

INFORMATION TO USERS

The most advanced technology has been used to photograph and reproduce this manuscript from the microfilm master. UMI films the original text directly from the copy submitted. Thus, some dissertation copies are in typewriter face, while others may be from a computer printer.

In the unlikely event that the author did not send UMI a complete manuscript and there are missing pages, these will be noted. Also, if unauthorized copyrighted material had to be removed, a note will indicate the deletion.

Oversize materials (e.g., maps, drawings, charts) are reproduced by sectioning the original, beginning at the upper left-hand corner and continuing from left to right in equal sections with small overlaps. Each oversize page is available as one exposure on a standard 35 mm slide or as a 17" × 23" black and white photographic print for an additional charge.

Photographs included in the original manuscript have been reproduced xerographically in this copy. 35 mm slides or 6" × 9" black and white photographic prints are available for any photographs or illustrations appearing in this copy for an additional charge. Contact UMI directly to order.



300 North Zeeb Road, Ann Arbor, MI 48106-1346 USA

PREVIEW

Order Number 8803994

**Effect of phosphorus fertilizer distribution in the band on grain
yield and P uptake of winter wheat and corn**

Eghball, Bahman, Ph.D.

The University of Nebraska - Lincoln, 1987

U·M·I

300 N. Zeeb Rd.
Ann Arbor, MI 48106

PREVIEW

PLEASE NOTE:

In all cases this material has been filmed in the best possible way from the available copy. Problems encountered with this document have been identified here with a check mark ☒.

1. Glossy photographs or pages _____
2. Colored illustrations, paper or print _____
3. Photographs with dark background _____
4. Illustrations are poor copy _____
5. Pages with black marks, not original copy _____
6. Print shows through as there is text on both sides of page _____
7. Indistinct, broken or small print on several pages ☒
8. Print exceeds margin requirements _____
9. Tightly bound copy with print lost in spine _____
10. Computer printout pages with indistinct print _____
11. Page(s) _____ lacking when material received, and not available from school or author.
12. Page(s) _____ seem to be missing in numbering only as text follows.
13. Two pages numbered _____. Text follows.
14. Curling and wrinkled pages _____
15. Dissertation contains pages with print at a slant, filmed as received ☒
16. Other _____

U·M·I

PREVIEW

EFFECT OF PHOSPHORUS FERTILIZER DISTRIBUTION IN THE BAND ON GRAIN
YIELD AND P UPTAKE OF WINTER WHEAT AND CORN

by

Bahman Eghball

A DISSERTATION

Presented to the Faculty of
the Graduate College in the University of Nebraska
in Partial Fulfillment of Requirements
For the Degree of Doctor of Philosophy

Major: Agronomy

Under the supervision of Dr. Donald H. Sander

Lincoln, Nebraska

September, 1987

TITLE

Effect of Phosphorus Fertilizer Distribution in the Band on
Grain Yield and P Uptake of Winter Wheat and Corn

BY

Bahman Eghball

APPROVED

DATE

<u>Dr. Donald H. Sander</u>	<u>9-25-1987</u>
<u>Dr. James F. Power</u>	<u>9-25-1987</u>
<u>Dr. James S. Schepers</u>	<u>9-25-1987</u>
<u>Dr. Herman W. Knoche</u>	<u>9-25-1987</u>
<u> </u>	<u> </u>
<u> </u>	<u> </u>
<u> </u>	<u> </u>

SUPERVISORY COMMITTEE

GRADUATE COLLEGE

UNIVERSITY OF NEBRASKA

EFFECT OF P FERTILIZER DISTRIBUTION IN THE BAND ON
GRAIN YIELD AND P UPTAKE OF WINTER WHEAT AND CORN

Bahman Eghball, Ph.D.

University of Nebraska, 1987

Advisor: Dr. Donald H. Sander

Phosphorus fertilizer distribution in the band is affected by band spacing, P application rate, and fertilizer P particle size. Twelve experiments were conducted over four years (1983-1986) to evaluate the effect of different factors influencing P fertilizer distribution in the band on grain yield and P uptake. From 1983 to 1985, five field experiments were conducted to determine the effect of P fertilizer particle size on grain yield and P uptake of winter wheat (Triticum aestivum, L.); in 1983, 1984 and 1986 four field experiments were conducted to determine the effect of band spacing of dual-placed N and P fertilizers on grain yield and P uptake of corn (Zea mays, L.); a "Field Pot" experiment was conducted in 1984 and 1985 to evaluate the effect of P fertilizer distance and distribution in the band on corn P uptake and dry matter production; and in 1986, effect of band spacing, P application rate, delivery tube size and traveling speed during application with a standard squeeze pump was evaluated on distribution of P fertilizer solution in the applied band.

The results indicate that phosphorus fertilizer particle size significantly affected grain yield and P uptake of winter wheat. Optimum particle size was about 0.025 mg which is much smaller than P fertilizer particle sizes farmers normally use (about 20 mg). Great surface area of applied P fertilizer at particle sizes smaller than optimum, and also noncontinuous distribution of large particles in the applied band

limited the efficiency of these particle sizes. Band spacing of dual-placed N and P fertilizers affected utilization of both nutrients. Effect of band spacing on N and P effectiveness were opposite in that applied P was more effective while N was less effective as the band spacing decreased. Distance that P fertilizer was applied from plants was important only at early stages of growth. Phosphorus uptake increased as spacing between injection points in the applied band increased. This was because as injection point spacing increased, the P target size (two dimensional surface of P affected soil exposed to the root system) increased, resulting in greater root-fertilizer contact. It was also found that P fertilizer solution is distributed as droplets in the band at low P application rates and narrow band spacings. Distance between droplets reduced probability of root-P fertilizer contact and decreased P fertilizer effectiveness.

While many factors influence P fertilizer efficiency, results indicate that P fertilizer distribution is a significant factor affecting efficiency in that it influences the probability of root-fertilizer contact.

ACKNOWLEDGMENTS

My sincere appreciation is extended to Dr. Donald H. Sander for his guidance and patience throughout the course of my study and providing me with the assistantship that made my education possible. I would also like to thank his wife, Harriet and his family for their care and openness.

I would like to thank my parents for their unlimited love and support and understanding during the past eight years I have been in this country.

Special thank is extended to Dr. James S. Schepers and Dr. James F. Power for reviewing the dissertation papers and serving on my committee and also Dr. Herman W. Knoche for serving on my committee.

I would acknowledge the advice of late Robert A. Olson during my course of study.

I would like to thank Patti Boehner for her love and understanding.

Appreciation is also extended to my fellow students for their help and advice during my course of study here in Nebraska.

I gratefully acknowledge the help of Kevin Raun, Myron Kumm, Dennis Michale and Ed Sauser for providing me with experimental sites in their farms.

I would also like to thank Donna Bryan for typing my papers as manuscripts.

TABLE OF CONTENT

	PAGE
SECTION I. EFFECT OF FERTILIZER P PARTICLE SIZE ON WINTER WHEAT YIELD AND P UPTAKE	1
ABSTRACT	2
INTRODUCTION	4
MATERIALS AND METHODS	6
RESULTS AND DISCUSSION	8
SUMMARY	15
REFERENCES	17
SECTION II. EFFECT OF BAND SPACING OF DUAL-PLACED P AND N FERTILIZERS ON CORN GRAIN YIELD AND P UPTAKE	31
ABSTRACT	32
INTRODUCTION	34
MATERIALS AND METHODS	36
RESULTS AND DISCUSSION	39
SUMMARY	46
REFERENCES	48
SECTION III. EFFECT OF P FERTILIZER APPLICATION DISTANCE AND DISTRIBUTION ON P EFFECTIVENESS FOR CORN	62
ABSTRACT	63
INTRODUCTION	65
MATERIALS AND METHODS	67
RESULTS AND DISCUSSION	70
SUMMARY	77

TABLE OF CONTENT (CONTINUE)

	PAGE
REFERENCES	79
SECTION IV. PHOSPHORUS FERTILIZER DISTRIBUTION IN THE BAND AS AFFECTED BY APPLICATION VARIABLES .	91
ABSTRACT	92
INTRODUCTION	94
METHODS	96
RESULTS	98
DISCUSSION	100
SUMMARY	105
REFERENCES	107
APPENDIX A - METHOD OF DETERMINING THE SURFACE AREA OF PARTICLE SIZES	119
APPENDIX B - FIGURES SHOWING SIGNIFICANT EFFECTS AND INTERACTIONS FOR EXPERIMENTS I, II AND III	121
SECTION I	122
SECTION II	128
SECTION III.	134

LIST OF TABLES

TABLE		PAGE
SECTION I.		
1	Soil characteristics of experimental sites, 1983 to 1985	20
2	Relationship between P fertilizer particle sizes and their surface area	21
3	Effect of P fertilizer particle size on grain yield, P uptake and yield components of winter wheat in Crete soil, 1983	22
4	Effect of P rate and particle size on grain yield, P uptake and yield components of winter wheat, 1984-1985	23
5	Multiple regression coefficients relating fertilizer P particle size (ranked) and P rate to winter wheat grain yield and P uptake from four soils. 1984-1985	24
6	Multiple regression coefficients relating fertilizer P particle size (ranked) and P rate to various yield components from four soils. 1984-1985	25
SECTION II.		
1	Soil characteristics of experimental sites	50
2	Analysis of variance showing the effect of P rate, band spacing, and application depth on grain yield, total P uptake, seven and leaf P increases due to applied P over no P plots in 1983	51
3	Effect of band spacing, P rate, and application depth on grain yield, total P uptake, seven and ear leaf P increases due to applied P over no P plots in 1983	52
4	Effect of band spacing and application depth on grain yield, total P uptake, seven and ear leaf P on plots receiving 200 kg N ha ⁻¹ and no applied P in 1983	53
5	Analysis of variance showing the effect of band spacing, application depth, P and N rate on grain yield, total P uptake, seven and ear leaf P. Coly sil, 1984	54

LIST OF TABLES (CONTINUE)

TABLE	PAGE
6 Effect of band spacing, application depth, P and N rate on grain yield, total P uptake, seven and ear leaf P. Coly sil, 1984	55
7 Effect of band spacing and P rate on grain yield, total P uptake, seven and ear leaf P uptake in Moody soil, 1986	56
8 Effect of band spacing and P rate on the variability between plants in the row, 1984 and 1986	57
SECTION III.	
1 Analysis of variance for plant P from fertilizer across two years, 1984 and 1985	81
2 Effect of P distance, injection point spacing P rate, and time on plant P from fertilizer . .	82
3 Analysis of variance showing the effect of P placement and rate on corn dry matter production at different stages of growth in 1984 and 1985. .	83
4 Effect of P placement and rate on dry matter production at different stages of growth in 1984 and 1985	84
SECTION IV.	
1 Regression coefficients from a multiple regression showing the effect of different P application variables on the distance between liquid fertilizer droplets ($R^2=0.78$) . .	110

LIST OF FIGURES

FIGURE		PAGE
SECTION I.		
1	Nonlinear regression showing the relationship between actual particle weight and the ranked numbers	26
2	Effect of P fertilizer particle size on the grain yield of winter wheat at three P rates in Holdrege soil	27
3	Effect of P fertilizer particle size on the grain yield of winter wheat at three P rates in Ascalon soil	28
4	Effect of P fertilizer particle size on the total P uptake of winter wheat in Holdrege soil	29
5	Effect of P fertilizer particle size on the winter wheat number of heads at three P rates in Rosebud soil	30
SECTION II.		
1	Effect of band spacing on corn grain yield at two P rates. Sharpsburg sil, 1983.	58
2	Effect of band spacing on corn grain yield at two application depth. Sharpsburg sil, 1983	59
3	Effect of band spacing on corn grain yield at two N rates, Coly sil, 1984	60
4	Effect of P rate on corn ear leaf P at two N rates. Coly sil, 1984.	61
SECTION III.		
1	Diagram showing the injection point spacing of 10 cm at four P distances from plants	85
2	Effect of P application rate on the movement of applied P in the soil	86
3	Movement of P fertilizer in the soil at four injection point spacings at 16 cm P distance from plants and 11.2 kg ha ⁻¹ P rate	87

FIGURE	LIST OF FIGURES (CONTINUE)	PAGE
4	Effect of P distance from plants on plant P from fertilizer at three sampling times over two years, 1984 and 1985	88
5	Effect of injection point spacing on plant P from fertilizer at four P distances over two years, 1984 and 1985	89
6	Effect of injection point spacing on plant P from fertilizer at two application rates over two years, 1984 and 1985	90

SECTION IV.

1	Effect of P application rate on the distance between droplets in an applied band as determined from multiple regression	111
2	Amount of calculated P in each droplet as affected by P application rate using multiple regression	112
3	Effect of band spacing on the distance between droplets at different rate of P application as determined by multiple regression	113
4	Effect of traveling speed on the distance between droplets in the applied band as determined by multiple regression	114
5	Effect of delivery tube size on the distance between fertilizer droplets at different rates of P as determined by multiple regression	115
6	Effect of method of P application on the wheat grain yield. From Sander and Penas (16)	116
7	Effect of method of P application on the corn grain yield. From Raun et. al. (15)	117
8	Effect of method of P application on the wheat grain yield. From Leikam et. al. (10)	118

LIST OF APPENDIX FIGURES

FIGURE	PAGE
SECTION I.	122
B-1 Effect of P fertilizer particle size on grain yield of winter wheat in Crete soil	123
B-2 Effect of P fertilizer particle size on total P uptake of winter wheat in Crete soil	124
B-3 Effect of P fertilizer particle size on grain yield of winter wheat at three P rates in Kuma soil	125
B-4 Effect of P fertilizer particle size on seed weight of winter wheat at three P rates in Kuma soil	126
B-5 Effect of P fertilizer particle size on seed weight of winter wheat at three P rates in Rosebud soil	127
SECTION II.	128
B-6 Effect of band spacing on corn P uptake at two application depth	129
B-7 Effect of band spacing on corn ear leaf P at two application depth	130
B-8 Effect of band spacing on corn grain yield from no P plots in two soils in 1983	131
B-9 Effect of band spacing on corn P uptake at two N rates	132
B-10 Effect of P rates on corn seven leaf stage P at two N rates	133
SECTION III.	134
B-11 Effect of P application distance on plant P from fertilizer in two years	135
B-12 Effect of time on plant P from fertilizer in two years	136
B-13 Effect of P rate on applied P utilization in two years	137

I. EFFECT OF FERTILIZER P PARTICLE SIZE ON WINTER WHEAT YIELD AND
P UPTAKE

PREVIEW

ABSTRACT

Five field experiments were conducted over three years (1983-85) to evaluate the effect of P fertilizer particle size on winter wheat (*Triticum aestivum* L.) yield and P uptake. In 1983, an introductory experiment indicated that P fertilizer particle size could greatly affect P fertilizer efficiency. Studies in 1984 and 1985 confirmed these observations. In these studies ammonium polyphosphate (11-24-0, N-P-K) at five particles of 0.0002, 0.0009, 0.025, 0.93 and 22 mg were applied at P rates of 8.4, 16.8 and 25.2 kg P ha⁻¹ on four different soils. Wheat grain yields were increased significantly by applied P on all four soils. However, grain yields were affected by P fertilizer particle size primarily on the two soils where yield increases from applied P were greatest. Maximum grain yield occurred at approximately the intermediate particle size studied (0.025 mg), although optimum particle size was dependent on P rate. As the P rate increased particle size became less of a factor influencing P fertilizer efficiency. The low effectiveness of particle sizes smaller than optimum probably resulted from increased soil-P fertilizer contact, while effectiveness of larger particles were reduced by lack of adequate root contact. Wheat grain yield at the 8.4 kg ha⁻¹ P rate was actually 0.31 Mg ha⁻¹ less for the 22 mg particle compared to the 0.025 mg particle on the two most P responsive soils. Calculations indicated that the 22 mg fertilizer particles had an average distance of 2.8 cm from one another in the band area, compared to 0.003 cm or a continuous band for the 0.025 mg particles. Phosphorus uptake and other yield components generally paralleled the results with grain yield. While optimum fertilizer size

probably ranges from 0.025 to 1 mg per particle, the optimum size in these experiments was less than the 20 mg particle size reported for farm fertilizers.

PREVIEW

INTRODUCTION

Particle size of P fertilizer influences the utilization of applied P in two ways. First, it affects the distribution of fertilizer in soil which has been shown to be an important factor in effectiveness of applied P (1,17). Second, it determines the effective surface area and therefore the reactivity of P fertilizer with soil which affects availability (9). Increasing particle size of P fertilizer increases P concentration in the soil solution of the treated zone after the excess P has diffused away (4). The extent of movement from the application point is proportional to the rate of P application (12).

Distribution of fertilizer particles in the soil is directly related to the rate of application and influences the probability of roots encountering P fertilizer (2). Nonuniform distribution is important because presence of P in one zone and absence in another may affect root distribution, P uptake and total dry matter production (18). When P application is restricted to part of the soil volume, roots in the P treated soil may differ in growth rate and morphology from roots in untreated soil (1). Rate of root growth is much greater in fertilized than unfertilized soil because roots may stop growing in unfertilized soil after a short time (6). For greater effectiveness of applied P it is essential to place the P fertilizer where root-fertilizer contact is the highest.

Some research has been reported on the effect of particle size of phosphorus fertilizer of different water solubilities on plant growth (11,14,15,16). Because most presently used P fertilizers have high water solubility, distribution of applied P may be an important factor

affecting fertilizer effectiveness when banded. Eghball and Sander (7) showed that when band applied with a squeeze pump, the P fertilizer solution is placed as droplets of different sizes varying in distance from each other. Distance between droplets increases as application rates are reduced or band spacings become closer. The authors suggest that this may be a factor influencing the effectiveness of banded P at low application rates compared to broadcasting at the same rate.

Little research has been done on the effect of particle size on the distribution of applied P in the band or if particle size of applied P fertilizer affects crop yield and fertilizer P efficiency. The objective of this research was to determine the effect of P application rate and P fertilizer particle size on the yield and yield components of winter wheat (Triticum aestivum L.).

PREVIEW

MATERIALS AND METHODS

Five experiments were conducted across Nebraska over a three year period (1983-85). An introductory experiment was conducted on a Crete silt (Pachic Argiustoll) in eastern Nebraska in 1983 (Table 1). Phosphorus fertilizer as ammonium polyphosphate (11-24-0, N-P-K) was applied as particles weighing 2.56, 1.28, 0.64, 0.32 grams per particle and as a powder obtained by grinding the fertilizer particles. The fertilizer particles were arranged on an application belt and placed with the wheat seed in 30 cm rows at a rate of $16.8 \text{ kg P ha}^{-1}$. The calculated distance between particles in the applied band were 15.0, 30.0, 60.0 and 120.0 cm for 0.32, 0.64, 1.28 and 2.56 gram particles, respectively.

Experiments were established in western Nebraska at two locations in 1984 and 1985 on four different soil types (Table 1). In these experiments smaller particles were utilized because particles used in the 1983 experiments were too large. Phosphorus fertilizer (11-24-0) particles of 22, 0.93, 0.025, 0.0009 and 0.0002 mg, prepared by Tennessee Valley Authority, were applied at application rates of 8.4, 16.8 and $25.2 \text{ kg P ha}^{-1}$. Fertilizer P was placed directly with the wheat seed in 30 cm rows by means of an application belt. Particle weight for the first three sizes was determined by weighing and for the two smallest particles was calculated based on sieve opening and density of the fertilizer (1.75 Mg m^{-3}). Sieve opening was used to approximate an average particle diameter. Centurk winter wheat was seeded in 30 cm rows at a rate of 50 kg ha^{-1} with a standard hoe drill in all years.

A randomized complete block experimental design with five fertilizer P particle sizes and four replications was used in 1983. In 1984 and 1985, a randomized complete block design with five replications was