with several vital functions in plants and is involved in plant growth functions such as: utilization of sugar and starch, energy transfer in photosynthesis, nucleus formation and cell division, fat and albumen formation, seed germination, cell organization and the transfer of heredity, fruiting, flowering, and, in fact, in every phase of a plant's vital processes. The reaction of P with an organic substance within the plant to form energy-rich compounds is one of the most important reactions of P in plant metabolism (Seatz and Stanberry, 1963).

Phosphorus is a mobile element within plant tissues and in growing plants is transferred from one plant part to another, particularly when phosphorus may be in short supply in the soil (Sauchelli, 1975).

Phosphorus is usually absorbed by plants as either the primary orthophosphate ion ($H_2PO_4^-$) or as the secondary orthophosphate ion ($HPO_4^=$). Under acid soil conditions, $H_2PO_4^-$ is the dominant ion in soil systems. There are about ten times as many absorption sites on plant roots for $H_2PO_4^-$ as there are for $HPO_4^=$ (Tisdale and Nelson, 1975).

The relative amounts of these two ions, which will be absorbed by plants, are affected by the pH of the medium surrounding the roots. Lower pH values favor the absorption of the $H_2PO_4^-$ ion, whereas, higher pH values favor the absorption of $HPO_4^=$ (Tisdale and Nelson, 1975).

Climate definitely influences the uptake of nutrients by plants. The intensity and duration of light, rainfall, and temperature are all factors which exert direct influence on the physiological processes and uptake of mineral nutrients.

During dry periods when soil moisture is at a low level, the absorption of phosphorus is depressed. The same also is true for high soil moisture conditions (Sauchelli, 1975).

Placement of Fertilizer Phosphorus

The efficiency with which fertilizer is utilized by a crop is a major factor in determining the economic returns from fertilization.

One important factor in the efficient use of fertilizer phosphorus is distance of placement from the plant roots. Placement of fertilizer phosphorus and/or nitrogen ranks in importance with choosing the correct amounts of nutrients (Tisdale and Nelson, 1975).

One objective of any fertilizer placement method is to insure positional availability for many plant roots throughout the entire growing season. Placement is particularly important with small grains because the root system is more limited than that of row crops, the effective growing season is shorter, and soil temperatures are cooler. Phosphorus moves very slowly from the point of placement since the phosphate ion is almost immobile in the soil (Olsen and Flowerday, 1971).

Deep placement of P bands in the subsoil by means of various chisels and knives should theoretically be advantageous to conventional placement in surface soil where the surface soil may dry more easily resulting in reduced water and P uptake. Deeper placed fertilizer would more likely be in a moist soil zone available for root exploitation (Olsen and Flowerday, 1971).

Phosphorus fertilizer applied in small compact bands results in less phosphorus-soil contact than other phosphorus application methods. This means less rapid P fixation in bands when compared to broadcast application.

In field studies conducted in Kansas with wheat, Leikam (1980) found that placement of N and P fertilizer into the same soil zone about 6 to 8 inches deep was in many cases agronomically superior to broadcast application of N and P fertilizer.

Fertilizer placement studies with cereal grains have usually compared only seed placement with broadcast application. Since placement with the seed has generally proven superior, and since there is little information on the effectiveness of other types of band applications, the fertilizer for cereal grains is generally applied with the seed. As the rate of fertilization increases which includes N or K, the injurious effects of seed placement will become greater than the beneficial effects of seed placement and the yield could be decreased due to an injurious concentration of salt. Generally, seedling damage can become significant if N + K_2O is greater than 20 lb/A. Thus, band placement away from the seed could allow much higher fertilizer rates without seedling injury and might result in greater yield responses.

Robertson et al. (1954) found early utilization of phosphorus by corn plants was greatest when the fertilizer bands were placed at seed level. Fertilizer placed (banded) two inches below seed level was not used as early as seed level placement.

Placement near the seed for early starter effects is not, in general, an ideal position under midwest conditions for continued feeding of the plant during the latter part of the growing season. Often because of moisture depletion and lack of absorbing roots, this zone no longer contains sufficient water for active uptake of P by roots.

MacLeod et al. (1975) in their work with placement, found grain yields of barley were generally higher when fertilizer was placed 5 cm to the side and 5 cm below the seed than when fertilizer was broadcast or drilled with the seed. Throughout the growing season, the uptake of P was lower from broadcast than from drilled or banded fertilizer.

Miller and Ashton (1960) conducted a greenhouse study to determine the influence of nitrogen rate on the absorption of fertilizer phosphorus. The three variables used were horizontal distance and depth from the seed, and rate of nitrogen. At the 14- day stage, fertilizer phosphorus absorption was greatest from fertilizer placed with the seed. However, at the 28- and 42- day stages, absorption was greatest from fertilizer that was placed 2.5 cm to the side and 5.1 or 7.6 cm below the seed. At the 58- day stage, fertilizer placed with the seed resulted in the greatest absorption of fertilizer phosphorus. Nitrogen increased fertilizer phosphorus absorption at all but the 14- day stage, increased plant weight to a lesser extent and decreased the percent phosphorus in the tops at the 58- day stage.

A greenhouse study was conducted by Werkhoven and Miller (1960) to determine the effects of placement of phosphorus and nitrogen on absorption of fertilizer phosphorus by sugar beets. The phosphorus placements included three band placements, two applications mixed with 5.1 cm of soil at the 7.6 to 12.7 cm depth with and without a starter, and two applications mixed with 5.1 cm of soil at the 0 - 5.1 cm depth with and without a starter. These P placements were used in combination with three nitrogen treatments - 0 and 22.4 kg N mixed with the soil, and 22.4 kg N applied with the phosphorus. The nitrogen source was ammonium nitrate. Their work showed that the placement of nitrogen had a greater influence on the uptake of fertilizer phosphorus than did the placement of phosphorus. Nitrogen applied with the phosphorus generally resulted in greater uptake of fertilizer phosphorus than did nitrogen mixed with the soil.

Welch et al. (1966) found that as the P fertility status of soils is raised to a higher level by past fertilization, then the advantage of band application as compared to broadcast application would be expected to decrease.

The choice of banded or broadcast P may be dependent on whether the grower is owner or tenant. Tenants might have little incentive to "build up" the P status of the soil, and, in this case, might prefer annual banded applications at a lower rate of

P application.

Using greenhouse studies with winter wheat, Gingrich (1964) found that band applied phosphate fertilizer increased top growth, P percentage in the tops, and total yield of P when compared to mixing the P with the soil. Phosphorus percentage in the forage was directly related to the water solubility of the phosphorus fertilizer. The percentage of phosphorus in the plants increased significantly as the percentage of water soluble phosphorus in the applied fertilizer increased.

In field and greenhouse studies, Olson and Dreier (1956a) found a yield advantage for wheat and oats when phosphate was banded with the seed as compared with broadcasting the P. Their data support the practice of seed placement of P with small grain, particularly where the preference is for fertilizing the crop rather than the soil.

Field studies conducted by Lutz et al. (1961) showed 20 pounds of P_2O_5 with the seed of wheat and oats was considerably more effective than 40 pounds either broadcast or topdressed when looking at forage yields. Comparing broadcast, topdressed and placement of P near the seed, a greater growth response was seen early in the season with placement of P near the seed.

Research by Garg and Welch (1967) indicates that P placed in contact with corn seed is more readily available for plant absorption, at least during the early stages of growth, than P banded 7.5 cm from the seed or mixed throughout the soil. This is based on results of dry matter yield, percent P and yield of P. Their field studies showed little difference in dry matter yield between banded and mixed P (broadcast). Greenhouse studies indicate that the time for the roots to reach the banded P increased as the distance between the P and the seed increased.

Cihacek et al. (1974) used a chisel plow for P application at 18 to 20 cm depth (chisel place). A squeeze pump was attached to the chisel plow for metering P solutions during the placement operation. They found that the benefits derived from band placement of P were: 1) tillage and fertilizer application accomplished simultaneously, 2) maximum season-long feeding by the crop (corn) on fertilizer P occurred when the P was placed at the depth of chisel plow operation, 3) runoff loss of fertilizer P which might contribute to surface water pollution, was minimized by the deep placement.

Field research by Barber (1958) indicated that broadcast applications of phosphorus as compared to no phosphorus application increased the yields of corn, soybean, wheat, and hay rotation over a 6-year period. The response to row phosphorus was reduced as the soil P level was increased. Results obtained in the first 6 years indicate that corn is unable to get sufficient phosphorus from row applications alone to produce maximum yields. Whereas wheat, having a narrower row spacing, gave maximum yields with either broadcast or row applications of phosphorus.

Field research with wheat conducted by Swart (1970), evaluated 3 orifice spacings for ammonia application with an undercutter blade. Distances between release points were 6, 16, and 40 inches. Field observations indicated that the 6- and 16-inch spacings created a more uniform plant growth in the field than did the 40-inch spacing. Results of this research indicated no significant influence on wheat yields. However, there was a trend for the 6- and 16-inch spacing to produce higher yields of wheat than the 40-inch spacing between release points.

Leikam (1980) conducted field research to evaluate the use of pre-plant band applications of ammoniacal N and liquid P fertilizers on wheat. Significant grain yield increases due to application of pre-plant band N and P were recorded when compared to treatments receiving N and P either as a combination broadcast or band.

Effect of Nitrogen on P Uptake

The increased absorption of phosphorus by plants when nitrogen is added to the soil has been recognized as a significant phenomenon in soil-plant relations. Much research has been done to characterize the effect of various factors on the extent to which N increases the absorption of fertilizer P.

In greenhouse experiments conducted by Miller and Ohlrogge (1958) it was shown that nitrogen had a pronounced effect on the uptake of phosphorus from a fertilizer band. The effect was greatest when the nitrogen was mixed with the phosphorus band. This effect would indicate that nitrogen caused a relative increase in the phosphorus uptake capacity of the root system. The authors suggested the N-P effect was due to either an increased availability of the banded phosphorus through chemical effects, or an increase in relative root sorption surfaces in the band volume due to root proliferation.

Garg and Welch (1967) showed a positive relationship between percent N and P in the plant by demonstrating that NH_4^+ - N placed with P enhances the absorption of fertilizer P by plants. This technique resulted in greater utilization of the fertilizer P than when no N was added.

Using a conventional pot experiment, Engelstad and Allen (1971b) studied the effect of proximity of banded N sources on uptake of banded fertilizer P at several rates. Their results showed that hybrid sorghum-sudan grass gave a marked forage yield response to added P layered 7.5 cm below the soil surface. Ammonium sulfate and ammonium nitrate placed in the P layer enhanced P uptake at all levels of applied P, while sodium nitrate had no effect, regardless of placement. The effect of ammonium sulfate and ammonium nitrate on enhanced P uptake was due to placement in relation to the P layer.

Miller (1965) conducted greenhouse experiments in which a single seminal root of a corn seedling was grown in a soil to which phosphorus band treatments were applied. The remainder of the root system was grown in sand. Addition of $(NH_4)_2SO_4$ to the P band increased the absorption of fertilizer P in each of 3 experiments. However, the results suggest that increased root growth in the band volume in the presence of $(NH_4)_2SO_4$ was not the primary cause of increased P absorption. The author felt that the $(NH_4)_2SO_4$ exerted a specific influence on the physiological activity that controls P absorption.

Blair et al. (1971) tested the hypothesis that reduction of pH at the soil-root interface was the cause of increased P absorption when NH_4^+ ions were absorbed. Phosphorus absorption by corn was determined in the greenhouse using four soils ranging in pH from 4.2 to 8.2. Application of $(NH_4)_2SO_4$ with monocalcium phosphate (MCP) was found to increase fertilizer P uptake when compared to MCP alone. Application of KNO_3 with MCP was intermediate. These results were for soils of pH 8.2, 7.4, and 5.5, with no difference in P uptake due to N source on the soil of pH 4.2.

Cole et al. (1963) concluded that the stimulation of P uptake with higher plant N levels involves a connection between N metabolism and P uptake processes. Phosphorus uptake studies with one-month old corn plants showed that N pretreatments stimulated the rate of P uptake more than did a tenfold increase in P concentration of the external solution.

Leonce and Miller (1966) conducted a series of soil and solution culture experiments with corn to study the mechanism responsible for increased P absorption when N is added to a P fertilizer band. The addition of $(NH_4)_2SO_4$ or NH_4Cl to a pellet of ^{32}P labelled concentrated superphosphate (CSP) greatly increased the labelled P content of plant tops as compared to the addition of KNO_3, labelled P accumulation occurred in the presence of NH_4^+ ions. The authors concluded that the NH_4^+ ion has a specific influence on the transfer of P across the root symplast to the xylem.

Olson and Dreier (1956b) conducted field and greenhouse experiments with small grains to study the action of N in promoting fertilizer P utilization. Their work showed that the NH_4^+ ion exceeded NO_3^- in stimulating plant use of fertilizer P, especially during early stages of plant growth. They also observed that the root concentration in the zone of joint N-P placement could largely account for the greater fertilizer P uptake.

Soon and Miller (1977) studied the effect of NH_4^+ and NO_3^-

on the pH and phosphate concentration in the rhizocylinder and on P absorption by corn seedlings. Their results agree with those of Olson and Dreier (1956b) in that P absorption was associated with NH_4^+ fertilization. Addition of NO_3^- did not significantly alter P absorption from that with no N addition.

Soon and Miller (1977) concluded that the difference in P absorption due to N source (NH_4^+ or NO_3^-) can be explained by changes in the $H_2PO_4^-$ concentration in the rhizosphere solution. The concentration of $H_2PO_4^-$ varied due to pH changes induced by unequal absorption of cations and anions.

Arnon (1939) conducted greenhouse studies using barley grown in nutrient solutions. The objective of this study was to determine the effect of ammonium and nitrate nitrogen on the plant mineral composition and sap characteristics. Plants grown in nutrient solutions at pH 4.0, 5.0, 6.0, and 6.7 containing nitrate were found to have a lower phosphorus concentration than those grown with ammonium. The phosphate concentration within the plant increased with an increase in the external pH, within the pH range of 4.0 - 6.7.

A series of greenhouse experiments were conducted by Bennett et al. (1962) to study N-P relationships in young corn plants. They found that N had a highly significant effect on percent P in the leaves and stalks in both sand and soil cultures. The authors postulated, however, that these results were due to physiological stimulation of the plant by applied N. Their results offer some evidence that applied N increases the N compounds within the plant, thus resulting in a greater need for absorption of P.

Miller et al. (1970) conducted greenhouse studies with corn to clarify the mechanisms responsible for increased absorption of P due to addition of NH_4^+ ions to P fertilizer bands. Fertilizer P concentration in the shoots were doubled by the addition of K_2SO_4 and tripled by the addition of $(NH_4)_2SO_4$. Autoradiographs of the area surrounding the fertilizer pellets indicated an accumulation of P on the surface of roots in the MCP treatment but not in the MCP plus $(NH_4)_2SO_4$. Electron microprobe scans of root cross-sections indicated a precipitation of Ca and P at the soil-root interface in the MCP and MCP + K_2SO_4 treatments. The pH of the soil-root interface was 0.6 units lower in the MCP + $(NH_4)_2SO_4$ treatment compared to MCP alone. The higher ratio of $H_2PO_4^-/HPO_4^=$ ions at the lower pH is thought to be responsible for the prevention of the precipitation and the increased absorption of P in the presence of $(NH_4)_2SO_4$.

Riley and Barber (1971) grew soybeans fertilized with either NH_4^+ -N or NO_3^- -N using soil with 4 different pH levels. They found that fertilization of soybeans with NH_4^+ -N decreased the pH of the rhizocylinder and NO_3^- -N increased the rhizocylinder pH. Ammonium fertilized soybeans absorbed more P and had a higher P concentration than NO_3^- fertilized soybeans. Their results showed that the P content of the shoots and roots were closely correlated with the pH of the rhizocylinder, but not the pH of the bulk soil. This suggests that the increased availability of P from the soil where NH_4^+ -N was used was mainly due to the effect of the nitrogen source on the pH of the rhizosphere soil.

Grunes et al. (1958a, 1958b) conducted growth chamber and field experiments to determine the effect of source and placement of nitrogen on the relative availability of fertilizer and soil phosphorus to plants. The addition of nitrogen fertilizer generally increased the percent of the total phosphorus absorbed by plants from bands of CSP. The addition of $(NH_4)_2SO_4$ with the phosphorus band was more effective in increasing the percent fertilizer phosphorus in the plant than was separating the nitrogen and phosphorus bands. Their study indicated that the effect of nitrogen, on increasing the relative uptake of banded fertilizer phosphorus, was associated with increased top and root growth, and also with a decrease in soil pH.

Blair et al. (1970) compared the effect of N source on the uptake of other ions by corn plants grown in solution culture. Their data showed higher P concentrations in the tops and roots of the NH_4^+ -N treatments. This was believed to be the result of stimulated anion uptake in response to cation (NH_4^+) uptake. Their results also showed an increase in pH of the solution in the NO_3^- treatment, presumably the result of the expulsion of OH^- and/or HCO_3^- ions from the plant to balance the high negative charge of the NO_3^- ions entering the plant. Likewise, the decrease in pH in the NH_4^+ solution resulted from the expulsion of H^+ ions from the plant to maintain a balance of anions and cations in the plant.

Mamaril and Miller (1970) found the concentration of P in the soil rather than the proportion of soil treated or the proportion of the root system exposed to the treated soil determined the influence of NH_4^+ on P absorption. The effect of NH_4^+ increased with increasing concentration of NH_4^+.

Thien and McFee (1970) studied the effect of metabolized N and N in solution on P absorption and translocation in corn grown in the growth chamber. Two-week-old corn plants were prepared by pretreatment in NH_4^+, NO_3^-, P, or water solutions for 24 hours. Plants were then transferred to treatment solutions containing labelled P alone or with a N source. They found that N pretreatment of corn plants significantly increased P absorption and translocation rates. These effects were absent when N was omitted from the pretreatment solution. There were no significant differences between the N sources, (NH_4Cl or $NaNO_3$).

In a later study, Thien and McFee (1972) found that N preconditioned corn plants had significantly higher P uptake rates and translocation. The degree to which P uptake was stimulated was dependent upon the N level used for preconditioning. Phosphorus transport to the upper part of the plant increased as N levels in the pretreatment increased.

Chapman (1936) conducted pot culture studies with Sudan grass to determine the effect of various nitrogenous fertilizers on the availability of phosphorus in three calcareous soils. Acid forming nitrogen fertilizers (NH_4NO_3, $NH_4)_2SO_4$, and urea) increased phosphate availability, the magnitude of the effect being related to the carbonate-phosphate ratio of the soil, the fertilizer material being used, and perhaps the rates at which they are nitrified in the soil.

Lorenz and Johnson (1953) tested the response of several crops to ammonium and nitrate sources of nitrogen and attempted to differentiate responses to nitrate and ammonium fertilization as related to phosphate availability. Their yield results indicated that all crops tested grew better when fertilized with

$(NH_4)_2SO_4$ than with $Ca(NO_3)_2$. In the fertilizer band the pH of the soil was lowered 2 to 3 units by $(NH_4)_2SO_4$ fertilization but no change in soil pH was detected in any area of the soil fertilized with $Ca(NO_3)_2$. The acid forming salt $(NH_4)_2SO_4$ effectively released native soil P, whereas N from $Ca(NO_3)_2$ and $NaNO_3$ did not. Response from NH_4NO_3 was intermediate.

Duncan and Ohlrogge (1958) conducted a series of greenhouse experiments with corn in the seedling stage using divided root systems. They found that fertilizer N and P mixed together in a portion of a soil or vermiculite culture caused proliferation of corn roots in the fertilized volume. Such root proliferation was the result of rapid growth of the smaller roots. The rate of growth of the first-order roots was not affected. Uptake of phosphate in the greenhouse was affected by the volume of soil fertilized if nitrogen was present, but not if nitrogen was absent. The volume of soil in which the fertilizer was placed made a difference in uptake of phosphorus, with the greatest uptake being between the two extremes in soil volume fertilized. When the entire soil volume was fertilized with P, the presence of N had no effect on the uptake of P.

In later research, Duncan and Ohlrogge (1959) showed the volume of soil fertilized had no effect on fertilizer uptake when phosphate was applied alone. However, the volume of soil fertilized caused significant differences when nitrogen was added to the fertilizer placement. They found that when the volume of soil fertilized was small in relation to the total soil volume, nitrogen increased the uptake of phosphorus in part by increasing root growth in the fertilized soil. As in their earlier study concerning fertilizer uptake, where the entire soil volume was treated with phosphorus, nitrogen had no noticeable effect on root growth or on the uptake of phosphorus.

Polyphosphates as a P Source

Some research workers have shown that polyphosphates are a relatively ineffective source of P prior to hydrolysis compared to orthophosphate. Since polyphosphate hydrolysis in soil is largely biological, soil temperature would affect the rate of hydrolysis.

Nearly one-half of the P in ammonium polyphosphate (APP) is present as pyrophosphate ($HP_2O_7^{-3}$ ion) with some minor quantities of more highly condensed phosphates. The other half of the P is in the form of orthophosphate.

Engelstad and Allen (1971a) conducted experiments to determine the influence of soil temperature on the effectiveness of triammonium pyrophosphate (TPP) and MAP. Their data revealed that pyrophosphate can be a less effective P source than orthophosphate when added to cool soil (16 C). Also, banding was generally more effective than mixing for unincubated and cool soil (16 C) in terms of subsequent plant growth. They conclude that if the P fertilizer is composed primarily of condensed phosphates, early growth in cool soils may not equal that from orthophosphates.

Subbarao and Ellis (1975) compared ammonium polyphosphate and diammonium orthophosphate as P sources for corn. They found in laboratory experiments using a slightly acid soil (Eudora silt loam), that both sources of P effectively supplied P for plant growth as indicated by increased dry weights, uptake of P by plants, and available soil P. Using an alkaline-calcareous soil (Ulysses silt loam), neither source of P increased dry weights, uptake of P by plants or available soil P as much as in the slightly acid soil indicating problems with P relationships in alkaline-calcareous soils. Also, dry weights and uptake of P by the corn plants were significantly less with polyphosphate than with orthophosphate at 36 ppm of P on the alkaline-calcareous soil. Polyphosphate did not increase available soil P, measured by the Bray P-1 test on the alkaline-calcareous soil.

Khasawneh et al. (1974) studied the mobility of P applied to soil columns. The phosphorus materials studied were diammonium orthophosphate (DAP), triammonium pyrophosphate (TPP), and ammonium polyphosphate (APP). They found the extent of P movement from all three sources were similar, but the distribution patterns were different. The extent of P movement was influenced more by initial soil moisture content than by the source of P. The ability of the polyphosphates to sequester soil Fe and Al did not prevent the precipitation of these phosphates nor did it make them more mobile than the orthophosphates.

Khasawneh et al. (1974) in a later study, determined the reactions of ammonium ortho- and polyphosphate fertilizers in soil. The diffusive movement of phosphates from TPP, APP, or DAP when surface applied to columns of Hartsells fsl soil was accomplished by two major types of reactions: hydrolysis of pyro- and polyphosphates to the orthophosphate form, and reaction of all phosphate anions with the soil. Hydrolysis of the water-soluble fraction of the condensed forms of P was faster than that of diffusion, mobility of the pyro- and polyphosphates occurred largely in the orthophosphate form and accounted for the similarity of P movement among the three sources of P.

Hashimoto and Lehr (1973) also conducted laboratory studies to determine the mobility of polyphosphates in soil. Ammonium ortho-, pyro-, tripoly-, tetrapoly-, and long-chain polyphosphates and cyclic ammonium tri- and tetrametaphosphates were surface applied to soil columns. After 1, 2, and 4 weeks, the soil columns were sliced into 1 mm sections and examined for the distance of movement and the distribution patterns of water-soluble P were similar for all the phosphates tested, but the polyphosphates differed markedly in the degree of immobilization of P and differed significantly in the positions of maximum retention of P in the soil columns. These positions of maximum retention had no apparent relation to the degree of condensation of the polyphosphates.

Miner and Kamprath (1971) conducted field studies with corn to compare the distribution and degree of retention of banded ortho- and polyphosphate anions in soils of low and high phosphorus availability. They found the concentration of fertilizer P from both superphosphate and polyphosphate decreased rapidly with increasing lateral distance from the band. The soil samples were extracted with 0.05 N HCL + 0.025 N H_2SO_4 at a a 1:4 soil-solution ratio to give a measure of readily extractable P; and then with 1 N H_2SO_4 at a 1:25 soil-solution ratio to give a measure of the difficultly extractable P. A higher proportion of the condensed phosphate ions were in the difficultly extractable form as compared with the orthophosphate ions, indicating that the condensed phosphate ions were held more strongly. Miner and Kamprath (1971) also noted that polyphosphate was as effective as superphosphate in supplying P for plant growth. Although condensed phosphate ions were held more strongly than orthophosphate ions by soil materials, there appeared to be no difference in their effectiveness as sources of P for plants.

MATERIALS AND METHODS

Field Studies

Studies were conducted at six locations in five Kansas counties over the 1978-79 and 1979-80 crop years. Locations of the sites were: one each in Osage, Riley, Labette, and Harper Counties, and two locations in Dickinson County. These studies were located in the eastern half of Kansas (Fig. 1).

Initial soil analyses for these locations were carried out by the Soil Testing Laboratory at Kansas State University. Soil test levels and general site information are presented in Table 1. Fertilizer application dates, seeding rates, seeding dates, cultivar selection, tissue sampling dates, and harvest dates are given in Table 2.

Individual plots measured 9.1 m long by 3.0 m wide for studies conducted in 1980 measured 9.1 m long by 3.7 m wide. The increase in the width of the 1980 plots allowed two passes of the applicator for the 25 and 38 cm spacings to increase the effective width of application. This was necessary because the swath width of the plot combine used was 1.9 m, which exceeded the fertilizer application width with only one pass of the applicator at the 25 and 38 cm spacing. A 6.1 m alley separated the replications at all locations. All experimental designs were randomized complete blocks with four replications.

The studies were seeded with a 1.5 m Ontario drill with disk openers spaced 17.8 cm apart. All studies were drilled perpendicular to the direction of pre-plant fertilizer applications.

ig. 1. Locations of the 1979 and 1980 field studies (denoted by X on the map).

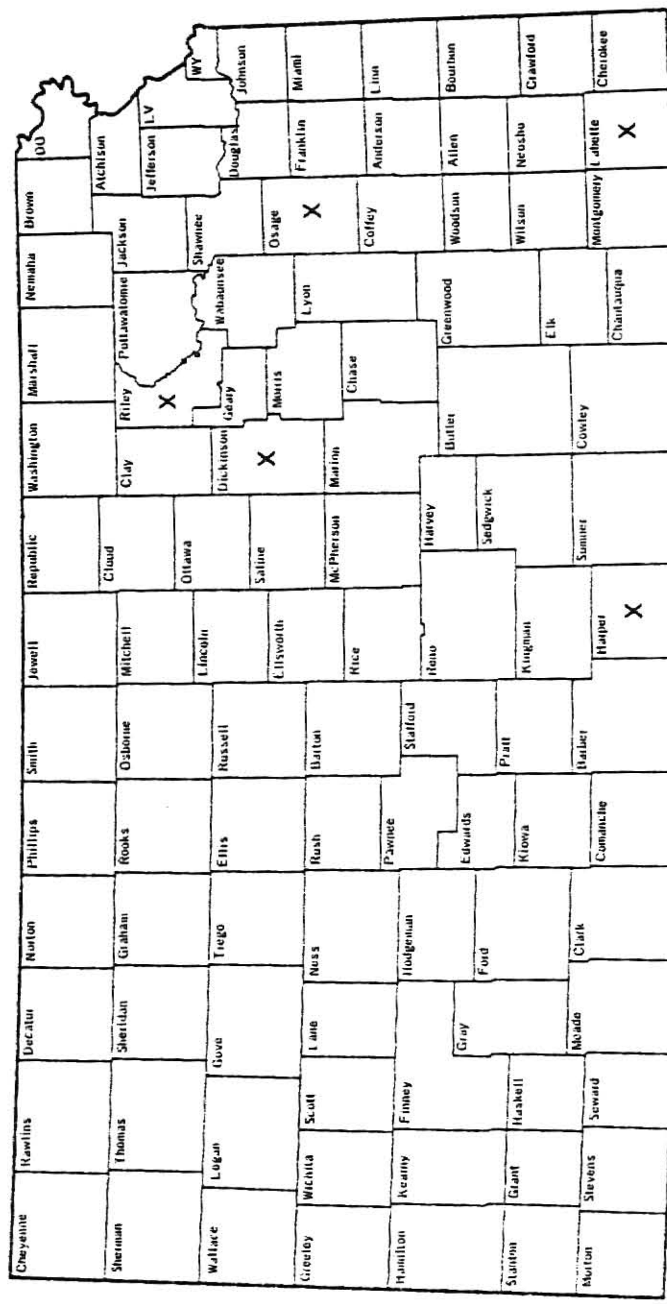

Cheyenne
Rawlins
Decatur
Norton
Phillips
Smith
Jewell
Republic
Washington
Marshall
Nemaha
Brown
DO
Atchison
Jefferson
LV
WY
Johnson
Sherman
Thomas
Sheridan
Graham
Rooks
Osborne
Mitchell
Cloud
Clay
Riley
Pottawatomie
Jackson
Shawnee
Douglas
Miami
Wallace
Logan
Gove
Trego
Ellis
Russell
Lincoln
Ottawa
Dickinson
Geary
Wabaunsee
Osage
Franklin
Linn
Greeley
Wichita
Scott
Lane
Ness
Rush
Barton
Ellsworth
Saline
Morris
Lyon
Coffey
Anderson
Bourbon
Hamilton
Kearny
Finney
Hodgeman
Pawnee
Stafford
Rice
McPherson
Marion
Chase
Greenwood
Woodson
Allen
Crawford
Stanton
Grant
Haskell
Gray
Ford
Edwards
Pratt
Reno
Harvey
Butler
Elk
Wilson
Neosho
Cherokee
Morton
Stevens
Seward
Meade
Clark
Kiowa
Barber
Kingman
Sedgwick
Cowley
Chautauqua
Montgomery
Labette
Comanche
Harper
Sumner

Table 1. SOIL TEST LEVELS AND GENERAL SITE INFORMATION.

Location	County	Soil Type	Soil Depth (cm)	pH	N	P	K
					-----	PPM	-------
Jarod Hoover Farm (1979)	Dickinson	Hastings sil	0-15	6.3	23	5.5	289.5
		Udic Argiustoll	15-60	6.6	20	3.0	299.0
Duane Lamond Farm (1979)	Osage	Woodson sicl Abruptic Argiaquoll	0-20	6.4	15	10.5	88.5
Dewey Ranch (1979)	Riley	Chase sicl	0-15	---	16	12.5	-----
		Aquic Argiudoll	15-60	6.5	16	6.0	282.5
Jarod Hoover Farm (1980)	Dickinson	Hastings sil Udid Argiustoll	0-15	6.3	--	6.5	353.5
Raymond Lamond Farm (1980)	Labette	Parsons sil	0-15	6.5	11	6.0	34.0
		Mollic Albaqualf	15-60	6.2	10	4.5	77.5
Dennis Baker Farm (1980)	Harper	Pond Creek sil Pachic Argiustoll	0-15	6.1	--	10.0	233.0
Greenhouse Study (1980)	Jackson (origin)	Pawnee cl Aquic Argiudoll	0-15	6.8	18	4.0	303.0
Greenhouse Study (1980)	Riley (origin)	Reading sil Typic Argiudoll	0-15	6.6	31	64.5	387.5

Table 2. FERTILIZER APPLICATION DATE, SEEDING RATE AND DATE, CULTIVAR SELECTION, TISSUE SAMPLING DATE AND GRAIN HARVEST DATE INFORMATION.

County	Year	Dates: Fertilizer Application	Dates: Tissue Sampling	Dates: Grain Harvest	Seeding: Date	Seeding: Rate (kg/ha)	Cultivar
Dickinson	1979	9/12/78	1) 4/16/79 2) 5/6/79	7/11/79	10/5/78	67	Newton
Osage	1979	9/16/78	1) 4/7/79 2) 4/28/79	7/12/79	9/26/78	67	Newton
Riley	1979	10/3/78	1) 4/17/79 2) 5/1/79	7/13/79	10/12/78	67	Newton
Harper	1980	9/7/79	4/23/80	6/25/80	10/2/79	67	Newton
Dickinson	1980	9/12/79	5/19/80	6/27/80	10/30/79	67	Newton
Labette	1980	9/24/79	4/14/80	6/23/80	10/17/79	67	Newton

Studies conducted in 1979 were in Dickinson, Osage, and Riley Counties. All treatments were deep placed pre-plant band applications (dual knifed) of liquid ammonium polyphosphate (APP, 10-34-0) and anhydrous ammonia. The nitrogen rate was constant at 84 kg N/ha, which was supplied partially by the APP and balanced by the anhydrous ammonia. Three phosphorus rates were used: 0, 12, and 24 kg P/ha in combination with three knife spacings with shanks on 25, 38, and 50 cm centers.

Studies conducted in 1980 were in Dickinson, Labette, and Harper Counties. Treatments for the 1980 studies were the same as for 1979, with the inclusion of a 6 kg P/ha phosphorus rate. Also, an unrandomized treatment consisting of 168 kg N/ha and 48 kg P/ha with a 25 cm knife spacing was added.

Fertilizer Application Equipment. Ammonia was applied by fitting a John Blue Nitrolator to the tool bar of a shank applicator. A 114 liter anhydrous ammonia tank was also mounted on two tool bars. However, only 5 shanks were used at any knife spacing. Shanks mounted on the front tool bar were positioned for the 50 cm spacing (Fig. 2). By lifting up or dropping down the appropriate shanks, the 38 or 25 cm spacings could be obtained. A series of valves were fitted to the nitrolator flow divider to shut off ammonia lines not in use. Each shank was fitted with two discharge tubes for simultaneous ammonia and liquid APP applications (Fig. 3). The front tube on the shank was for ammonia injection, while the rear tube was for liquid APP applications. To prevent freezing of the liquid line due to the cooling effect of the ammonia and formation af a precip-

THIS BOOK CONTAINS SEVERAL DOCUMENTS THAT ARE OF POOR QUALITY DUE TO BEING A PHOTOCOPY OF A PHOTO.

THIS IS AS RECEIVED FROM CUSTOMER.

Fig. 2. The top photograph shows a side view of the shank applicator mounted on a Massey Ferguson 135 tractor. The lower photograph shows the arrangement of the nine shanks mounted on the tool bars. Anhydrous ammonia is carried in the large tank in the center and liquid APP is carried in small buckets (19 liter) to the right.

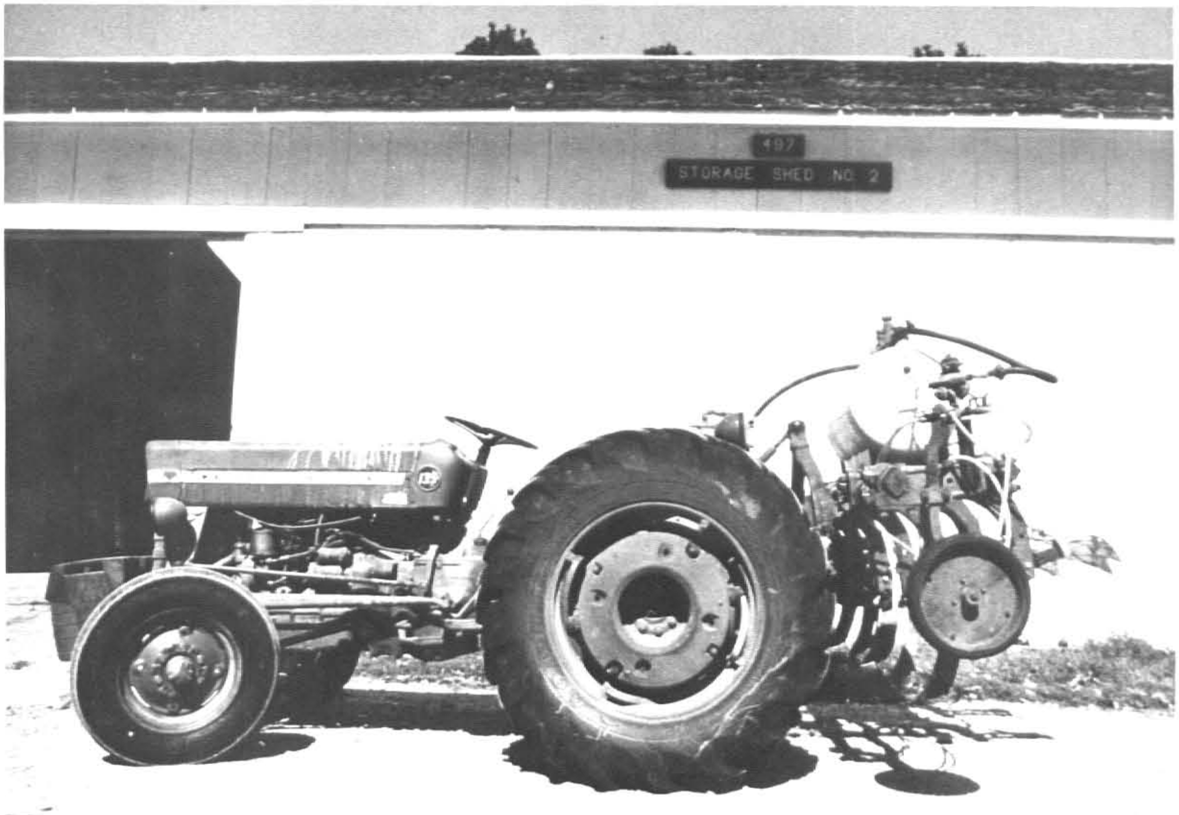
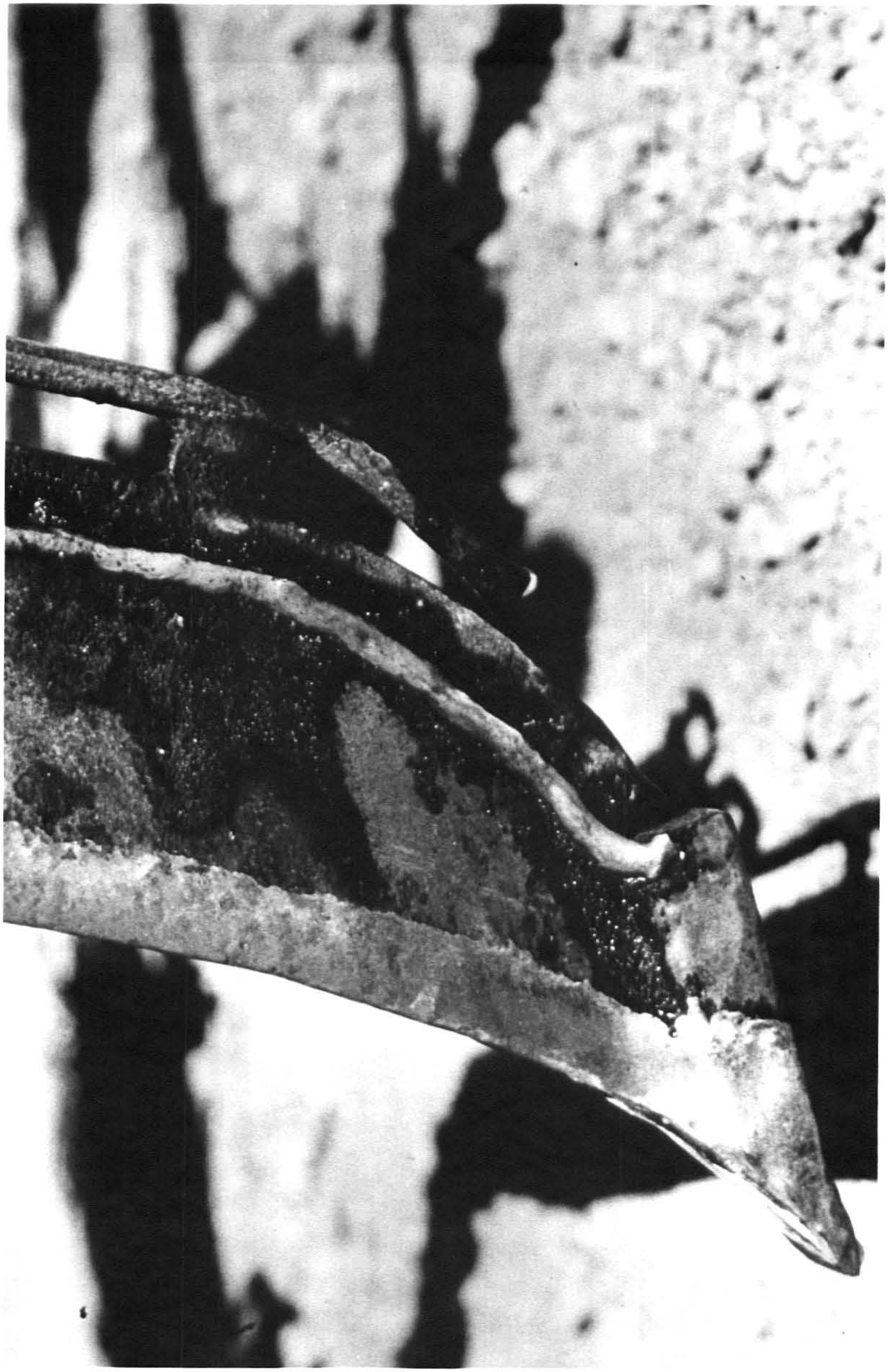

497
STORAGE SHED NO. 2

Fig. 3. A close-up view of the anhydrous ammonia shank equipped for dual knife N-P application of ammonia-APP. Anhydrous ammonia is injected from the tube nearest to the shank and liquid APP is pumped through the rear tube. The tubes are separated to prevent freezing of the liquid line by the cooling effect of the anhydrous ammonia.



itate in the liquid line, the two tubes were separated by 3.8 cm. A liquid discharge hole was located at the rear of the tube to prevent liquid solution from spraying directly into the ammonia stream.

A John Blue L-1094 positive displacement pump was mounted on a Massey-Ferguson 135 tractor. The tractor was equipped with a ground speed dependent power take-off, which eliminated variations in application rate due to varying ground speeds. From the pump, a line was run to a flow divider mounted on the tool bar, where the liquid was directed to the nine shanks. Valves were fitted on the flow divider to shut off the flow of liquid to the four shanks not in use. Solutions were then discharged from the rear tube of the five shanks in use. Applications were made at a depth of approximately 12.7 to 15.2 cm below the soil surface.

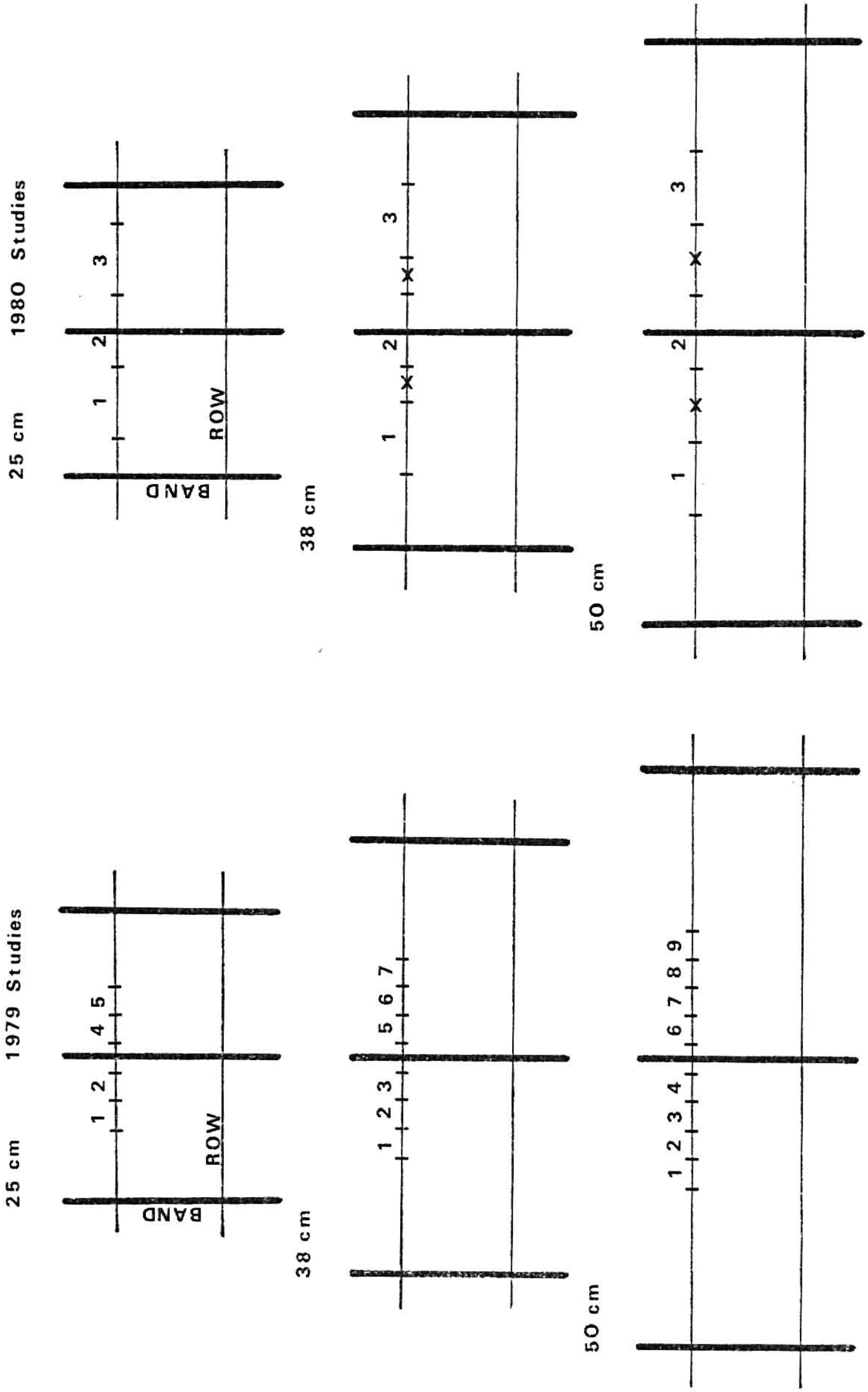
Leaf Tissue Sampling. Tissue samples for the 1979 studies were taken at two dates at all locations. The first sampling was during early spring growth before jointing. The second sampling was at jointing (Table 2).

The objective of this sampling was to determine the effect of knife spacing and P-rate on leaf tissue P content and dry matter production.

Samples were taken in 5.1 cm increments along the wheat row, which was perpendicular to the direction of fertilizer application. The first sample taken along the drill row was approximately equidistant between two knifed bands, regardless of knife spacing. This sampling continued over one knife band (the center knife band) and ended at a point equidistant between the adjacent knife bands. Thus, five samples (each 5.1 cm of row length) were taken for treatments with the 25 cm spacing, seven samples for the 38 cm spacing, and nine samples for the 50 cm spacing (Fig 4). Tissue samples were clipped at the soil surface and placed in paper sacks. Dry weights were taken for the second sampling date at all locations. However, only those from the Dickinson County location will be presented in this thesis, because of lack of a P response at the other two locations. Tissue sample preparation and chemical analysis are discussed later in this section.

Since the 1979 studies did not have flags placed over the knife bands at the time of fertilizer application, an estimate of the band's location was made for the sampling procedure. This resulted in some sampling variation and inconsistency, as witnessed by the data from this sampling.

Tissue sampling for the 1980 studies was revised from experience in 1979. The plots at the Labette County location had 2 to 3 flags placed over the exact location of pre-plant fertilizer bands in each plot. Tissue samples were taken only once, at the jointing stage (Table 2). The samples were taken in three separate 12.7 cm increments for all treatments, regardless of knife spacing. The first 12.7 cm increment was taken midway between two knife bands to the left of the flag (centered between bands). The second, or middle sample, was centered directly over the flagged knife band (centered over band), and the third sample was taken midway between the next knife band (centered between bands) of the flag (Fig. 4). The two samples centered between bands were the same in relation to the knife bands, but 'ig. 4. These diagrams show the position and sequence in which leaf tissue and grain head samples were taken for the 1979 and 1980 studies. In reference to studies conducted in 1980, samples #1 and #3 shall be referred to as centered between bands and sample #2 as centered over the band.


1980 Studies
25 cm
38 cm
50 cm
ROW
BAND
1
2
3
1979 Studies
25 cm
38 cm
50 cm
ROW
BAND
1 2 4 5
1 2 3 5 6 7
1 2 3 4 6 7 8 9

were taken on opposite sides of the flagged knife band. Samples were clipped at the soil surface and placed in paper sacks. Dry weights were recorded for each sample.

Leaf tissue samples taken at the Harper and Dickinson County location for 1980 were collected by randomly pulling leaf tissue from throughout the individual plot areas, then placed in paper sacks.

Grain Head Sampling. In 1979, grain head samples were taken at the Dickinson County location only. Sampling consisted of cutting the wheat grain heads from the stem at maturity in the same manner in which tissue was sampled in 1979. The objective of this sampling was to examine the effect of knife spacing and P-rate on head number and grain composition. Grain heads from each 5.1 cm increment were clipped and placed in a paper sack. In the lab, grain heads were counted and then threshed through a small electric thresher. Total grain weight, average kernal weight, grain protein, and %P were then determined for each 5.1 cm increment. As with the 1979 tissue sampling, a great deal of variation and inconsistency were evident due to lack of precise marking of fertilizer bands.

In 1980, grain head samples were taken at the Labette County location only. Sampling consisted of cutting the grain heads in the same manner in which tissue was sampled in 1980. Sampling was more accurate and less variable than 1979 sampling due to marking of fertilizer bands with flags. Again, the heads were counted and grain was threshed from the head by a small electric thresher in the laboratory. The yield of grain, % protein, % P, N uptake, and P uptake were determined for each 12.7 cm increment. Grain sample preparation and chemical analysis are discussed later in this section.

Harvesting of Plots. All plots for the 1979 and 1980 studies were harvested mechanically with a model E Allis Chalmers (Gleaner) combine that had been rebuilt specifically for small plot harvesting. The combine header width was reduced to 1.9 m so that only the center of each plot was harvested. A scale was mounted on the combine and the grain weight from each plot was recorded. Approximately 500 g of the grain from each plot was saved for moisture determination and chemical analysis. All plot grain weights were adjusted to 12.5% moisture.

Greenhouse Studies

A greenhouse study was initiated on January 24, 1980 to look at the effects of different P levels on wheat seedling dry weight and P uptake. The objective of this study was to observe when wheat seedlings would absorb external P in addition to that P available within the wheat seed.

Wheat seedlings were grown in or on four different mediums, which constituted the four treatments of this study. Treatments were as follows; 1) wheat seedlings grown on white paper towels; 2) fine, white, acid-washed quartz sand (no P); 3) a soil testing very low in available P (4 ppm P); and 4) a soil testing very high in available P (64.5 ppm P). Soil test levels of available P were determined by the Kansas State University Soil Testing Laboratory (Table 1) using the Bray P-1 procedure (Bingham, 1962).

Approximately 50 wheat seeds of the variety Newton were planted at random in each 2.5 liter plastic pot. Each treatment had four sets of pots, each with three replications, to enable sampling of each treatment at four dates. Sampling of the shoots only, which were clipped at the soil surface, occurred at 7, 14, 21, and 28 days after planting. The wheat seedlings were watered by saturating the towels with the nutrient solution. Tissue sample preparation and chemical analysis are discussed later in this section.

A second greenhouse study was conducted in relation to the one described previously. The objective of this study was to break down by plant part (shoot, root, and seed remnant) the dry weight and P content of each part of the wheat seedlings. Samples from the original seed lot had been previously analyzed for P content and was compared to the P content of the wheat seedlings.

Using only the fine, white, acid-washed quartz sand (no available P), measurements could be taken to determine where phosphorus contained within the seed was directed to in the seedling.

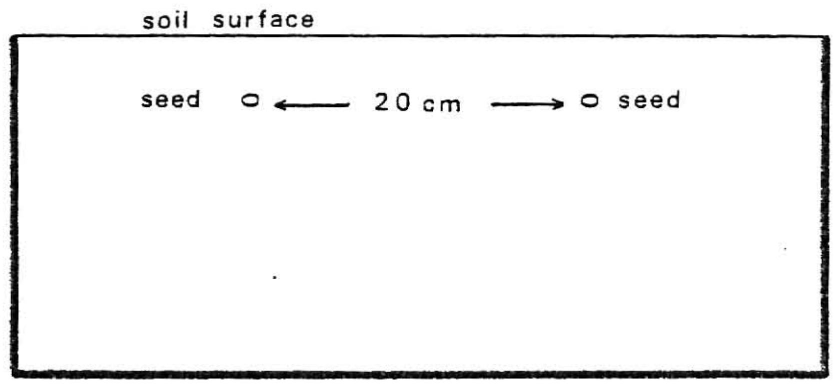
As in the first greenhouse study, approximately 50 wheat seeds of the variety Newton were planted at random in each 2.5 liter plastic pot. The pots were watered throughout the study with a complete nutrient solution minus phosphorus. Three replications were sampled at each of the two sampling dates, 7 and 14 days after planting. The seedlings were separated from the sand and then rinsed thoroughly with distilled deionized water. The seedlings were then cut into shoots, roots, and seed remnants. The average dry weights from fifty seedlings were recorded for each plant part.

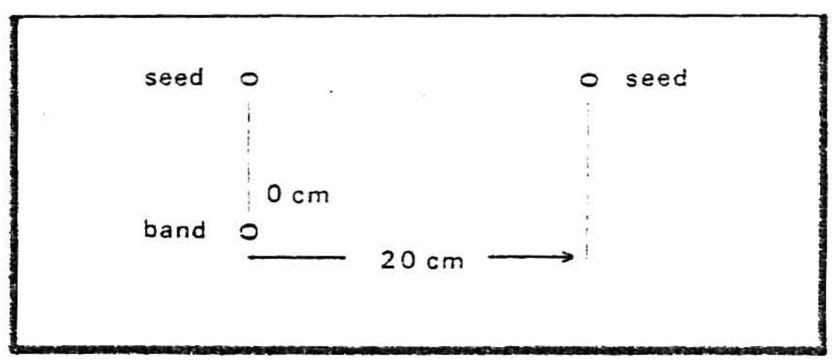
A third greenhouse study was conducted in 1980 to look at the effect of horizontal distance of a N-P fertilizer band from a row of wheat seedlings on P uptake from the fertilizer band.

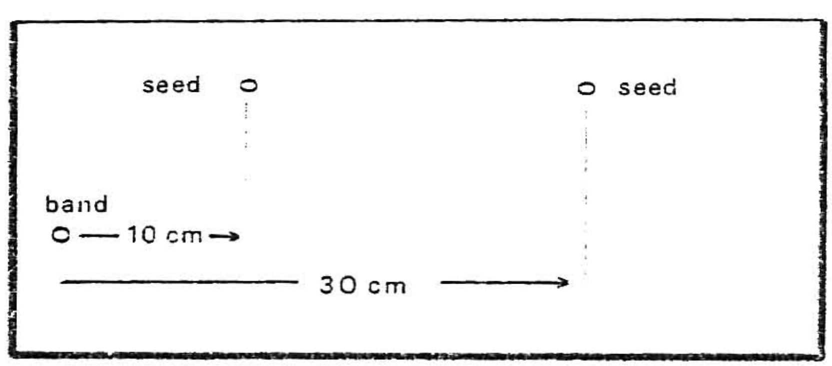
The soil used for this study tested very low (4 ppm) in available P (Table 1).

The study consisted of 6 treatments: a check (0 N + 0 P); a check + 84 kg N/ha as NH_4NO_3 broadcast on the soil surface, and N-P fertilizer bands placed at horizontal distances of 0, 10, 20, and 30 cm from the row of wheat seedlings. The fertilizer bands were placed a vertical distance of 10.2 cm below the seed, which was planted 3.8 cm below the soil surface. A schematic diagram of the experimental set up is shown in Fig. 5. Wheat seeds of the variety Newton were planted in two rows in each of six boxes at the rate of one seed per 1.3 cm of row. Rows of wheat were spaced 20.0 cm apart. Dimensions of the boxes used for this study were 45.7 cm long, 45.7 cm wide, and 22.9 cm deep. Each treatment was replicated twice. The plots were prepared for fertilizer application by filling each box with soil to a point 14.0 cm below the top of each box. Ammonium- N and P were applied in the same band by making a small furrow 0.5 cm deep. The ammonia and P solution were then uniformly applied in the furrow by using a pipette. The furrow was then immediately covered with soil to prevent ammonia loss and the boxes were filled to within 3.8 cm of the top of the box. Wheat seeds were then planted, covered and watered.

Banded treatments consisted of 84 kg N/ha and 20 kg P/ha applied as separate solutions but placed in the same band in the ig. 5. The upper diagram shows the cross section view of the check treatment. The middle diagram shows the cross section of the 0 and 20 cm band treatments in relation to the seedling rows. The lower diagram shows the cross section of the 10 and 30 cm band treatments in relation to the seedling rows.


soil surface
seed
20 cm
seed


seed
seed
0 cm
band
20 cm


seed
seed
band
10 cm
30 cm

soil. The nitrogen solution contained 40.0 ml of NH_4OH (22.0% N) and 60.0 ml of water. Twenty milliliters of the NH_4OH solution was applied to the furrow in the four boxes receiving treatment, which corresponded to 84 kg N/ha on a length of row basis. The phosphorus solution was labelled with ^{32}P obtained from New England Nuclear to allow calculation of %P from fertilizer P in the plant tissue. The solution was made by first dissolving 7.57 g of reagent grade monoammonium phosphate in 50.0 ml of distilled deionized water. Five mCi of ^{32}P as orthophosphoric acid in 1 ml of approximately 0.02 M HCl solution was then added and made up to 100.0 ml volume with distilled deionized water. Twenty milliters of this solution, containing 1 mCi ^{32}P, was applied to the furrow in each of the four boxes receiving treatments. This application corresponded to 20 kg P/ha on a length of row basis. The remaining 20.0 ml of this solution was saved until the completion of the study as a reference used in determining the amounts of ^{32}P in the leaf tissue samples. The boxes were watered with distilled deionized water in sufficient quantity to keep the soil at near field capacity.

Leaf tissue samples were collected at 11, 22, 33, and 44 days after planting. The shoots (leaf tissue) of five plants from each treatment were clipped at the soil surface at each sampling date. The samples were dried and weighed. Tissue sample preparation, chemical analysis, and assay of radioactivity are discussed later in this section.

Laboratory Analyses

Leaf Tissue. Leaf tissue samples were dried in a forced air dryer at 60C for five days. The samples were then ground through a Udy rotary-abrasion mill and placed in sealed, plastic vials. Immediately prior to weighing of samples for chemical analysis, the samples were redried at 60C for 24 hours to insure dryness.

A 0.25 g sample of the ground tissue was weighed into a digestion tube and a 2 ml aliquot of sulfuric acid (concentrated) was added (Linder and Harley, 1942). The samples were then placed under a hood in an aluminum digestion block and 1 ml of 30% H_2O_2 was added. The samples were heated at a temperature of 375 C for approximately 45 minutes. The samples were removed from the digestion block and an additional 1 ml of H_2O_2 was added and the samples were reheated. This procedure was repeated until the digest solution remained clear. The digestion tubes were then removed from the heat, diluted to 50 ml with distilled deionized water and stored in polyethylene bottles. Nitrogen and phosphorus determinations were carried out on the diluted solutions using a Technicon Auto Analyzer.

The nitrogen determinations were made based on a colorimetric method in which an emerald-green color is formed by the reaction of ammonia, sodium salicylate, sodium nitroprusside and sodium hypochlorite at a pH of 12.8-13.0. The ammonia-salicylate complex is read on a spectrophotometer at 660 nm (Technicon Industrial Systems, 1977).

Grain Analysis. Grain samples were ground through a Udy rotary-abrasion mill and placed in sealed, plastic vials. Grain samples were handled and analyzed for N and P in the same manner as leaf tissue smaples. The percent protein in the grain was calculated by multiplying the percent N in the grain by a factor of 5.7.

Assay of Radioactivity. The radioactivity of leaf tissue was measured by counting in a Beckman LS-100 Liquid Scintillation System (ambient temperature soft-beta spectrometer). Samples were prepared for counting by pipetting a 5 ml aliquot of the original sulfuric digest, which had been diluted to 25 ml, into a liquid scintillation vial. Ten milliliters of Aquasol, the scintillation solvent, was added to each vial. A standard was prepared for counting by measuring 2 microliters of the reference solution into a liquid scintillation vial and adding 10 ml of Aquasol.

Each sample was counted for 10 minutes to minimize counting error. This reading was then converted to counts per minute (CPM). The sample readings were corrected for background radiation by subtracting the average background radiation of check treatments (no ^{32}P added) from the values of those treatments which received labelled P. Because of the relatively short half-life of ^{32}P (14.3 days), the activity was adjusted for decay at each reading. The reference solution contained 0.39 g of P in 20.0 ml of solution. A 2 microliter sample of the reference solution was used for a standard reading. Calculations for %P from fertilizer P in leaf tissue are as follows:

$$\text{g of P} = 3.90 \times 10^{-5} \text{ g in 2 microliter sample}$$

$$\text{specific activity} = \frac{\text{Net CPM in standard}}{\text{g of P in standard}}$$

$$\text{g of fert. P in sample} = \frac{\text{Net CPM for sample}}{\text{specific activity}}$$

$$\text{\%P from fert. P} = \frac{\text{g of fert. P in sample}}{\text{g of P in the chemical analysis}}$$

Statistical Analysis Procedures

The data collected from 1979 and 1980 studies was analyzed by the Statistical Analysis System (SAS) developed at North Carolina State University. This system was available at the computing center at Kansas State University. Least significant differences are expressed at the 5% level of significance.

The figures in the results and discussion section of this thesis were produced using a Calcomp plotter and plotting program developed by Kemp et al. (1976).

RESULTS AND DISCUSSION

Field Studies

During the two years of this study, 1979 and 1980, visual responses to fertilizer P application in conjunction with band spacing were evident at some locations. These responses were seen as a marked increase in plant growth directly over the N-P bands of treatments with the wider knife spacings (38 cm and 50 cm). This increased plant growth was primarily a phosphorus response since N alone gave no visual response at locations testing low in available P. At locations where response to P was good, a wavy appearance across the N-P fertilized bands resulted, particularly with the 38 and 50 cm knife spacings. However, at most locations, these wavy effects tended to diminish as the plants approached maturity. Differences in head number could be seen over the N-P fertilized band and unfertilized areas of plots receiving treatments with the 38 and 50 cm knife spacings at some locations. Those plots receiving treatments of N and P with the 25 cm spacing exhibited more uniform plant growth across the fertilized area, during the spring (early growth) and also at maturity. None of the wavy effect, characteristic of the two wider spacings, was evident with the 25 cm spacing.

1979 Field Study Results. Excellent visual differences due to P response in conjunction with knife spacing were apparent at Dickinson County by mid-April (Fig. 6). Plots receiving pre-plant bands (dual N-P applications) with band spacings of 38 and 50 cm showed the characteristic wavy effect on plant growth. Fertiliz-

Fig. 6. Visual appearance of winter wheat responses to knife spacing and P-rate at Dickinson County in mid-April, 1979. Top photograph compares the 50 cm (left) and 25 cm (right) knife spacings. Middle photograph compares the 50 cm (left) and 38 cm (right) knife spacings. Bottom photograph compares the 12 kg (left) and 0 kg (right) P rates applied with the 50 cm knife spacing.


N P KNIFE
SPACING
75 N NH_3
20 IN 10 IN
25 P_2O_5 50 P_2O_5


N P KNIFE
SPACING
75 N NH_3
20 IN 15 IN
50 P_2O_5 50 P_2O_5


N P KNIFE
SPACING
75 N NH_3
20 IN 20 IN
25 P_2O_5 0 P_2O_5

er application with the 25 cm band spacing did not exhibit any wavy effect on plant growth, and in general, gave more uniform plant growth. The wavy effect due to application with either the 38 or 50 cm spacing tended to diminish as the plants matured, although differences were still apparent at harvest. Studies conducted at Osage and Riley Counties showed very little response to fertilizer P and therefore, visual and yield differences due to fertilizer P application and/or band spacing were nonexistent.

The data obtained from the Dickinson County location (Table 3) indicate that an excellent grain yield response to fertilizer P was obtained. Mean grain yield from plots receiving 12 kg P/ha averaged 1055 kg/ha more than those receiving no P. There was no significant difference in mean grain yields between the 12 and 24 kg P/ha rates. The average grain protein of plots receiving 12 and 24 kg P/ha were significantly lower than those receiving no P. This reduction in grain protein would be expected since N application rates for all treatments were balanced to 84 kg N/ha and only a certain amount of N was available for crop use, regardless of grain yields. The treatments giving the highest grain yields would be expected to contain a lower percentage of grain protein due to a dilution effect. The P-rate had no significant effect on the percent P in the grain, as plots receiving 24 kg P/ha gave only .01% more P in the grain than plots receiving no P. A significant increase in both N uptake (GNUP) and P uptake (GPUP) by the grain was recorded for the means of the 12 and 24 kg P/ha rates over those plots receiving no P. There were no significant differences between the means of the 12 and 24 kg

Table 3. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD AND GRAIN COMPOSITION. (Dickinson Co., 1979)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein (%)	Grain %P	Grain GNUP* kg/ha	Grain GPUP** kg/ha
25	84	0	2117	14.4	.44	53.5	9.3
38	84	0	1996	13.4	.34	46.7	6.8
50	84	0	1640	13.7	.36	39.1	5.9
25	84	12	3145	13.0	.37	71.8	11.8
38	84	12	2816	13.0	.41	64.1	11.2
50	84	12	2957	12.7	.43	65.9	12.9
25	84	24	3326	12.0	.39	70.1	13.1
38	84	24	3132	12.7	.42	69.7	13.1
50	84	24	2883	11.8	.36	59.4	10.3
Treatment	$LSD_{(.05)}$		732	1.1	NS	15.1	3.2
Mean Values:							
Knife Spacing		25 cm	2863	13.1	.40	65.1	11.4
		38 cm	2648	13.0	.39	60.1	10.4
		50 cm	2493	12.7	.39	54.8	9.7
	$LSD_{(.05)}$		NS	NS	NS	NS	NS
P-Rate		0 P	1915	13.8	.38	46.5	7.4
		12 P	2970	12.9	.41	67.2	12.0
		24 P	3111	12.2	.39	66.3	12.2
	$LSD_{(.05)}$		423	0.6	NS	8.7	1.9

* Grain nitrogen uptake

** Grain phosphorus uptake

P/ha rates for N uptake or P uptake by the grain.

The effect of knife spacing on grain yield was not significant at Dickinson County. However, mean grain yields from plots receiving applications with the 25 cm spacing were greater than those receiving applications with the 38 or 50 cm spacing. Knife spacing had no significant effect on the means for grain protein, %P in the grain, GNUP or GPUP.

As previously mentioned, studies conducted at Osage and Riley Counties showed virtually no response to P applications (Tables 4-5). Visual differences due to knife spacing and P-rate were negligible throughout the growing season at both locations. Studies at these locations showed no significant responses to either knife spacing or P-rate as measured by the means for grain yield, grain protein, %P in the grain, GNUP, and GPUP. It should be noted that grain yields at both locations were very good. The lack of response to N-P treatments was most probably due to the relatively higher soil test levels of available P at these two locations, as compared to the relatively low level of available P at the Dickinson County location.

Leaf Tissue Sampling (1979 Studies). Results of leaf tissue sampling at Dickinson County indicate a response to fertilizer P (Table 6 and Appendix Table I). Samples which were taken directly over an N-P band tended to have a higher %P in the tissue than those samples taken farthest away from the band at the first sampling date on 4/16/79 (for example, see 24 kg P/ha at the 50 cm knife spacing). The data indicate that treatments receiving no P yielded plants which were deficient in P using

Table 4. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD AND GRAIN COMPOSITION. (Osage Co., 1979)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein (%)	Grain %P	Grain GNUP* kg/ha	Grain GPUP** kg/ha
25	84	0	4153	12.3	.30	89.2	12.2
38	84	0	3575	11.7	.31	73.0	11.2
50	84	0	3535	11.4	.37	70.9	13.1
25	84	12	3817	11.4	.28	75.7	10.6
38	84	12	3864	11.9	.32	80.9	11.8
50	84	12	3622	11.7	.32	74.5	11.3
25	84	24	3830	11.7	.30	78.7	11.3
38	84	24	3683	12.1	.29	78.1	10.6
50	84	24	3992	12.1	.34	84.0	13.6
Treatment	$LSD_{(.05)}$		NS	NS	NS	NS	NS
Mean Values:							
Knife Spacing		25 cm	3931	11.8	.29	81.2	11.4
		38 cm	3709	11.9	.31	77.3	11.3
		50 cm	3716	11.7	.34	76.5	12.7
	$LSD_{(.05)}$		NS	NS	NS	NS	NS
P-Rate		0 P	3756	11.8	.32	77.7	12.2
		12 P	3770	11.7	.31	76.9	11.4
		24 P	3837	12.0	.31	80.3	11.9
	$LSD_{(.05)}$		NS	NS	NS	NS	NS

* Grain nitrogen uptake

** Grain phosphorus uptake

Table 5. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD AND GRAIN COMPOSITION. (Riley Co., 1979)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein (%)	Grain %P	Grain GNUP* kg/ha	Grain GPUP** kg/ha
25	84	0	3300	14.2	.36	82.3	11.9
38	84	0	3441	14.1	.33	84.4	11.9
50	84	0	3683	14.3	.34	92.1	12.5
25	84	12	3790	14.0	.36	92.6	13.8
38	84	12	3508	13.8	.38	84.2	13.1
50	84	12	3857	13.7	.37	93.1	14.3
25	84	24	3783	14.3	.33	94.5	12.4
38	84	24	3709	13.8	.35	89.9	13.2
50	84	24	3777	13.9	.39	91.8	14.7
Treatment	$LSD_{(.05)}$		NS	NS	NS	NS	NS
Mean Values:							
Knife Spacing		25 cm	3622	14.2	.35	89.8	12.8
		38 cm	3528	13.9	.35	86.1	12.8
		50 cm	3770	13.9	.37	92.3	13.9
	$LSD_{(.05)}$		NS	NS	NS	NS	NS
P-Rate		0 P	3474	14.2	.34	86.2	12.1
		12 P	3716	13.8	.37	89.9	13.8
		24 P	3756	14.0	.36	92.1	13.4
	$LSD_{(.05)}$		NS	NS	NS	NS	NS

* Grain nitrogen uptake

** Grain phosphorus uptake

Table 6. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Dickinson Co., 1979)

Sampling Date #1: 4/16/79

	Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Rep. 1							%P				
	25	0	.12	.11	.11	.11	.11				
	25	12	.11	.11	.12	.14	.15				
	25	24	.19	.15	.15	.14	.16				
	38	0	.11	.11	.13	.11	.11	.12	.11		
	38	12	.11	.16	.21	.22	.22	.18	.14		
	38	24	.27	.23	.25	.28	.30	.29	.24		
	50	0	.11	.11	.10	.10	.11	.12	.11	.12	.11
	50	12	.14	.19	.19	.21	.22	.17	.14	.12	.12
	50	24	.17	.18	.26	.26	.26	.25	.20	.14	.13
							%N				
	25	0	2.76	2.63	2.57	2.55	2.28				
	25	12	2.39	2.22	2.42	2.51	2.62				
	25	24	2.31	2.30	2.56	2.40	2.61				
	38	0	2.67	2.68	3.29	3.04	2.89	2.81	2.63		
	38	12	2.41	2.90	3.30	3.32	3.52	3.12	2.88		
	38	24	3.71	3.32	3.58	3.58	3.61	3.92	3.25		
	50	0	2.60	2.60	2.47	2.60	2.72	2.80	2.73	2.72	2.60
	50	12	2.77	2.98	3.18	3.41	3.33	2.88	2.71	2.44	2.40
	50	24	2.75	2.70	3.49	3.51	3.44	3.20	3.29	2.51	2.48
Sampling Date #2: 5/6/79											
Rep. 1							%P				
	25	0	.16	.16	.16	.17	.15				
	25	12	.13	.15	.13	.13	.14				
	25	24	.13	.15	.14	.16	.17				
	38	0	.19	.20	.20	.18	.19	.17	.17		
	38	12	.16	.16	.15	.14	.17	.18	.16		
	38	24	.16	.15	.16	.17	.17	.18	.20		
	50	0	.17	.15	.16	.16	.16	.17	.16	.16	.20
	50	12	.15	.16	.16	.13	.15	.10	.15	.16	.18
	50	24	.22	.15	.18	.17	.18	.21	.19	.21	.23

Table 6 (Dickinson Co., 1979 - Continued)

	Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:		5/6/79	(Continued)								
Rep. 1			%N								
	25	0	1.95	2.07	2.24	2.20	2.16				
	25	12	1.71	1.76	1.66	1.86	1.77				
	25	24	1.39	1.44	1.32	1.52	1.60				
	38	0	2.65	2.70	2.73	2.36	2.51	2.40	2.44		
	38	12	2.00	1.93	1.85	1.55	1.99	1.91	1.48		
	38	24	1.86	1.75	1.59	1.89	1.58	2.27	2.26		
	50	0	1.94	1.87	2.08	1.98	1.90	2.15	2.06	2.18	2.63
	50	12	1.54	1.90	1.86	1.45	1.33	1.03	1.47	1.82	1.96
	50	24	1.58	1.50	1.88	1.64	1.64	1.54	1.33	1.77	2.46
			Dry Wt. (g)								
	25	0	2.9	3.3	2.8	2.0	2.0				
	25	12	3.3	3.4	2.7	4.4	4.6				
	25	24	4.4	4.8	4.6	3.4	2.6				
	38	0	1.9	1.5	1.6	2.3	2.4	1.5	2.6		
	38	12	2.2	2.4	4.1	9.7	2.8	2.2	2.7		
	38	24	2.7	6.3	6.5	12.0	6.4	6.0	3.2		
	50	0	1.4	1.6	1.4	2.0	1.9	1.7	2.5	1.2	1.8
	50	12	2.4	2.5	2.3	4.8	9.5	6.6	7.6	2.4	2.8
	50	24	2.4	4.7	2.8	5.0	4.7	6.2	7.4	3.7	3.3

.22% P and below as a guideline for deficiency (Walsh and Beaton, 1973). In fact, treatments receiving P were in some instances very near deficiency levels of tissue P, although characteristic visual deficiency symptoms were never apparent.

Leaf tissue samples taken at the second sampling date (5/6/79) tended to be more uniform across the area sampled in terms of percent P in the tissue compared to the first sampling date. Dry weights of leaf tissue tended to be the highest directly over the N-P band of those treatments with either the 38 or 50 cm spacing.

The percent N in the leaf tissue taken at Dickinson County tended to be the highest directly over the fertilizer band at the first sampling regardless of P-rate. Leaf tissue samples taken at the second date were lower in %N as compared to the first sampling date. This was due to a dilution effect of N in the plant tissue where high leaf tissue dry weights accompanied somewhat lower %N levels and vice versa.

Results of tissue sampling at Osage (Table 7 and Appendix Table II) and Riley Counties (Table 8 and Appendix Table III) showed some increases in N and P percent of plants directly over the fertilizer band as compared to those samples taken between bands. At both dates of sampling and at both locations, the N and P levels in the leaf tissue were well above deficiency levels, even for treatments receiving no P. These two locations, as mentioned before, were unresponsive to applied P. The dry weights for the second sampling date are not presented in this thesis since no differences were observed.

The leaf tissue data taken for 1979 was not analyzed statistically, so no definite conclusions can be drawn as to the

Table 7. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Osage Co., 1979)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/7/79										
Rep. 1						%P				
25	0	.28	.34	.33	.29	.37				
25	12	.30	.28	.27	.30	.30				
25	24	.27	.28	.30	.29	.30				
38	0	.36	.32	.27	.25	.26	.27	.27		
38	12	.31	.32	.33	.31	.27	.22	.26		
38	24	.28	.25	.29	.33	.35	.34	.31		
50	0	.22	.21	.21	.21	.20	.19	.21	.21	.24
50	12	.27	.26	.33	.34	.35	.37	.33	.27	.23
50	24	.25	.23	.25	.33	.35	.36	.38	.32	.24
						%N				
25	0	4.31	4.73	4.59	4.24	4.51				
25	12	4.44	4.12	3.98	4.39	4.45				
25	24	4.21	4.30	4.29	4.25	4.48				
38	0	4.62	4.55	4.31	4.17	4.28	4.08	4.08		
38	12	4.47	4.40	4.50	4.36	4.21	3.65	4.19		
38	24	4.39	4.30	4.27	4.50	4.82	4.62	4.55		
50	0	4.10	4.01	3.93	3.88	3.76	3.80	3.91	3.59	3.89
50	12	4.29	3.92	4.68	4.49	4.67	4.68	4.59	4.39	3.92
50	24	3.98	3.78	3.85	4.02	4.38	4.22	4.62	4.18	3.81

Table 7 (Osage Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2: 4/28/79										
Rep. 1						%P				
25	0	.26	.30	.28	.26	.26				
25	12	.26	.28	.28	.32	.29				
25	24	.28	.26	.26	.27	.24				
38	0	.27	.26	.24	.23	.26	.22	.22		
38	12	.31	.29	.27	.29	.29	.26	.27		
38	24	.27	.27	.28	.27	.28	.25	.25		
50	0	.21	.22	.21	.24	.23	.24	.24	.26	.24
50	12	.21	.22	.26	.26	.28	.26	.26	.29	.24
50	24	.23	.28	.30	.24	.28	.27	.29	.25	.32
						%N				
25	0	2.54	2.98	3.00	2.81	2.80				
25	12	2.39	2.34	2.07	2.48	2.18				
25	24	2.78	2.79	2.79	3.09	2.68				
38	0	2.53	2.87	2.58	2.59	3.09	2.55	2.80		
38	12	2.88	2.79	2.99	2.58	2.99	2.71	2.67		
38	24	2.42	2.96	3.02	3.19	2.91	3.11	2.91		
50	0	2.79	2.87	2.33	2.53	2.67	2.74	2.55	2.59	2.62
50	12	2.34	2.67	2.68	2.94	3.13	2.88	2.81	3.31	2.93
50	24	2.68	2.94	3.02	2.55	3.02	2.80	2.76	2.20	2.82

Table 8. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Riley Co., 1979)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1:	4/17/79									
Rep. 1						%P				
25	0	.33	.32	.32	.37	.33				
25	12	.26	.35	.36	.36	.35				
25	24	.35	.33	.37	.25	.35				
38	0	.38	.38	.35	.37	.33	.31	.32		
38	12	.31	.35	.38	.36	.40	.36	.41		
38	24	.41	.37	.32	.35	.42	.42	.42		
50	0	.31	.30	.30	.30	.27	.29	.27	.29	.29
50	12	.40	.33	.34	.36	.41	.43	.46	.43	.48
50	24	.41	.39	.35	.34	.43	.39	.43	.32	.46
						%N				
25	0	4.57	4.42	3.91	4.29	4.20				
25	12	3.24	4.08	3.90	4.00	3.98				
25	24	4.47	4.28	4.59	2.98	4.39				
38	0	4.45	4.87	4.69	4.39	4.17	4.27	4.10		
38	12	3.89	3.92	4.30	4.41	4.50	4.39	4.44		
38	24	4.32	4.25	3.78	4.09	4.34	4.34	4.30		
50	0	4.10	4.30	4.21	4.33	4.01	4.19	3.87	4.12	4.28
50	12	4.42	4.17	4.22	4.50	4.65	4.34	4.30	3.60	4.39
50	24	4.30	4.03	4.18	4.20	4.60	4.21	4.29	4.18	4.08

Table 8 (Riley Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/1/79									
Rep. 1						%P				
25	0	.25	.31	.30	.27	.30				
25	12	.33	.26	.25	.31	.29				
25	24	.29	.30	.28	.25	.30				
38	0	.31	.33	.37	.28	.41	.30	.28		
38	12	.30	.31	.34	.30	.29	.30	.29		
38	24	.28	.28	.27	.29	.30	.30	.30		
50	0	.27	.26	.23	.31	.31	.26	.26	.26	.29
50	12	.30	.33	.36	.32	.31	.34	.40	.36	.36
50	24	.32	.27	.35	.31	.34	.34	.30	.31	.36
						%N				
25	0	2.79	3.30	3.42	3.08	3.37				
25	12	3.45	2.59	2.63	3.12	2.89				
25	24	3.30	3.12	3.02	2.95	3.08				
38	0	3.28	3.20	3.55	3.02	3.31	3.38	3.20		
38	12	2.97	3.13	3.32	2.79	2.58	3.37	2.79		
38	24	2.69	2.43	2.73	2.72	2.79	2.68	2.83		
50	0	2.58	2.93	2.67	3.40	3.31	2.98	3.19	3.22	3.28
50	12	2.58	2.66	2.90	2.87	2.59	3.00	3.12	3.11	3.19
50	24	3.20	2.45	3.05	2.85	2.82	2.51	2.45	2.28	2.97

effect of knife spacing and P-rate on nutrient levels and dry weights of leaf tissue.

Grain Head Sampling (Dickinson County 1979). Grain head samples were collected from the Dickinson County location in a similar manner to the leaf tissue samples and data is presented in Table 9 and Appendix Table IV. The number of heads per sample (5.1 cm of row) tended to be the greatest directly over the fertilizer band of those treatments receiving P at the wider spacings (38 and 50 cm). Although somewhat variable, head number was more uniform across the area sampled for the 25 cm spacing as compared to the 38 and particularly the 50 cm spacing. The number of heads per sample (5.1 cm of row) tended to increase as the P-rate increased. Likewise, total grain weight per sample tended to increase as head number per sample increased and vice versa. The average kernel weight per sample, grain protein, and percent P in the grain per sample are also presented in Table 9. The average kernel weight tended to increase with an increase in P rate in conjunction with the narrower knife spacings. Grain protein was highest for those treatments which received no P. The percent P in the grain was highest in those treatments receiving P compared to treatments receiving no P. As with the 1979 leaf tissue data, the head sample data was not analyzed statistically.

1980 Field Study Results. Studies conducted in Labette, Harper, and Dickinson Counties showed visual responses to P and the effect of band spacing was evident in varying degrees up through the time of harvest. The wavy effect due to the wider band spac-

Table 9. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN HEAD NUMBER AND GRAIN COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Dickinson Co., 1979)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 1							
38 cm	0	1	2	1.2	31.5	14.5	.29
		2	3	2.7	31.6	14.6	.21
		3	5	3.8	31.1	14.6	.21
		4	3	3.0	30.5	15.1	.24
		5	3	2.5	33.6	14.1	.21
		6	2	1.9	27.6	14.4	.25
		7	2	1.2	29.3	14.6	.24
25 cm	12	1	12	8.1	34.5	12.4	.23
		2	12	7.9	31.3	11.2	.21
		3	8	5.4	33.7	10.9	.21
		4	4	3.0	33.8	11.6	.21
		5	9	6.1	34.6	11.6	.21
38 cm	12	1	5	3.1	31.2	12.4	.20
		2	3	2.1	31.1	12.1	.24
		3	5	3.4	32.7	11.1	.23
		4	7	8.6	34.5	10.9	.18
		5	6	5.3	31.5	11.6	.26
		6	5	4.8	31.4	10.9	.21
		7	3	2.5	30.9	11.4	.30
50 cm	12	1	2	1.3	33.2	12.4	.40
		2	3	2.3	34.0	11.5	.30
		3	10	8.3	33.0	11.3	.26
		4	13	10.4	31.5	10.9	.23
		5	17	15.4	33.7	11.5	.29
		6	5	3.5	34.1	11.3	.31
		7	5	3.3	28.6	11.4	.26
		8	4	2.7	29.0	11.7	.39
		9	6	3.9	33.7	10.9	.29

Table 9 (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 1							
25 cm	24	1	13	9.6	33.8	10.1	.28
		2	9	4.9	33.2	10.2	.33
		3	10	8.3	32.7	9.9	.34
		4	5	2.6	35.0	11.3	.34
		5	10	6.3	32.5	10.1	.29
38 cm	24	1	7	4.2	28.7	12.5	.23
		2	7	5.7	30.3	11.9	.20
		3	6	4.8	29.6	12.4	.20
		4	9	8.9	33.5	12.5	.21
		5	7	4.8	31.1	11.9	.20
		6	5	5.3	29.0	12.1	.23
		7	8	4.2	28.2	12.1	.25
50 cm	24	1	9	4.3	29.7	11.2	.24
		2	7	5.7	28.0	10.5	.28
		3	20	15.0	32.4	10.4	.24
		4	13	8.3	27.8	10.7	.25
		5	17	10.1	27.8	10.5	.22
		6	14	9.2	28.1	10.5	.23
		7	10	7.4	30.6	10.4	.23
		8	9	4.8	30.2	10.3	.24
		9	3	1.2	27.8	11.1	.33
Rep. 2							
38 cm	0	1	6	1.2	28.0	14.5	.23
		2	4	2.9	28.8	13.3	.21
		3	11	7.5	29.3	12.9	.18
		4	7	4.0	29.1	14.1	.21
		5	10	6.6	31.7	12.1	.21
		6	6	3.6	30.7	14.9	.22
		7	6	3.9	31.7	14.4	.19

Table 9 (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 2							
25 cm	12	1	4	3.1	30.8	12.9	.24
		2	7	6.6	33.8	13.1	.20
		3	11	7.6	33.1	12.4	.21
		4	6	4.8	32.5	12.5	.18
		5	10	5.8	28.7	12.2	.23
38 cm	12	1	6	3.8	28.1	11.3	.21
		2	10	6.8	30.8	11.4	.23
		3	7	3.9	27.8	12.1	.28
		4	6	4.2	29.0	12.1	.23
		5	2	1.9	31.6	11.7	.31
		6	9	5.7	31.4	11.7	.12
		7	6	5.8	33.3	11.7	.20
50 cm	12	1	10	7.5	32.3	11.2	.23
		2	7	4.3	35.0	11.4	.26
		3	5	4.7	32.6	10.5	.23
		4	12	9.8	33.0	10.3	.22
		5	10	5.3	31.6	10.7	.27
		6	4	3.7	34.2	11.1	.27
		7	9	7.7	31.8	10.8	.26
		8	11	6.5	28.8	10.7	.22
		9	4	2.5	30.8	12.3	.31
25 cm	24	1	5	3.6	34.2	10.7	.38
		2	5	3.0	27.7	10.7	.39
		3	5	3.9	33.2	10.3	.31
		4	3	2.3	32.8	10.5	.35
		5	9	5.7	30.0	10.5	.38

Table 9 (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernal Wt. (mg)	Grain Protein %	% P
Rep. 2							
38 cm	24	1	5	5.0	35.8	10.2	.37
		2	4	2.0	33.6	10.3	.37
		3	4	2.5	30.4	10.1	.24
		4	7	4.0	30.5	10.4	.23
		5	11	8.7	35.5	11.1	.33
		6	5	3.7	31.3	9.8	.25
		7	5	2.6	32.3	10.1	.23
50 cm	24	1	10	4.3	32.7	9.3	.29
		2	5	5.7	31.1	10.7	.36
		3	6	15.0	33.2	11.2	.31
		4	15	8.3	31.3	9.8	.26
		5	19	10.1	32.1	9.6	.34
		6	6	9.2	32.0	9.6	.30
		7	9	7.4	32.9	9.6	.29
		8	6	4.8	32.8	9.6	.31
		9	5	1.6	30.9	10.9	.37

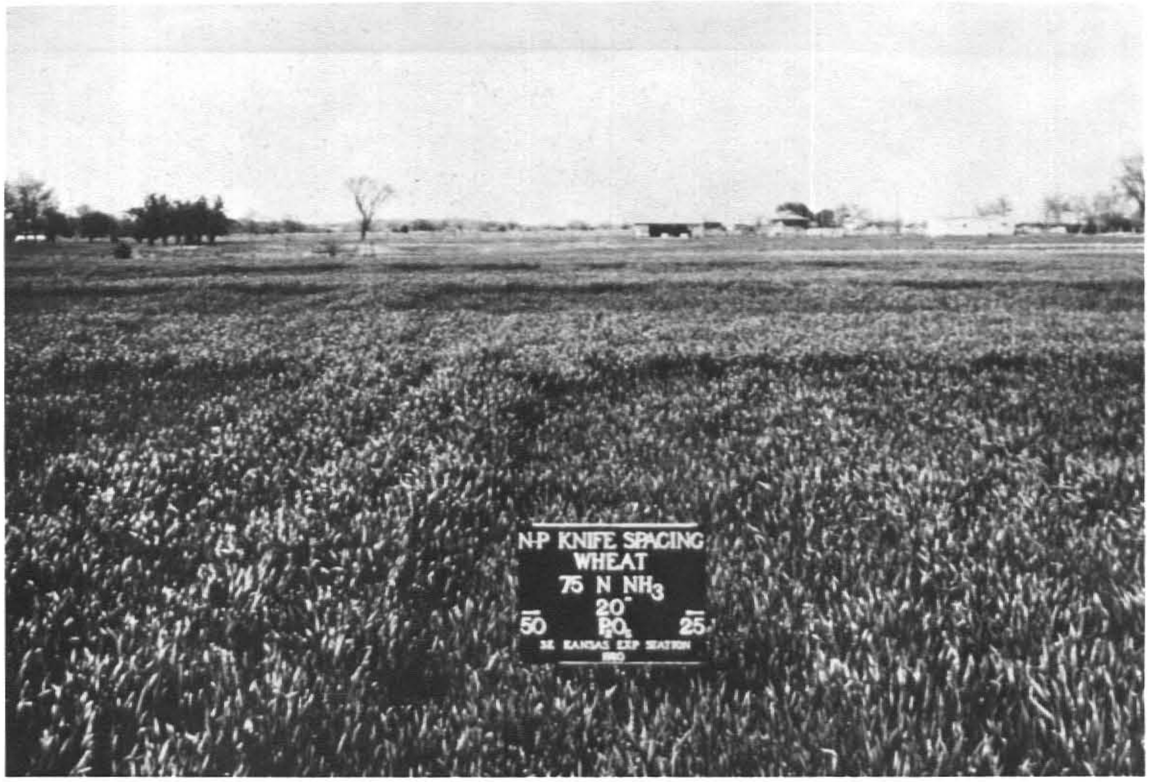
ings (38 and 50 cm) was evident at all locations during the latter part of April and through mid-May, but tended to diminish as the plants reached maturity (Fig. 7).

At Labette County, a grain yield response to fertilizer P was obtained (Table 10). Plots receiving 6 kg P/ha averaged 271 kg/ha more than those receiving no P. There were no significant grain yield differences between the means for the 6, 12, and 24 kg P/ha rates. A treatment receiving 168 kg N/ha and 48 kg P/ha applied with the 25 cm knife spacing gave a grain yield increase of 186 kg/ha over the mean for the 24 kg P/ha rate. This treatment, however, was not included in the statistical analysis. The P-rate had no significant effect on mean grain protein or %P in the grain, but did have a significant effect on GNUP and GPUP. The 24 kg P/ha rate gave significantly higher N and P uptake values than did either the 0 or 6 kg P/ha rates, but the 24 kg P/ha rate did not significantly increase GNUP or GPUP over the 12 kg P/ha rate.

Knife spacing had no significant effect on grain yield, grain protein, %P, GNUP, or GPUP. A possible factor for this lack of response to knife spacing could be the low amount of rainfall received during heading and grain filling at this location. The potential for excellent grain yields was evident early in the growing season, but high yields failed to be realized at harvest.

A fertilizer P response was also obtained at the Harper County location (Table 11). Treatments which received 24 kg P/ha gave a significant mean grain yield increase of 306 kg/ha over treatments receiving 6 kg P/ha and 504 kg/ha more than

Fig. 7. Visual appearance of winter wheat responses to knife spacing and P-rate at Labette County in 1980. The top photograph shows the 50 cm spacing with 24 and 12 kg P/ha during mid-April. The bottom photograph shows the 50 cm spacing with 24 kg P/ha at heading. Notice the growth of wheat directly over the pre-plant bands.


N-P KNIFE SPACING
WHEAT
75 N NH_3
20
50 P_2O_5 25
SE KANSAS EXP STATION


KNIFE
PACING
N AS NH_3
20 IN
P_2O_5 50
MAY 15

Table 10. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD AND GRAIN COMPOSITION. (Labette Co., 1980)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein (%)	Grain %P	Grain GNUP 2/ kg/ha	Grain GPUP 3/ kg/ha
25	84	0	2146	12.4	.23	46.6	4.9
38	84	0	2160	12.7	.23	49.7	5.0
50	84	0	2234	12.6	.26	49.3	5.8
25	84	6	2421	12.5	.25	53.0	6.1
38	84	6	2450	12.4	.25	53.4	6.0
50	84	6	2482	12.2	.24	53.1	6.0
25	84	12	2490	12.4	.24	54.2	6.1
38	84	12	2551	12.5	.24	56.1	6.2
50	84	12	2550	12.1	.25	54.1	6.4
25	84	24	2567	12.9	.24	58.0	6.3
38	84	24	2572	12.8	.27	57.8	7.0
50	84	24	2567	12.2	.25	54.9	6.4
25 1/	168	48	2755	12.8	.25	62.0	6.9
Treatment $LSD_{(.05)}$			208	NS	.02	5.0	0.7
Mean Values:							
Knife Spacing	25 cm		2406	12.5	.24	52.9	5.8
	38 cm		2433	12.6	.25	54.2	6.0
	50 cm		2458	12.3	.25	52.9	6.1
		$LSD_{(.05)}$	NS	NS	NS	NS	NS

Table 10 (Labette Co., 1980 - Continued, Mean Values)

		Yield kg/ha	Grain Protein (%)	Grain		
				%P	GNUP 2/ kg/ha	GPUP 3/ kg/ha
Mean Values:						
P-Rate	0 P	2180	12.6	.24	48.5	5.2
	6 P	2451	12.4	.25	53.1	6.0
	12 P	2530	12.3	.24	54.9	6.2
	24 P	2569	12.6	.25	56.9	6.5
	$LSD_{(.05)}$	120	NS	NS	2.9	0.4

1/ Not included in statistical analysis

2/ Grain nitrogen uptake

3/ Grain phosphorus uptake

Table 11. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD, TISSUE COMPOSITION, AND GRAIN COMPOSITION. (Harper Co., 1980)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein (%)	Tissue		Grain		
					%N	%P	%P	GNUP 2/ kg/ha	GPUP 3/ kg/ha
25	84	0	2688	12.8	3.67	.22	.28	59.9	7.6
38	84	0	2776	12.9	3.79	.23	.29	62.3	7.9
50	84	0	2481	12.7	3.99	.22	.29	54.7	7.2
25	84	6	2915	12.5	3.80	.22	.29	63.9	8.5
38	84	6	2708	12.7	3.91	.24	.29	60.3	7.9
50	84	6	2917	12.1	3.83	.26	.29	61.6	8.5
25	84	12	3259	12.4	3.90	.25	.30	70.8	9.9
38	84	12	2959	12.4	3.91	.25	.30	64.4	8.9
50	84	12	2826	12.2	3.36	.24	.31	60.6	8.9
25	84	24	3180	12.0	3.75	.27	.31	67.1	10.0
38	84	24	2915	12.3	3.87	.27	.31	62.8	9.1
50	84	24	3362	11.6	4.25	.33	.31	67.7	10.6
25 1/	168	48	3251	13.4	4.30	.32	.37	75.8	12.1
Treatment	$LSD_{(.05)}$		450	0.5	NS	.03	.02	NS	1.6
<u>Mean Values:</u>									
<u>Knife Spacing</u>		25 cm	3011	12.4	3.78	.24	.30	65.4	9.0
		38 cm	2839	12.6	3.87	.24	.30	62.5	8.5
		50 cm	2896	12.1	3.86	.26	.30	61.1	8.8
		$LSD_{(.05)}$	NS	0.2	NS	.01	NS	NS	NS

Table 11 (Harper Co., 1980 - Continued, Mean Values)

		Yield kg/ha	Grain Protein (%)	Tissue		Grain		
				%N	%P	%P	GNUP 2/ kg/ha	GPUP 3/ kg/ha
Mean Values:								
P-Rate	0 P	2648	12.8	3.82	.22	.29	58.9	7.6
	6 P	2846	12.4	3.85	.24	.29	61.9	8.3
	12 P	3015	12.3	3.72	.25	.31	65.3	9.2
	24 P	3152	12.0	3.96	.29	.31	65.9	9.9
	$LSD_{(.05)}$	260	0.3	NS	.01	.01	NS	0.9

1/ Not included in statistical analysis

2/ Grain nitrogen uptake

3/ Grain phosphorus uptake

treatments receiving no P. There was no significant difference in mean grain yield between the 12 and 24 kg P/ha rates. Mean grain protein was significantly higher for the 0 kg P/ha rate compared to the 6, 12, and 24 kg P rates. The %N in leaf tissue was not significantly affected by P-rate, however, %P in the leaf tissue was significantly increased by increasing amounts of P applied. The percent P in the grain was significantly higher for the 12 and 24 kg P/ha rates compared to the 0 and 6 kg P/ha rates. There was no significant difference in percent P in the grain between the 0 and 6 kg P/ha rates. There were no significant increases in GNUP due to P-rate, but GPUP levels were significantly increased by the 12 and 24 kg P/ha rates over the 0 and 6 kg P rates. There was no significant difference in GPUP between the 0 and 6 kg P rates.

The effect of knife spacing on the mean grain yield, leaf tissue %N, %P in the grain, GNUP, and GPUP were not significant. Mean grain protein and %P in the leaf tissue were significantly affected by knife spacing. Grain protein was variable with no trend towards the 25 or 50 cm spacing. The mean percent P in the leaf tissue of the 50 cm treatments was significantly higher than for the 38 or 25 cm treatments.

The data collected from the Dickinson County location indicated a good yield response to fertilizer P (Table 12). Yields, however, were low and variable due to late planting and subsequently poor stand. Plots receiving 6, 12, and 24 kg P/ha were not significantly different in mean grain yield but gave significantly higher mean grain yields than did plots receiving no P. A treatment receiving 168 kg N/ha and 48 kg P/ha applied with the

Table 12. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN YIELD, TISSUE COMPOSITION, AND GRAIN COMPOSITION. (Dickinson Co., 1980)

Knife Spacing (cm)	N-Rate kg/ha	P-Rate kg/ha	Yield kg/ha	Grain Protein	Tissue		Grain		
					%N	%P	%P	GNUP 2/ kg/ha	GPUP 3/ kg/ha
25	84	0	929	15.4	2.94	.20	.26	25.1	2.5
38	84	0	1608	15.1	2.52	.20	.26	41.7	4.6
50	84	0	1873	14.7	2.78	.22	.27	47.9	5.2
25	84	6	2050	14.6	2.17	.22	.27	52.1	5.5
38	84	6	2275	14.9	2.18	.21	.29	59.4	6.6
50	84	6	1783	15.0	2.55	.22	.26	46.4	4.6
25	84	12	2094	14.9	2.16	.21	.27	54.5	5.6
38	84	12	2219	14.6	2.65	.22	.25	56.5	5.6
50	84	12	2105	14.5	2.48	.21	.26	53.0	5.5
25	84	24	2080	15.2	2.34	.22	.28	54.6	5.7
38	84	24	2374	13.9	2.26	.22	.26	58.6	6.9
50	84	24	2224	14.4	2.37	.24	.27	55.9	6.1
25 1/	168	48	2695	14.9	2.75	.27	.26	70.2	7.1
Treatment	$LSD_{(.05)}$		664	NS	.49	.02	NS	15.8	2.0
<u>Mean Values:</u>									
<u>Knife Spacing</u>		25 cm	1788	15.0	2.40	.21	.27	46.6	4.8
		38 cm	2119	14.6	2.40	.21	.27	54.0	5.9
		50 cm	1996	14.6	2.54	.22	.26	50.9	5.3
		$LSD_{(.05)}$	NS	NS	NS	.01	NS	NS	NS

Table 12 (Dickinson Co., 1980 - Continued, Mean Values)

		Yield kg/ha	Grain Protein	Tissue		Grain		
				%N	%P	%P	GNUP 2/ kg/ha	GPUP 3/ kg/ha
Mean Values:								
P-Rate	0 P	1470	15.0	2.75	.21	.27	38.2	4.1
	6 P	2036	14.8	2.30	.21	.27	52.8	5.6
	12 P	2139	14.6	2.43	.21	.26	54.7	5.6
	24 P	2226	14.5	2.32	.23	.27	56.4	6.2
	$LSD_{(.05)}$	383	NS	.28	.01	NS	9.1	1.1

1/ Not included in statistical analysis

2/ Grain nitrogen uptake

3/ Grain phosphorus uptake

25 cm spacing gave a 469 kg/ha grain yield increase over the mean for the 24 kg P/ha rate. There was no significant influence of P-rate on grain protein or %P in the grain. Leaf tissue N and P levels were significantly affected by P-rate as were GNUP and GPUP. Plots receiving no P were significantly higher in mean leaf tissue %N than the 6, 12, or 24 kg P rates. The 24 kg P rate gave significantly higher mean P in the leaf tissue than the 0, 6, or 12 kg P rates. Both the mean GNUP and GPUP showed significant increases due to 6 kg P compared to 0 kg P. There were no significant differences in mean GNUP or GPUP between the 6, 12, or 24 kg P rates.

Knife spacing had no significant effect on mean grain yield at Dickinson County, nor on mean grain protein, leaf tissue %N, %P in the grain, GNUP, and GPUP. The leaf tissue P content was significantly higher for the 50 cm spacing compared to either the 38 or 25 cm spacing.

Leaf Tissue Sampling (Labette County 1980). Leaf tissue sampling, as outlined in the materials and methods section, consisted of samples of samples of leaf tissue, each taken from 12.7 cm of row. Detailed sampling of this type was conducted at the Labette County location only. Sampling included one set of three samples from each treatment in all four replications. Replications were averaged for each treatment (Table 13).

The change in N and P levels in the leaf tissue due to knife spacing was not large. As would be expected, the %P in the tissue of the sample centered over the band from the 50 cm spacing with the 24 kg P rate was the highest. However, it was not sig-

Table 13. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AND DRY MATTER PRODUCTION. (Labette Co., 1980)

		Location of Sample in Relation to Band				
Knife Spacing (cm)	P-Rate kg/ha	Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		%N				
25	0	3.24	3.18	3.16	NS	
38	0	3.35	2.98	3.26	.25	
50	0	3.24	3.05	3.14	NS	
25	6	2.94	2.85	2.59	NS	
38	6	2.82	2.68	2.88	NS	
50	6	2.82	2.43	2.98	.41	
25	12	3.00	2.75	3.01	NS	
38	12	2.92	2.70	2.72	NS	
50	12	3.06	2.84	2.80	NS	
25	24	2.84	2.78	2.73	NS	
38	24	2.81	2.85	2.69	NS	
50	24	2.89	2.73	2.93	NS	
25*	48	2.74	2.77	2.69		
	$LSD_{(.05)}$	.31	NS	NS		
		%P				
25	0	.19	.20	.19	NS	
38	0	.19	.17	.19	.02	
50	0	.20	.18	.18	.02	
25	6	.19	.20	.18	NS	
38	6	.20	.18	.20	NS	
50	6	.22	.20	.21	NS	
25	12	.22	.21	.21	NS	
38	12	.21	.19	.19	NS	
50	12	.22	.21	.22	NS	
25	24	.21	.21	.21	NS	
38	24	.23	.23	.21	NS	
50	24	.26	.26	.26	NS	
25*	48	.26	.26	.26		
	$LSD_{(.05)}$	.04	.05	.03		

* Received 168 kg N/ha; not included in statistical analysis.

Table 13 (Labette Co., 1980 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		---- Dry Matter (kg/ha) -----				
25	0	1118	1649	1184	NS	
38	0	819	1383	1262	NS	
50	0	1140	1240	1040	NS	
25	6	1450	2335	2988	610	
38	6	1395	2014	1350	NS	
50	6	1572	3232	1129	1122	
25	12	2446	3542	2468	NS	
38	12	1992	3331	2357	NS	972
50	12	1893	4172	2247	1795	
25	24	1804	2357	1970	NS	
38	24	2424	4361	2191	1202	
50	24	2048	4737	1439	1405	
25*	48	3309	4405	2855		
	$LSD_{(.05)}$	860	1347	1197		
		----- N Uptake (kg/ha) ------				
25	0	35.6	51.2	36.5	NS	
38	0	26.9	39.5	38.0	NS	
50	0	35.9	36.1	31.7	NS	
25	6	42.3	66.7	77.7	16.8	
38	6	38.8	54.0	37.7	NS	
50	6	41.7	78.2	33.6	22.6	
25	12	73.6	96.7	74.4	NS	
38	12	57.0	87.2	60.7	NS	
50	12	56.9	118.7	59.0	NS	46.4
25	24	49.8	64.0	54.0	NS	
38	24	66.2	124.8	56.4	28.7	
50	24	59.6	128.2	39.8	36.5	
25*	48	92.4	127.8	76.9		
	$LSD_{(.05)}$	23.4	37.9	30.5		

* Received 168 kg N/ha; not included in statistical analysis.

Table 13 (Labette Co., 1980 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		----- P Uptake (kg/ha) -------				
25	0	2.1	3.2	2.2	NS	
38	0	1.6	2.2	2.5	NS	
50	0	2.2	2.1	1.8	NS	
25	6	2.8	4.6	5.3	1.4	
38	6	2.8	3.7	2.7	NS	
50	6	3.4	6.4	2.4	2.5	
25	12	5.3	7.3	5.1	NS	
38	12	4.1	6.2	4.3	NS	
50	12	4.0	9.3	4.9	NS	4.0
25	24	3.7	5.2	4.3	NS	
38	24	5.4	10.0	4.6	2.9	
50	24	5.2	12.1	3.6	4.2	
25*	48	8.7	11.9	7.5		
	$LSD_{(.05)}$	1.9	3.5	NS		
	(.10)			2.1		

Mean Values: Knife Spacing

		------------ %N ------------		
25 cm		3.00	2.89	2.87
38 cm		2.97	2.80	2.89
50 cm		3.00	2.76	2.96
	$LSD_{(.05)}$	NS	NS	NS
		------------ %P ------------		
25 cm		.20	.20	.20
38 cm		.21	.19	.20
50 cm		.22	.21	.22
	$LSD_{(.05)}$	NS	NS	.02
	(.10)	.03		
		---- Dry Matter (kg/ha) -----		
25 cm		1704	2471	2153
38 cm		1657	2772	1790
50 cm		1663	3345	1464
	$LSD_{(.05)}$	NS	673	NS
	(.10)			498

* Received 168 kg N/ha; not included in statistical analysis.

Table 13 (Labette Co., 1980 - Continued)

	Location of Sample in Relation to Band		
	Centered Between Bands	Centered Over Band	Centered Between Bands
Mean Values: Knife Spacing			
	------ N Uptake (kg/ha) ------		
25 cm	50.3	69.7	60.6
38 cm	47.2	76.4	48.2
50 cm	48.5	90.3	41.0
$LSD_{(.05)}$	NS	NS	15.3
$(.10)$		15.3	
	------ P Uptake (kg/ha) ------		
25 cm	3.5	5.1	4.2
38 cm	3.5	5.5	3.5
50 cm	3.7	7.5	3.2
$LSD_{(.05)}$	NS	1.8	NS
Mean Values: P-Rate			
	------------- %N -----------		
0 P	3.28	3.07	3.19
6 P	2.86	2.65	2.81
12 P	2.99	2.76	2.84
24 P	2.84	2.78	2.78
$LSD_{(.05)}$	.18	.26	.26
	------------- %P -----------		
0 P	.19	.18	.19
6 P	.20	.19	.20
12 P	.21	.20	.21
24 P	.23	.23	.23
$LSD_{(.05)}$	.02	.03	.02
	----- Dry Matter (kg/ha) -----		
0 P	1026	1424	1162
6 P	1472	2527	1823
12 P	2110	3682	2357
24 P	2092	3818	1867
$LSD_{(.05)}$	497	777	691

Table 13 (Labette Co., 1980 - Continued)

	Location of Sample in Relation to Band		
	Centered Between Bands	Centered Over Band	Centered Between Bands
Mean Values: P-Rate			
	----- N Uptake (kg/ha) -------		
0 P	32.8	42.2	35.4
6 P	40.9	66.3	49.6
12 P	62.5	100.9	64.7
24 P	58.5	105.7	50.1
$LSD_{(.05)}$	13.5	21.9	17.6
	----- P Uptake (kg/ha) -------		
0 P	1.9	2.5	2.2
6 P	3.0	4.9	3.5
12 P	4.5	7.6	4.8
24 P	4.8	9.1	4.2
$LSD_{(.05)}$	1.1	2.0	1.5

nificantly higher than either the 38 or 25 cm spacings with the 24 kg P rate. The higher %P was probably a result of the higher concentration of N and P in the band of the 50 cm spacing as compared to the 38 or 25 cm spacings.

The dry weights were significantly higher in the sample centered over the band of the wider spacings. The fertilizer bands at the 50 cm spacing contained twice the concentration of N and P as the fertilizer bands at the 25 cm spacings. However, both spacings were equal in terms of kg/ha of N or P applied. The mean dry weight of the sample centered over the band of the 50 cm spacing was significantly greater than the mean dry weight of the sample centered over the band of the 25 cm spacing. Mean dry weights of samples centered between bands trended lower for the wider spacings (38 and 50 cm) as would be expected, since the distance from the plant to the fertilizer band was greater than the distance from plant to band for the 25 cm spacing. A more uniform growth of plants across the plots of the 25 cm spacing was observed visually and the dry weights obtained from sampling seem to substantiate this observation.

Uptake of N was also more uniform between samples taken from the 25 cm spacing. The 38 cm and 50 cm spacing showed a relatively high amount of N uptake in the sample centered over the band with lesser amounts in samples centered between bands. Uptake of P was significantly greater in the sample centered over the band of the 50 cm spacing than either the 38 or 25 cm spacings. There were no significant differences in mean P uptake due to knife spacing for samples centered between bands.

Averaged across spacing, the %N in the leaf tissue of samples centered over the band and centered between bands were significantly lowered by the addition of P in the treatments as compared to treatments receiving no P. This would be due to a dilution effect, since the dry weights of those samples receiving no P were significantly less than those samples that did receive P. Both samples centered between bands and centered over bands showed a negative correlation between the P-rate and %N in the leaf tissue. The correlation between %N, %P, dry matter production, and P-rate is given in Table 14. The table presents the correlation coefficients and the regression equation for %N, %P, dry matter production as influenced by P-rate for samples between bands and centered over the bands.

The %P in the leaf tissue was significantly increased by P-rate for samples centered between bands and centered over bands. The correlation coefficients for the effect of P-rate on %P on %P in the tissue were r=.47 and r=.53 for samples centered between bands and centered over bands, respectively, (Table 14) which were significant at the 1% level of significance. Dry matter yields for the samples centered between bands and centered over bands were both positively correlated with P-rate with correlation coefficients of r=.60 and r=.53, respectively, (Table 14) which were significant at the 1% level of significance. The 12 and 24 kg P/ha rates gave higher mean N and P uptake rates than did either the 0 or 6 kg P/ha rates for all three samples.

Grain Head Sampling (Labette County 1980). Grain head sampling as outlined in the materials and methods section, consisted of samples of grain heads, each taken from 12.7 cm of row.

Table 14. CORRELATION OF %N, %P, AND DRY MATTER OF LEAF TISSUE AS AFFECTED BY P-RATE ON SAMPLES* CENTERED BETWEEN BANDS AND CENTERED OVER BANDS TAKEN AT THE EARLY SAMPLING DATE. (Labette Co., 1980)

Correlation Coefficients For Samples Centered Between Bands

	%P	Dry Matter	P-Rate
%N	.01	-.55**	-.39**
%P		.19	.47**
Dry Matter			.53**

Regression Equations

%N = 3.13 - .0066(P-Rate)	r = -.39**
%P = .194 + .00072(P-Rate)	r = .47**
Dry Matter = 976.4 + 60.83(P-Rate) - 0.76(P-Rate)^2	r = .60**

Correlation Coefficients For Samples Centered Over Bands

	%P	Dry Matter	P-Rate
%N	.19	-.37**	-.19
%P		.47**	.53**
Dry Matter			.60**

Regression Equations

%N = 2.90 - .0036(P-Rate)	r = -.19
%P = .179 + .0010(P-Rate)	r = .53**
Dry Matter = 1367.1 + 127.39(P-Rate) - 1.56(P-Rate)^2	r = .67**

* Samples taken from .127m of row.
** Indicates significance at the 1% level.

Sampling included one set of three samples from each treatment in all four replications, and replications were averaged for each treatment. Sampling of this type was conducted at the Labette County location only (Table 15).

The effect of knife spacing on the number of heads per sample even though non-significant, was noteworthy. When looking at mean values across P-rates, samples centered over bands of the 50 cm spacing yielded 6 more heads per sample than the 25 cm spacing and 3 more heads per sample than the 38 cm spacing. When looking at the values for the 24 kg P-rate only, the 50 cm spacing yielded 12 more heads than the 25 cm spacing for samples centered over bands which was significant at the 10% level. The 25 cm spacing yielded 7 and 4 more heads than the 50 cm spacing for the two samples centered between bands. The increase in head number directly over the band was primarily due to the high concentration of N and P in the band of the 50 cm spacing at a given P-rate, which was twice the concentration of the P in the band of the 25 cm spacing. Possible explanations for the lower head number in samples centered between bands of treatments receiving the 50 cm spacings would be the greater distance for plant roots to reach the fertilizer bands. The 25 cm spacing provided a fertilizer band in closer proximity to plant roots of plants centered between bands, resulting in more uniform head number, or tillering across the area sampled, compared to the 50 cm spacing. The compensation in the number of heads in the sample centered over the band of the 50 cm spacing compared to the number of heads in samples centered between bands of the 25 cm spacing could have been a major factor in causing no significant

Table 15. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN HEADS/.127m, GRAIN YIELD, AND GRAIN COMPOSITION. (Labette Co., 1980)

Knife Spacing (cm)	P-Rate kg/ha	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		------ Grain Heads/.127m -----				
25	0	13	14	13	NS	
38	0	12	15	10	NS	
50	0	16	16	11	NS	
25	6	18	19	17	NS	
38	6	15	22	12	NS	
50	6	13	21	16	NS	
25	12	16	20	14	NS	
38	12	20	22	15	NS	
50	12	14	25	10	9	
25	24	22	21	18	NS	
38	24	21	25	13	NS	9
50	24	15	33	14	14	
25*	48	26	28	28		
	LSD(.05)	NS	NS	NS		
	(.10)		9			
		----- Grain Yield (kg/ha) ----				
25	0	3278	3454	2713	NS	
38	0	2725	2528	2226	NS	
50	0	3966	3889	2545	NS	
25	6	4729	4593	3951	NS	
38	6	3706	5176	2663	1797	
50	6	3086	4782	4343	NS	
25	12	3785	4449	3192	NS	
38	12	4318	4832	2903	NS	1443
50	12	3427	6892	2244	2769	
25	24	5106	4936	4024	NS	
38	24	4620	5601	2836	NS	1985
50	24	3600	7790	3719	2830	
25*	48	4744	4706	5262		
	LSD(.05)	NS	NS	NS		
	(.10)		2130			

* Received 168 kg N/ha; not included in statistical analysis.

Table 15 (Labette Co., 1980 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		------ Grain Protein % -------				
25	0	12.6	13.5	13.7	NS	
38	0	13.8	14.0	14.1	NS	
50	0	13.4	13.8	13.7	NS	
25	6	13.2	13.5	13.5	NS	
38	6	12.5	12.5	13.0	NS	
50	6	12.4	12.0	12.2	NS	
25	12	13.6	13.9	13.9	NS	
38	12	12.7	13.8	13.9	NS	
50	12	12.3	11.9	12.3	NS	
25	24	13.5	13.2	13.4	NS	
38	24	12.9	12.9	13.3	NS	
50	24	12.6	12.4	12.4	NS	
25*	48	14.7	14.7	14.2		
	$LSD_{(.05)}$	NS	NS	NS		
		--------- Grain %P ----------				
25	0	.29	.30	.31	NS	
38	0	.26	.34	.30	NS	
50	0	.30	.34	.30	NS	
25	6	.30	.30	.31	NS	
38	6	.31	.29	.31	NS	
50	6	.33	.32	.32	NS	
25	12	.30	.29	.30	NS	
38	12	.30	.30	.30	NS	
50	12	.33	.30	.35	NS	
25	24	.35	.31	.33	.03	
38	24	.32	.31	.33	NS	
50	24	.38	.30	.33	.06	
25*	48	.34	.38	.34		
	$LSD_{(.05)}$	.06	NS	NS		

* Received 168 kg N/ha; not included in statistical analysis.

Table 15 (Labette Co., 1980 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands	LSD(.05)	(.10)
		-------- GPUP (kg/ha) --------				
25	0	9.8	10.1	8.0	NS	
38	0	7.2	12.4	6.3	NS	4.2
50	0	11.4	13.1	7.3	NS	
25	6	13.7	13.9	12.2	NS	
38	6	11.6	14.9	8.4	NS	4.8
50	6	9.8	15.1	13.5	NS	
25	12	11.7	13.0	9.7	NS	
38	12	12.8	14.5	9.1	NS	
50	12	10.8	20.5	7.8	8.8	
25	24	18.3	15.3	13.5	NS	3.4
38	24	14.3	17.3	9.2	6.1	
50	24	13.8	23.2	12.1	NS	7.8
25*	48	16.1	17.9	17.8		
	$LSD_{(.05)}$	NS	NS	NS		
		-------- GNUP (kg/ha) --------				
25	0	71.5	75.4	58.2	NS	
38	0	64.9	85.4	53.0	NS	
50	0	93.0	94.1	59.6	NS	
25	6	109.0	106.5	93.0	NS	
38	6	82.4	116.7	61.7	NS	38.9
50	6	68.0	98.7	95.8	NS	
25	12	90.3	108.4	78.4	NS	
38	12	96.0	117.5	70.0	NS	30.2
50	12	72.4	145.8	48.3	60.0	
25	24	118.2	113.8	94.6	NS	17.2
38	24	104.7	126.4	65.0	NS	44.4
50	24	79.7	169.6	80.8	67.0	
25*	48	120.2	120.0	130.4		
	$LSD_{(.05)}$	NS	NS	NS		

* Received 168 kg N/ha; not included in statistical analysis.

Table 15 (Labette Co., 1980 - Continued)

		Location of Sample in Relation to Band		
		Centered Between Bands	Centered Over Band	Centered Between Bands
Mean Values: Knife Spacing				
		----- Grain Heads/.127m ------		
25 cm		17	18	16
38 cm		17	21	12
50 cm		14	24	13
	$LSD_{(.05)}$	NS	NS	NS
		----- Grain Yield (kg/ha) ----		
25 cm		4224	4358	3470
38 cm		3842	4787	2657
50		3520	5838	3213
	$LSD_{(.05)}$	NS	NS	NS
	(.10)		1065	
		------ Grain Protein % -------		
25 cm		13.2	13.5	13.6
38 cm		13.0	13.3	13.6
50 cm		12.7	12.5	12.6
	$LSD_{(.05)}$	NS	NS	NS
		--------- Grain %P -----------		
25 cm		.31	.30	.31
38 cm		.30	.31	.31
50 cm		.33	.31	.32
	$LSD_{(.05)}$	NS	NS	NS
	(.10)	.02		
		------- GPUP (kg/ha) ---------		
25 cm		13.4	13.0	10.9
38 cm		11.5	14.8	8.2
50 cm		11.4	18.0	10.2
	$LSD_{(.05)}$	NS	4.0	NS

Table 15 (Labette Co., 1980 - Continued)

	Location of Sample in Relation to Band: Centered Between Bands	Centered Over Band	Centered Between Bands
Mean Values: Knife Spacing			
	------- GNUP (kg/ha)	---------	
25 cm	97.2	101.0	81.0
38 cm	87.0	111.5	62.4
50 cm	78.3	127.0	71.1
$LSD_{(.05)}$	NS	NS	NS
Mean Values: P-Rate			
	----- Grain Heads/.127m	------	
0 P	14	15	11
6 P	15	21	15
12 P	16	22	13
24 P	19	26	15
$LSD_{(.05)}$	NS	7	NS
(.10)	4		
	----- Grain Yield (kg/ha)	----	
0 P	3323	3627	2495
6 P	3840	4850	3652
12 P	3843	5391	2780
24 P	4442	6109	3526
$LSD_{(.05)}$	NS	1478	NS
(.10)			833
	------ Grain Protein %	-------	
0 P	13.3	13.8	13.8
6 P	12.7	12.6	12.9
12 P	12.9	13.2	13.4
24 P	13.0	12.8	13.0
$LSD_{(.05)}$	NS	NS	NS

Table 15 (Labette Co., 1980 - Continued)

		Location of Sample in Relation to Band		
		Centered Between Bands	Centered Over Band	Centered Between Bands
Mean Values: P-Rate				
		---------- Grain %P ----------		
0 P		.28	.32	.30
6 P		.31	.30	.31
12 P		.31	.30	.32
24 P		.35	.31	.33
	$LSD_{(.05)}$	.03	NS	NS
		-------- GPUP (kg/ha) --------		
0 P		9.5	11.9	7.2
6 P		11.7	14.6	11.4
12 P		11.8	16.0	8.8
24 P		15.4	18.6	11.6
	$LSD_{(.05)}$	3.0	4.6	3.2
		-------- GNUP (kg/ha) --------		
0 P		76.5	85.0	56.9
6 P		86.5	107.3	83.5
12 P		86.3	123.9	65.6
24 P		100.9	136.6	80.1
	$LSD_{(.05)}$	NS	33.7	NS
	(.10)			19.0

yield increases due to knife spacing. There were no significant grain yield increases due to knife spacing, since the grain yield calculated from each sample was closely correlated with head number per sample, regardless of treatment. A plot showing the wheat yield as affected by head number in the sampling study described above is given in Fig. 8. The correlation coefficient is r=.92. The mean grain yield for the three samples taken on plots with the 25 cm spacing were relatively more uniform as compared to those samples taken from plots with the 38 and 50 cm spacing.

Mean grain protein was not significantly affected by knife spacing (Table 15). However, a trend towards higher grain protein with the narrower knife spacings existed. The %P in the grain and GNUP were not significantly affected by knife spacing. The GPUP was significantly increased in samples centered over the band of the 50 cm spacing over samples centered over the band of the 25 cm spacing. Samples centered between bands were not significantly different between knife spacings. However, the 25 cm spacing gave a higher mean GPUP than either the 38 or 50 cm spacings in samples centered between bands.

The mean number of grain heads per sample was significantly increased by the P-rate (Table 15). Samples centered over the band for the 12 and 24 kg P/ha rates gave significantly more grain heads than treatments receiving no P. However, there were no significant differences between P-rates for samples centered between bands. As was previously mentioned, grain yield was closely correlated to head number with r=.92. As with head number, mean grain yield for the 12 and 24 kg P/ha rates gave sig-

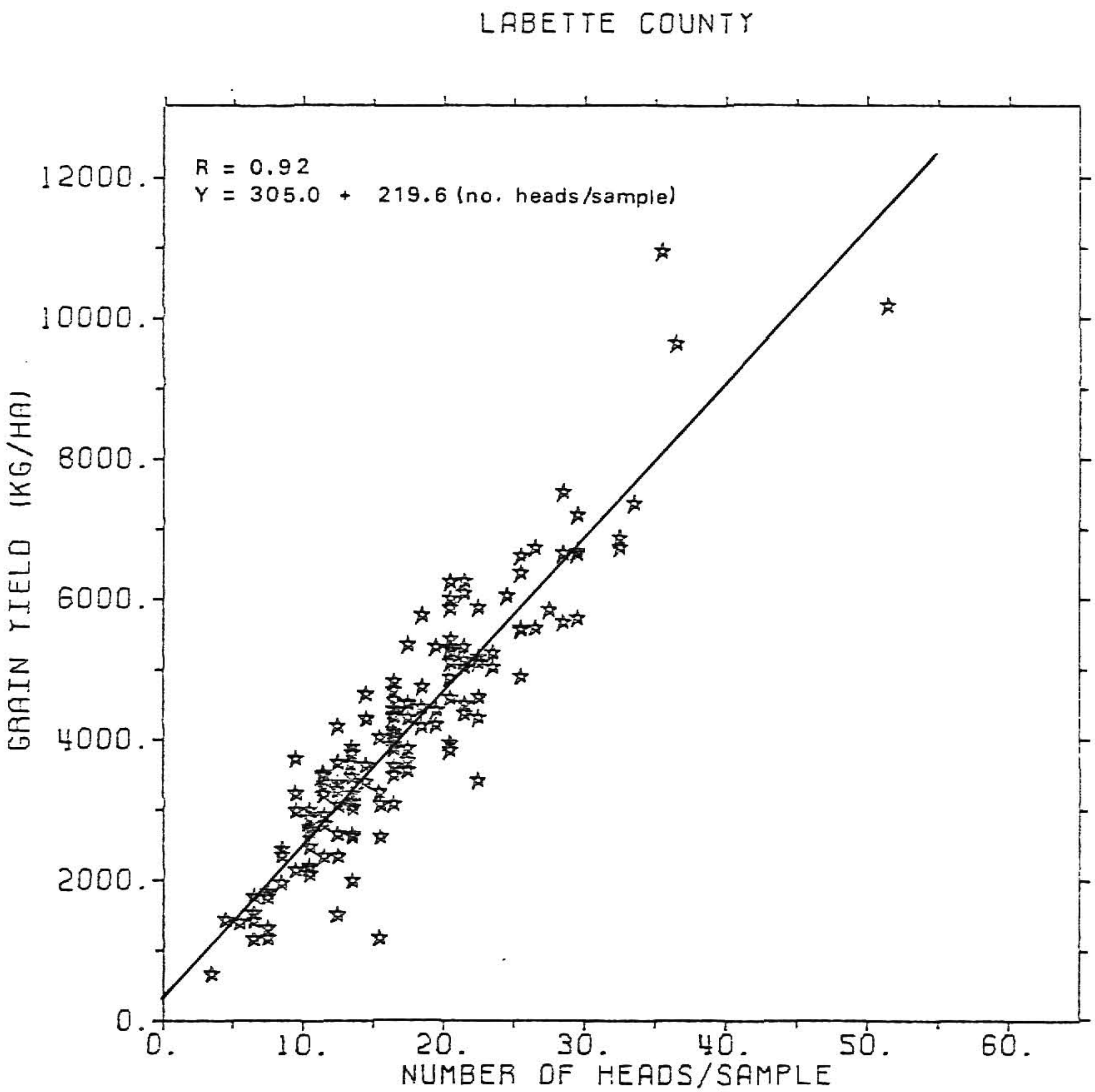


Fig. 8. Grain yield as affected by head number per sample. (Labette Co., 1980)

nificant increases over the 0 P rates for the sample centered over the band. Samples centered between bands were not significantly different in mean grain yield between P rates. Mean grain protein was not significantly affected by P-rate, either.

The correlation between the grain yield per sample as influenced by N uptake, P uptake, and dry matter production per sample at the early sampling date are given in Table 16, along with the regression equations for yield as affected by these variables.

The grain yield per sample was not highly correlated with the N uptake, P uptake, or dry matter production per sample at the early sampling date with correlation coefficients of r=.40, r=.42, and r=.41, respectively. However, all correlation coefficients were significant at the 1% level.

The positive correlation between early dry matter production and subsequent grain yield, which was significant at the 1% level, would suggest that increased dry matter production increased the photosynthetic ability of the plant due to increased leaf area. Thus, the potential of the plant to produce the maximum number of heads per plant is increased. Since grain yield and head number were closely correlated, and a significant correlation between early dry matter production and grain yield exists, an early response to fertilizer P resulting in increased dry matter production would conceivably result in increased grain yield at harvest.

The results of this sampling show that mean GPUP increased significantly with increases in the P-rate. The P-rate also significantly affected the mean GNUP of the sample centered over the

Table 16. CORRELATION OF SAMPLE* GRAIN YIELDS WITH N UPTAKE, P UPTAKE, AND DRY MATTER OF LEAF TISSUE ON SAMPLES CENTERED BETWEEN BANDS AND CENTERED OVER BANDS TAKEN AT THE EARLY SAMPLING DATE. (Labette Co., 1980)

Correlation Coefficients For Samples Centered Between Bands And Centered Over Bands

	N Uptake	P Uptake	Dry Matter
Grain Yield	.40**	.42**	.41**
N Uptake		.95**	.97**
P Uptake			.95**

Regression Equations

Grain Yield = 2683.1 + 22.1(N Uptake)	r = .40**
Grain Yield = 2858.9 + 257.0(P Uptake)	r = .42**
Grain Yield = 2739.8 + 0.59(Dry Matter)	r = .41**

* Samples taken from .127m of row.
** Indicates significance at the 1% level.

band, with an increase in mean GNUP with the higher P rates. There were no significant differences in mean GNUP as affected by P-rate in samples centered between bands.

Greenhouse Studies

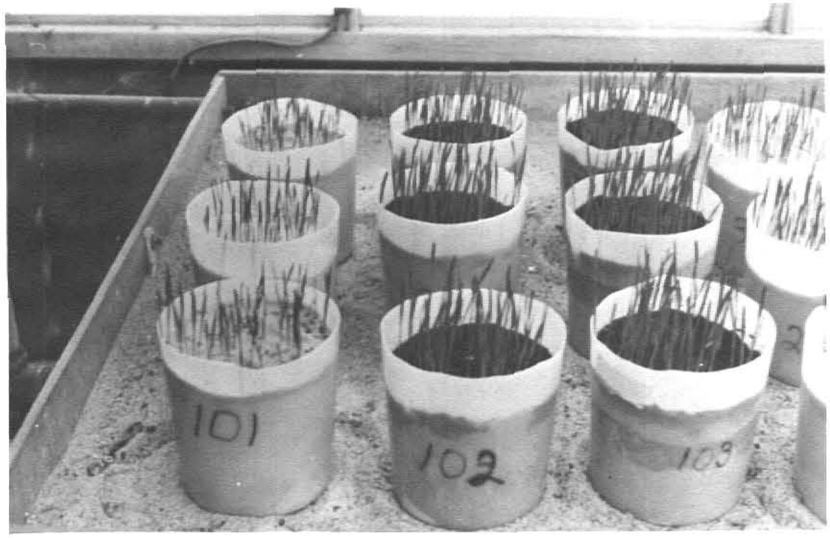
A greenhouse study was conducted to determine the effect of different phosphorus levels on P uptake and dry matter production of wheat seedlings (Table 17 and Fig. 9). Samples of wheat shoots taken 7, 14, 21, and 28 days after planting indicate that shoots from plants grown in very high P soil consistently yielded significantly more dry matter than did shoots from plants grown in a very low P soil (Fig. 10). The data indicates that a good external P source is needed very soon after germination as most of the P within the seed is used very fast. Wheat plants grown in the fine, acid-washed quartz sand (no P) yielded significantly less dry matter than those grown in the very high P soil at all dates sampled. Dry matter production was not significantly different between plants grown in the fine, acid-washed quartz sand (no P), and plants grown in the very low P soil at 14, 21, and 28 days after planting. The %P of wheat shoots grown in the high P soil was significantly higher than those grown in either the low P soil or fine, acid-washed quartz sand, at all dates sampled (Fig. 11). Likewise, the P uptake of plants grown in the high P soil was significantly greater than those grown in either the low P soil or the fine, acid-washed quartz sand at all dates sampled (Fig. 12). These results indicate that wheat seedlings are capable of absorbing P external to what is available in the seed

Table 17. EFFECT OF PHOSPHORUS LEVEL ON N AND P CONTENT, N AND P UPTAKE, AND DRY MATTER PRODUCTION BY WINTER WHEAT SEEDLINGS. (Greenhouse Study, 1980)

Days After Planting	Treatment	Dry Wt. mg/plant*	%N*	%P*	P Uptake mg/plant*
7 Days	Filt. Paper	4.88	4.55	.67	.032
	Fine Sand	2.93	6.21	.72	.021
	Low P Soil	4.23	5.30	.63	.029
	High P Soil	4.93	5.40	1.05	.052
	$LSD_{(.05)}$	.38	.31	.11	.002
14 Days	Filt. Paper	9.83	5.16	.60	.059
	Fine Sand	13.32	6.13	.46	.061
	Low P Soil	14.83	5.23	.46	.068
	High P Soil	16.73	5.06	.90	.151
	$LSD_{(.05)}$	1.65	.18	.07	.012
21 Days	Filt. Paper	12.58	5.46	.59	.073
	Fine Sand	28.25	4.90	.24	.067
	Low P Soil	27.05	4.90	.28	.075
	High P Soil	37.10	5.00	.54	.199
	$LSD_{(.05)}$	7.08	.30	.07	.022
28 Days	Filt. Paper	-----	----	---	----
	Fine Sand	30.05	4.25	.19	.056
	Low P Soil	38.43	4.40	.20	.077
	High P Soil	51.23	4.56	.45	.228
	$LSD_{(.05)}$	10.95	.19	.03	.044

* Shoots only

Fig. 9. Visual appearance of winter wheat seedlings grown in mediums with different phosphorus levels. The top photograph shows seedlings grown in (from left to right) fine sand (no P), low P soil, and high P soil at 7 days after planting. The middle and bottom photographs show seedlings at 14 and 21 days after planting, respectively. (Greenhouse Study, 1980)


101
102
103


FEB 7 1980
FILTER PAPER
FINE SAND
LO P SOIL
HI P SOIL


FILTER PAPER
FINE SAND
LO P SOIL
HI P SOIL
FEB 13 1980

Fig. 10. Effect of phosphorus level on dry matter production by winter wheat seedlings. (Greenhouse Study, 1980)

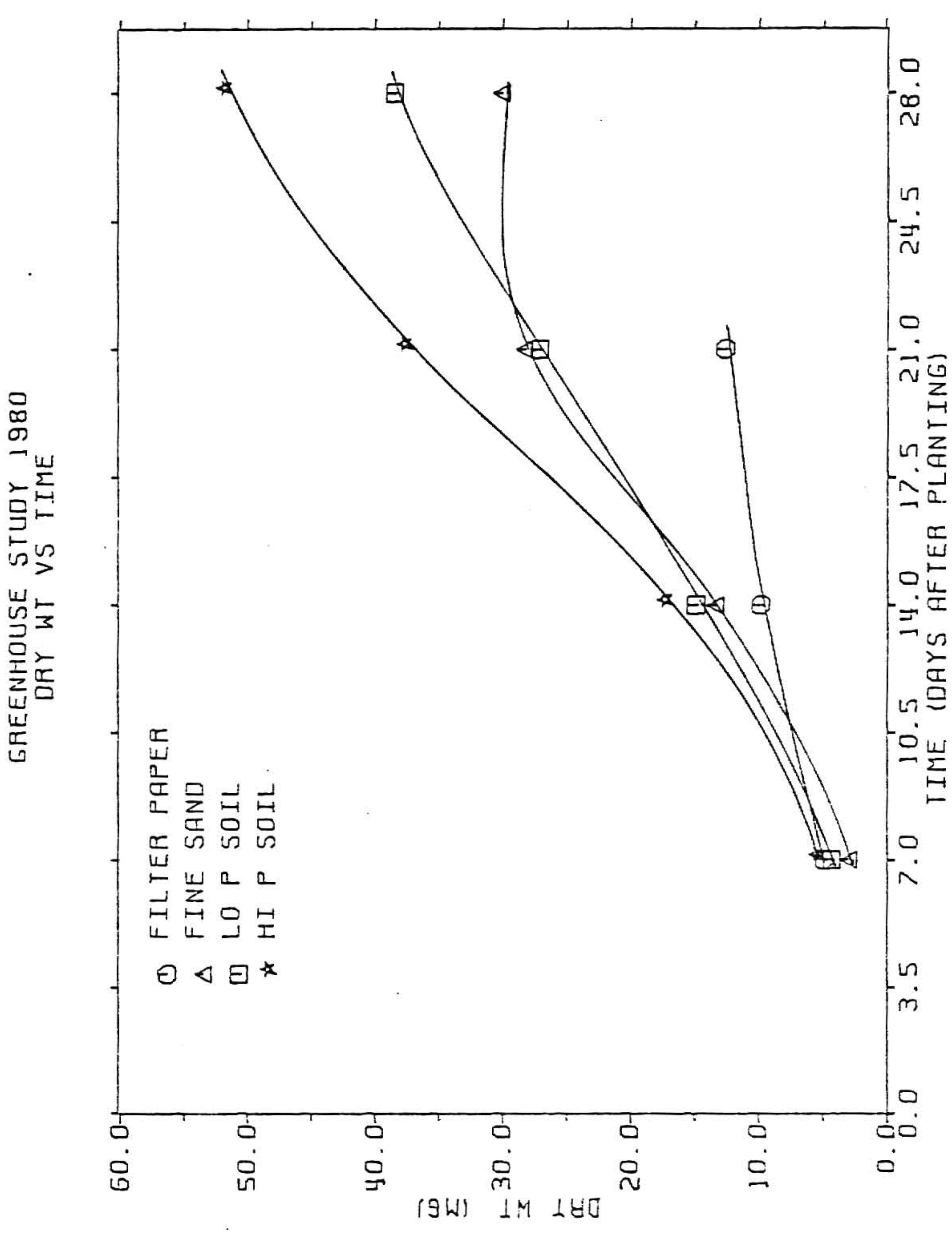
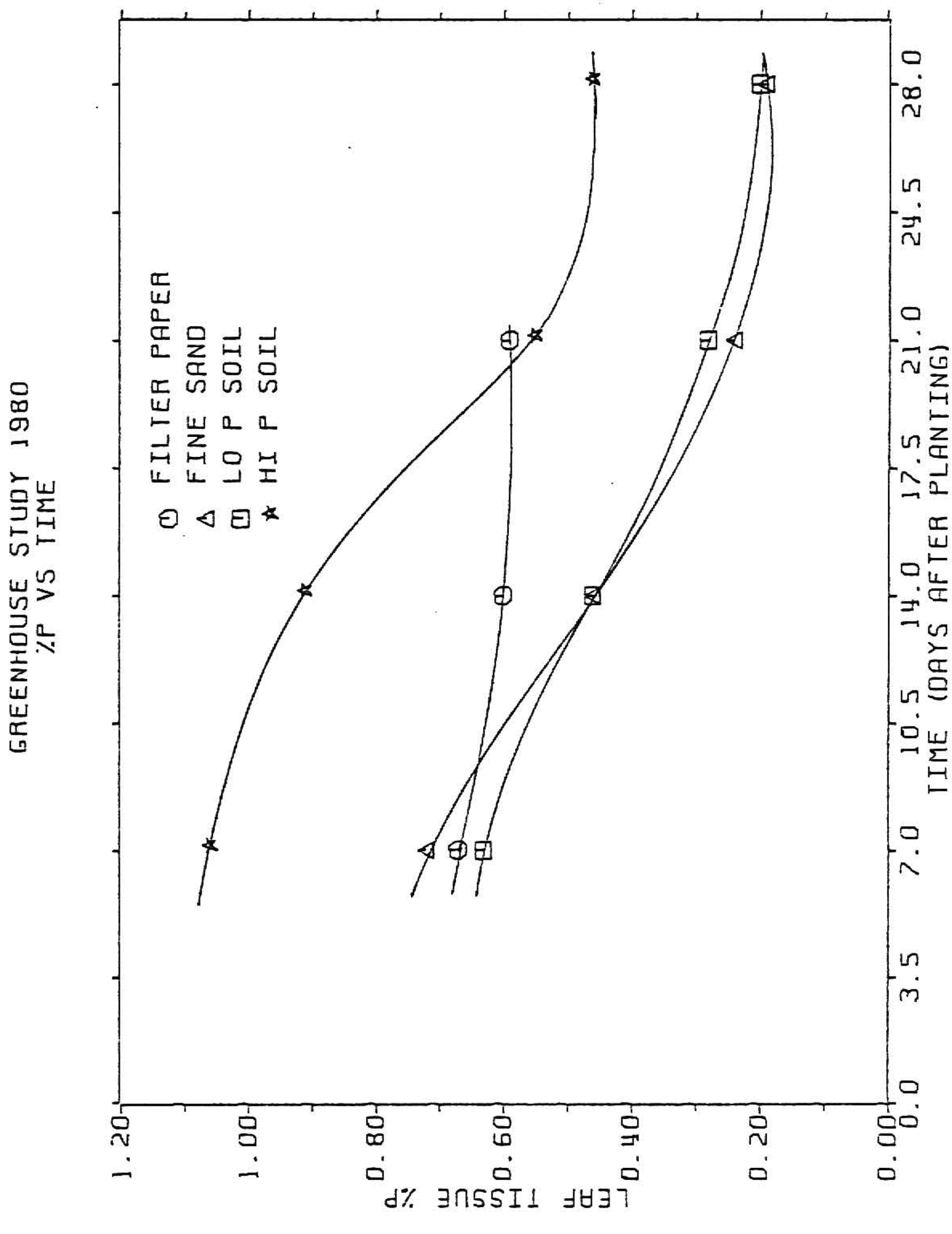
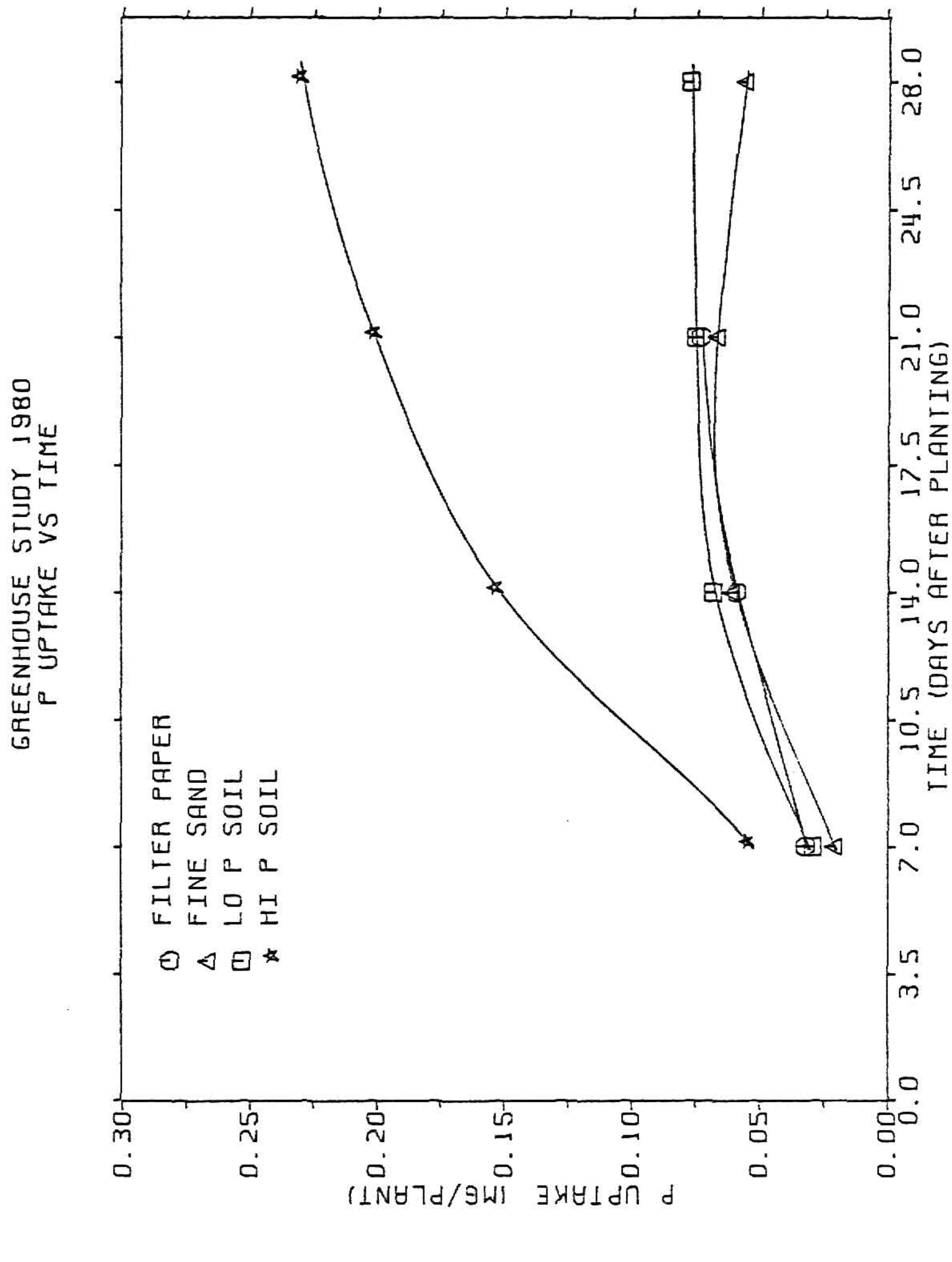

GREENHOUSE STUDY 1980
DRY WT VS TIME
FILTER PAPER
FINE SAND
LO P SOIL
HI P SOIL
DRY WT (MG)
0.0
10.0
20.0
30.0
40.0
50.0
60.0
TIME (DAYS AFTER PLANTING)
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
28.0

Fig. 11. Effect of phosphorus level on %P in the leaf tissue of winter wheat seedlings. (Greenhouse Study, 1980)


GREENHOUSE STUDY 1980
%P VS TIME
FILTER PAPER
FINE SAND
LO P SOIL
HI P SOIL
TIME (DAYS AFTER PLANTING)
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
28.0
LEAF TISSUE %P
0.00
0.20
0.40
0.60
0.80
1.00
1.20

ig. 12. Effect of phosphorus level on P uptake by winter wheat seedlings. (Greenhouse Study, 1980)


GREENHOUSE STUDY 1980
P UPTAKE VS TIME
FILTER PAPER
FINE SAND
LO P SOIL
HI P SOIL
P UPTAKE (MG/PLANT)
0.00
0.05
0.10
0.15
0.20
0.25
0.30
TIME (DAYS AFTER PLANTING)
0.0
3.5
7.0
10.5
14.0
17.5
21.0
24.5
28.0

very early in their growth. This would also indicate that seed P does not last very long in the growth process of the seedling and is not enough for maximum dry matter production, even in the first few weeks after emergence. Plants grown on paper towels maintained a very high P level in their shoots, even though external P was not available, but dry matter production was limited soon after emergence. Plants grown on paper towels were not sampled at 28 days due to wilting and generally poor plant growth. The P uptake of seedlings grown on the paper towels, in the fine sand, and the low P soil was essentially the same at the first three sampling dates. These results indicate that the low P soil gave little P for plant growth.

These data also indicate that wheat seedlings growing in soils which are limiting in the amount of available P should have fertilizer P applied with or banded close to the seed at planting. When present with or near the seed the seedlings can easily absorb and utilize external P early in their growth processes.

A second greenhouse study was conducted using only the fine acid-washed quartz sand (no P) to grow wheat seedlings (Table 18). The objective of this study was to break down by plant parts (shoot, root, and seed remnant) the dry weight and %P of each part of the wheat seedling.

The dry weights of the shoots and seed remnant 7 days after planting were essentially the same, with a slightly smaller dry weight contributed by the roots. The shoots and seed remnant of the seedlings contained an average of .53% P compared to .27% P

Table 18. DRY MATTER AND N AND P CONTENT OF WINTER WHEAT SEEDLINGS GROWN ON P DEFICIENT SAND AT 7 AND 14 DAYS AFTER PLANTING. (Greenhouse Study, 1980)

		Mean Values:			
Days After Planting	Plant Part	Dry Wt. mg/plant	%N	%P	micrograms P/ plant (seed)
7 Days*					
	Shoot	7.3	6.06	.54	39.4
	Root	5.7	2.98	.27	15.5
	Seed Remnant	7.2	2.38	.52	37.3
	Total	20.2			92.2
14 Days*					
	Shoot	14.6	5.68	.43	62.9
	Root	7.6	3.26	.21	15.9
	Seed Remnant	3.4	1.94	.19	6.4
	Total	25.6			85.2
	Original Seed Lot**	26.1	2.33	.42	109.6

* Avg. of 50 plants.
** Avg. of 50 seeds.

in the roots. Data from samples taken 14 days after planting show that the dry weight of the shoots was about twice that of the roots. The dry weight of the seed remnant was less than half that at the first sampling. The N and P levels were highest in the shoots, a lesser amount in the roots, and the seed remnant. This data indicates that the P available within the seed was rapidly being used by the growing seedlings. An analysis of the original seed lot was made and an average of 109.6 micrograms of P was in each wheat seed. About 84% of the original P in the seed was accounted for in the seedling at 7 days after planting. About 78% of the original P in the seed was accounted for in the seedling at 14 days after planting. The data from this study show that the majority of P in the seed is translocated to the shoots with a lesser amount received in the roots. The P content of the seed remnant decreased sharply as the wheat seedlings grew and the requirement for P was increased. As was pointed out in the previous study, the %P contained in the seed was less than needed for maximum growth very soon after emergence. Data from this study indicate that the seed source of P would be diminished very early in the growing season and fertilizer P should be placed in close proximity of the wheat seed at planting for good early plant growth in soils testing low in available P.

A third greenhouse study was conducted to look at horizontal distance of a row of wheat seedlings from an N-P fertilizer band and the effect of horizontal distance on fertilizer P uptake and dry matter yield (Table 19 and Fig. 13). The use of ^{32}P labelled monoammonium phosphate allowed for calculation of percent fertil-

Table 19. EFFECT OF DISTANCE FROM ROW TO FERTILIZER BAND ON P UPTAKE AND DRY MATTER PRODUCTION OF WINTER WHEAT SEEDLINGS. (^{32}P Greenhouse Study, 1980)

Days After Planting	Lateral Distance From Fert. Band To Row (cm)	Dry Wt. mg/plant*	%N*	%P*	N Uptake mg/plant*	P Uptake mg/plant*	%P From Fertilizer*	Fert. P Uptake mg/plant*
11 Days	Check	12.60	4.93	.50	.62	.06	0.0	0.000
	Check + B'cst N	12.16	4.82	.52	.59	.06	0.0	0.000
	0 cm	12.74	4.94	.48	.63	.06	0.0	0.000
	10 cm	14.17	5.01	.47	.71	.07	0.0	0.000
	20 cm	14.32	4.88	.49	.70	.07	0.0	0.000
	30 cm	11.75	4.86	.47	.57	.06	0.0	0.000
	$LSD_{(.05)}$	NS	NS	.02	NS	NS		
22 Days	Check	59.08	4.49	.32	2.65	.19	0.0	0.000
	Check + B'cst N	60.89	4.40	.34	2.67	.21	0.0	0.000
	0 cm	65.01	4.65	.33	3.02	.22	3.0	0.006
	10 cm	67.25	4.50	.31	3.03	.21	1.3	0.003
	20 cm	55.91	4.54	.32	2.54	.18	0.3	0.001
	30 cm	62.50	4.38	.32	2.73	.20	0.0	0.000
	$LSD_{(.05)}$	NS	NS	NS	NS	NS		
33 Days	Check	182.23	4.18	.34	7.60	.62	0.0	0.000
	Check + B'cst N	162.35	4.31	.36	6.99	.58	0.0	0.000
	0 cm	221.20	4.31	.45	9.55	1.01	29.6	0.322
	10 cm	189.28	4.31	.43	8.15	.81	17.3	0.140
	20 cm	199.72	4.25	.46	8.49	.92	7.4	0.067
	30 cm	163.61	4.24	.38	6.94	.63	0.4	0.003
	$LSD_{(.05)}$	NS	.08	NS	NS	NS		

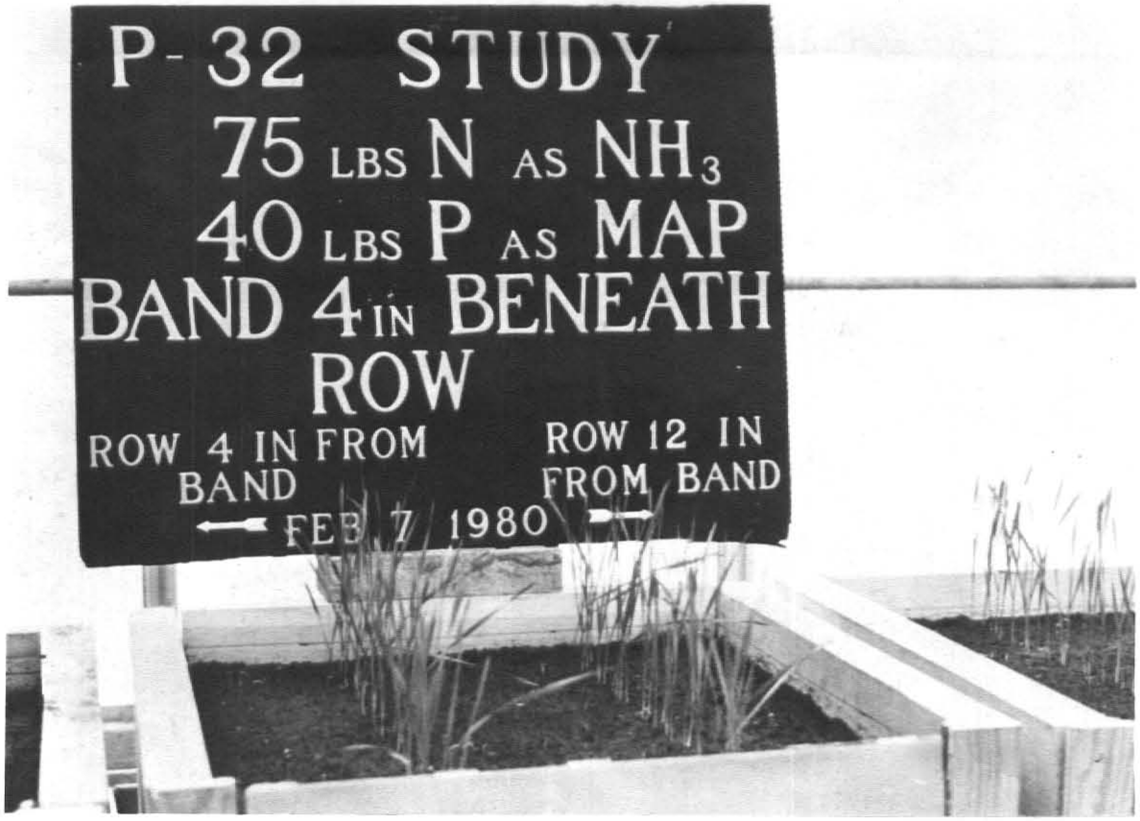
* Shoots only

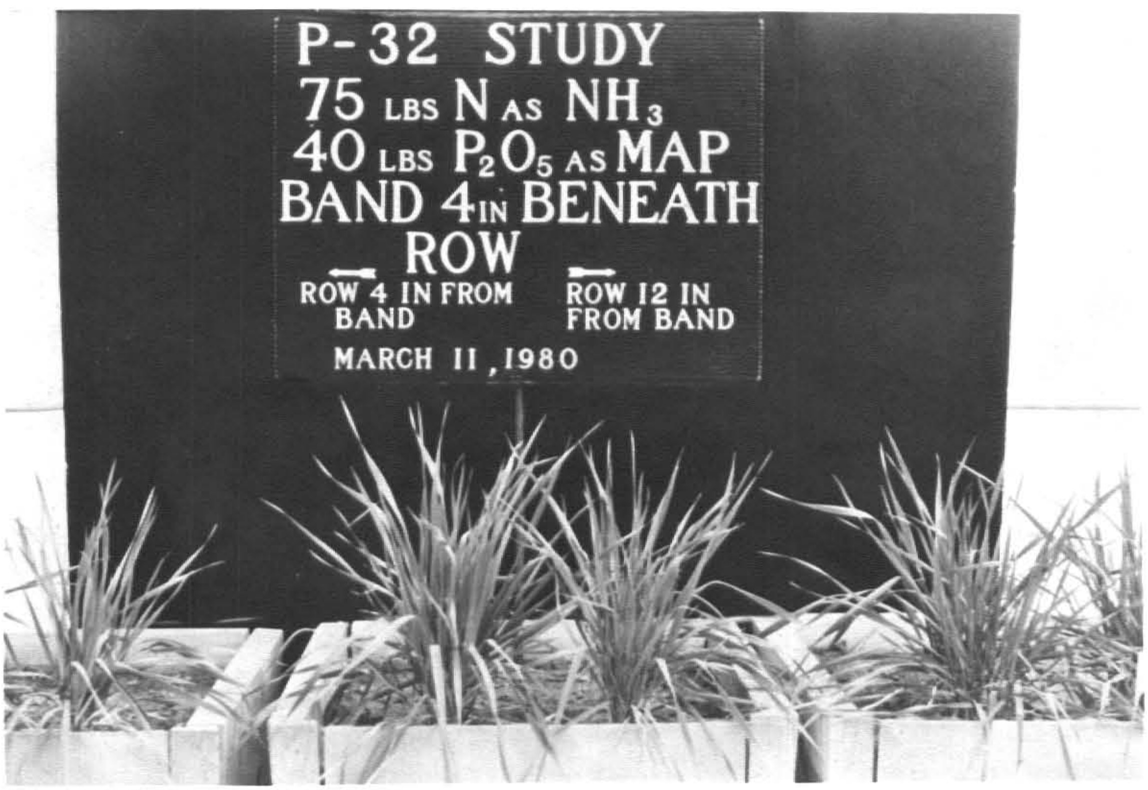
Table 19 (^{32}P Greenhouse Study, 1980 - Continued)

Days After Planting	Lateral Distance From Fert. Band To Row (cm)	Dry Wt. mg/plant*	%N*	%P*	N Uptake mg/plant*	P Uptake mg/plant*	%P From Fertilizer*	Fert. P Uptake mg/plant*
44 Days	Check	511.36	3.71	.30	18.95	1.55	0.0	0.000
	Check + B'cst N	574.26	4.03	.32	23.18	1.86	0.0	0.000
	0 cm	710.56	4.45	.50	31.67	3.58	47.7	1.712
	10 cm	740.77	4.46	.50	33.09	3.73	48.9	1.828
	20 cm	646.15	3.93	.46	25.43	2.95	49.5	1.471
	30 cm	550.61	3.68	.34	20.21	1.88	2.2	0.037
	$LSD_{(.05)}$	NS	.47	.07	8.49	1.00		

* Shoots only

g. 13. Visual appearance of winter wheat seedlings grown at horizontal distances of 10 cm and 30 cm from the pre-plant band of N and P fertilizer at 11 days (top) and 44 days (bottom) after planting. (^{32}P Greenhouse Study, 1980)


P-32 STUDY
75 LBS N AS NH3
40 LBS P AS MAP
BAND 4 IN BENEATH ROW
ROW 4 IN FROM BAND
ROW 12 IN FROM BAND
1980

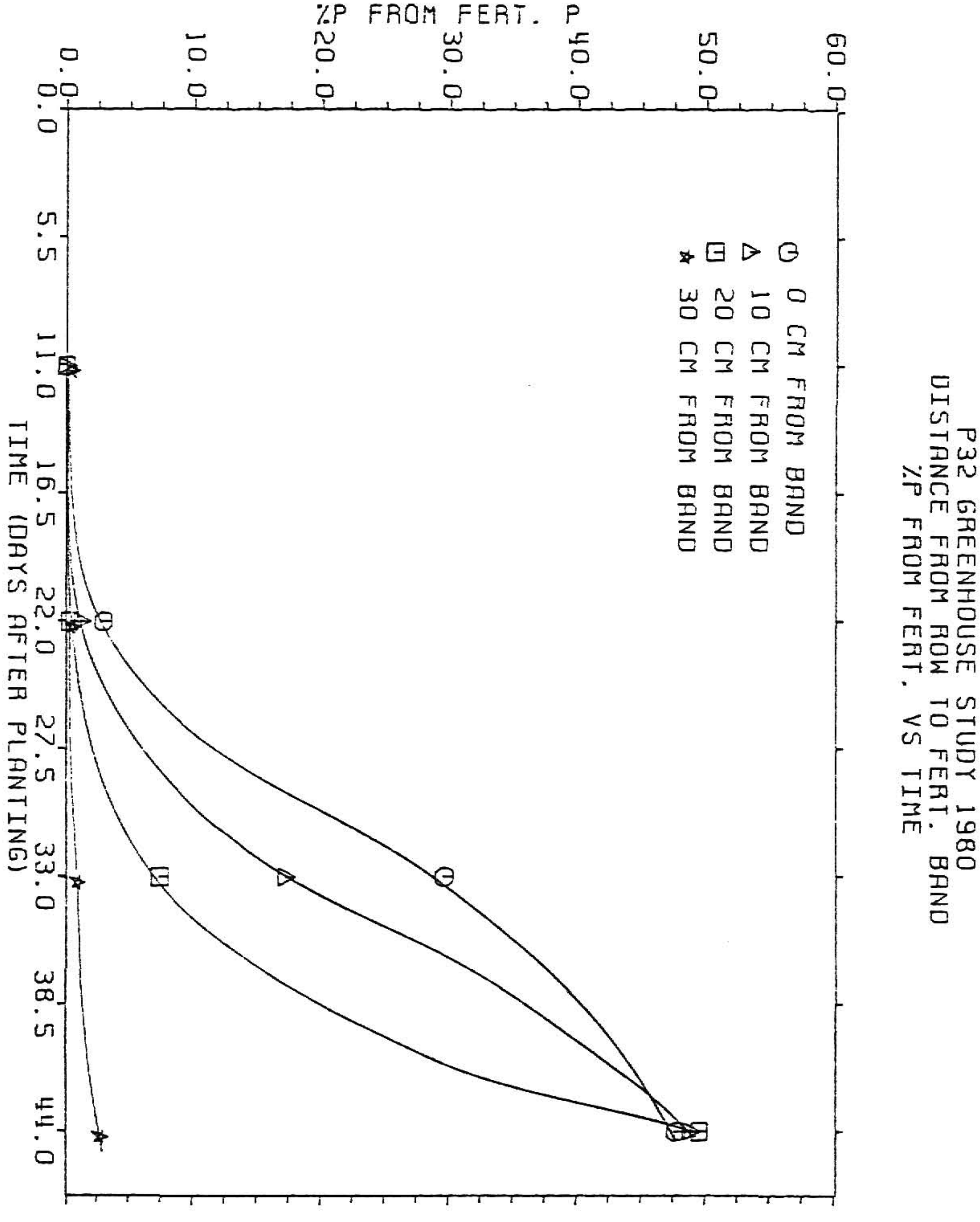

P-32 STUDY
75 LBS N AS NH3
40 LBS P2O5 AS MAP
BAND 4 IN BENEATH ROW
ROW 4 IN FROM BAND
ROW 12 IN FROM BAND
MARCH 11, 1980

izer P in the leaf tissue and fertilizer P uptake.

The distance of the fertilizer band from the wheat seedlings had no significant effect on dry matter yield of shoots at any of the four sampling dates. However, horizontal distance did affect the %P from fertilizer absorbed by the plant (Fig. 14). The seedlings began absorbing fertilizer P between 11 and 22 days after planting. Wheat plants directly above the fertilizer band of P (0 cm) had absorbed 3.0% of the total P in the shoots from the N-P fertilizer band by 22 days. Rows of plants which were horizontal distances of 10 and 20 cm from the N-P fertilizer band had taken up 1.3 and 0.3%, respectively, of the total P in their shoots from the fertilizer band by 22 days. Plants which were a horizontal distance of 30 cm from the fertilizer band had not yet absorbed any fertilizer P by 22 days after planting. However, the fact that the 30 cm treatment must grow across the adjacent row of wheat to reach the fertilizer band may have had some influence on roots reaching the band. At thirty-three days after planting, the 0, 10, 20, and 30 cm treatments and absorbed 29.6%, 17.3%, 7.4%, and 0.4%, respectively, of their total P in the shoots from the fertilizer band. Forty-four days after planting, the 0, 10, and 20 cm treatments were not greatly different in the amount of fertilizer P absorbed. However, all had absorbed greater percentages of P from the fertilizer band than the 30 cm treatment.

The data from this study indicate that the bands placed 30 cm from the row of plants had not yet been reached by the plant roots until 33 days after planting. By 44 days after planting,

Fig. 14. Effect of distance from row to fertilizer band on %P from fertilizer phosphorus in the leaf tissue of winter wheat seedlings. (^{32}P Greenhouse Study, 1980)


P32 GREENHOUSE STUDY 1980
DISTANCE FROM ROW TO FERT. BAND
%P FROM FERT. VS TIME
0 CM FROM BAND
10 CM FROM BAND
20 CM FROM BAND
30 CM FROM BAND
%P FROM FERT. P
0.0
10.0
20.0
30.0
40.0
50.0
60.0
0.0
5.5
11.0
16.5
22.0
27.5
33.0
38.5
44.0
TIME (DAYS AFTER PLANTING)

plant roots had not yet absorbed a major portion of the plant's P from the fertilizer band. Possibly the roots would absorb much more fertilizer P from the band placed 30 cm from the row at some later point in plant growth. However, for maximum early season absorption of fertilizer P, the 30 cm treatment could not provide adequate fertilizer P to the wheat seedling due to physical limitations in plant growth. This would suggest the use of band placement no greater than 20 cm from the row of wheat, in low available P soils, to obtain maximum uptake of fertilizer P during early growth. Furthermore, if P uptake during the first couple of weeks after emergence is critical to tillering and eventual head number, P may need to be placed even closer to the seed row on soils testing low in available P.

SUMMARY AND CONCLUSIONS

The results of the field studies suggest that application of pre-plant bands of N and P at spacings no greater than 50 cm are adequate for production of winter wheat in soils testing low in available P. However, spacings of 38 and 25 cm, while not significantly superior to the 50 cm spacing in terms of grain yield, did seem to give more uniform plant growth and dry matter production early in the growing season. The 38 and 25 cm spacings did give a non-significant yield advantage over the 50 cm spacing in some instances. The "wavy effect" on plant growth associated with wider spacings of pre-plant bands may not be as inhibiting to grain yield as once thought. Sampling data show an increase in head number directly over the knife bands of the 50 cm spacing as compared to the 38 and 25 cm spacings at a given P rate. This increase in head number directly over the band could compensate for the lower head number between bands and might partially explain why the 38 and 25 cm spacings, while giving more uniform plant growth and head number, are not significantly superior to the 50 cm spacing in terms of grain yield. Results, of course, are inconclusive and further research is needed to substantiate these results.

Phosphorus response on soils testing low in available P were generally good and significant grain yield increases were obtained with the application of P. Phosphorus application gave increased early season growth and correlated positively with increased grain yield. Grain yield was in turn highly correlated with head number. Thus, the field studies suggested that phosphorus fertilizer needs to be in close contact with the growing wheat plant for maximum early season dry matter production and consequently, a high potential grain yield.

Greenhouse studies indicate that wheat seedlings can absorb both soil and fertilizer P early in their development. As was shown in the greenhouse, P available in the seed alone was not adequate for maximum dry matter production for very long. Seedlings grown in soils deficient in available P were also limited as to the amount of dry matter produced, even by 1 week after emergence. Therefore, it is very important that an external source of P be placed in close proximity of the seed for maximum early season growth since dry matter production and grain yield are positively correlated.

Greenhouse studies indicate that the closer the pre-plant band of P is to the wheat seedling the greater the early season uptake. Since uptake of fertilizer P was shown to be crucial in promoting maximum dry matter production in the field, uptake of fertilizer P early in the season is critical to the eventual head number and grain yield. Greenhouse studies showed that pre-plant bands placed directly beneath (0 cm) and 10 cm from the wheat seedlings gave substantially more fertilizer P uptake than did bands placed 20 or 30 cm from the seedlings at early sampling dates. Thus, greenhouse studies indicate that pre-plant bands should be placed closer than 20 cm from the wheat seedlings on low P soils if maximum P uptake and dry matter production are to be obtained early in the growing season. The need for early season uptake of P to promote maximum dry matter production and eventual grain yield would point to the use of 25 and possibly 38 cm spacings to accomplish these objectives in the field.

LITERATURE CITED

1. Arnon, D.I. 1939. Effect of ammonium and nitrate nitrogen on the mineral composition and sap characteristics of barley. Soil Sci. 48:295-307.

2. Barber, S.A. 1958. Relation of fertilizer placement to nutrient uptake and crop yield. I. Interaction of row phosphorus and the soil level of phosphorus. Agron. J. 50:535-539.

3. Bennett, W.F., J. Pesek and J. Hanway. 1962. Effect of nitrogen on phosphorus absorption by corn. Agron J. 54:437-442.

4. Bingham, F.T. 1962. Chemical soil tests for available phosphorus. Soil Sci. 94:87-95.

5. Blair, G.J., M.H. Miller and W.A. Mitchell. 1970. Nitrate and ammonium as sources of nitrogen for corn and their influence on the uptake of other ions. Agron. J. 62:530-532.

6. Blair, G.J., C.P. Mamaril and M.H. Miller. 1971. Influence of nitrogen source on phosphorus uptake by corn from soils differing in pH. Agron. J. 63:235-237.

7. Chapman, H.D. 1936. Effect of nitrogenous fertilizers, organic matter, sulfur, and colloidal silica on the availability of phosphorus in calcareous soils. J. Amer. Soc. Agron. 28:135:145.

8. Cihacek, L.J., D.L. Mulvaney, R.A. Olson, L.F. Welch and R.A. Wiese. 1974. Phosphate placement for corn in chisel and moldboard plowing systems. Agron. J. 66:665-668.

9. Cole, C.V., D.L. Grunes, L.K. Porter and S.R. Olsen. 1963. The effects of nitrogen on short-term phosphorus absorption and translocation in corn (Zea mays). Soil Sci. Soc. Amer. Proc. 27:671-674.

10. Duncan, W.G. and A.J. Ohlrogge. 1958. Principles of nutrient uptake from fertilizer bands. II. Root development in the band. Agron. J. 50:605-608.

11. Duncan, W.G. and A.J. Ohlrogge. 1959. Principles of nutrient uptake from fertilizer bands: III. Band volume, concentration, and nutrient composition. Agron. J. 51:103-106.

12. Engelstad, O.P. and S.E. Allen. 1971 a. Ammonium pyrophosphate and ammonium orthophosphate as phosphorus sources: Effects of soil temperature, placement, and incubation. Soil Sci. Soc. Amer. Proc. 35:1002-1004.

13. Engelstad, O.P. and S.E. Allen. 1971 b. Effect of form and proximity of added N on crop uptake of P. Soil Sci. 112:330-337.

14. Garg, K.P. and L.F. Welch. 1967. Growth and phosphorus uptake by corn as influenced by phosphorus placement. Agron. J. 59:152-154.

15. Gingrich, J.R. 1964. Relationship of soil temperature, water soluble phosphorus in applied fertilizer, and method of placement to growth of winter wheat. Agron. J. 59:152-154.

16. Grunes. D.L., F.G. Viets, Jr. and S.H. Shih. 1958 a. Proportionate uptake of soil and fertilizer phosphorus by plants as affected by nitrogen fertilization: I. Growth chamber experiment. Soil Sci. Soc. Amer. Proc. 22:43-48.

17. Grunes, D.L., H.R. Haise and L.O. Fine. 1958 b. Proportionate uptake of soil and fertilizer phosphorus by plants as affected by nitrogen fertilization: II. Field experiments with sugar beets and potatoes. Soil Sci. Soc. Amer. Proc. 22:49-52.

18. Hashimoto, I. and J.R. Lehr. 1973. Mobility of polyphosphates in soil. Soil Sci. Soc. Amer. Proc. 37:36-41.

19. Kemp, K.E., G.W. Wallingford, B.R. Asrabadi and M. Love. 1976. A user's guide for a plotter program package for the IBM 360-70. Cont. No. 239, Dept. of Stat., Statistical Laboratory, Kansas State University, Manhattan, Kansas.

20. Khasawneh, F.E., E.C. Sample and I. Hashimoto. 1974. Reactions of ammonium ortho- and polyphosphate fertilizers in soil: I. Mobility of phosphorus. Soil Sci. Soc. Amer. Proc. 38:446-451.

21. Leikam, D.F. 1980. Evaluations of simultanious knifed N and P applications for winter wheat (Triticum aestivum L.). Ph.D. Dissertation, Kansas State University.

22. Leonce, F.S. and M.H. Miller. 1966. A physiological effect of nitrogen on phosphorus absorption by corn. Agron. J. 58:245-249.

23. Linder, R.C. and C.P. Harley. 1942. A rapid method for the determination of nitrogen in plant tissue. Science. 96:565-566.

24. Lorenz, O.A. and C.M. Johnson. 1953. Nitrogen fertilization as related to the availability of phosphorus in certain California soils. Soil Sci. 75:119-129.

25. Lutz, J.A. Jr., G.L. Terman and J.L. Anthony. 1961. Rate and placement of phosphorus for small grains. Agron. J. 53:303-305.

26. MacLeod, L.B., J.D.E. Sterling and J.A. MacLeod. 1975. Effects of rate, source and method of application of N, P and K on growth, nutrient uptake and yield of barley. Can. J. Soil Sci. 55:61-67

27. Mamaril, C.P. and M.H. Miller. 1970. Effects of ammonium on the uptake of phosphorus, sulfur, and rubidium by corn. Agron. J. 62:753-758.

28. Miller, M.H. 1965. Influence of $(NH_4)_2SO_4$ on root growth and P absorption by corn from a fertilizer band. Agron. J. 57:393-396.

29. Miller, M.H. and G.C. Ashton. 1960. The influence of fertilizer placement and rate of nitrogen on fertilizer phosphosphorus utilization by oats as studied using a central composite design. Can. J. Soil Sci. 40:157-167.

30. Miller, M.H., C.P. Mamaril and G.J. Blair. 1970. Ammonium effects on phosphorus absorption through pH changes and phosphorus precipitation at the soil-root interface. Agron. J. 62:524-527.

31. Miller, M.H. and A.J. Ohlrogge. 1958. Principles of nutrient uptake from fertilizer bands. I. Effect of placement of nitrogen fertilizer on the uptake of band-placed phosphorus at different soil phosphorus levels. Agron. J. 50:95-97.

32. Miner, G. and E. Kamprath. 1971. Reactions and availability of banded polyphosphate in field studies. Soil Sci. Soc. Amer. Proc. 35:927-930.

33. Olsen, S.R. and A.D. Flowerday. 1971. In "Fertilizer Technology and Use". 2nd ed. Soil Science Society of America pp. 153-185.

34. Olson, R.A. and A.F. Dreier. 1956 a. Fertilizer placement for small grains in relation to crop stand and nutrient efficiency in Nebraska. Soil Sci. Soc. Amer. Proc. 20:19-24.

35. Olson, R.A. and A.F. Dreier. 1956 b. Nitrogen, a key factor in fertilizer phosphorus efficiency. Soil Sci. Soc. Amer. Proc. 20:509-514.

36. Riley, D. and S.A. Barber. 1971. Effect of ammonium and nitrate fertilization on phosphorus uptake as related to root-soil interface. Soil Sci. Soc. Amer. Proc. 35:301-306.

37. Robertson, W.K., P.M. Smith, A.J. Ohlrogge and K.M. Kinch. 1954. Phosphorus utilization by corn as affected by placement and nitrogen and potassium fertilization. Soil Sci. 77:219-226.

38. Sauchelli, V. 1965. In "Phosphates in agriculture". Reinhold Publ. Corp. New York. pp. 86-108.

39. Seatz, L.F. and C.O. Stanberry. 1963. In "Fertilizer Technology and Usage. Soil Science Society of America. pp. 155-187.

40. Soon, Y.K. and M.H. Miller. 1977. Changes in the rhizosphere due to NH_4^+ and NO_3^- fertilization and phosphorus uptake by corn. Soil Sci. Soc. Am. J. 41:77-80.

41. Subbarao, Y.V. and R. Ellis, Jr. 1975. Reaction products of polyphosphates and orthophosphates with soils and influence on uptake of phosphorus by plants. Soil Sci. Soc. Amer. Proc. 39:1085-1088.

42. Swart, C.L. 1970. Retention patterns and loss of anhydrous ammonia applied with an undercutting blade. Masters Thesis, Kansas State University.

43. Technicon Industrial Systems. 1977. Industrial method no. 334-74 W/B +. pp. 1-7. Individual/simultaneous determination of nitrogen and/or phosphorus in BD acid digests. Tarrytown, N.Y.

44. Thien, S.J. and W.W. McFee. 1970. Influence of nitrogen on phosphorus absorption and translocation in Zea mays L. Soil Sci. Soc. Amer. Proc. 36:617-620.

45. Thien, S.J. and W.W. McFee. 1972. Effect of nitrogen on phosphorus transport systems in Zea mays L. Soil Sci. Soc. Amer. Proc. 36:617-620.

46. Tisdale, S.L. and W.L. Nelson. 1975. In "Soil Fertility and Fertilizers". 3rd ed. Macmillan Publishing Co. Inc. New York. pp. 189-242.

47. Walsh, L.M. and J.D. Beaton. 1973. In "Soil Testing and Plant Analysis". Soil Sci. Soc. of America, Inc. Madison, Wisconsin pp. 329-348.

48. Welch, L.F., D.L. Mulvaney, L.V. Boone, G.E. McKibben and J.W. Pendleton. 1966. Relative efficiency of broadcast versus banded phosphorus for corn. Agron. J. 58:283-287.

49. Werkhoven, C.H.E. and M.H. Miller. 1960. Absorption of fertilizer phosphorus by sugarbeets as influenced by placement of phosphorus and nitrogen. Can. J. Soil Sci. 40:49-58.

VITA

The author was born October 22, 1956, at Iola, Kansas. High school was completed in 1974 at Iola High School, Iola, Kansas. He then entered Allen County Community College and graduated in 1976 with an Associate of Arts Degree. A Bachelor of Science Degree in Agronomy was completed in 1978 at Kansas State University. In August of 1978, he entered graduate school at Kansas State University and worked on a Master of Science Degree with the Agronomy Department. While completing the requirements for this degree, he was employed as a graduate research assistant with the Agronomy Department. He is married to the former Jane Elizabeth Wall of Salina, Kansas.

The author is currently a graduate student member of the American Society of Agronomy and Soil Science Society of America. The author is also a member of Gamma Sigma Delta, an agricultural honor society.

APPENDIX

Table I. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Dickinson Co., 1979)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/16/79 Rep. 2										
		%P								
25	0	.13	.14	.18	.17	.14				
25	12	.15	.14	.14	.14	.14				
25	24	.15	.16	.19	.18	.14				
38	0	.10	.10	.12	.10	.10	.11	.10		
38	12	.16	.20	.18	.21	.18	.13	.15		
38	24	.19	.21	.21	.25	.26	.14	.16		
50	0	.12	.09	.09	.11	.12	.12	.12	.11	.12
50	12	.12	.20	.23	.25	.29	.24	.14	.14	.13
50	24	.26	.21	.33	.32	.33	.26	.27	.14	.15
		%N								
25	0	2.84	2.96	3.60	3.36	2.81				
25	12	2.68	2.70	2.57	2.62	2.62				
25	24	2.75	2.89	3.14	2.98	2.50				
38	0	2.68	2.69	3.00	2.82	2.62	2.68	2.51		
38	12	3.00	3.38	2.88	3.24	3.00	2.49	2.80		
38	24	3.08	3.32	3.12	3.60	2.62	2.42	2.88		
50	0	2.53	2.02	2.10	2.67	2.79	3.14	2.97	2.63	2.61
50	12	2.59	3.49	3.38	3.20	3.92	3.80	3.02	2.75	2.68
50	24	3.31	3.22	3.51	3.58	3.58	3.09	3.55	2.62	2.63

Table I (Dickinson Co., 1979 - Continued)

	Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/16/79 Rep. 3							%P				
	25	0	.10	.10	.10	.11	.09				
	25	12	.12	.15	.20	.20	.16				
	25	24	.21	.22	.22	.14	.16				
	38	0	.13	.17	.16	.12	.14	.12	.12		
	38	12	.18	.16	.14	.20	.19	.18	.19		
	38	24	.22	.27	.29	.18	.15	.12	.19		
	50	0	.10	.09	.09	.10	.08	.09	.11	.10	.10
	50	12	.11	.18	.18	.19	.17	.11	.14	.10	.12
	50	24	.24	.32	.32	.31	.29	.24	.14	.12	.16
							%N				
	25	0	2.76	2.58	2.41	2.51	2.22				
	25	12	2.60	3.02	3.40	3.20	2.72				
	25	24	2.86	3.50	3.25	2.56	2.73				
	38	0	2.59	3.21	3.29	2.59	2.84	2.65	2.71		
	38	12	3.25	2.96	2.22	3.16	2.91	2.73	2.77		
	38	24	3.25	3.70	3.40	2.90	2.58	2.00	3.17		
	50	0	2.06	2.09	2.40	2.70	2.10	2.20	2.86	2.56	2.66
	50	12	2.56	3.19	3.17	3.21	2.91	2.41	2.94	2.15	2.57
	50	24	3.16	3.74	3.79	3.60	3.69	3.57	2.65	2.48	2.72

Table I (Dickinson Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1:	4/16/79									
Rep. 4						%P				
25	0	.10	.12	.13	.12	.12				
25	12	.13	.23	.17	.14	.13				
25	24	.19	.27	.21	.22	.16				
38	0	.12	.13	.13	.14	.13	.13	.13		
38	12	.22	.24	.20	.19	.21	.19	.24		
38	24	.18	.16	.27	.20	.21	.25	.19		
50	0	.16	.11	.11	.11	.10	.10	.13	.10	.10
50	12	.10	.21	.31	.22	.30	.35	.28	.22	.13
50	24	.11	.20	.31	.31	.36	.34	.37	.33	.23
						%N				
25	0	2.49	2.70	3.08	2.80	3.09				
25	12	3.09	3.64	3.03	3.03	2.90				
25	24	3.20	3.64	3.32	3.40	3.00				
38	0	2.87	2.89	3.53	3.17	3.00	2.92	3.17		
38	12	3.72	4.12	3.77	3.35	3.70	3.80	3.52		
38	24	3.03	2.96	3.90	3.43	3.47	3.46	3.17		
50	0	3.55	2.46	2.69	2.64	2.44	2.57	2.82	2.40	2.60
50	12	2.55	3.52	4.05	3.00	3.46	4.26	3.86	3.80	2.89
50	24	2.55	3.29	3.86	3.77	4.13	4.21	4.18	4.08	3.51

Table I (Dickinson Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/6/79									
Rep. 2						%P				
25	0	.20	.23	.23	.25	.21				
25	12	.23	.24	.17	.15	.16				
25	24	.19	.22	.20	.16	.21				
38	0	.18	.18	.18	.20	.21	.20	.20		
38	12	.12	.13	.13	.13	.15	.16	.17		
38	24	.16	.14	.16	.18	.15	.17	.21		
50	0	.19	.19	.22	.20	.20	.21	.20	.20	.21
50	12	.15	---	.15	.13	.18	.13	.14	.15	.19
50	24	.21	.20	.15	.15	.14	.15	.17	.18	.18
						%N				
25	0	2.56	2.73	2.88	3.07	2.90				
25	12	2.53	2.76	2.00	2.04	1.99				
25	24	1.50	1.40	1.57	1.20	2.00				
38	0	2.05	2.05	2.14	2.86	2.35	2.25	2.23		
38	12	1.50	1.58	1.88	1.91	2.28	2.03	2.07		
38	24	1.66	1.50	1.53	1.52	1.23	1.87	2.21		
50	0	2.73	2.61	2.91	2.76	2.86	2.77	2.63	2.58	2.66
50	12	2.11	----	2.16	1.79	2.24	1.54	2.00	2.00	2.56
50	24	1.97	2.02	1.54	1.66	1.58	1.71	1.87	2.00	2.04
						Dry Wt. (g)				
25	0	2.5	3.3	2.5	3.1	3.2				
25	12	2.3	2.2	2.7	1.3	4.0				
25	24	6.7	3.2	12.4	5.5	3.6				
38	0	2.2	1.8	2.2	3.0	2.6	1.8	1.9		
38	12	4.3	5.6	4.2	2.0	4.0	1.7	1.7		
38	24	2.2	4.7	7.2	8.5	6.6	10.8	5.0		
50	0	2.5	2.6	2.0	2.3	2.0	2.3	2.5	2.1	2.5
50	12	2.5	---	4.9	6.7	6.4	5.9	5.9	5.0	1.6
50	24	1.7	2.5	4.8	4.7	9.8	4.2	4.3	3.4	2.4

Table I (Dickinson Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2: 5/6/79										
Rep. 3						%P				
25	0	.20	.20	.18	.20	.20				
25	12	.21	.17	.16	.21	.17				
25	24	.18	.17	.16	.18	.21				
38	0	.22	.23	.22	.22	.21	.21	.24		
38	12	.18	.15	.15	.15	.17	.15	.21		
38	24	.21	.19	.16	.16	.20	.24	.23		
50	0	.22	.24	.23	.24	.23	.18	.20	.15	.21
50	12	.20	.20	.17	.16	.17	.16	.20	.21	.22
50	24	.19	.18	.15	.18	.19	.17	.17	.18	.19
						%N				
25	0	2.50	2.56	2.22	2.47	2.87				
25	12	2.52	2.45	2.08	2.73	2.34				
25	24	1.67	1.77	1.69	2.08	2.41				
38	0	2.78	2.84	2.82	2.78	2.48	2.85	2.85		
38	12	2.22	1.73	1.65	1.75	1.94	1.55	2.36		
38	24	2.03	2.07	1.71	1.84	2.13	2.66	2.45		
50	0	2.45	2.65	2.53	2.43	3.22	2.10	2.57	2.14	2.46
50	12	2.24	2.34	1.76	1.80	1.83	1.53	2.22	2.30	2.63
50	24	2.12	1.83	1.82	1.63	1.45	1.92	2.05	1.68	2.23
						Dry Wt. (g)				
25	0	1.9	2.2	3.1	2.7	1.3				
25	12	4.9	5.6	5.2	2.9	3.7				
25	24	4.2	8.3	8.3	2.8	2.8				
38	0	2.1	1.9	2.0	2.3	2.3	2.5	2.1		
38	12	3.2	6.2	8.7	7.0	6.3	4.1	3.0		
38	24	2.8	4.7	6.4	4.6	3.9	1.8	2.1		
50	0	3.0	3.7	4.0	6.1	12.4	7.8	6.2	3.3	3.3
50	12	1.6	1.9	6.3	7.8	15.3	12.0	3.6	1.7	1.3
50	24	1.5	3.4	6.8	11.0	9.0	6.9	5.5	4.3	2.3

Table I (Dickinson Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/6/79									
Rep. 4						%P				
25	0	.22	.22	.24	.23	.24				
25	12	.24	.20	.18	.16	.16				
25	24	.22	.21	.20	.22	.21				
38	0	.24	.22	.21	---	.24	.25	.23		
38	12	.18	.20	.20	.20	.20	.25	.23		
38	24	.22	.21	.29	.38	.27	.28	.26		
50	0	.20	.21	.20	.21	.20	.21	.23	.22	.22
50	12	.25	.22	.20	.21	.19	.22	.21	.21	.21
50	24	.19	.16	.17	.16	.15	.13	.16	.21	.22
						%N				
25	0	3.03	2.75	2.97	2.92	2.92				
25	12	3.00	2.54	2.17	2.14	1.94				
25	24	3.05	3.02	2.62	2.90	2.80				
38	0	3.10	2.89	2.89	----	3.09	3.14	2.90		
38	12	2.19	2.61	2.32	2.35	2.60	3.06	2.87		
38	24	2.35	2.13	2.43	2.29	1.86	2.35	2.46		
50	0	2.89	2.78	2.33	2.63	2.48	2.63	2.93	2.66	2.67
50	12	3.07	2.73	2.54	2.52	2.26	2.50	2.24	2.65	2.68
50	24	2.15	1.77	1.64	1.72	1.39	1.32	1.94	2.70	2.49
						Dry Wt. (g)				
25	0	2.0	2.2	3.6	1.8	2.0				
25	12	2.1	1.5	2.8	4.5	4.1				
25	24	1.4	1.6	2.3	2.6	2.1				
38	0	3.0	2.2	2.0	---	1.9	3.0	2.3		
38	12	6.1	4.4	5.4	4.4	3.5	2.6	1.9		
38	24	4.5	5.3	8.2	10.7	8.9	4.7	3.6		
50	0	1.9	2.2	3.5	2.2	2.6	3.2	1.5	2.4	2.8
50	12	2.3	1.8	3.9	3.8	9.1	6.2	5.7	4.4	3.3
50	24	2.4	5.2	8.6	9.0	12.4	7.3	3.4	2.6	2.6

Table II. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Osage Co., 1979)

Knife Spacing (cm)	P-Rate kg/ha	Sample #								
		1	2	3	4	5	6	7	8	9
Sampling Date #1:	4/17/79									
Rep. 2						%P				
25	0	.23	.23	.24	.24	.23				
25	12	.31	.33	.31	.30	.37				
25	24	.30	.32	.32	.32	.26				
38	0	.21	.22	.21	.21	.23	.22	.23		
38	12	.36	.34	.37	.37	.34	.33	.29		
38	24	.31	.27	.29	.23	.34	.32	.34		
50	0	.22	.22	.24	.22	.22	.22	.19	.20	.22
50	12	.26	.23	.30	.36	.37	.36	.38	.31	.28
50	24	.29	.34	.35	.38	.35	.32	.27	.28	.25
						%N				
25	0	4.09	4.12	4.00	4.22	4.09				
25	12	4.09	4.68	4.21	4.43	4.70				
25	24	3.45	3.49	3.70	3.69	3.52				
38	0	3.99	4.01	3.89	3.52	4.18	3.58	3.80		
38	12	4.58	4.70	4.69	4.93	4.61	4.60	4.49		
38	24	4.46	3.98	4.49	3.84	4.49	4.50	4.53		
50	0	3.52	3.41	3.60	3.70	3.82	3.78	3.09	3.45	3.57
50	12	4.29	3.86	4.11	4.70	4.61	4.49	4.49	4.24	4.09
50	24	4.10	4.13	4.12	4.42	4.39	4.29	3.98	3.97	3.89

Table II (Osage Co., 1979 - Continued)

	Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/17/79											
Rep. 3							%P				
	25	0	.25	.31	.37	.36	.28				
	25	12	.29	.30	.26	.23	.28				
	25	24	.43	.37	.37	.33	.33				
	38	0	.22	.25	.22	.23	.26	.25	.21		
	38	12	.33	.29	.28	.30	.30	.32	.31		
	38	24	.23	.27	.33	.32	.35	.33	.31		
	50	0	.27	.24	.27	.28	.30	.26	.23	.29	.28
	50	12	.20	.20	.27	.26	.28	.32	.30	.33	.22
	50	24	.34	.37	.47	.49	.46	.39	.31	.26	.29
							%N				
	25	0	4.26	4.38	4.88	4.80	4.12				
	25	12	4.47	4.50	4.21	3.95	4.49				
	25	24	4.88	4.83	4.80	4.53	4.81				
	38	0	3.81	3.93	3.65	3.94	4.21	4.00	3.64		
	38	12	4.58	4.22	4.50	4.05	3.85	4.67	4.62		
	38	24	4.18	4.50	4.73	4.60	4.75	4.70	4.66		
	50	0	4.49	4.21	4.46	4.52	4.65	4.14	3.85	4.49	4.20
	50	12	3.20	3.12	3.90	3.90	3.90	4.34	4.30	4.21	3.81
	50	24	4.46	4.45	5.03	5.00	5.14	4.94	4.58	4.10	4.49

Table II (Osage Co., 1979 - Continued)

	Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/17/79 Rep. 4											
			%P								
	25	0	.25	.29	.28	.31	.29				
	25	12	.21	.20	.18	.21	.21				
	25	24	.43	.38	.33	.33	.34				
	38	0	.33	.34	.32	.29	.29	.20	.20		
	38	12	.29	.36	.46	.41	.44	.46	.41		
	38	24	.35	.30	.36	.38	.38	.38	.35		
	50	0	.17	.20	.18	.20	.20	.19	.18	.20	.23
	50	12	.26	.25	.32	.32	.33	.36	.30	.31	.28
	50	24	.20	.21	.29	.36	.42	.39	.35	.34	.30
			%N								
	25	0	3.96	4.38	4.49	4.62	4.59				
	25	12	3.69	3.58	3.29	3.90	3.69				
	25	24	4.79	4.40	4.39	4.35	4.59				
	38	0	4.29	4.49	4.30	4.40	4.39	3.39	3.61		
	38	12	4.07	4.21	4.62	4.67	4.91	4.71	4.65		
	38	24	4.60	4.39	4.87	4.71	4.46	4.38	4.61		
	50	0	3.36	3.43	3.29	3.61	3.32	3.28	3.37	3.69	4.00
	50	12	3.98	4.10	4.30	4.40	4.47	4.48	4.00	4.21	4.18
	50	24	3.51	3.61	4.17	4.49	4.75	4.68	4.60	4.59	4.40

Table II (Osage Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	4/28/79									
Rep.2						%P				
25	0	.25	.26	.24	.28	.30				
25	12	.27	.27	.23	.25	.25				
25	24	.25	.29	.31	.28	.27				
38	0	.26	.25	.23	.22	.23	.25	.24		
38	12	.26	.24	.25	.28	.24	.28	.25		
38	24	.33	.30	.26	.30	.24	.24	.28		
50	0	.29	.27	.24	.21	.27	.25	.26	.26	.26
50	12	.32	.31	.35	.37	.35	.31	.27	.29	.35
50	24	.29	.22	.26	.29	.30	.29	.30	.30	.28
						%N				
25	0	3.15	2.87	2.96	3.30	3.60				
25	12	3.40	3.12	2.82	2.75	3.18				
25	24	2.24	2.20	2.52	2.06	2.12				
38	0	3.28	3.08	2.85	2.30	2.79	3.08	3.08		
38	12	2.75	2.68	3.20	3.12	2.80	3.12	2.88		
38	24	2.87	2.79	2.52	2.91	2.58	2.88	2.79		
50	0	2.94	2.95	2.70	2.67	2.20	2.79	2.53	2.85	2.74
50	12	3.31	2.90	2.80	2.80	3.03	3.36	2.91	2.91	3.03
50	24	2.97	2.54	2.62	2.71	2.90	2.54	2.75	2.62	2.67

Table II (Osage Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	4/28/79									
Rep. 3						%P				
25	0	.26	.24	.27	.23	.31				
25	12	.18	.22	.20	.19	.25				
25	24	.34	.35	.36	.27	.32				
38	0	.29	.26	.26	.25	.25	.25	.22		
38	12	.27	.28	.26	.27	.25	.25	.25		
38	24	.25	.28	.30	.25	.29	.32	.32		
50	0	.24	.25	.24	.28	.28	.25	.26	.22	.22
50	12	.22	.24	.24	.28	.20	.23	.23	.23	.24
50	24	.20	.33	.41	.30	.32	.32	.30	.26	.31
						%N				
25	0	3.08	2.90	3.17	2.80	2.68				
25	12	2.30	2.69	2.58	2.48	3.19				
25	24	3.22	2.95	3.35	2.90	3.43				
38	0	3.00	2.80	2.70	2.82	2.55	2.72	2.25		
38	12	2.10	2.55	2.49	2.38	2.18	2.60	2.38		
38	24	2.80	3.27	3.30	2.58	3.00	3.52	2.65		
50	0	2.87	3.00	3.02	3.05	3.42	2.98	3.19	2.79	2.91
50	12	2.68	2.70	3.05	3.32	3.00	2.94	3.20	2.75	3.24
50	24	1.93	3.30	3.75	2.86	2.66	3.02	3.00	2.62	3.22

Table II (Osage Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	4/28/79									
Rep. 4						%P				
25	0	.25	.24	.21	.13	.22				
25	12	.24	.23	.24	.22	.20				
25	24	.34	.36	.35	.29	.27				
38	0	.24	.25	.23	.23	.23	.22	.24		
38	12	.27	.27	.27	.33	.34	.30	.26		
38	24	.30	.32	.29	.27	.28	.29	.28		
50	0	.21	.24	.23	.24	.24	.23	.21	.18	.18
50	12	.23	.24	.23	.24	.27	.31	.25	.25	.27
50	24	.26	.23	.25	.21	.30	.30	.31	.34	.32
						%N				
25	0	2.74	2.95	2.80	1.58	2.79				
25	12	3.08	2.74	2.59	2.17	2.30				
25	24	3.25	3.39	2.19	2.90	2.80				
38	0	2.81	3.00	2.74	2.48	2.70	2.46	2.75		
38	12	2.88	2.53	2.70	2.95	3.40	2.41	2.50		
38	24	2.70	2.91	2.88	2.70	2.99	3.01	2.91		
50	0	2.59	2.92	2.88	2.95	2.67	2.59	2.62	2.33	2.67
50	12	2.79	2.91	2.75	2.79	2.58	2.96	2.74	2.67	2.68
50	24	3.00	2.22	2.51	2.38	2.80	3.27	3.01	3.19	2.90

Table III. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT LEAF TISSUE COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Riley Co., 1979)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1:	4/17/79									
Rep. 2						%P				
25	0	.41	.36	.34	.32	.39				
25	12	.37	.36	.38	.38	.37				
25	24	.42	.42	.42	.45	.39				
38	0	.33	.32	.36	.34	.32	.33	.35		
38	12	.33	.37	.37	.38	.31	.32	.36		
38	24	.39	.38	.41	.49	.45	.38	.35		
50	0	.41	.42	.46	.42	.43	.43	.42	.44	.41
50	12	.47	.48	.44	.36	.37	.40	.37	.35	.39
50	24	.46	.42	.46	.39	.37	.39	.37	.39	.39
						%N				
25	0	4.10	3.70	3.85	3.58	3.65				
25	12	4.12	4.18	3.92	4.09	3.92				
25	24	3.89	3.65	3.80	3.92	3.81				
38	0	3.98	3.92	4.00	3.98	3.79	3.70	4.00		
38	12	4.09	4.18	4.00	4.42	3.58	3.72	3.98		
38	24	3.93	4.09	4.30	4.21	3.89	3.49	3.29		
50	0	3.85	3.95	4.13	3.79	3.90	4.10	3.98	4.00	3.98
50	12	4.21	4.34	4.12	4.00	4.26	3.98	4.11	3.65	3.71
50	24	4.21	4.09	4.18	3.78	3.86	3.83	3.98	3.88	3.98

Table III (Riley Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date 1:	4/17/79									
Rep. 3						%P				
25	0	.37	.39	.38	.42	.37				
25	12	.32	.35	.33	.35	.39				
25	24	.37	.36	.30	.34	.38				
38	0	.32	.31	.34	.29	.28	.28	.27		
38	12	.38	.41	.38	.40	.45	.45	.42		
38	24	.41	.40	.39	.39	.47	.46	.51		
50	0	.23	.26	.24	.26	.23	.24	.26	.24	.24
50	12	.48	.47	.45	.43	.42	.39	.39	.43	.38
50	24	.33	.34	.29	.37	.42	.42	.39	.36	.44
						%N				
25	0	3.65	3.72	3.40	3.50	3.70				
25	12	4.09	4.19	4.01	4.10	4.10				
25	24	3.66	3.70	3.89	3.98	4.17				
38	0	3.89	4.01	4.06	3.89	3.84	3.78	3.72		
38	12	3.92	3.79	4.01	3.92	3.84	3.81	3.88		
38	24	3.81	3.85	4.13	4.18	4.34	4.00	3.83		
50	0	3.57	3.18	3.61	3.73	3.61	3.59	3.81	3.58	3.79
50	12	3.58	3.88	3.25	3.65	3.80	3.60	3.25	3.41	3.81
50	24	3.81	3.92	3.78	4.01	4.26	4.29	4.25	3.69	3.93

Table III (Riley Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #1: 4/17/79										
Rep. 4						%P				
25	0	.35	.35	.32	.36	.31				
25	12	.33	.39	.38	.36	.43				
25	24	.36	.36	.38	.38	.41				
38	0	.34	.34	.34	.35	.33	.29	.28		
38	12	.34	.36	.40	.37	.35	.43	.43		
38	24	.43	.46	.52	.57	.53	.56	.48		
50	0	.32	.32	.34	.26	.31	.29	.29	.33	.31
50	12	.45	.44	.41	.45	.46	.44	.44	.43	.48
50	24	.35	.33	.35	.36	.39	.37	.38	.38	.31
						%N				
25	0	4.11	4.14	3.80	3.78	3.79				
25	12	4.27	4.39	4.22	4.12	4.19				
25	24	3.95	3.87	4.08	3.95	4.18				
38	0	3.90	4.01	3.98	4.10	3.85	3.69	3.52		
38	12	4.10	4.20	4.30	4.04	3.82	4.30	4.35		
38	24	4.31	4.60	4.20	4.43	4.56	4.20	4.22		
50	0	3.92	3.85	4.10	3.45	3.69	3.61	3.79	4.06	4.01
50	12	4.06	4.22	3.98	4.09	4.18	4.19	4.18	4.00	4.31
50	24	3.87	3.69	4.11	4.10	3.59	3.39	3.34	3.86	2.93

Table III (Riley Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/1/79									
Rep. 2						%P				
25	0	.29	.30	.30	.30	.33				
25	12	.27	.29	.30	.30	.31				
25	24	.32	.33	.43	.34	.35				
38	0	.28	.29	.29	.28	.26	.31	.34		
38	12	.33	.32	.29	.33	.27	.29	.31		
38	24	.29	.31	.37	.34	.35	.35	.37		
50	0	.31	.28	.30	.27	.29	.30	.32	.28	.28
50	12	.38	.37	.35	.41	.35	.40	.33	.36	.31
50	24	.38	.36	.34	.38	.31	.35	.29	.29	.32
						%N				
25	0	2.96	2.83	2.95	3.08	2.75				
25	12	2.75	2.86	2.96	3.08	2.69				
25	24	2.75	2.85	3.40	3.40	3.24				
38	0	3.34	3.09	2.93	2.93	2.90	3.07	3.12		
38	12	2.97	2.86	2.96	3.18	2.44	3.26	3.22		
38	24	2.39	2.64	3.09	2.86	2.83	2.82	2.73		
50	0	3.20	2.63	2.73	2.52	2.67	2.87	2.90	2.32	2.73
50	12	3.14	3.45	3.08	3.28	2.53	3.22	2.96	3.30	2.73
50	24	2.73	3.08	2.92	3.08	2.52	3.14	2.50	2.65	2.66

Table III (Riley Co., 1979 - Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/1/79									
Rep. 3						%P				
25	0	.33	.32	.29	.31	.36				
25	12	.32	.31	.35	.37	.35				
25	24	.26	.25	.32	.31	.31				
38	0	.27	.23	.25	.29	.23	.24	.25		
38	12	.32	.35	.32	.31	.28	.33	.34		
38	24	.29	.32	.31	.37	.34	.37	.30		
50	0	.27	.23	.22	.25	.28	.23	.25	.30	.25
50	12	.37	.37	.34	.34	.34	.36	.39	.37	.40
50	24	.28	.33	.33	.35	.35	.38	.34	.38	.30
						%N				
25	0	2.67	2.47	2.82	2.58	2.57				
25	12	3.07	2.85	3.07	2.97	3.42				
25	24	2.35	2.39	2.64	2.47	2.62				
38	0	3.05	2.41	2.79	3.24	2.67	2.69	2.88		
38	12	2.96	2.62	2.66	2.52	2.57	2.45	2.47		
38	24	2.69	2.84	2.98	2.90	3.42	2.79	2.15		
50	0	2.98	2.38	2.64	2.65	3.08	2.39	2.58	3.06	2.86
50	12	3.22	3.07	2.92	2.92	2.17	2.66	3.48	2.19	1.96
50	24	2.38	2.70	2.82	2.56	2.44	2.45	2.18	2.73	2.14

Table III (Riley Co., 1979 -Continued)

Knife Spacing (cm)	P-Rate kg/ha	Sample # 1	2	3	4	5	6	7	8	9
Sampling Date #2:	5/1/79									
Rep. 4						%P				
25	0	.36	.34	.37	.33	.32				
25	12	.36	.31	.30	.32	.30				
25	24	.23	.22	.25	.32	.30				
38	0	.27	.27	.30	.32	.30	---	---		
38	12	.25	.27	.30	.27	.26	.23	.25		
38	24	.27	.28	.31	.29	.30	.30	.33		
50	0	.33	.32	.28	.26	.31	.27	.28	.28	.30
50	12	.34	.39	.33	.42	.39	.38	.38	.36	.29
50	24	.26	.28	.25	.28	.25	.25	.33	.29	.24
						%N				
25	0	3.65	3.10	3.36	3.08	3.23				
25	12	2.97	2.74	2.82	2.71	2.80				
25	24	2.38	2.01	2.27	2.37	2.45				
38	0	2.63	2.79	2.79	3.38	3.22	----	----		
38	12	1.94	2.13	2.15	2.19	2.05	1.86	2.06		
38	24	2.35	2.67	2.62	2.05	2.43	2.50	2.42		
50	0	3.21	3.72	2.55	2.84	3.33	2.98	3.12	3.26	3.20
50	12	2.60	2.86	2.45	3.25	3.44	2.75	2.59	2.90	2.88
50	24	2.65	2.57	2.19	2.47	2.32	1.84	2.43	2.41	2.40

Table IV. EFFECTS OF KNIFE SPACING AND P-RATE ON WINTER WHEAT GRAIN HEAD NUMBER AND GRAIN COMPOSITION AT VARIABLE DISTANCES FROM A PRE-PLANT BAND. (Dickinson Co., 1979)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 3							
38 cm	0	1	3	2.7	30.5	12.1	.20
		2	6	4.0	33.5	12.8	.22
		3	2	2.0	28.6	14.1	.25
		4	2	1.7	30.8	13.6	.30
		5	7	6.2	29.8	12.9	.23
		6	6	5.0	30.0	12.5	.34
		7	2	1.3	28.4	12.8	.26
25 cm	12	1	14	9.0	30.9	11.7	.23
		2	7	3.9	32.2	12.0	.22
		3	9	5.5	33.3	11.8	.21
		4	10	6.4	33.7	11.7	.21
		5	8	5.0	34.4	11.9	.22
38 cm	12	1	4	1.8	25.2	13.1	.20
		2	8	6.3	29.7	12.6	.19
		3	10	8.9	32.5	12.4	.17
		4	9	6.9	29.5	12.8	.25
		5	7	4.3	27.0	12.1	.19
		6	11	6.7	30.1	12.1	.20
		7	3	3.0	30.2	12.3	.24
50 cm	12	1	3	0.7	23.5	16.4	.31
		2	4	4.1	29.3	13.6	.18
		3	8	5.9	27.6	12.9	.19
		4	10	8.0	28.1	12.7	.20
		5	15	14.9	30.6	13.6	.21
		6	10	9.0	33.0	12.9	.18
		7	6	3.3	28.8	13.6	.26
		8	5	4.1	33.7	12.2	.22
		9	6	3.3	29.2	12.1	.22

Table IV (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 3							
25 cm	24	1	15	9.9	31.4	11.7	.24
		2	13	9.0	30.9	11.1	.24
		3	10	7.0	30.3	11.0	.26
		4	11	8.1	32.7	11.0	.25
		5	6	3.5	31.9	11.4	.27
38 cm	24	1	8	4.4	30.7	10.7	.25
		2	14	10.0	30.3	10.5	.23
		3	14	11.8	31.1	10.3	.22
		4	13	12.4	32.5	11.4	.30
		5	7	6.3	31.9	11.2	.24
		6	5	4.9	33.4	11.6	.25
		7	8	4.6	32.2	12.1	.32
50 cm	24	1	4	2.4	30.3	11.4	.32
		2	12	8.0	28.8	11.1	.23
		3	10	4.9	28.0	10.7	.26
		4	5	4.1	33.0	11.5	.21
		5	8	6.8	33.9	10.5	.22
		6	9	5.0	29.5	10.9	.25
		7	9	7.5	29.4	11.4	.29
		8	4	1.6	29.7	11.4	.27
		9	5	3.1	29.7	12.4	.26
Rep. 4							
38 cm	0	1	5	2.6	27.9	12.4	.25
		2	5	3.5	31.1	11.7	.22
		3	5	3.0	29.8	11.9	.28
		4	4	2.9	29.0	11.4	.21
		5	9	6.5	29.6	11.4	.29
		6	3	1.1	28.0	14.1	.32
		7	1	1.5	28.5	12.8	.26

Table IV (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 4							
25 cm	12	1	9	6.4	32.2	11.7	.21
		2	6	4.8	33.0	11.3	.23
		3	9	5.6	32.6	11.9	.22
		4	6	2.5	26.5	12.4	.25
		5	5	3.2	31.5	12.5	.30
38 cm	12	1	7	2.6	31.2	11.7	.25
		2	9	4.0	31.6	12.3	.20
		3	9	4.3	26.7	12.5	.21
		4	14	10.4	33.8	11.7	.17
		5	10	9.4	35.1	10.8	.18
		6	6	3.5	28.7	11.1	.21
		7	4	3.2	32.1	12.0	.22
50 cm	12	1	4	2.6	29.6	13.1	.25
		2	9	4.6	28.8	12.0	.19
		3	5	3.0	28.0	12.0	.21
		4	11	3.7	29.2	11.5	.16
		5	9	6.4	34.3	12.1	.20
		6	3	3.3	36.8	11.3	.18
		7	9	5.8	33.3	10.5	.19
		8	2	1.2	29.9	11.3	.21
		9	7	5.5	34.7	11.4	.22
25 cm	24	1	6	3.5	35.0	10.3	.27
		2	11	7.9	31.2	10.0	.38
		3	11	9.5	32.5	9.2	.25
		4	6	4.1	33.9	10.4	.27
		5	7	4.4	35.5	9.9	.24

Table IV (Dickinson Co., 1979 - Continued)

Knife Spacing	P-Rate kg/ha	Sample Number	Heads/ .051m	Total Grain Wt. (g)	Avg. Kernel Wt. (mg)	Grain Protein %	% P
Rep. 4							
38 cm	24	1	8	7.5	33.7	12.1	.24
		2	4	4.3	34.7	12.4	.22
		3	5	3.8	27.1	12.3	.24
		4	10	6.1	29.9	12.7	.21
		5	7	4.2	31.5	12.0	.24
		6	5	3.1	31.7	12.0	.21
		7	6	4.4	31.0	12.0	.21
50 cm	24	1	7	3.7	29.5	12.0	.27
		2	7	4.5	34.0	12.3	.28
		3	12	9.2	32.8	10.7	.23
		4	14	10.1	30.4	10.4	.22
		5	13	7.8	32.2	10.5	.25
		6	8	5.2	30.6	11.1	.33
		7	6	2.3	26.1	12.0	.35
		8	6	1.4	29.2	12.0	.42
		9	4	2.2	32.5	11.7	.35

OPTIMUM SPACING OF PRE-PLANT BANDS OF N AND P FERTILIZER FOR WINTER WHEAT

by

THOMAS MARK MAXWELL

B.S., Kansas State University, 1978

AN ABSTRACT OF A MASTER'S THESIS

submitted in partial fulfillment of the

requirements for the degree

MASTER OF SCIENCE

Department of Agronomy

KANSAS STATE UNIVERSITY
Manhattan, Kansas

1980

Field studies consisting of combinations of spacings of pre-plant bands and rates of P fertilizer were conducted on winter wheat at several locations in eastern Kansas. All treatments were pre-plant band applications of liquid ammonium polyphosphate (APP, 10-34-0) and anhydrous ammonia. Band spacings of 25, 38, and 50 cm in combination with rates of 0, 6, 12, and 24 kg P/ha were selected for this study.

The growth of winter wheat was influenced by the distance between bands as well as the P rates at some locations. Grain yield was influenced significantly by P rate at some locations. Spacing effects were non-significant at all locations but tended to be higher with narrower spacing of pre-plant bands at some locations.

Plant sampling at various distances from the fertilizer band indicated differences in dry matter, head number, and grain yield due to P rate and knife spacing.

Studies conducted in the greenhouse indicate that the application of P fertilizer is very important early in the wheat seedlings. Phosphorus uptake by young wheat seedlings was significantly influenced by the distance of the fertilizer band from the plant. Fertilizer bands 0, 10, and 20 cm from the plant row influenced fertilizer P uptake at early sampling times. Fertilizer bands 30 cm from the plant row influenced P fertilizer uptake at later sampling times but gave substantially less fertilizer P uptake than closer bands.