Phosphorus Time, rate, and placement methods as influencing dryland small grain production
by Roger Lavern Wilson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree of DOCTOR OF PHILOSOPHY in Crop and Soil Science
Montana State University

Abstract:
Spring and winter wheat were grown under dryland conditions at three Montana locations in 1967 1968, and 1969.

The influence of time, rate, and placement of P fertilizer was evaluated by using grain yield, dry matter yield, P yield, and culm count measurements.

Placement of fertilizer P with-the-seed at rates of 20 and 30 lb, per acre increased grain yields more than did broadcast rates of 30 to 60 lb. P/A, Thirty pounds P with-the-seed and 90 lb, P broadcast gave comparable yields. Starter fertilizer (51b, N plus 2,5 lb. P/A") with-the-seed significantly increased grain yields with broadcast P-rates of 0, 10, 20, and 30 lb. P/A consistently, and only occasionally at 60 and 90 lb. P/A.

P yield increased at a constant rate throughout the growing season, as a function of P treatment. Continued P uptake after heading was noted only with treatments which contained low broadcast P-rates of 0, 10, and 20 lb/A whereas little or none occurred with 60 and 90 lb. P/A.

P percentage values showed good correlation with final grain yields only at the very early stages of plant development and at low rates of added P.

Culm count was directly related to P treatment, and with increasing P-rates significant increases occurred with both culm count and grain yield.

There was no significant loss in 1969 grain yields due to reduced P availability with 10, 20, and 60 lb. P/A applied for the 1967 crop.

PHOSPHORUS--TIME, RATE, AND PLACEMENT METHODS AS INFLUENCING DRYLAND SMALL GRAIN PRODUCTION

by

Roger Lavern Wilson

A thesis submitted to the Graduate Faculty in partial fulfillment of the requirements for the degree

of

DOCTOR OF PHILOSOPHY

in

Crop and Soil Science

Approved:

Erhardt R. Stelm
Head, Major Department

Charles M Smith
Chairman, Examining Committee

K Goering
Dean, Graduate Division

MONTANA STATE UNIVERSITY
Bozeman, Montana

March, 1970

ACKNOWLEDGEMENT

The author would like to express a sincere thanks to Dr. C. M. Smith for patience, consideration, and assistance during the course of this work.

Also, the author would like to acknowledge the help and instruction received from the other committee members: Drs. J. R. Sims, J. H. Brown, E. R. Hehn, I. K. Mills, and V. H. Schmidt.

A special thanks to Glennis Boatwright and Dr. Paul Brown, A.R.S., for helpful comments and suggestions and to Dr. Ervin P. Smith and Roger Stewart for assistance with computer programming.

Thanks also to the Central Exchange Foundation for the Grant-in-Aid which partially financed the work and to the Montana Cooperative Extension Service.

To those involved with the fieldwork; County Extension Agents, Central Exchange fieldmen, and personnel of the Montana Agricultural Experiment Stations, Soil Conservation Service and Agricultural Research Service; thank you.

Lastly, the author wishes to express thanks to his patient family and a very understanding wife who helped at all times, typed the thesis, and provided constant encouragement.

TABLE OF CONTENTS

Table of Contents

(Continued)

LIST OF TABLES

Context Tables

List of Tables

Context Tables
(Continued)

List of Tables

Context Tables
(Continued)

Appendix Tables

List of Tables

Appendix Tables
(Continued)

List of Tables

Appendix Tables
(Continued)

LIST OF FIGURES

List of Figures

(Continued)

ABSTRACT

Spring and winter wheat were grown under dryland conditions at three Montana locations in 1967, 1968, and 1969.

The influence of time, rate, and placement of P fertilizer was evaluated by using grain yield, dry matter yield, P yield, and culm count measurements.

Placement of fertilizer P with-the-seed at rates of 20 and 30 lb. per acre increased grain yields more than did broadcast rates of 30 to 60 lb. P/A. Thirty pounds P with-the-seed and 90 lb. P broadcast gave comparable yields. Starter fertilizer (5 lb. N plus 2.5 lb. P/A) with-the-seed significantly increased grain yields with broadcast P-rates of 0, 10, 20, and 30 lb. P/A consistently, and only occasionally at 60 and 90 lb. P/A.

P yield increased at a constant rate throughout the growing season, as a function of P treatment. Continued P uptake after heading was noted only with treatments which contained low broadcast P-rates of 0, 10, and 20 lb/A whereas little or none occurred with 60 and 90 lb. P/A.

P percentage values showed good correlation with final grain yields only at the very early stages of plant development and at low rates of added P.

Culm count was directly related to P treatment, and with increasing P-rates significant increases occurred with both culm count and grain yield.

There was no significant loss in 1969 grain yields due to reduced P availability with 10, 20, and 60 lb. P/A applied for the 1967 crop.

INTRODUCTION

Agriculture is the main source of income for Montana, and small grain production furnishes the largest segment of this economy. With a needed increase in the economy of the state, more and more fertilizer is used to boost small grain yields. This creates a need to better understand how fertilizers can be used more efficiently.

There has been a great deal of concern about fertilizer application methods and residual influence. To date very little has been done on P fertilized small grain production especially where methods of application and residual influence have been studied in a crop-summer fallow system. Therefore, this experiment was designed to study the effectiveness of methods of applications: P placed with-the-seed, broadcast on the fallow, or just before seeding. The residual carryover from various application rates in previous years will also be studied. In order to study the outlined problems, two sites were selected in predominantly winter wheat producing areas and one in the spring wheat area of Montana for the five-year study.

The present research data include soil and plant analysis for phosphorus, phosphorus uptake by plants at different stages of growth, culm counts, kernel counts, grain protein percentage, grain yield, dry matter yield, and P yield. Although several years will be needed to completely evaluate the residual fertilizer-P influence, this thesis will include three years' results; 1967, 1968, and 1969.

From this research, it is hoped that some specific recommendations can be made on methods, time, and rates of phosphorus applications for small grain production.

LITERATURE REVIEW

PLACEMENT OF FERTILIZER

The first recorded use of fertilizer placement in the United States was in 1621 in Plymouth, Massachussets when the white man harvested his first corn crop. According to Lang (38) the main reason he was able to produce corn on that poor land was because Squanto, an Indian, had taught him to place a fish in each hill of corn when it was planted.

Considerable work has been done with fertilizer placement in the corn belt where several placement methods are used. The bulk of the fertilizer is broadcast in the fall or before plowing, and then a small amount is added with or near the seed at seeding time in the spring. When the small amount is placed with-the-seed it is commonly referred to as "pop-up", "split-boot", 2" x 2" placement, or starter fertilizer (12). Advantages of starter fertilizer are better stands, hastened emergence, earlier maturity, crops which are more competitive with weeds, and increased yields shown by Jacob (33). Disadvantages of starter are reduced germination at higher rates of fertilizer and the extra expense of additional time and equipment needed for application (81).

Guttay (29) in working on germination of wheat and oats with banded fertilizer found 100 pounds of nutrients in contact with-the-seed delayed germination and emergence and that phosphorus was as detrimental as nitrogen and potassium. Low quality seed and dry conditions led to a more pronounced detrimental effect. Oats were less affected than wheat, probably because the lemma and palea are attached to the caryopsis while wheat is detached.

Cummins and Parks (20) did not agree with Guttay that phosphorus caused as much damage to germination of wheat and corn and listed the following fertilizers in decreasing order of damage to germination: anhydrous ammonia, urea, muriate of potash, nitrate of soda, ammonium nitrate, ammonium sulfate, sulfate of potash, 6-12-12, 48 percent superphosphate, and 20 percent superphosphate.

Hood and Ensminger (31) recorded at lowered germination due to diammonium phosphate on wheat and cotton was not osmotic effects alone and that the ions per se were not causing the effects. They thought the high acid condition was causing the reduction as damage cound be reduced by adjusting the pH. The corrective effect of $MgSO_4$ and $MgCl_2$ suggested that $(NH_4)_2HPO_4$ may have adversely affected Mg utilization by lowering enzyme activity.

Nelson (52) and Ohlrogge (53) stated there was a greater chance of "fertilizer burn" with banded fertilizer than with broadcast fertilizer. Fertilizer salts may draw water from the germinating plant causing a burned or injured seedling. Other workers have recorded some detrimental effects on seedlings at critical moisture levels when the fertilizer was either placed with-the-seed or banded (58)(63).

Alessi and Power (1) working with barley indicated percent P and P uptake in the plants were higher when P was placed with-the-seed as compared with a two-inch depth in the soil. Fertilizer placed with-the-seed gave the greatest fertilizer P uptake early but as the season progressed more soil P was absorbed. They concluded that P was as beneficial to the plant placed at a two-inch depth beside the seed if water was present and soil P was in the medium to moderate low range. The placement method was less critical when water was adequate. Sherrell et al. (72) found results similar to Alessi and Power when working with oats in Canada.

Smith and Stanford (76) reported P fertilizers at low rates of application are more efficiently used by grain crops when the fertilizer is banded with or near the seed. In their work at Iowa using radioactive phosphorus for oats, disking the P was about 40 to 48 percent as efficient as drilling when the rate was 40 lb. P_2O_5 per acre. However, that efficiency increased to 55 to 65 percent for 80 lb. P_2O_5 per acre. Also, on calcareous soil topdressing the P fertilizer at 40 lb. per acre soon after seeding was 64 percent as efficient as drilling. Most research in Canada and the United States has shown band-placed P fertilizers were used by grain plants with about double the efficiency of broadcast and disked fertilizer applied prior to seeding.

Barber (2) showed response advantage due to banded or seed applications of fertilizer decreased as the soil level of nutrients increased. Simpson (73) showed similarly that the level of soil P and the rates of application influenced which placement method was best for oat crops.

Considerably less fertilizer was needed banded or with-the-seed as compared with broadcast for good wheat yields as shown by Smith (77). Lutz et al. (44) working with small grains in the South, found that by applying 40 lb. P_2O_5 per acre it was only 42 percent as effective broadcast and disked and 33 percent as effective topdressed as compared with placement with-the-seed. Olson et al. (60) and Gingrich (26) reported maximum efficiency of fertilizer P by placing it with-the-seed on small grains and clover. In England, Cooke (19) reported one-half as much grain was produced by broadcasting P and K as was produced by placement with-the-seed. He believed the increased grain yield from placement with-the-seed was due to stimulated root growth.

Prummel (66) in the Netherlands reported P was 2.45 times as effective on cereals placed with-the-seed as broadcast and 1.9 for potatoes, 1.2 for beets, and 2.9 for maize. Placement with-the-seed gave early growth and prevented fixation of P fertilizer.

Banding of phosphate gave the most economical results at lower application rates of fertilizer on corn; but at higher rates, a combination of broadcast and with-the-seed was more economical (Welch et al. (84). Bates et al. (4) found fertilizer with-the-seed markedly increased the early uptake of nutrients and growth of corn. Less K was needed banded than broadcast to obtain the most economical yields of corn according to Welch et al. (83) and Mortensen (50); however, Mortensen found a detrimental effect when N was placed with-the-seed.

Only one-half as much banded phosphorus was needed to produce similar yields on safflower as was needed broadcast reported Werkhoven and Massanitini (85).

Generally, higher rates of fertilizer are broadcast and lower rates applied with-the-seed or banded. Nebraska research of Olson and Dreier (58) showed the upper limit for nitrogen with-the-seed to be 15 lb. per acre on oats and wheat.

Nelson (51) reporting on work done in Wisconsin with small grains under high moisture conditions, stated that up to 75 lb. per acre of N or K_2O could be placed with-the-seed before damage occurred. At higher rates, banding one and one-half inches to the side and one inch below the seed gave better results.

Fertilizer such as 5-20-20 caused considerable damage to seedlings at a rate of 500 lb. per acre placed with wheat seed; but under the same set of conditions, 5-20-0 did not cause detrimental effects reported Lawton and Davis (40).

Of the three major fertilizer nutrients, N, P, and K, P seems to be the least detrimental to seedling development when placed in contact with the seed. Nitrogen and K are more water soluble and most likely to cause fertilizer burn than P (Nelson (52)).

Much of the work in the past has shown that fertilizer placement with-the-seed especially N and K at rates above 25 lb. per acre, can be detrimental to small grain germination and seedling development. Therefore, the higher rates of fertilizer must be applied broadcast. Most of the data reported was based on a one-year, one-crop experiment (18)(44)(58). In order to consider the total effect of higher rates of with-the-seed and broadcast placement of fertilizer, the two will need to be evaluated together and for more than one crop.

Several workers (66)(85)(75)(76)(87) have shown the high efficiency of low rates of fertilizer with-the-seed. More work is needed to show what combination of rates broadcast and/or banded is best suited for each situation.

EFFECT OF ASSOCIATED SALTS ON PHOSPHATE ABSORPTION

The associated salts of other fertilizer materials may have an effect on P uptake by plants. Terman (80) reported ammonium salts increased P uptake by plants. He attributed the increase to stimulated root activity or increased acidity on alkaline soils from the nitrification of the ammonium nitrogen.

Leonce and Miller (42) found the interaction of N with P to be physiological with corn. When $(NH_4)_2SO_4$ or NH_4Cl was added to phosphorus fertilizer labeled P_{32} and placed 1/2 inch to the side of corn roots, the P content in the plant tops was greatly imcreased. Additions of KNO_3 reduced P in the tops compared with superphosphate only. When P alone or P plus KNO_3 was added, the labeled P accumulated in the roots. Accumulation did not occur in the presence of NH_4^+ ions. Addition of NH_4NO_3 to nutrient solution increased transfer of P through a one-inch segment of corn root. They concluded that NH_4^+ has a specific influence on transfer of phosphorus across the root symplast to the xylem.

Olson and Dreier (59) stated that increased absorption of P was a result of N stimulating root activity. Nitrogen increased N, P, and K concentration in oats. The number of small roots was also increased according to Grunes and Krantz (27).

Duncan and Ohlrogge (22) stated that with N and P together, corn growth was greater and considerably more branching of smaller roots occurred. They believed uptake of P was closely related to root development and volume of fertilized soil if N was present.

Rennie and Soper (67) also found for N to increase P uptake, the N must be in the ammonium form and that N and P be mixed and applied to the soil by restricted placement.

Blanchar and Caldwell (8) found in work with sandy loam soils to which P plus NH_4Cl and P plus KCL were added, that the uptake of P was nearly three fold with P plus NH_4Cl than with P plus KCl or P alone.

Other workers (13)(49)(28) have determined the beneficial effect on P uptake by N on the basis of double banding experiments.

Cole et al. (17) found P uptake to be greatly increased by adding supplemental N treatments. P uptake per unit dry weight of roots was increased more by higher N levels in the roots than by a ten fold increase in the P concentration of the external solution.

Boatwright and Haas (10) working with wheat showed that N increased P uptake mostly in the early plant development stages. Robertson et al. (69) noted that placement of N with a N and P mixture significantly increased the percent P in the plant as well as yields. However, the best utilization of P was obtained by mixing N, K, and P together before placement.

Application of N and P banded together gave much better yields than when the two were banded separately as stated by Nelson (52). Absorption of P was enhanced by the application of N, especially when the two were mixed before application as shown by Miller and Ashton (48), Nelson (51), and Miller and Ohlrogge (49).

Werkhoven and Miller (86) found N increased P uptake with sugar beets and N was more effective where P was banded than mixed with soil.

SOIL pH

It has been known for several years that the pH of the soil influences P uptake by plants. Several facts have been summarized by Pierre and Norman (62). For example the results of various investigations agree generally that P solubility in calcareous soils is at a minimum in the range of pH 7.0 to 7.5. Solubility increases with either an increase or decrease of pH.

It is also known that with changing pH values, the predominant form of P ions in the soil changes and as reported by Pierre and Norman (62), the predominant P ion was $H_2PO_4^-$ at pH values of 3 to 8 and predominantly $HPO_4^=$ at pH 9.

Hendrix (30) stated that the most important factors affecting P uptake are the forms of the P ions and the effects of pH per se on anion uptake. He also stated OH^- concentrations associated with increasing pH competitively inhibited anion uptake.

Arnon et al as reported in the book by Pierre and Norman (62) noted pH influence on P uptake and suggested that, since anions appear to be absorbed by plant roots in exchange of OH^- and HCO_3^-, an increasing OH^- concentration might decrease the rate of exchange of $H_2PO_4^-$ on the root membrane.

Smith (74) noted that in general as the soil pH increases, the proportion of calcium phosphates increases and the iron and aluminum phosphates decrease. He also noted when P fertilizer was added, the adjoining soil pH was much lower than the surrounding soil.

Research work in Oklahoma on wheat reported by Robertson (68) showed broadcast rates greater than 20 lb. P_2O_5 per acre were as good for increasing grain yields as banded fertilizer on neutral to calcareous soils. Higher rates of fertilizer were needed under similar conditions to obtain the same response with acid soils. This agrees in principle with work in Iowa by Smith and Pesek (75) and Smith and Stanford (76) as the efficiency of topdressed or disked-in P fertilizer was closer to that of drilling with-the-seed on calcareous soils than acid soils.

TEXTURE, TEMPERATURE, AND MOISTURE INFLUENCE ON P

Several studies have shown soil texture, temperature, and moisture to significantly influence P response.

This research was conducted at three locations in Montana. Widely varying climatic and soil conditions at these locations prompted the consideration of soil temperature, precipitation, and soil characteristics. A brief literature review of the influence of texture, moisture, and temperature was included to allow comparisons of previous studies with this study.

Olsen and Watanabe (57) stated that plant uptake of P was greater from clay textured soils than from sandy soils. There were three factors involved: concentration gradient between soil and root surface, diffusion coefficient, and the capacity of the soil to replenish

P removed by the plant. With more soil particles as in a clay soil, the concentration of P was greater closer to the plant root due to reactions of soil particles with phosphate. At any given moisture tension, a clay soil had more available water for diffusion than a sandy soil and the solution renewal was greater for clay soil as more particles were closer to the root. Their equation, relating uptake of P by plant roots to the diffusion coefficient and the phosphate capacity, predicted the rate of uptake to be approximately 1/3 as much for a sandy soil as clay soil at equal concentrations of P in the soil solution. Actual P uptake was very close to the predicted results for P concentrations less than 0.2 ppm.

Levesque (43) studied P uptake as influenced by soil texture and temperature. He concluded temperature had more influence on P fixation in fine textured soils and therefore coarse textured soils would make better use of native P supply than fine textured soils at low soil temperatures.

Nelson (51) found that clay soils require more fertilizer for a particular situation than sandy soils. This was partially a result of nutrient "tie-up" (chemical fixation by the soil) by the finer clay soil particles.

The absorption of P was influenced by soil temperatures according to Simpson (73). A 5° C. increase in temperature increased P uptake especially in soils low in P. A rise in temperature also increased fertilizer P uptake from soils high in P. Power et al. (65) noted that growth response of barley to P fertilizer was more dependent on the temperature for soils low in P than for soils medium in P.

Mack and Barber (45) incubated two soils for 74 days at three temperatures (23°, 2.7°, and -20° C). They found the higher the temperature prior to cropping, the greater was the yield of dry matter and P uptake by plants.

Dadykin (21) and Ketcheson (34) showed that the effectiveness of P fertilizer was greater at 20° C than at 5° C which indicated a lower P availability in colder soils. Similar results were found by Ellis (23) and Beaton et al. (6).

Robinson et al. (70) related slow P uptake and slow growth to low soil temperature and rapid uptake of P and increased yields to higher soil temperature. Gingrich (26) noted similar response in winter wheat when yield of P and top growth were significantly higher in soils maintained at 15.5° and 21° C than at 10° C.

The research data indicate that P availability was increased by increased temperatures but there is also some evidence that a cold period may be beneficial in increasing P availability. Phung (61) in studying the effect of soil freezing and thawing found P uptake by winter wheat to be higher on soils incubated under frozen conditions as compared with soils incubated at room temperature. Dry matter yields were lower on soils incubated under the frozen conditions but this was believed to be due mainly to the impaired physical properties of the frozen soils.

In a study by Beaton and Read (5) P was added to soils stored at 5°, 16°, and 27° C for one and seven weeks. Phosphorus uptake by oats was increased at 5° C than at 16° and 27° C.

Simpson (73) working with soil moisture found P uptake by oats increased when soil moisture tension was lowered to field capacity. High moisture tension decreased the rate of fixation of phosphorus and helped to confirm the statement that temperature and moisture effects were responsible for low recovery of fertilizer phosphorus in warm, dry seasons as compared with cool, moist seasons. Barber (2) agreed with Simpson that during dry, warm seasons less P was fixed and less was absorbed by corn plants.

Boatwright et al. (9) reported that spring wheat did not absorb fertilizer P from a dry soil and a lag in absorption followed watering, depending on the age of the plant. If the fertilizer zone was not wet for at least three or four days, it contributed little to P uptake.

Choriki (15) noted that only one of several soils low in P showed response to added P fertilizer. He concluded this lack of response must have been due to the low spring moisture conditions at this location. Fawcett and Quirk (24) found that moisture stress did not reduce P uptake in wheat until the roots were damaged by wilting.

Power et al. (64) showed that with spring wheat, P fertilizer had no effect on total water use; but P fertilizer increased plant material produced per unit of water used at the soft dough and harvest stages of growth.

As noted by Brown and Campbell (11) wheat fertilized with P or N and P used water at an accelerated rate during the early season as compared with the nonfertilized check treatment. Reduced moisture use later in the growing season was attributed to a depleted moisture supply.

Yield increases as shown by Power et al. (63) on medium P soils were directly proportional to the amount of moisture available at seeding and to the sum of seeding time moisture plus precipitation received during tillering to heading. On relatively high or low P soils the availability of soil P largely determined how P applications affected yield increases.

Olsen et al. (56) working with sugar beets found that in a dry year, band placed P beside the seed increased uptake of P by plants in the later stages of growth more than P fertilizer placed with-the-seed. During wet years uptake of P was equal.

RESIDUAL PHOSPHORUS

The effectiveness of residual P from P fertilizer applications in providing crop yield response is a major consideration in evaluating broadcast P for dryland grain.

Mannering et al. (46) working with a six-year rotation of barley, alfalfa, field beans, and sugar beets on calcareous soils in Idaho, concluded that with applications of 120 lb. per acre of P_2O_5 that even after six years sufficient P was available to furnish a large part of the crop requirements.

Research by Campbell and Brown (14) with residual P on a six-year irrigated rotation of barley, alfalfa, corn, and sugar beets in Montana obtained results similar to Mannering et al.. Phosphorus rates of 26, 52, 105, and 210 lb. per acre gave yield increases for 4, 6, 9, and 9 years respectively. The experiment was terminated at the end of nine years. Crop yields declined to check plot levels when 42 percent and 49 percent of the 26 and 52 lb. P/A application rates had been taken up by the crops grown.

Leamer (41) also found yield increases after up to six years with 26, 52, 105, and 210 lb. of P/A in the Southwest with irrigated rotations.

McAuliffe et al (47) indicated a response from 400 lb. of P_2O_5 per acre after eight years but did get an added response from 11 lb. P_2O_5 per acre.

In comparing sources of P fertilizer on calcareous soils, Webb and Pesek (82) found the residual effect of superphosphate, concentrated superphosphate, and calcium metaphosphate on oats to be equal; but on acid soils fused tri-calcium phosphate was more available.

Smith and Pesek (75) found in working with three Iowa soils that residual fertilizer P applied one to two years previously averaged 56 to 72 percent as effective as currently applied P.

Koehler (36) showed very little phosphorus fixation in eastern Washington soils as rates of 0, 20, 40, and 80 lb. of P/A resulted in respective yields of 12, 27, 29, and 20 bu. of wheat the second crop year. Several soils showed a second year crop response from the residual P.

Regardless of differences in rate of fertilizer addition, soil pH, $CaCO_3$ content, level of available soil P, soil organic matter, and soil texture; Koswara and Hanway (37) found little difference in fertilizer P uptake on ten principal soil associations in Iowa. In greenhouse experiments approximately 50 percent of added P was taken up in one year by rye plants.

Olsen and Watanabe (57) reported that applied P recovery on calcareous soils was only two percent on first year alfalfa and 12 percent on sugar beets. Values were less on acid soils.

MATERIALS AND METHODS

This research project was initiated in the spring of 1967 to study the effects of rate, time, and method of placement of phosphorus on dryland spring and winter wheat in Montana.

Three representative sites were selected with the aid of soil survey maps, field checking with the assistance of soil scientists with the USDA Soil Conservation Service, soil sampling, and visual observation. Soil series descriptions are given in Appendix tables 29, 30, and 31. Two locations were in winter wheat producing areas and one in the major spring wheat area of the state. Adjacent strips were selected so that crops could be alternated with fallow in each area for the five-year study. After the sites were selected wooden posts were buried at plot corners and steel posts driven at the strip edge to aid in later staking and location.

The first year, spring barley (Hordeum distichum L., var. Hypana) was grown on the two winter wheat locations at Power and Stanford, Montana. The Power experimental area is located approximately 20 miles NW of Great Falls on the Carl Neuman farm in the SE¼ of the SW¼ of section 13, T22N, R1E. Stanford is approximately 60 Miles SE of Great Falls, Montana. Spring wheat (Triticum vulgare L., var. Fortuna) was grown at the Froid location on the Vernon Danielson farm in the SW¼ of section 32, T31N, R56E. Figure 0 shows the locations of each site in the state.