



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  
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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.

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INFLUENCING DRYLAND SMALL GRAIN PRODUCTION

by

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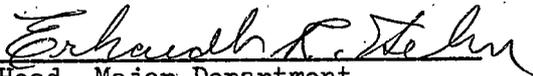
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ABSTRACT

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, Massachusetts 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 could 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  $(\text{NH}_4)_2\text{SO}_4$  or  $\text{NH}_4\text{Cl}$  was added to phosphorus fertilizer labeled  $\text{P}_{32}$  and placed 1/2 inch to the side of corn roots, the P content in the plant tops was greatly increased. Additions of  $\text{KNO}_3$  reduced P in the tops compared with superphosphate only. When P alone or P plus  $\text{KNO}_3$  was added, the labeled P accumulated in the roots. Accumulation did not occur in the presence of  $\text{NH}_4^+$  ions. Addition of  $\text{NH}_4\text{NO}_3$  to nutrient solution increased transfer of P through a one-inch segment of corn root. They concluded that  $\text{NH}_4^+$  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, R, 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.

Blanchard and Caldwell (8) found in work with sandy loam soils to which P plus  $\text{NH}_4\text{Cl}$  and P plus KCl were added, that the uptake of P was nearly three fold with P plus  $\text{NH}_4\text{Cl}$  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.

Coble 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  $\text{H}_2\text{PO}_4^-$  at pH values of 3 to 8 and predominantly  $\text{HPO}_4^{2-}$  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  $\text{OH}^-$  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  $\text{OH}^-$  and  $\text{HCO}_3^-$ , an increasing  $\text{OH}^-$  concentration might decrease the rate of exchange of  $\text{H}_2\text{PO}_4^-$  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  $5^{\circ}$  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 ( $23^{\circ}$ ,  $2.7^{\circ}$ , and  $-20^{\circ}$  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  $20^{\circ}$  C than at  $5^{\circ}$  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  $15.5^{\circ}$  and  $21^{\circ}$  C than at  $10^{\circ}$  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,  $\text{CaCO}_3$  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 SE $\frac{1}{4}$  of the SW $\frac{1}{4}$  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 SW $\frac{1}{4}$  of section 32, T31N, R56E. Figure 0 shows the locations of each site in the state.

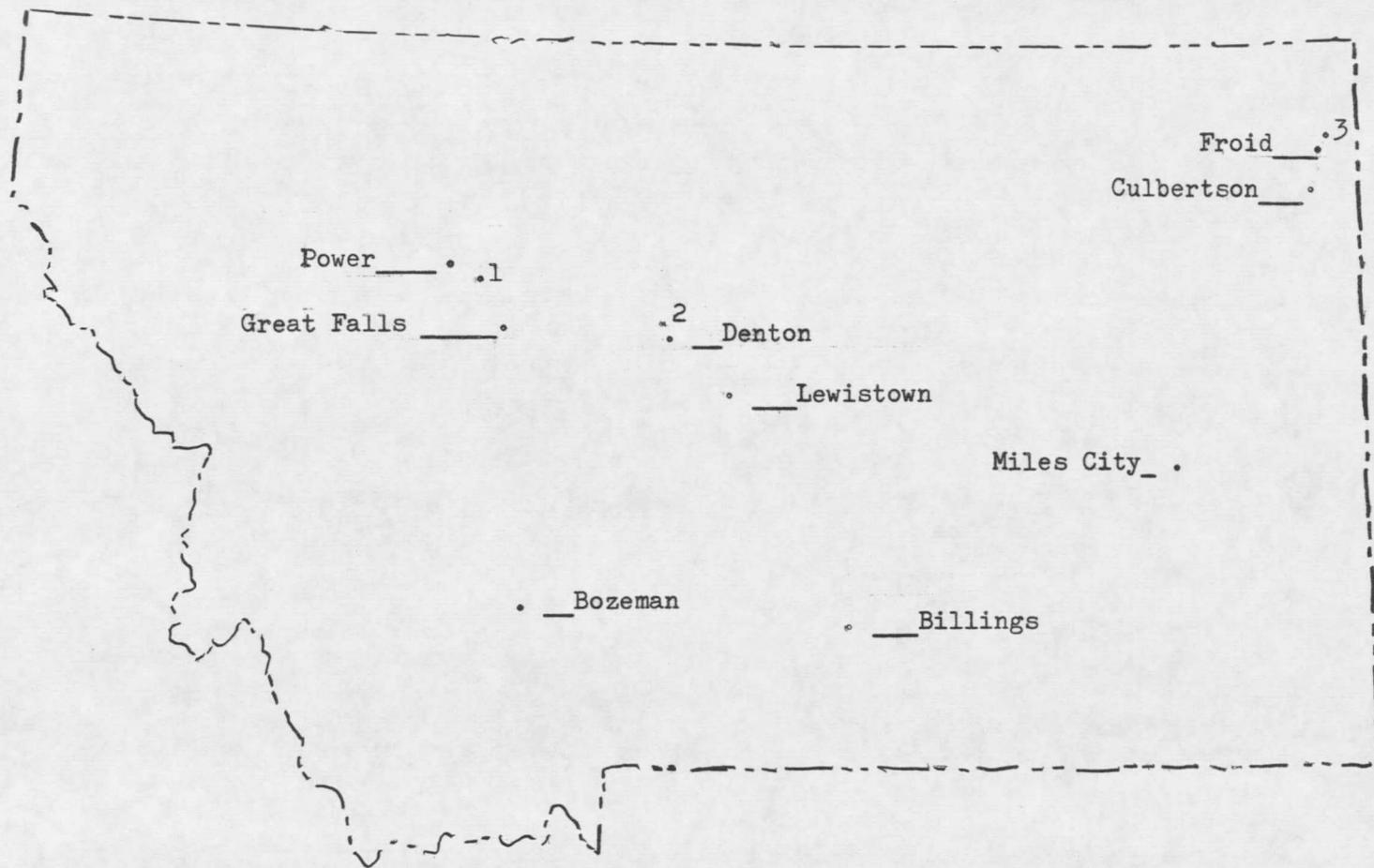


Figure 0. Location of experimental areas in Montana; 1--Power area, 2--Denton area, and 3--Froid area.

#### EXPERIMENTAL DESIGN

A randomized block experiment was established with 46 treatments and four replications. Plot size was 14 by 40 feet. Treatments for phosphorus applications include: broadcasting, spring and fall, with and without starter fertilizer (5 N and 2.5 P); and various phosphorus rates applied with-the-seed. N and K were applied uniformly at the rate of 40 pounds of N and 25 pounds of K per acre to reduce the chances for deficiency of these nutrients. See Table 1 for listing of treatments. Where more than one treatment is listed together, these treatments are alike and only the average values were listed.

Broadcasting of fertilizer was done by hand in the fall and the soil worked with a disk just prior to seeding. In the spring, fertilizer was applied by hand as soon as fields were workable and incorporated during the first summer fallow operation. The growing winter wheat crop was topdressed with N and K.

Rates of phosphorus applied broadcast were 10, 20, 30, 60, and 90 pounds of P per acre. After incorporating the fertilizer with about the upper two inches of soil, the plots were seeded using a tractor-pulled seven-row furrow drill with special fertilizer attachments for metering the fertilizer uniformly in each row. Row spacing was set at one foot. Barley was seeded at 50 lb. per acre and wheat at 60-65 lb. per acre. Higher seeding rates than are commonly recommended for producers have been used to insure a good stand. Fertilizer

Table 1. Listing of fertilizer treatments for experiments at three locations.

Treatment No.	Fall Broadcast After Fallow		N-Spring Topdressing	Spr. or Fall With-the-Seed	
	Crop 1	Crop 2,3	Crop 1,2,3	Crop 1,2,3	
	P	P	N	N	P
	lb/A	lb/A	lb/A	lb/A	lb/A
1, 39 1/	0	0	0		
2, 40	0	0	0		
3			40		
4			40	5	
5			40		2.5
6			40	5	2.5
7			40	5	5
8			40	5	10
9			40	5	20
10			40	5	30
11			40		10 2/
12			40		20 2/
13	10		40		
14	10		40	5	2.5
15	10	10	40		
16	10	10	40	5	2.5
17	20		40		
18	20		40	5	2.5
19	20	20	40		
20	20	20	40	5	2.5
21	20	20	0	5	2.5
22	20	20	20	5	2.5
23	30		40		
24	30		40	5	2.5
25	30	30	40		
26	30	30	40	5	2.5
27	60		40		
28	60		40	5	2.5
29	90		40		
30	90		40	5	2.5
41	20	20	40	5	5
42	30	30	40	5	5
43	20	20	60	5	2.5
44	20	20	80	5	2.5
45	10	10	40		2.5
46	20	20	40		2.5

Table continued. . .

Table 1 Continued.

Treatment No.	Spring Broadcast Before Fallow				N-Spring Topdressing	Spring or Fall With-the-Seed	
	Crop 1		Crop 2,3		Crop 1,2,3	Crop 1,2,3	
	N	P	N	P	N	N	P
	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A	lb/A
31		10			40		
32		10			40	5	2.5
33		20			40		
34		20			40	5	2.5
35	40	10	40	10			
36 <u>3/</u>	40	10	40	10			
37	40	20	40	20			
38 <u>3/</u>	40	20	40	20			

1/ 25 lbs. K/A on all treatments except 1 and 39.

2/ Broadcast just prior to seeding.

3/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

applied with-the-seed was delivered down the fertilizer tubes and dropped directly with-the-seed. This also included starter fertilizer (5 N and 2.5 P) that was applied in addition to one-half of the broadcast phosphorus treatments giving a split plot design for all broadcast phosphorus applications. Fertilizer was either measured or weighed from ammonium nitrate (33.5-0-0) and concentrated superphosphate (0-45-0). One other fertilizer, ammonium polyphosphate (15-60-0), was used to check the effect of source of phosphorus on residual carryover. Potassium was applied as muriate of potash (0-0-60).

#### 1967 PROCEDURE

To get the project initiated in early 1967, spring grains were seeded on the winter wheat location the first year. Barley was seeded at Power, May 26 and at Stanford, May 25. Spring wheat was seeded at Froid, May 18. A very poor stand of barley at Power necessitated the reseeded of three of the four replications on June 14. Fertilizers of appropriate treatments were applied on the adjacent strips for seeding of winter wheat in the fall of 1967. Before application of fertilizer treatments, soil samples were taken from 16 blocks in a grid pattern (see Table 2) within the experimental areas and analyzed for pH, conductivity, organic matter, phosphorus, and nitrate to help characterize the sites for uniformity. Table 3 lists average values for these five soil properties for all three locations. Individual values for soil pH, conductivity, and organic matter for Power,

Table 2. Grid pattern for soil samples at three locations.

	A	B	C	D
I	I-A	I-B	I-C	I-D
II	II-A	II-B	II-C	II-D
III	III-A	III-B	III-C	III-D
IV	IV-A	IV-B	IV-C	IV-D

Table : Soil analysis information (average values from samples 0-6")  
for Power, Denton, and Froid.

Location	Soil pH <u>1/</u>	Soil Conductivity <u>2/</u> millimohs/cm.	Soil O.M. <u>3/</u> %	Bray P <u>4/</u> ppm	NO <sub>3</sub> <u>5/</u> ppm N
Power	7.4	.19	2.6	18 <u>6/</u>	5.5 <u>7/</u>
Denton	6.3	.13	1.9	32 <u>8/</u>	1.6 <u>7/</u>
Froid	6.8	.08	2.3	22 <u>6/</u>	2.4 <u>7/</u>

1/ Soil pH determination procedure in Appendix table 37.

2/ Soil conductivity determination procedure in Appendix table 38.

3/ Organic matter determination procedure in Jackson (32) pp. 219-221.

4/ Bray P determination in Olsen (55) and Smith (77).

5/ Soil NO<sub>3</sub> determination procedure in Jackson (32) pp. 197-201.

6/ Bray P range 0-30 ppm - very low.

7/ Soil samples for NO<sub>3</sub> determination 0-6'; average value/foot.

8/ Bray P range 30-60 ppm - low.

Denton, and Froid are listed in Appendix table 32. Soil P analyses using the Bray and  $\text{NaHCO}_3$  methods are shown for all three locations in Appendix tables 33, 34, and 35. Soil nitrate determinations for each location are in Appendix table 36.

Harvesting of plots was done with a gasoline-powered three-foot mower with mounted catcher on the sickle bar. Three one-foot spaced rows approximately 20 feet in length were cut after the outside rows of the seven-foot drill width were eliminated to avoid tractor tire compaction and approximately ten feet on each end of the plots to avoid nonuniform fertilizer delivery. All plots were measured for length of area harvested to determine grain and dry matter yields.

The moisture percentage of straw plus grain was determined and total dry matter yields calculated. The weight of the oven-dry above ground plant portion was reported as dry matter yield. Bundles from the cut area were weighed, threshed, and grain collected for individual plots. Grain samples were then cleaned with a small blower, weighed, test weight determined, and protein analysis made using the Kjeldahl method (32) pp. 183-190. Grain yields were converted to bushels per acre using 48 lb. per bu. for barley and 60 lb. per bu. for wheat. Culm counts were made in the field by counting all culms in two four-foot sections of row in individual plots.

Due to soil variability, the Stanford location was discontinued after 1967 and another site was selected at Denton, Montana which is

approximately 25 miles north of the Central Montana Branch Experiment Station on the Larry Barber farm in the NW $\frac{1}{4}$  of NE $\frac{1}{4}$  of section 18, T19N, R14E. The Denton soils information is given in Table 3 and Appendix tables 32, 34, and 36.

#### 1968 PROCEDURE

The Power location was fertilized on September 19, 1967 and the seeding completed by September 21. The Denton plots were fertilized on September 28, 1967 and seeded by September 30. At Denton the P treatments which should have been applied in early summer, 1967, were applied just prior to seeding, by necessity.

On November 9, 1967, when the plants were in the three-leaf stage (stage 2 designated by Feekes (26) and illustrated by Large (40)); see Table 4 for listing of growth stages and Feekes scale, plant samples were collected from two feet of row with a spade to a depth of approximately six inches. Two replications of treatments 3, 4, 5, 6, 8, 9, 13, 14, 17, 18, 23, 24, 27, 28, 29, and 30 were sampled at Denton and Power, the two winter wheat locations. Soil was partially shaken from the roots and samples were sealed in plastic bags and kept cool. The roots were later washed free of soil and tops and roots separated by clipping just above the point of attachment of roots. Plant samples were then dried at 65° C for 48 hours, weighed, and ground for analysis. The percent phosphorus was determined

Table 4. Stages of plant development when plant samples were collected.

Plant Stage	Feekes Scale <u>1/</u>
3-4 leaf	2
5 leaf	4
6 leaf	4-5
Heading	10.1-10.5
Heading to Soft-Dough	10.5-10.5.5
Mature	11.2-11.4

1/ As illustrated by Large (39).

colorimetrically with ammonium vanadate, using the method of Barton (3) and Kitson (36).

The following spring, plant samples were collected at the Power location on May 27 and on May 28 at Denton. Plants were mostly in the six-leaf stage (Feekes stage 4-5) of growth. Although fertilizer treatments caused considerable change in plant development, especially later in the season, all treatments were sampled on the same date. The Feekes rating scale was used to identify the most predominant developmental stage. Beginning with the spring samples, all plants were clipped within one inch of the soil. Plants from two four-foot sections were taken from two corresponding rows in each plot of all four replications. Treatments 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 14, 17, 18, 23, 24, 27, 28, 29, 30, 31, 32, 33, 34, 35, 36, 37, 38, 41, 42, 45, and 46 were sampled at Power. These same treatments except 31-34 were sampled at Denton. The same treatments sampled at Power plus treatments 11 and 12 were sampled at Froid. Seeding at Froid was completed on May 3. Plant samples were taken on June 20 when they reached the six-leaf (Feekes 4-5) stage.

Due to the distance between Bozeman and the experiment locations, approximately 200 miles to Denton and Power and 500 miles to Froid, it was decided to concentrate on the Power location for the most intensified plant sample collection. Samples were collected June 27, during the boot-to-heading stage (Feekes 10.1) and again July 15 at full

heading-dough stage (Feekes 10.5.0-10.5.4) and the final sample made at maturity (Feekes 11.4 stage) on August 1. Beside the first samples, others were taken at Denton, July 10, at heading (Feekes 10.4) and August 6 at maturity (Feekes 11.2) and at Froid, July 30, at maturity (Feekes 11.2).

All samples collected were placed in an oven at Bozeman for 48 hours at 65° C; then weighed and the small subsample, approximately 25 stems collected at random from the larger sample, was ground through a Wiley mill for later phosphorus determination. The entire above ground plant portion was ground for analysis which included the grain on the mature plants.

Culm counts were made by counting the number of culms in two four-foot sections of row at harvest. Harvesting and measurements for 1968 were the same as for 1967 except the Denton grain samples contained buckwheat seed which was practically removed by running all samples through a dockage machine.

Soil temperature at the two-inch depth was recorded at both winter wheat locations, Power and Denton, by the use of a thermograph. Rain gauges were used at all locations. Temperature and precipitation data are recorded in Appendix tables 39, 41, 44, 45, and 46.

#### 1969 PROCEDURE

The Power plots were fertilized and seeded October 1, 1968 and the Denton plots were fertilized and seeded September 27. There was

a miscalculation on the setting of the fertilizer attachment for the two locations seeded in the fall of 1968 which resulted in a 15 percent increase over the original fertilizer rates applied with-the-seed. Rates for 1967 and 1968 with-the-seed were 5 N plus 0, 2.5, 5, 10, 20, 30 P. In 1969 all rates with-the-seed were 5.75 N plus 0, 2.875, 5.75, 11.5, 23.0, and 34.5, respectively.

Because moisture was lacking and seedlings were extremely small in late November, no plant samples were taken in the fall of 1968 for plant analysis. Plants were collected after growth occurred in the spring at the five-leaf (Feekes 4) stage at all locations. A second set of samples was collected at heading to dough stage (Feekes stage 10.4) and a final set at maturity (Feekes stage 11.2) from all three locations. Sampling and analysis were the same as the previous years.

Grain and dry matter yields were measured on four rows about 20 feet in length instead of three rows as in the previous years to give a more uniform harvest area.

The culm counts for 1969 included only culms which contained heads with three or more kernels and the two four-foot sections of row counted were threshed and kept separate to determine the number of kernels per head. Kernels were counted for a ten-gram sample and the number of kernels calculated for the eight-foot sample. With very few barren culms, the number of heads and culms were practically the same.

Soil temperatures were recorded at the Power and Denton locations and are listed in Appendix tables 40 and 42. Rain gauges were used at all locations and precipitation data are included in Appendix tables 47, 48, and 49. Complete data are available at Froid at the ARS research farm south of Froid. Soil moisture data are listed in Appendix table 50 for all locations.

#### STATISTICAL PLAN

All data for 1967, 1968, and 1969 harvests were coded, recorded, and punched on computer cards for analysis. The Sigma 7 computer at Montana State University Computer Center was used to process the data.

Two statistical methods were used to analyze the data for 1967; standard analysis of variance and least squares analysis. There was some question which analysis would be most valid with the duplication of treatments that occurred the first year. The duplication of treatments was necessary the first season permitting additional fertilizer on some treatments so that residual P response could be studied in the following years.

Duplicate analyses were made on the data from the locations, Power and Froid, and evidently with several treatments, 46 in this instance, the difference between methods of analyses was insignificant. F values for grain yields were 1.69 for standard analysis of variance and 1.75 on least squares analysis for the Froid grain yields. The values at the Stanford location were 1.39 and 1.44 respectively.

The small difference in values did not change their significance at either location. Since the duplication of treatments decreased each year and the least squares program would not be applicable after 1968, it was decided to use the standard analysis of variance program throughout the experiment.

In addition to analysis of variance on grain and dry matter yields for 1967, 1968, and 1969; analyses have been made on culm count per eight feet of row in 1967, 1968, and 1969; kernels per eight feet of row in 1969; phosphorus yield (P% x dry weight) in 1968 for four dates on the Power data, two dates on the Denton data, and two on the Froid data. In 1969 three dates for P yield for each location were analyzed.

Analyses of variance were made for percentage P and dry matter yield for each plant sample date for 1968 and 1969. The correlation of the first plant samples in the spring with grain yields for 1968 was determined.

Significant differences were listed at the five percent level unless stated otherwise. Many comparisons have been made by using the LSD and single degree of freedom tests. Standard statistical methods were followed (82).

## RESULTS AND DISCUSSION

### 1967 Results On Barley And Spring Wheat

The results and discussion are mostly centered around grain yields as influenced by phosphorus fertilizer treatments. Dry matter yields are included in the data tables but are not discussed separately. In general, dry matter yield changes were reflected by grain yields.

Due to the limited moisture and the late seeding of spring grains, fertilizer response was low in 1967. The dry season did help in emphasizing soil variability at the Stanford location, which resulted in the selection of another site to continue the experiment. Precipitation data are listed in Appendix table 43.

Significant yield responses were limited to four treatments at the Froid location. There were some interesting trends noted in the data at Power and Stanford.

The Power data are listed in Table 5 for barley grain yield, dry matter yield, and culm count. Treatment response comparisons for P fertilizer broadcast should be made with treatment 3 which had a grain yield of 25 bu/A. Comparisons for treatment response for P with-the-seed should be made with treatment 4. Least significant difference (LSD) values are listed with analysis of variance figures near the bottom of each table. Yields or culm counts are not starred unless significantly different from treatment 3.

Table 5. Grain yield, dry matter yield, and culm count - Power, 1967; barley.

Treatment No.	Fertilizer				Total Dry Matter lbs/A	Grain Yield Bu/A	Culm Count <u>1/</u> 8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 <u>2/</u>	0	0	0	0	1971	20.3	161
2, 40	0	0	0	0	2054	21.7	167
3	40	0	0	0	2301	25.1	175
4	40	0	5	0	2602	24.3	202
5	40	0	0	2.5	2296	24.4	186
6, 43	40	0	5	2.5	2231	25.1	165
7, 44	40	0	5	5	2629	25.8	184
8	40	0	5	10	2324	27.6	171
9	40	0	5	20	2473	28.0	198
10	40	0	5	30	2735	28.7	188
11, 13, 15, 31, 35	40	10	0	0	2464	25.2	180
14, 16, 32	40	10	5	2.5	2608	26.9	177
12, 17, 19, 33, 37	40	20	0	0	2179	24.1	177
18, 20, 34	40	20	5	2.5	2289	23.5	173
21	0	20	0	0	2051	21.3	180
22	20	20	0	0	2157	21.8	176
23, 25	40	30	0	0	2258	23.8	182
24, 26	40	30	5	2.5	2223	24.7	181
27	40	60	0	0	2601	27.5	206
28	40	60	5	2.5	2934	26.4	194
29	40	90	0	0	2305	24.3	179
30	40	90	5	2.5	2341	25.1	217
36	40	10	0	0	2123	24.0	172
38	40	20	0	0	2278	25.6	171
41	40	20	5	5	2628	28.1	172
42	40	30	5	5	2699	28.2	175
45	40	10	0	2.5	2229	26.0	194
46	40	20	0	2.5	2143	24.3	155

Analysis of Variance						
Source of Variation	df	MS	df	MS	df	MS
Treatments	45	248940	45	12.8	45	920
Experimental Error	135	275021	135	10.4	135	714
LSD (.05)		727		5.6		37

1/ All culms counted (heads not considered).  
2/ 25 lb. K on all treatments except 1 and 39.

The trends in grain yield response to P are shown by observing the yields of 5 lb/A N plus 5 to 30 lb/A P placed with-the-seed, treatments 4, 6, 7, 8, 9, and 10. The greatest yield response was noted with treatment 10 with a 4.4 bu/A increase over treatment 4. Two other treatments that note observation are treatments 41 and 42. The only difference between treatments 18, 20, and 34 and 41 was the starter fertilizer (5 N plus 5 P) for 41 compared with 5 N plus 2.5 P for 18, 20, and 34. The same difference exists between treatments 24 and 26 with 42. Grain yield for treatments 18, 20, and 30 was 23.5 compared with 28.1 for treatment 41. Grain yield for treatments 24 and 26 was 24.7 compared with 28.2 for treatment 42. This was an appreciable increase for only 2.5 lb. P per acre difference in treatments and may indicate that 2.5 lb. P per acre in the starter was low.

The Stanford data for barley shown in Table 6 indicated that very similar trends were evident as at Power. Treatments 6, 7, 8, 9, and 10 and 41 and 42 increased yields compared with treatment 4. It was unusual that the exact treatments showed this same trend. There was some inconsistency with treatments 8 and 9, though, as they were lower in yields than treatment 7. Dry matter yields were also lower for the same treatments.

Harvest data for spring wheat grown at Froid shown in Table 7 did not follow the same trends as noted at the Power and Stanford locations with respect to with-the-seed treatments as very little difference in

Table 6. Grain yield, dry matter yield, and culm count - Stanford, 1967; barley.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/ 8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 2/	0	0	0	0	1152	14.3	214
2, 40	0	0	0	0	1301	16.4	205
3	40	0	0	0	1810	21.3	271
4	40	0	5	0	1736	20.0	250
5	40	0	0	2.5	1975	22.7	284
6, 43	40	0	5	2.5	1991	21.9	272
7, 44	40	0	5	5	2238	25.0	307
8	40	0	5	10	2070	24.0	292
9	40	0	5	20	2146	24.5	311
10	40	0	5	30	2310	27.1	341
11, 13, 15, 31, 35	40	10	0	0	1797	21.1	243
14, 16, 32	40	10	5	2.5	1683	19.4	243
12, 17, 19, 33, 37	40	20	0	0	1832	20.9	293
18, 20, 34	40	20	5	2.5	1794	21.0	257
21	0	20	0	0	1332	16.6	207
22	20	20	0	0	1738	20.4	238
23, 25	40	30	0	0	1976	22.3	278
24, 26	40	30	5	2.5	1928	23.4	246
27	40	60	0	0	2149	25.0	296
28	40	60	5	2.5	2211	25.6	264
29	40	90	0	0	2273	24.8	301
30	40	90	5	2.5	2258	25.5	294
36	40	10	0	0	2015	24.6	
38	40	20	0	0	1905	22.3	
41	40	20	5	5	1993	25.0	
42	40	30	5	5	1992	25.6	
----- Analysis of Variance -----							
Source of Variation	df	MS	df	MS	df	MS	
Treatments	43	383059*	43	30.5	23	5870**	
Experimental Error	129	235190	129	21.9	69	3225	
LSD (.05)		672		8.1		80	

1/ All culms counted (heads not considered).

2/ 25 lb. K on all treatments except 1 and 39.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 7. Grain yield, dry matter yield, and culm count - Froid, 1967; spring wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count <u>1/</u> 8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 <u>2/</u>	0	0	0	0	2682	23.2	225
2, 40	0	0	0	0	2635	23.7	229
3	40	0	0	0	2885	23.3	217
4	40	0	5	0	2849	24.6	240
5	40	0	0	2.5	2798	23.6	226
6	40	0	5	2.5	2796	24.1	227
7	40	0	5	5	2763	25.5	236
8	40	0	5	10	3059	24.8	232
9	40	0	5	20	2909	24.3	242
10	40	0	5	30	2881	23.2	247
11, 13, 15, 31, 35	40	10	0	0	2767	23.4	228
14, 16, 32	40	10	5	2.5	2947	24.4	243
12, 17, 19, 33, 37	40	20	0	0	2826	23.8	247
18, 20, 34	40	20	5	2.5	2975	25.2	242
21	0	20	0	0	2763	24.0	229
22	20	20	0	0	2943	24.2	234
23, 25	40	30	0	0	3033	24.8	213
24, 26	40	30	5	2.5	3034	24.5	237
27	40	60	0	0	2766	23.1	226
28	40	60	5	2.5	2842	22.3	219
29	40	90	0	0	2920	25.6	248
30	40	90	5	2.5	3036	26.3*	230
36	40	10	0	0	2793	22.7	
38	40	20	0	0	2921	24.3	
41	40	20	5	5	3082	26.5*	
42	40	30	5	5	3155	26.2*	
43	60	20	5	2.5	2961	24.8	
44	80	20	5	2.5	3172	27.1*	
45	40	10	0	2.5	2813	23.3	
46	40	20	0	2.5	2915	25.7	

Analysis of Variance

Source of Variation	df	MS	df	MS	df	MS
Treatments	45	89947*	45	5.8*	23	380
Experimental Error	135	54249	135	3.4	69	397
LSD (.05)		323		2.6		28

1/ All culms counted (heads not considered).

2/ 25 lb. K on all treatments except 1 and 39.

\* Significant at the .05 level.

yields was noted. This location did show some response, although not significant at the level tested, to starter fertilizer, 5 N plus 2.5 P placed with-the-seed in combination with broadcast P. Grain yields due to starter fertilizer plus 10, 20, and 90 P broadcast compared with those same rates broadcast and no starter fertilizer were 24.4 to 23.4, 25.2 to 23.8, and 26.3 to 25.6, respectively. The only significant yield increases for 1967 were for yields of treatments 30, 41, 42, and 44 at Froid. Grain yields of treatments 41 and 42 were increased at Power and Stanford but were non-significant.

It was noted that in most cases dry matter yield corresponds fairly close to grain yields especially with those treatments showing significant grain yield increases.

Culm count was quite variable at all locations for 1967 but there were some increases over the check noted at higher rates of P with-the-seed and higher broadcast rates.

Even though test weight and protein percentage measurements were made, differences due to P fertilizer were insignificant and are not included in this thesis write-up. Yield information was helpful in estimating P use and for determining residual phosphorus effectiveness in later years.

1968 Results On Winter And Spring Wheat

The experimental results for 1968 could be better handled in sections, especially with three locations to compare. For this reason the data, including treatments for dry matter yields, grain yields, and culm count are listed in the following tables: Power, Table 8; Denton, Table 9; and Froid, Table 10. P yield data are discussed in a later section.

A few general points are listed that may help in understanding the data. Grain and dry matter yields were significantly increased with P fertilizer at all locations in 1968. Grain yields were in the range of 35 to 45 bu/A at Power, the highest yields recorded for 1968. Grain yields at Denton were lower due to hail damage, estimated at 12 to 18 percent. There may have been some variation in hail damage due to treatment effect. Check treatments 1, 39 and 2, 40 and 21 seemed to show more damage with fewer culm/A than other treatments with thicker stands. Grain yields at Froid were not exceptional, but fair for spring wheat in that area being in the 23 to 28 bu/A range. Test weight values were in the 61-64 lb/bu range at both Denton and Power and 58-60 at Froid. Normally, test weight of spring wheat will be approximately 2 lb/bu less than winter wheat.

It was noticeable that the number of treatments with significant differences was greater with dry matter yield than with grain yield. This could and probably does mean that P has more influence on dry

Table 8. Grain yield, dry matter yield, and culm count-Power, 1968; winter wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 2/	0	0	0	0	4240	32.8	225
2, 40	0	0	0	0	4295	32.0	223
3	40	0	0	0	4426	38.4	250
4	40	0	5	0	4487	34.7	243
5	40	0	0	2.5	5132	40.3	266
6	40	0	5	2.5	5093	40.0	290
7	40	0	5	5	5077	41.9	277
8	40	0	5	10	5495*	41.6	340*
9	40	0	5	20	6128*	41.5	337*
10	40	0	5	30	6316*	43.1	353*
11, 13, 15	40	10	0	0	4940	38.5	270
14, 16	40	10	5	2.5	5009	38.8	281
12, 17, 19	40	20	0	0	5015	38.3	254
18, 20	40	20	5	2.5	5486*	44.3	284
21	0	20	0	0	4215	34.8	235
22	20	20	0	0	4780	38.8	245
23, 25	40	30	0	0	5408*	40.1	256
24, 26	40	30	5	2.5	5530*	43.2	326
27	40	60	0	0	5855*	43.9	279
28	40	60	5	2.5	5957*	44.3	313
29	40	90	0	0	6127*	45.6*	326
30	40	90	5	2.5	6719*	45.8*	340*
31 3/	40	10	0	0	5069*	40.2	268
32	40	10	5	2.5	5639*	43.8	299
33	40	20	0	0	5692*	44.0	282
34	40	20	5	2.5	6016*	41.7	311
35	40	10	0	0	4882	38.9	261
36 4/	40	10	0	0	4959	39.3	231
37	40	20	0	0	5671*	42.9	296
38 4/	40	20	0	0	5838*	45.0*	321
41	40	20	5	5	5652*	42.8	332*
42	40	30	5	5	5216*	44.4	307
43	60	20	5	2.5	5801*	44.3	298
44	80	20	5	2.5	5668*	45.1*	272
45	40	10	0	2.5	5151*	41.1	264
46	40	20	0	2.5	5385*	40.4	290

Table continued. . .

Table 8. Continued. . .

	Total		Grain Yield		Culm Count <u>1/</u>	
	Dry Matter		Bu/A		8' of Row	
	lb/A		Bu/A			
Analysis of Variance						
Source of Variation	df	MS	df	MS	df	MS
Treatments	45	1390546**	45	55.4**	45	8154**
Experimental Error	135	258776	135	22.3	135	3196
LDS (.05)		712		6.6		79

1/ All culms counted (heads not considered).

2/ 25 lb. K on all treatments except 1 and 39.

3/ Treatments 31-38 were applied in the spring before fallow.

4/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 9. Grain yield, dry matter yield, and culm count - Denton, 1968; winter wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count $\frac{1}{8'}$ of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 $\frac{2}{1}$	0	0	0	0	2640	16.3	274
2, 40	0	0	0	0	3003	17.5	230
3	40	0	0	0	4281	25.2	260
4	40	0	5	0	4571	25.0	290
5	40	0	0	2.5	4354	26.8	306
6	40	0	5	2.5	4879*	30.0	328
7	40	0	5	5	4741	27.8	311
8	40	0	5	10	4712	26.9	330
9	40	0	5	20	4828	27.9	348*
10	40	0	5	30	5011*	28.4	305
11, 13, 15, 31, 35	40	10	0	0	4566	25.5	287
14, 16, 32	40	10	5	2.5	4905*	29.3	317
12, 17, 19, 33, 37	40	20	0	0	4680	28.1	303
18, 20, 34	40	20	5	2.5	4994*	31.0*	309
21	0	20	0	0	2690	15.5	232
22	20	20	0	0	3767	21.4	281
23, 25	40	30	0	0	4844	29.9	316
24, 26	40	30	5	2.5	4908*	29.9	316
27	40	60	0	0	4920*	29.4	300
28	40	60	5	2.5	5049*	29.0	304
29	40	90	0	0	5018*	29.4	319
30	40	90	5	2.5	5282*	29.9	321
36	40	10	0	0	4719	27.7	321
38	40	20	0	0	4835	28.0	320
41	40	20	5	5	4495	26.9	340*
42	40	30	5	5	5358*	30.5*	325
43	60	20	5	2.5	5726*	35.2*	323
44	80	20	5	2.5	5305*	32.7*	353*
45	40	10	0	2.5	3928	27.5	315
46	40	20	0	2.5	4680	28.1	328

Table continued. . .

Table 9. Continued. . .

	Total		Grain Yield		Culm Count <u>1/</u>	
	Dry Matter		Bu/A		8' of Row	
	lb/A		Bu/A			
Analysis of Variance						
Source of Variation	df	MS	df	MS	df	MS
Treatments	45	2042356**	45	76.8**	45	4091
Experimental Error	135	182757	135	12.4	135	2952
LSD (.05)		595		4.9		76

1/ All culms counted (heads not considered).

2/ 25 lb. K on all treatments except 1 and 39.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 10. Grain yield, dry matter yield, and culm count - Froid, 1968; spring wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 2/	0	0	0	0	2868	22.7	213
2, 40	0	0	0	0	2940	23.6	209
3	40	0	0	0	2893	23.1	195
4	40	0	5	0	2855	23.4	209
5	40	0	0	2.5	2870	22.7	211
6	40	0	5	2.5	3134	24.4	217
7	40	0	5	5	3241	25.1	253*
8	40	0	5	10	3677*	27.0*	257*
9	40	0	5	20	3542*	26.0	269*
10	40	0	5	30	3466*	26.5*	307*
11	40	10	3/	0	3066	23.7	227
12	40	20	3/	0	3292*	24.9	239
13, 15	40	10	0	0	3120	24.5	230
14, 16	40	10	5	2.5	3474*	26.5*	250*
17, 19	40	20	0	0	3127	23.8	232
18, 20	40	20	5	2.5	3369*	26.2*	252*
21	0	20	0	0	3424*	27.9*	236
22	20	20	0	0	3521*	26.4*	236
23, 25	40	30	0	0	3248	24.5	248*
24, 26	40	30	5	2.5	3367*	25.0	250*
27	40	60	0	0	3153	22.8	254*
28	40	60	5	2.5	3523*	25.3	259*
29	40	90	0	0	3527*	25.2	276*
30	40	90	5	2.5	3513*	26.8*	257*
31 4/	40	10	0	0	3058	24.3	238
32	40	10	5	2.5	3329*	26.8*	251*
33	40	20	0	0	2733	21.4	228
34	40	20	5	2.5	3026	23.4	196
35	40	10	0	0	3015	24.6	218
36 5/	40	10	0	0	2944	24.0	212
37	40	20	0	0	2833	24.5	202
38 5/	40	20	0	0	2915	24.1	228
41	40	20	5	5	3362*	25.9	267*
42	40	30	5	5	3461*	25.8	258*
43	60	20	5	2.5	3303*	25.0	279*
44	80	20	5	2.5	3340*	24.3	291*
45	40	10	0	2.5	3459*	26.7*	237
46	40	20	0	2.5	3876*	29.2*	226

Table continued. . .

Table 10. Continued. . .

	Total		Grain Yield		Culm Count <u>1/</u>	
	Dry Matter		Bu/A		8' of Row	
	lb/A		Bu/A			
Analysis of Variance						
Source of Variation	df	MS	df	MS	df	MS
Treatments	45	285707**	45	10.4**	45	2584**
Experimental Error	135	70332	135	4.9	135	1016
LSD (.05)		371		3.1		45

1/ All culms counted (heads not considered).

2/ 25 lb. K on all treatments except 1 and 39.

3/ Broadcast in spring just prior to seeding

4/ Treatments 31-38 were applied in the spring before fallow.

5/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

matter production than grain yield. It could also mean that less variation existed within treatments among replications, and the relative error was smaller, probably because seed production is more subject to small differences in available water and nutrients in the soil than is production of vegetative growth.

#### Placement Of Fertilizer With-The-Seed

At this point meaningful comparisons can be made between the locations. Table 11 shows grain yields for all three locations with respect to rates of fertilizer with-the-seed.

The true check for rates of P with-the-seed is treatment 4 which received 5 lb. N per acre and no P, with all these treatments receiving 40 lb. N/A, topdressed. At Power, grain yield of treatment 4 was very low--less than the check (treatments 2, 40). It is not surprising that this occurred considering the responses from P evident in early growth, through heading. N alone apparently compounded P deficiencies.

Significant grain yield increases were recorded at the Froid location with spring wheat. Treatments 8, 9, and 10 showed increases of up to 3.6, 3.2, and 3.1 bu/A, respectively, compared with treatment 4. Treatment means were also significant at Power and Denton with yield increases of up to 8.4 bu/A at Power.

Treatment 6 at Denton seemed out of line compared with 7, 8, 9, and 10 which did not show the yield increase with higher rates of P. This variation was not noted at the other locations.

Table 11. Grain yield for rates of fertilizer placed with-the-seed for 1968; winter wheat at Power and Denton, spring wheat at Froid.

Treatment No.	With-the-Seed <u>1/</u>		Power bu/A	Denton bu/A <u>2/</u>	Froid bu/A
	N	P			
3	0	0	38.4	25.2	23.1
4	5	0	34.7	25.0	23.4
5	0	2.5	40.3	26.8	22.7
6	5	2.5	40.0	30.0*	24.4
7	5	5	41.9*	25.6	25.1
8	5	10	41.6*	26.8	27.0*
9	5	20	41.5*	27.9	26.6*
10	5	30	43.1*	28.4	26.5*
LSD (.05) level			6.6	4.9	3.1

1/ All treatments have 40 lb. N and 25 lb. K/A, topdressed in the spring.

2/ Hail damage of 12-18% reduced yields.

\* Significant at the .05 level compared with treatment 4.

Spring grain as at the Froid location seemed to benefit from the higher rates of fertilizer application with-the-seed. This may be due partially to the length of time roots are in contact with the soil and fertilizer compared with winter wheat. With the higher concentration of fertilizer near the seed, spring wheat yields may show a greater increase.

#### Broadcast P Fertilizer And Its Relationship With Starter

For this thesis, starter fertilizer is defined as 5 lb. N and 2.5 lb. P per acre applied with-the-seed and will be termed "starter". Figure 1 shows the starter influence on grain yields at 0 to 90 lb. P per acre broadcast at Power.

Starter had the greatest influence on yields at 20 lb. P broadcast and somewhat less at 30 lb. P per acre. This response was significant at the 10% probability level using single degrees of freedom comparisons. At the higher rates, 60 and 90 lb. P/A, the expected occurred with little added response due to starter fertilizer. To explain why little or no response was obtained from starter at zero P and 10 P, broadcast is not easy; however, it may be that available P was enough to produce some plant response but not enough to carry through to increased grain yield.

The Denton grain yields were plotted in Figure 2 with reference to broadcast P with and without starter. There were noticeable increases from starter through the rate of 20 lb. P per acre. Using a single

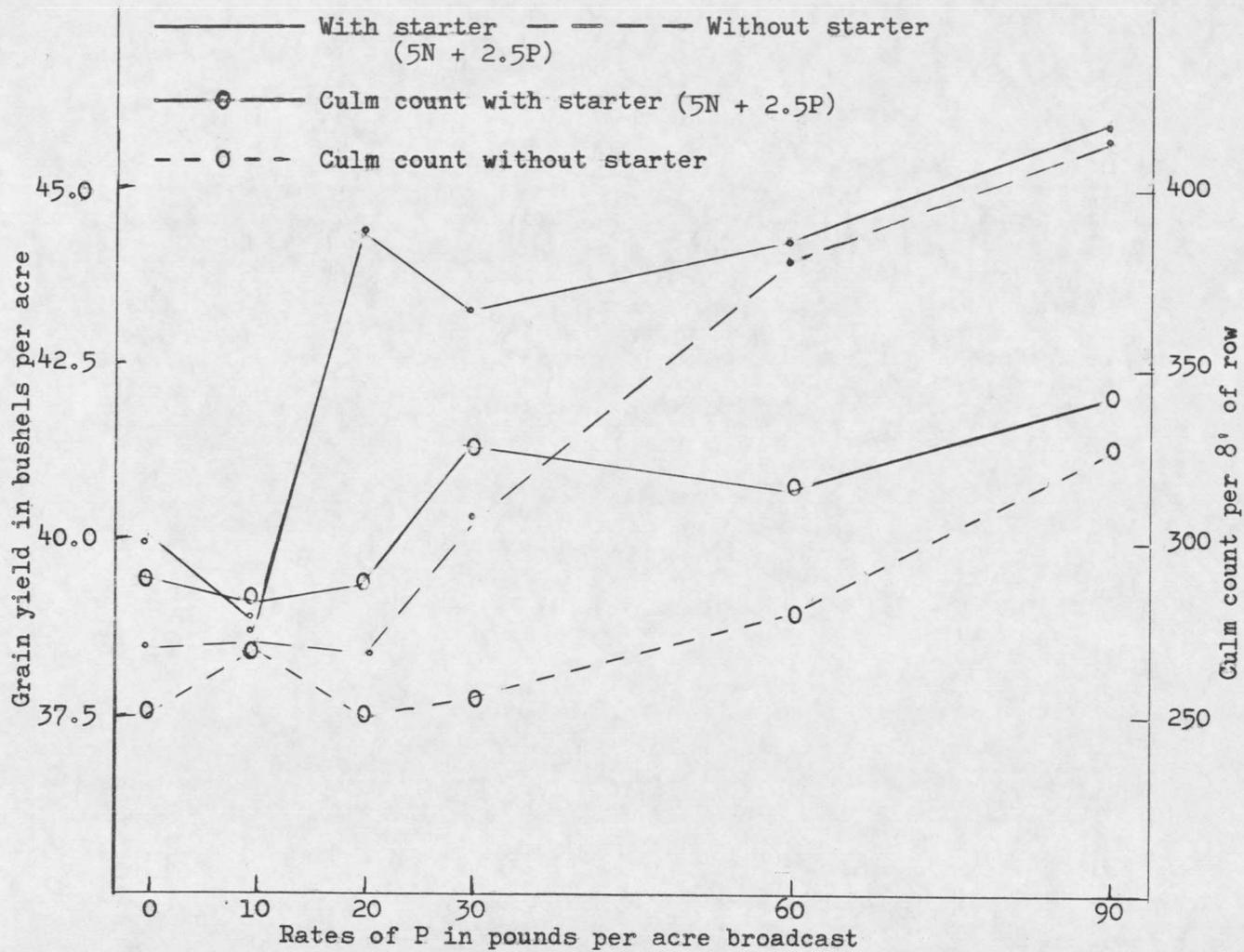


Figure 1. Grain yield and culm count for broadcast P with and without starter fertilizer - Power, 1968; winter wheat (all treatments had 40 lb. N/A and 25 lb. K/A, topdressed in the spring).

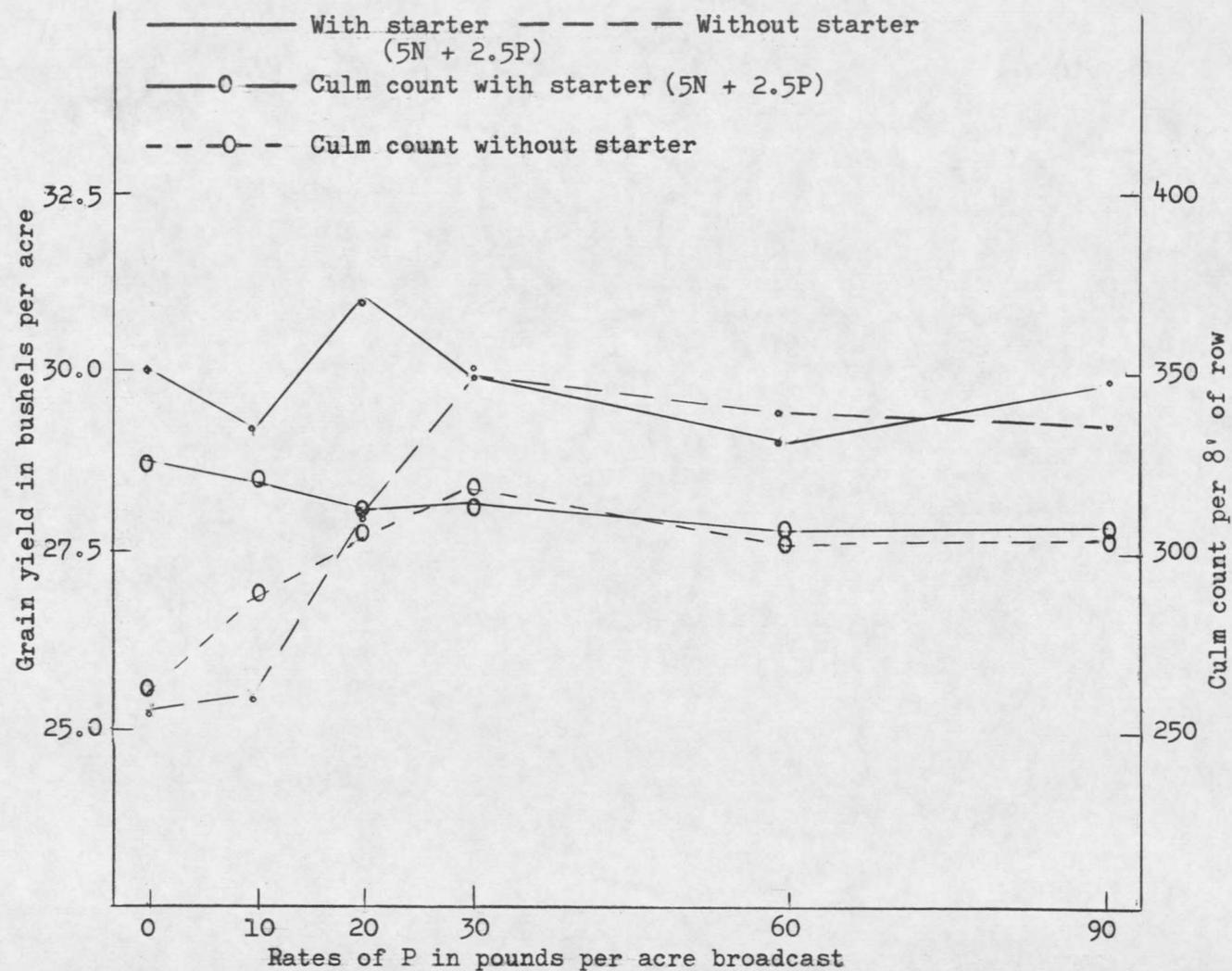


Figure 2. Grain yield and culm count for broadcast P with and without starter fertilizer - Denton, 1968; winter wheat (all treatments had 40 lb. N/A and 25 lb. K/A, topdressed in the spring).

degree of freedom test, yields were significantly increased with starter fertilizer at broadcast P-rates of 0, 10, and 20 lb. P per acre. Yield differences were significant at the 1% probability level, while at higher broadcast rates of 30 lb. P/A and above there was little or no influence. The differences in the level of broadcast P for starter effect at Denton compared with Power may be related to the soil P level. Soil P level at Power was "very low", 18 ppm, while at Denton the P level was "low", 32ppm. Starter influenced yields up to 60 lb. P per acre broadcast at Power and only up to 30 lb. P/A at Denton. This may have practical significance for making fertilizer recommendations if grain yield responses are closely related to the results obtained by soil tests on available P.

Figure 3 is included for the Power data to show the influence of starter on grain yield as related to broadcast P at 0 and 20 lb/A. It can be observed with 40 lb. N/A without starter, there was little difference in yields with 0 and 20 lb. P broadcast. At 40 lb. N plus starter, grain yield increased from 40 bu/A to 44 bu/A with the 20 lb. P per acre addition. Similar results were obtained at Denton and Froid with a 1.8 bu/A increase due to starter at Froid and 1 bu/A increase at Denton. At Denton there was also a 2.9 bu/A yield increase with 20 lb. P/A over 0 P without starter.

Different results were obtained at the Froid location with starter fertilizer. Figure 4 indicates that there was a starter influence with

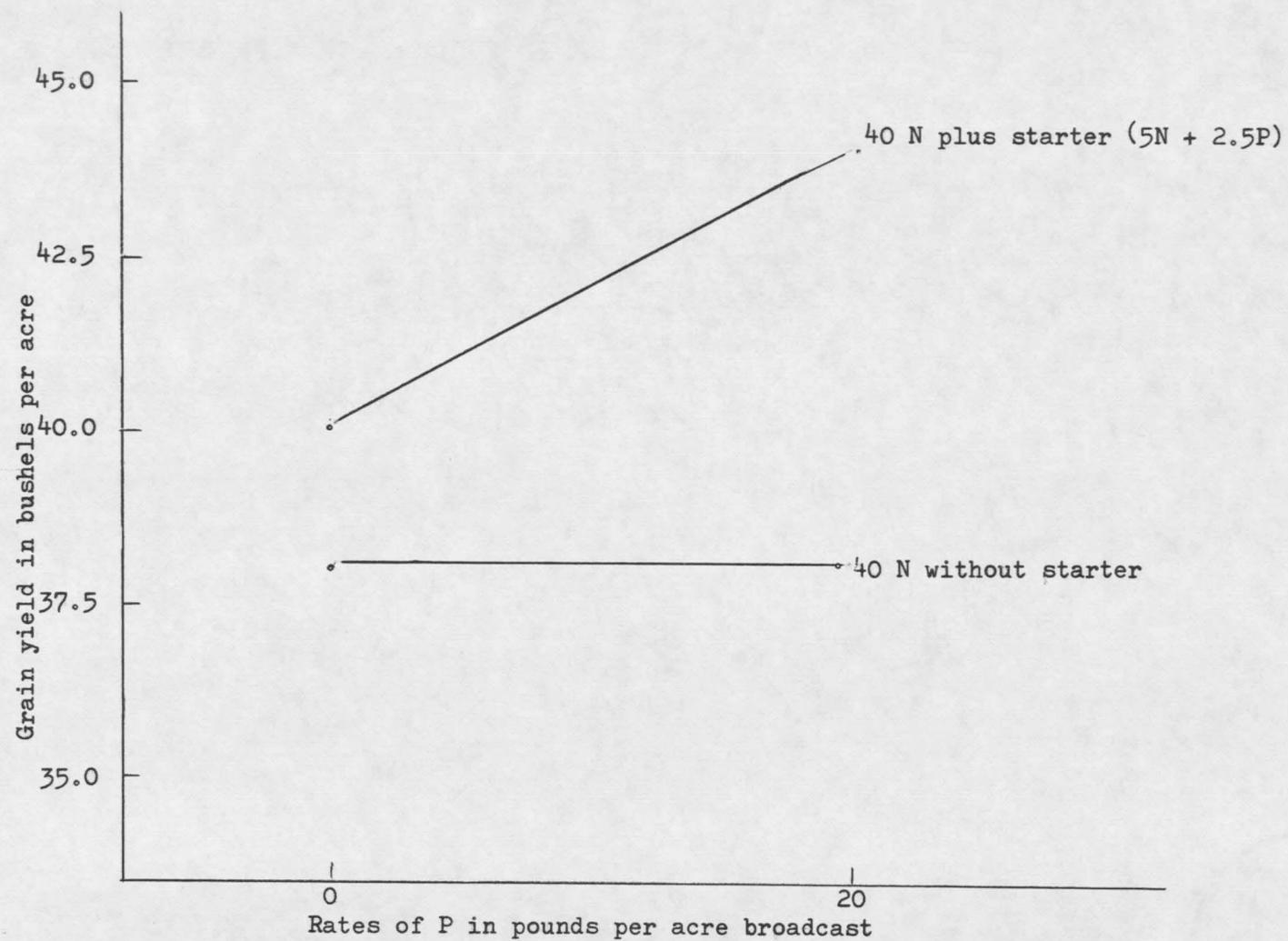


Figure 3. Grain yield as influenced by 0 and 20 lb P/A broadcast - Power, 1968; winter wheat (all treatments had 25 lb. K/A).

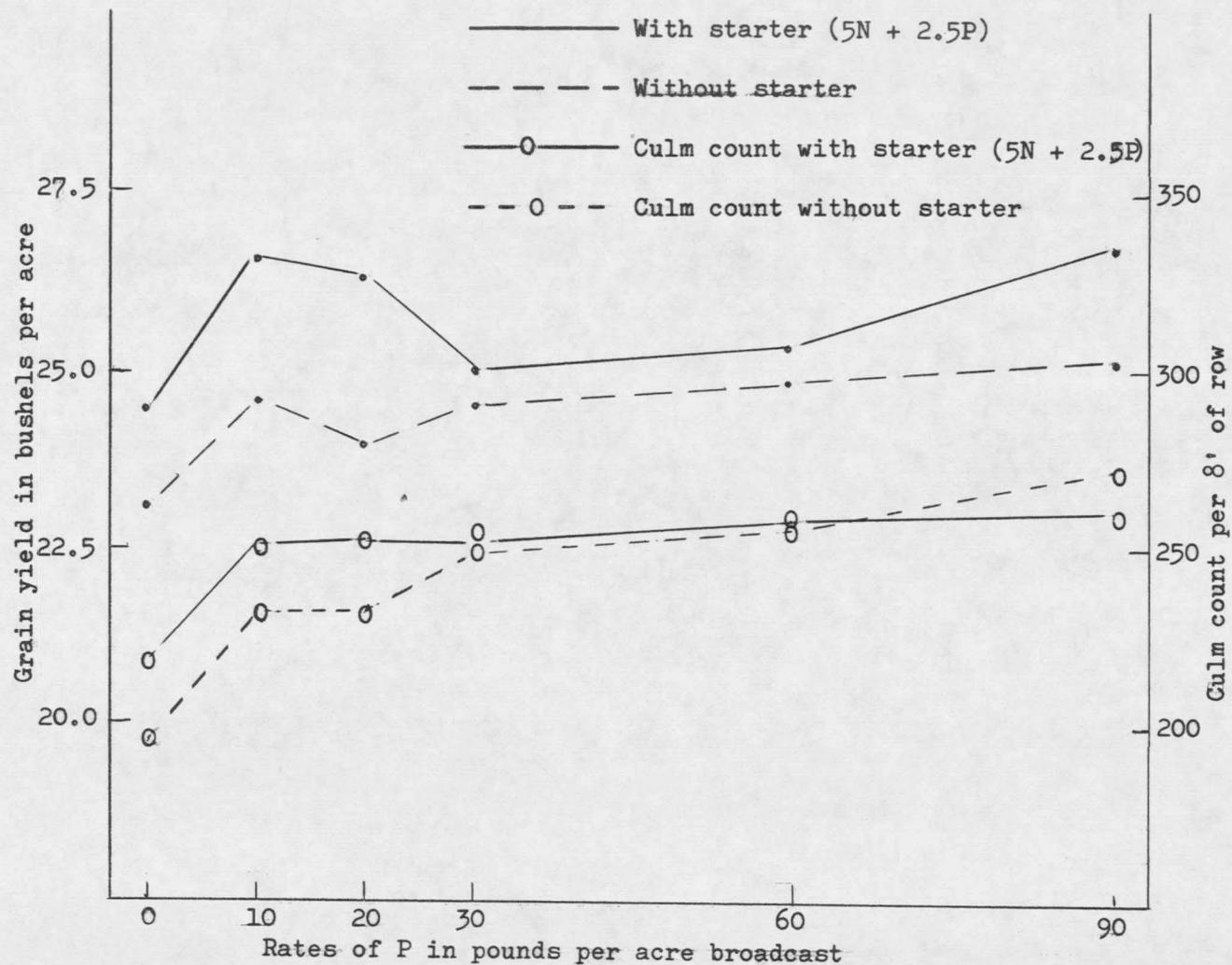


Figure 4. Grain yield and culm count for broadcast P with and without starter fertilizer - Froid, 1968; spring wheat (all treatments had 40 lb. N/A and 25 lb. K/A, topdressed in the spring).

up to 90 lb. P per acre broadcast. The average yield response to starter was significant at the 1% level. This yield response pattern may be only characteristic of spring wheat. Spring wheat does not have the length of time for root development that winter wheat does and starter fertilizer near the rooting area may be more beneficial for spring wheat than winter wheat. The broadcast P was worked into the soil in the fall before spring seeding and if reduced availability were not a problem, it should have been positionally more available to the plants. Also, there were two treatments, 11 and 12, broadcast in the spring to check on possible loss of availability overwinter because of soil and P reaction. There appeared to be no advantage or disadvantage of this spring application.

#### 1969 Results On Winter And Spring Wheat

With the discussion which follows being so interrelated between 1968 and 1969, the first sections will be those in 1969 results which can be separated, then the sections will combine 1968 and 1969.

The dry matter yields, grain yields, and culm counts for the 1969 crops are listed in Tables 12 for Power, 13 for Denton, and 14 for Froid. Yields were influenced by a cold, late spring and frost damage during the heading stage of growth. Although frost damage on these experiments was not considered major, the low temperatures probably reduced yields. The soil temperatures recorded in Appendix tables 41 and 42 for 1968 and 1969 at Denton showed the lower temperatures in

Table 12. Grain yield, dry matter yield, and culm count - Power, 1969; winter wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count $\frac{1}{8}$ ' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 $\frac{2}{}$	0	0	0	0	3407	24.6	157
2, 40	0	0	0	0	3229	23.9	225
3	40	0	0	0	3166	23.6	197
4	40	0	5	0	3258	23.7	169
5	40	0	0	2.5	3254	23.4	185
6	40	0	5	2.5	3395	24.2	180
7	40	0	5	5	3841*	25.6	217
8	40	0	5	10	4100*	28.1*	232
9	40	0	5	20	4009*	25.6	264*
10	40	0	5	30	4465*	29.4	250*
11	40	10	$\frac{3}{}$	0	3867*	27.7*	196
12	40	20	$\frac{3}{}$	0	4167*	29.7*	194
13	40	0	$\frac{4}{}$	0	3524	26.2	184
14	40	0	$\frac{4}{}$	5	3498	26.8	196
15	40	10	0	0	3906*	28.3*	182
16	40	10	5	2.5	4071*	29.4*	220
17	40	0	$\frac{5}{}$	0	4273*	30.2*	212
18	40	0	$\frac{5}{}$	5	4398*	29.8*	221
19	40	20	0	0	3868*	26.5	214
20	40	20	5	2.5	3853*	27.7*	212
21	0	20	0	0	3489	26.8	194
22	20	20	0	0	3523	25.9	195
23	40	0	$\frac{6}{}$	0	3763*	26.1	236
24	40	0	$\frac{6}{}$	5	3942*	26.5	214
25	40	30	0	0	4332*	29.9*	229
26	40	30	5	2.5	4189*	28.7*	258*
27	40	60	0	0	4191*	28.9*	222
28	40	60	5	2.5	4179*	28.5*	220
29	40	90	0	0	4829*	32.4*	246*
30	40	90	5	2.5	4766*	31.0*	245*
31 $\frac{7}{}$	40	10	0	0	3713*	27.3	195
32	40	10	5	2.5	3874*	28.5*	181
33	40	20	0	0	3627	25.5	210
34	40	20	5	2.5	3824*	26.7	210
35	40	10	0	0	4305*	30.1*	174
36 $\frac{8}{}$	40	10	0	0	4028*	28.2*	207

Table continued. . .

Table 12. Continued. . .

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/ 8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
37	40	20	0	0	3976*	28.8*	214
38 8/	40	20	0	0	4172*	30.1*	270*
41	40	20	5	5	3932*	26.8	227
42	40	30	5	5	4224*	28.1*	249*
43	60	20	5	2.5	3610	25.6	196
44	80	20	5	2.5	3967*	28.2*	186
45	40	10	0	2.5	3558	26.3	214
46	40	20	0	2.5	3686	25.9	232

Analysis of Variance

Source of Variation	df	MS	df	MS	df	MS
Treatments	45	658995**	45	20.1**	45	3240**
Experimental Error	135	141969	135	7.6	135	1015
LSD (.05)		526		3.9		45

1/ Includes culms with heads containing three or more kernels.

2/ 25 lb. K on all treatments except 1 and 39.

3/ P broadcast in spring just prior to seeding.

4/ 10 lb. P/A applied broadcast in 1967.

5/ 20 lb. P/A applied broadcast in 1967.

6/ 30 lb. P/A applied broadcast in 1967.

7/ Treatments 31-38 applied in spring before fallow.

8/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 13. Grain yield, dry matter yield, and culm count - Denton, 1969; winter wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/8' or Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 <u>2/</u>	0	0	0	0	1448	9.5	129
2, 40	0	0	0	0	1316	9.1	115
3	40	0	0	0	2281	14.1	144
4	40	0	5	0	2252	14.9	173
5	40	0	0	2.5	2389	17.1*	177
6	40	0	5	2.5	2553	18.2*	224*
7	40	0	5	5	2409	16.9	198
8	40	0	5	10	2354	17.6*	222*
9	40	0	5	20	2653	18.2*	216*
10	40	0	5	30	2762*	18.6*	207*
11, 13, 15	40	10	0	0	2268	15.3	167
14, 16	40	10	5	2.5	2462	16.8	193
12, 17, 19	40	20	0	0	2156	14.7	149
18, 20	40	20	5	2.5	2501	17.0	158
21	0	20	0	0	1470	9.8	132
22	20	20	0	0	1979	12.7	149
23, 25	40	30	0	0	2331	17.7*	182
24, 26	40	30	5	2.5	2437	17.6*	219*
27	40	60	0	0	2586	17.0	222*
28	40	60	5	2.5	2597	17.3*	197
29	40	90	0	0	2390	16.3	155
30	40	90	5	2.5	2610	17.5*	220*
31 <u>3/</u>	40	10	0	0	2462	15.3	169
32	40	10	5	2.5	2407	16.9	208*
33	40	20	0	0	2281	14.7	167
34	40	20	5	2.5	2325	15.2	166
35	40	10	0	0	1048	6.8	112
36 <u>4/</u>	40	10	0	0	1128	7.6	133
37	40	20	0	0	1194	8.2	109
38 <u>4/</u>	40	20	0	0	1201	8.3	106
41	40	20	5	5	2675*	17.0	237*
42	40	30	5	5	2784*	19.5*	207*
43	60	20	5	2.5	2863*	19.6*	236*
44	80	20	5	2.5	2953*	20.3*	225*
45	40	10	0	2.5	2372	16.0	196
46	40	20	0	2.5	2219	14.6	163

Table continued. . .

Table 13. Continued.

	Total Dry Matter lb/A		Grain Yield Bu/A		Culm Count <u>1</u> / 8' of Row	
Analysis of Variance						
Source of Variation	df	MS	df	MS	df	MS
Treatments	45	1018863**	45	46.9**	45	5816**
Experimental Error	135	78681	135	4.7	135	1754
LSD (.05)		393		3.0		59

1/ Includes culms with heads containing three or more kernels.

2/ 25 lb. K on all treatments except 1 and 39.

3/ Treatments 31-38 applied in spring before fallow.

4/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 14. Grain yield, dry matter yield, and culm count - Froid, 1969; spring wheat.

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count 1/8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
1, 39 2/	0	0	0	0	3409	17.6	241
2, 40	0	0	0	0	3236	20.6	206
3	40	0	0	0	3139	20.9	188
4	40	0	5	0	3629	21.3	186
5	40	0	0	2.5	3377	22.0	211
6	40	0	5	2.5	3638	21.1	214
7	40	0	5	5	3806*	25.3	242*
8	40	0	5	10	3501	23.9	241*
9	40	0	5	20	3867*	26.2*	257*
10	40	0	5	30	3564	24.2	250*
11	40	10 3/	0	0	3649	21.6	195
12	40	20 3/	0	0	3608	22.8	218
13	40	0 4/	0	0	3511	22.5	198
14	40	0 4/	5	2.5	3809*	25.6*	218
15	40	10	0	0	3360	21.4	215
16	40	10	5	2.5	3500	22.1	206
17	40	0 5/	0	0	3045	19.1	227
18	40	0 5/	5	2.5	3197	20.0	225
19	40	20	0	0	2610	22.3	227
20	40	20	5	2.5	3808*	24.9	233
21	0	20	0	0	3432	22.3	213
22	20	20	0	0	3736	24.1	250*
23	40	0 6/	0	0	3386	21.6	254*
24	40	0 6/	5	2.5	3664	24.3	255*
25	40	30	0	0	3706	24.2	215
26	40	30	5	2.5	3694	24.1	249*
27	40	60	0	0	3408	21.9	215
28	40	60	5	2.5	3565	23.9	224
29	40	90	0	0	3805*	25.7*	233
30	40	90	5	2.5	3960*	26.1*	252*
31 7/	40	10	0	0	3099	19.1	240*
32	40	10	5	2.5	3428	21.5	210
33	40	20	0	0	3433	22.2	224
34	40	20	5	2.5	3593	23.0	188

Table continued. . .

Table 14. Continued. . .

Treatment No.	Fertilizer				Total Dry Matter lb/A	Grain Yield Bu/A	Culm Count <u>1/</u> 8' of Row
	Broadcast		With-Seed				
	N	P	N	P			
35	40	10	0	0	3712	24.5	231
36 <u>8/</u>	40	10	0	0	3692	25.7*	235
37	40	20	0	0	3473	24.6	172
38 <u>8/</u>	40	20	0	0	4013*	27.0*	240*
41	40	20	5	5	3792*	25.6*	242*
42	40	30	5	5	3906*	24.9	231
43	60	20	5	2.5	3675	23.0	189
44	80	20	5	2.5	3664	23.8	234
45	40	10	0	2.5	3410	22.1	233
46	40	20	0	2.5	3491	22.7	225

Analysis of Variance

Source of Variation	df	MS	df	MS	df	MS
Treatments	45	319874*	45	21.1**	45	1819
Experimental Error	135	199549	135	11.3	135	1256
LSD (.05)		625		4.7		50

1/ Includes culms with heads containing three or more kernels.

2/ 25 lb. K on all treatments except 1 and 39.

3/ P broadcast in spring just prior to seeding.

4/ 10 lb. P/A applied in 1967.

5/ 20 lb. P/A applied in 1967.

6/ 30 lb. P/A applied in 1967.

7/ Treatments 31-38 applied in spring before fallow.

8/ 15-60-0 TVA (ammonium polyphosphate) and 33.5-0-0.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

late May and early June for 1969. However, the differences recorded at the Power location between 1968 and 1969, Appendix tables 39 and 40 do not show the lower temperatures for 1969, as clearly. Evidently, the thermograph sensing element was either placed at a shallower depth in 1969 or the soil was disturbed above the element as temperatures seemed to show a wider range between high and low as compared with 1968. The range was approximately 10° - 12° F in 1968 and 15° - 18° F in 1969. It also appeared that the thermograph might have been calibrated slightly higher in 1969 which would record the temperatures higher than they actually were.

Yields at Denton in 1969 were influenced by cheatgrass and were further affected by low moisture. Effective moisture received at the Denton location for the growing season was approximately one inch in May. See appendix table 47 for precipitation data. The 2.6 inches of precipitation on June 28 was too late to affect the 1969 crop, except to help mature what was already developed. Plant samples were taken June 18 and at this time, plants were in the heading stage of development (Feekes stage 10.2). Test weight was slightly lower in 1969 at Denton than in 1968, probably due to the lower moisture. Average values were approximately 61 lb/bu at Denton, 62.5 lb/bu at Power, and 59.5 lb/bu at Froid.

Fertilizer Applied With-The-Seed

In 1969, the wheat yields were influenced by fertilizer applications with-the-seed for the 1967 crop in addition to 1969 at two locations, Power and Froid. There was an influence of treatments on yield at the two locations as noted in Table 15. Significant yield increases were obtained at Power in 1969 from P fertilizer banded with-the-seed. Yields ranged from 23.7 bu/A for zero P to 29.4 bu/A for 30 lb. P/A, (total of 60 lb. P/A for two crop years).

Froid had yields which ranged from 21.3 bu/A for zero P to 26.2 bu/A at 20 lb. P/A with-the-seed (a two-year total of 40 P). However, at both Power and Froid, the response to rates of P did not show the typical increase in yields with increasing fertilizer with-the-seed. A contributing factor may have been the residual effects of P fertilizer applied with-the-seed for the 1967 crop.

At the Denton location, a more normal pattern of yield increases occurred with increasing rates of P especially from 5 to 30 lb. P/A. Significance level is listed in Table 15. The yields listed in the table indicate that the small amount of P, 2.5 lb/A, was adequate to show good yield increases with little added increase at higher P rates. This location did not have the P applications for the 1967 crop.

Starter Influence On Broadcast P - 1969

The fertilizer treatments for Power and Froid differed from Denton for 1969. This was the third year for the experiment at both

Table 15. Grain yield for rates of fertilizer placed with-the-seed for 1969; winter wheat at Power and Denton, spring wheat at Froid.

Treatment No.	With-the-Seed <sup>2/</sup>		Power Bu/A	Denton Bu/A	Froid Bu/A
	N	P			
3	0	0	23.6	14.1	20.9
4	5	0	23.7	14.9	21.3
5	0	2.5	23.4	17.1	22.0
6	5	2.5	24.2	18.2*	21.1
7	5	5	25.6	16.9	25.3
8	5	10	28.1*	17.6	23.9
9	5	20	25.6	18.2*	26.2*
10	5	30	29.4*	18.6*	24.2
LSD (.05)			3.9	3.0	4.7

<sup>1/</sup> All treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring.

<sup>2/</sup> All treatments with-the-seed were also applied for the 1967 crop at Power and Froid.

\* Significant at the .05 level compared with treatment 4.

Power and Froid and the second at Denton. There were two sets of broadcast treatments for the 1969 crop year which differed primarily by year of application. One set consisting of 10, 20, 30, 60, and 90 lb. P per acre was broadcast for the 1967 crop. The second set consisting of 10, 20, and 30 P was applied for the 1969 crop in addition to 1967 making totals of 20, 40, and 60 P, respectively. The influence of starter on the 1969 crop was evaluated for these treatments.

Figure 5 indicated practically no additional response was shown at the Power location due to starter fertilizer as compared with no starter, except a small increase at the 0 and 10 lb. P-rate. Note the increased grain yield with only 10 lb. P per acre after two years; this increase was not significant at the levels tested. Yield increases were significant at 20, 60, and 90 lb. P per acre applied for the 1967 crop as compared with the check treatment, No. 3; complete data are in Table 12.

The comparisons for the second set of treatments were also included on this same figure to observe the additive effects of two broadcast applications, 1967 plus 1969. Rates of 10, 20, and 30 lb. P per acre were applied broadcast in 1967 and again in 1969 and yields are shown with the other designated lines. These treatments totaled 20, 40, and 60 lb. P per acre for the two years.

Applications of 20 lb. P (10 P for 1967 plus 10 P for 1969) showed a greater yield increase from starter fertilizer than did one application.

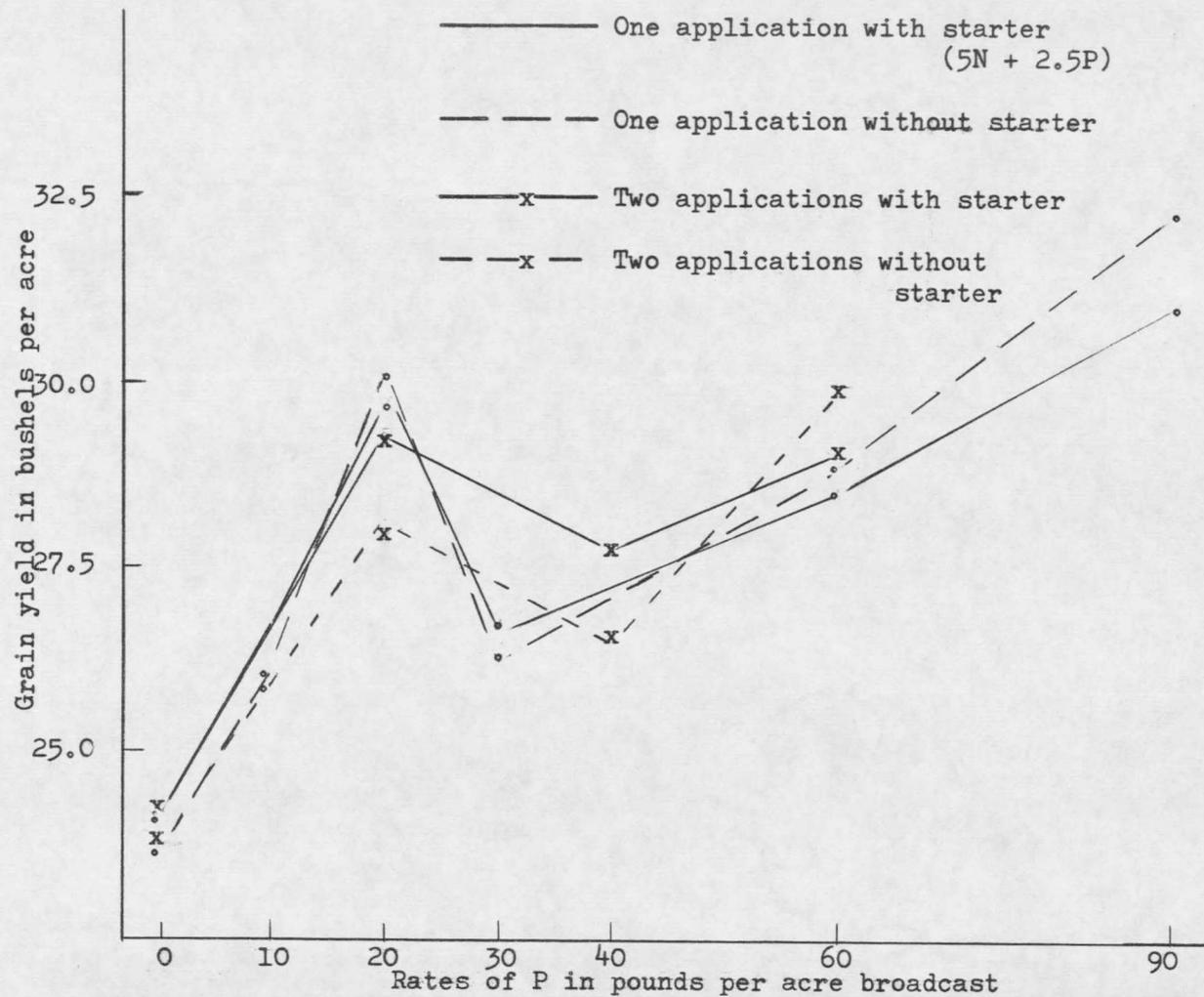


Figure 5. Grain yield comparisons for broadcast P for one application for 1967 and two applications (one for 1967 and one for 1969) with and without starter fertilizer - Power, 1969; winter wheat (Tr. had 4C lb. N & 25. lb. K).

of 20 or 30 lb. P applied in 1967. The same occurred at 40 lb. P (20 P plus 20 P) but added response was not noted at 60 lb. P (30 P plus 30 P). However, overall yields showed the same general trend with one application of 20, 30, and 60 lb. P per acre as with two applications of 10 P, 20 P, or 30 P, respectively.

Figure 6 is the result of plotting the corresponding data for spring wheat at Froid. Complete data are in Table 14. A significant response was shown for starter at the residual P levels produced by P applied in 1967. Yields at the 20 lb. P per acre level were out of line and not explainable as compared with the check treatment No. 3. Two applications of P (10 P for 1967 plus 10 P for 1969) produced over two bushels more wheat than the comparable rate of 20 lb. P per acre applied for the 1967 crop.

Starter effects were virtually identical whether P was all residual or a combination of residual and currently applied fertilizer, except at 60 lb. P per acre (30 P plus 30 P) where starter produced no measurable increase in yields. This indicates there was no great loss of availability of the P applied for the 1967 crop.

The Denton grain yields are plotted with rates of P broadcast in Figure 7. Treatments at this location included only the one-year application of broadcast P for the 1969 crop. The trends for 1969 were very similar to those of 1968 for the Denton data as were shown in Figure 2, with the influence of starter dropping to zero at 30 lb. P/A broadcast.

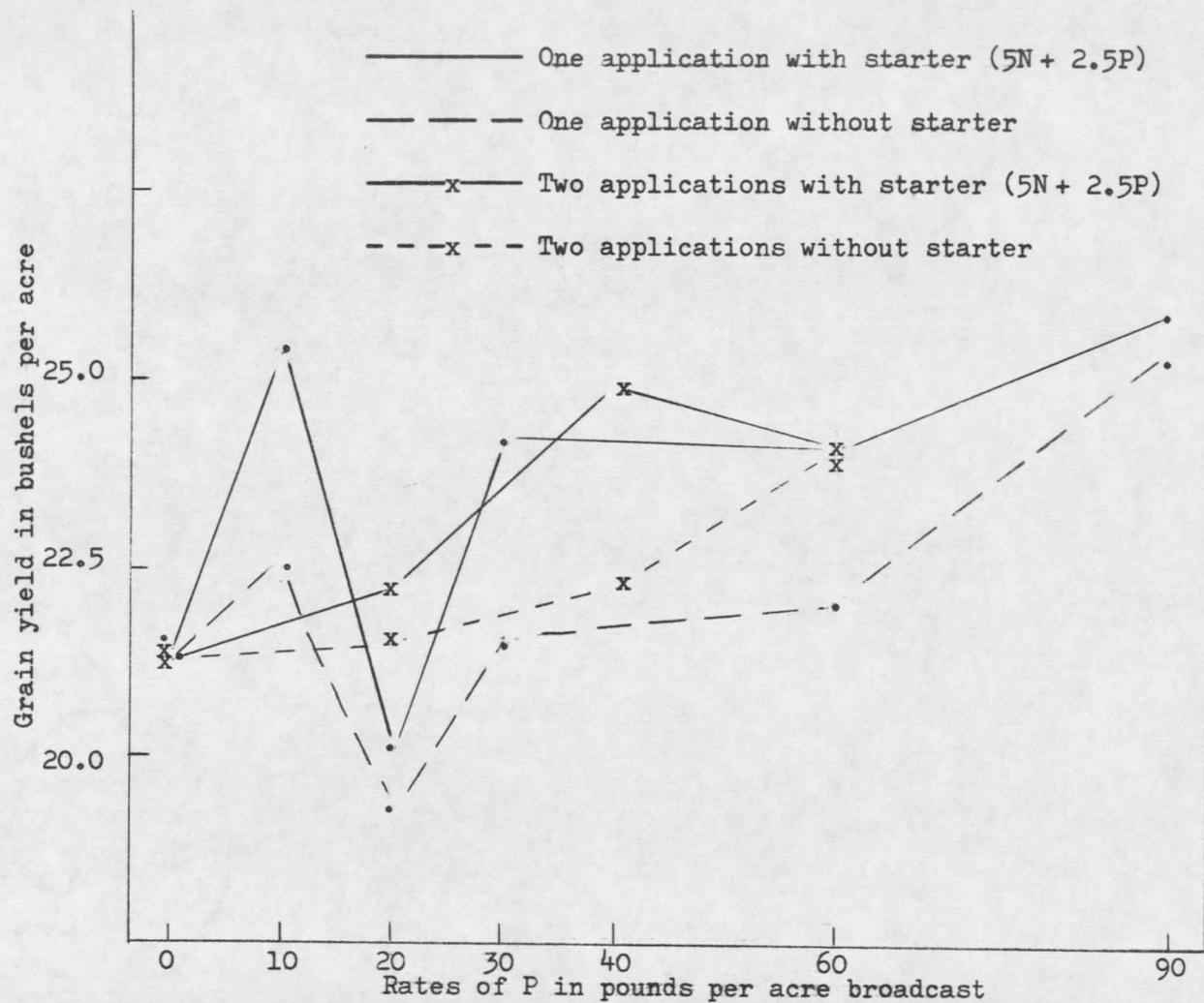


Figure 6. Grain yield comparisons for broadcast P for one application for 1967 and two applications (one for 1967 and one for 1969) with and without starter fertilizer - Froid, 1969; spring wheat (Tr. had 40 lb. N & 25 lb. K).

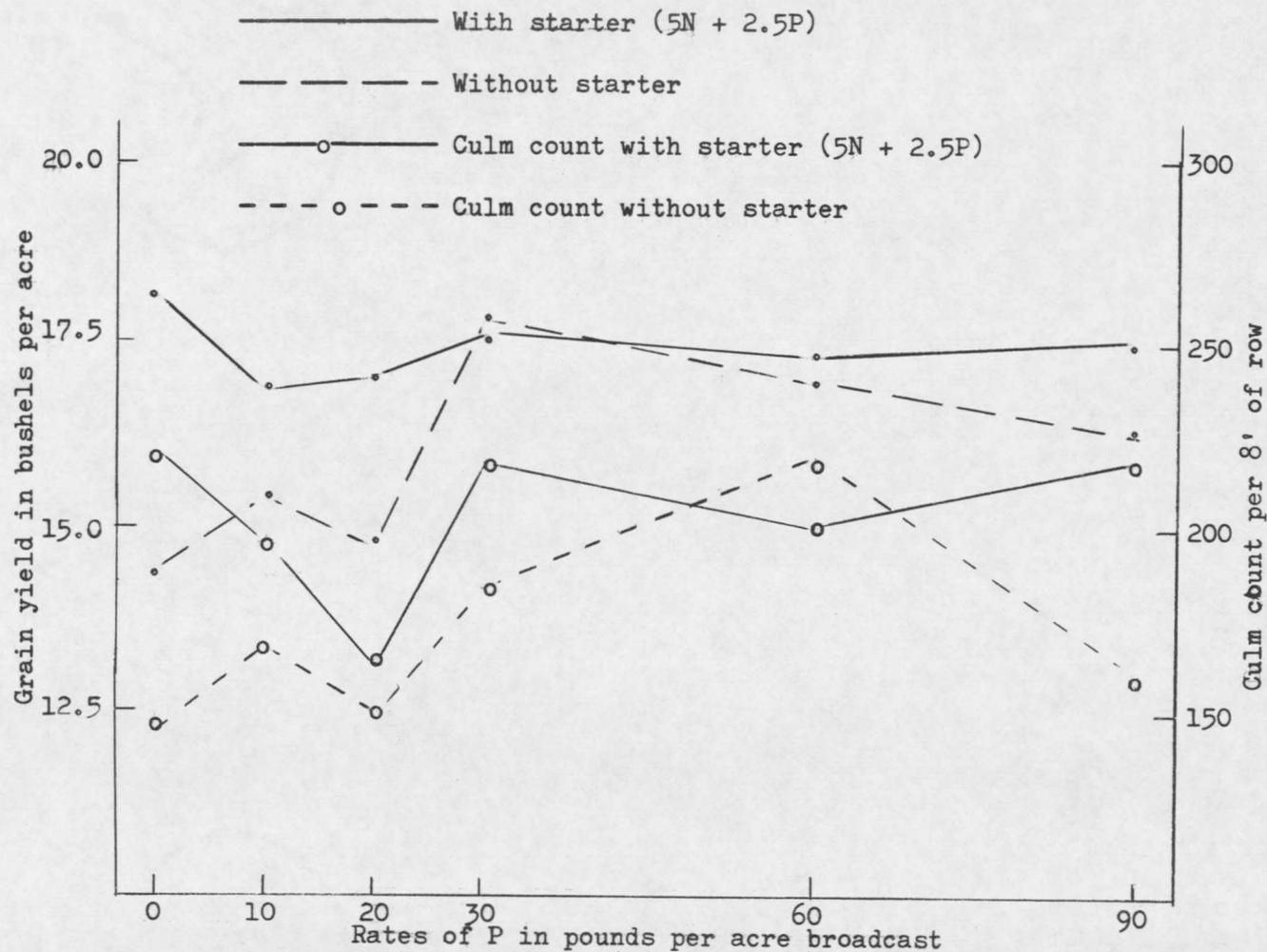


Figure 7. Grain yield and culm count for broadcast P with and without starter fertilizer - Denton, 1969; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

The influence of starter compared with no starter on 0, 10, and 20 lb. P per acre broadcast averaged 2.5 bu/A and was significantly different at the 1% probability level, Figure 7. Response to P was low and all yields were very low for 1969 at Denton caused by a very dry summer.

At each location there was a characteristic dip in yields as noted at 30 lb. P at Power and 20 lb. P at Froid and Denton. Why this dip occurred was not evident from the data. The reduced yield was evident at all locations with and without starter except at Denton where only the non-starter treatments showed lowered yields.

#### P Percentage Of Plants For 1968 And 1969

Plant dry weight and P percentage were determined for several stages of plant development for the 1968 crop. The data for P percentage from the young plants collected in the fall of 1967 from treatments where fertilizer was placed with-the-seed, showed good correlation with final grain yields ( $r = .863$ ) which was significant at the 10% probability level. Figure 8 shows final yields as related with P percentage where the correlation existed (treatments 4, 5, 6, 8, and 9).

All values for P percentage and dry matter yields are included in Table 16. Statistical significance is recorded in the table. At the Power location, the range of P percentage in plants for P with-the-seed was 0.119 to 0.182% as shown by treatments 5, 6, 8, and 9 with a gradual increase as P-rate increased. Starter fertilizer also had a marked

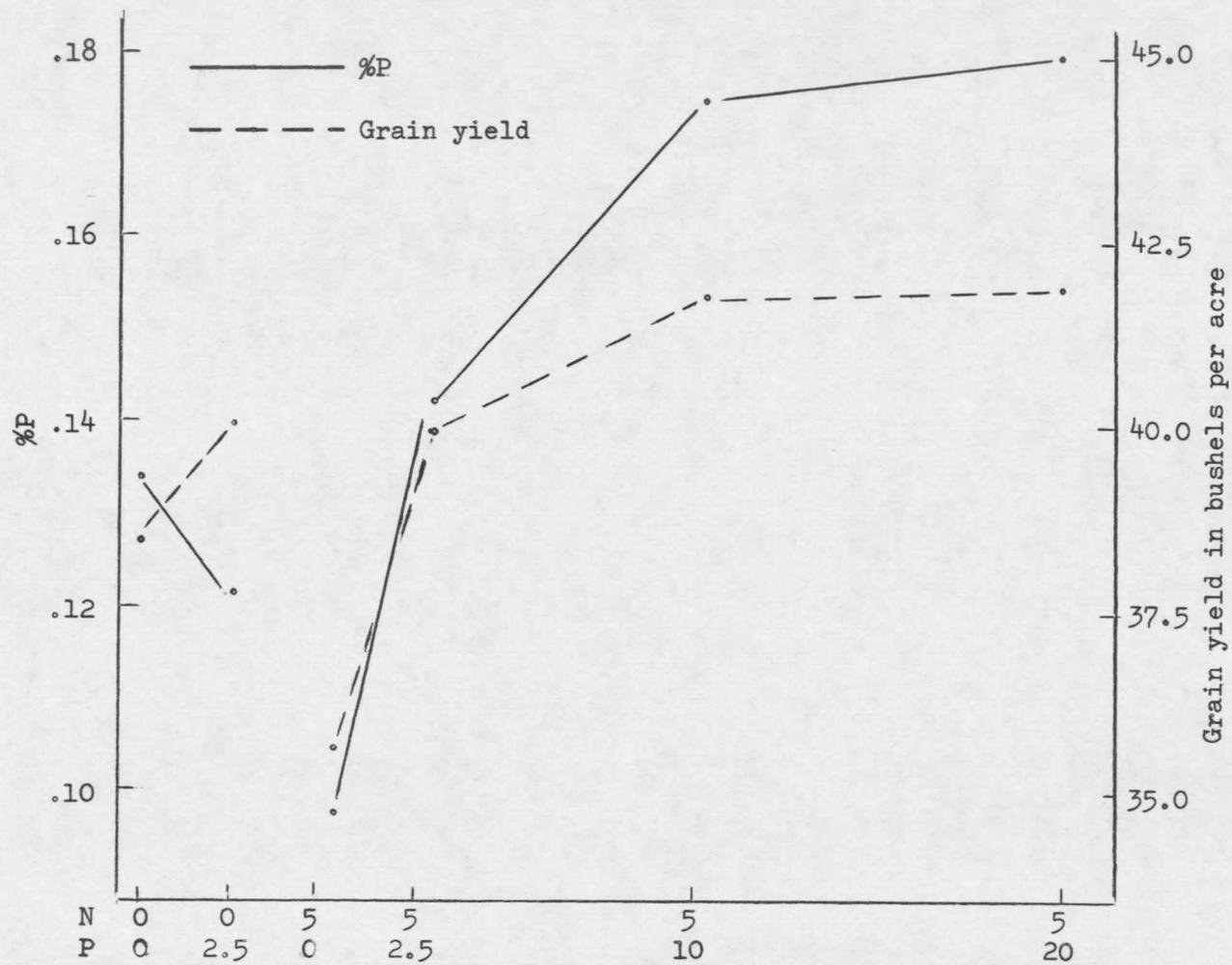


Figure 8. Percent P of young plants (Feekes stage 2) as related to final grain yield for placement of fertilizer with-the-seed - Power, 1968; winter wheat (all treatments had 40 lb.N and 25 lb.K/A, topdressed in the spring).

Table 16. Weight and P percentage of young plants, Feekes stage 2, and final grain yield - Power and Denton, 1968; winter wheat.

Treatment No. <u>1/</u>	Power			Denton		
	Dry Matter Yield lb/A	%P	Grain Yield Bu/A	Dry Matter Yield lb/A	%P	Grain Yield Bu/A
3	110	.133	33.5	57	.188	25.0
4	92	.093	34.7	84	.101	25.0
5	90	.119	40.3	80	.127	26.8
6	60	.138	40.0	86	.123	30.0
8	114	.175	41.6	74	.269	26.8
9	156	.182*	41.5	74	.344*	27.9
13	85	.116	39.8	64	.101	28.5
14	122	.145	38.4	57	.153	30.7
17	115	.139	36.6	70	.111	25.8
18	95	.148	43.6	80	.157	30.7
23	82	.112	40.2	77	.123	30.9
24	123	.143	46.5	74	.160	29.0
27	.04	.101	43.9	68	.176	29.4
28	102	.154	44.3	71	.171	29.0
29	131	.101	45.6	70	.181	29.4
30	126	.175	45.8	81	.171	29.9
LSD (.05)	62	.059	6.6	30	.100	4.9

1/ Fertilizer treatments are listed in Table 1.

\* Significant at the .05 level.

affect on P percentage. The average for broadcast P without starter was 0.114% while the average with starter was 0.153%.

Phosphorus percentage showed wide variation due to treatment in the early plant development stages, Feekes stage 2, while dry matter yield showed little influence by P treatments. This was not found at any other time of year with plant samples collected on winter wheat. Generally, P percentage showed little influence of P treatment on samples taken after early spring on winter wheat, whereas dry matter weight did reflect the P treatments.

Figure 9 shows the variation in P percentage due to fertilizer placed with-the-seed on plant samples collected in the early stage of growth, Feekes stage 2, and mature plant samples, Feekes stage 11.3. Note the P percentage of mature samples is very close to 0.1% regardless of fertilizer treatment. The data in Table 17 indicate differences in P percentages at Power had nearly disappeared by the time growth had progressed to the six-leaf, or Feekes stage 4-5 in the spring. Plant dry matter weight on the other hand showed significant increases due to fertilizer treatment.

The Denton area was seeded approximately 10 days later in the fall of 1967 than the Power area. In general, P percentage values in Table 17 showed the same general trends as Power with less influence due to treatments and greatest magnitude of response reflected in dry matter yields as contrasted with the small plant samples in the fall.

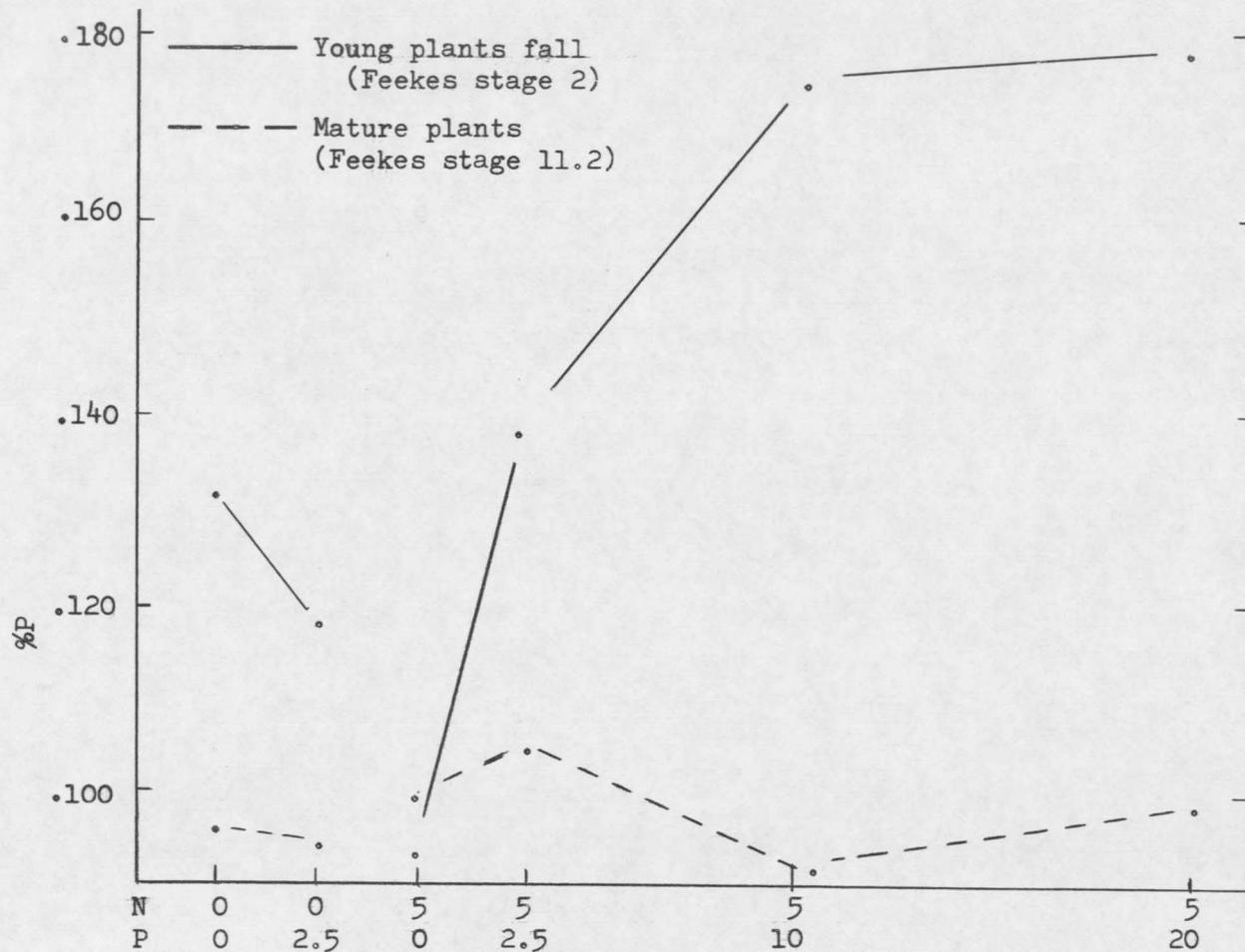


Figure 9. Variation in percent P of young plants, Feekes stage 2, and mature plants, Feekes stage 11.2, at Power, 1968; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

Table 17. Dry matter yield and P percentage as related to fertilizer treatments for plant growth stage Feekes 4-5. Winter wheat, Power and Denton; spring wheat at Froid, 1968.

Treatment No. <u>1/</u>	Power		Denton		Froid	
	lb/A	%P	lb/A	%P	lb/A	%P
3	312	.105	744	.157	480	.282
4	336	.092	780	.154	360	.327
5	324	.080	984	.166	492	.274
6	468	.087	1068	.145	576*	.271
7	504	.098	996	.154	884*	.286
8	624*	.102	1272	.169	708*	.316
9	852*	.091	1428*	.198*	720*	.343
10	1006*	.096	1392*	.203*	696*	.408*
13	360	.101	888	.172	504	.305
14	480	.096	1140	.162	648	.301
17	372	.109	1020	.185	540	.323
18	504	.109	1332*	.188*	636	.323
23	420	.096	1176	.193	516	.385*
24	504	.092	1332*	.199*	648	.325
27	780*	.107	1092	.206*	612	.378*
28	876*	.106	1356*	.205*	624	.369*
29	792*	.118	1236	.223*	672*	.475*
30	1068*	.105	1452*	.233*	624	.484*
LSD (.05)	216	.023	504	.031	180	.061

1/ Fertilizer treatments are listed in Table 1.

\* Significant at the .05 level (treatments 4-10 compared with treatment 4)(treatments over 10 compared with treatment 3).

At Froid, Table 17, these trends of lowered P percentage values and increased dry matter weight had not been fully expressed at Feekes stage 4-5. This would be expected at the Froid location as spring wheat would not show the early spring growth comparable with winter wheat. In fact the very high P percentage values, especially with higher rates of broadcast P were not too different from the early winter wheat samples, Feekes stage 2. Very little change in dry matter weight due to fertilizer treatment was noted.

With the indications noted in the data for 1968, plans were made to obtain plant samples earlier in the spring of 1969 than they were taken in 1968.

By comparing the data for the first spring sample, Feekes stage 4, in Table 18 for 1969 with the data for 1968 at Feekes stage 4-5 in Table 17, P percentage values were greater at Power in 1969 than in 1968. Dry matter yields were lower in 1969.

However, with spring wheat, P percentage values were lower in 1969 with a range of 0.240 to 0.300% compared with 0.300 to 0.480% in 1968. Dry matter yields were lower in 1969 with a range of 70 to 120 lb/A compared with 360 to 610 lb/A in 1968. The time between seeding date and sampling date was 10 days less in 1969 than in 1968. These data indicate that P percentage values were not entirely dependent of plant stage of development as P percentage values were considerably lower in

Table 18. Weight and percent P comparisons for winter wheat at Power and spring wheat at Froid with respect to fertilizer treatments, 1969.

Treatment No. 1/	Power 1 <sup>st</sup> Sample		Froid 1 <sup>st</sup> Sample		Froid 2 <sup>nd</sup> Sample	
	Feekes stage 4		Feekes stage 4		Feekes stage 10.2	
	Dry Matter lb/A	%P	Dry Matter lb/A	%P	Dry Matter lb/A	%P
2	102	.164	174	.256	1776	.142
3	100	.170	60	.255	1572	.146
4	64	.166	108	.245	1788	.148
5	214*	.155	84	.241	2016	.150
6	142	.152	87	.229	1668	.125
7	220*	.183	126*	.279	2256*	.128
8	252*	.179	144*	.278	2124*	.141
9	330*	.181	159*	.288	2160*	.145
10	346*	.206*	123	.335*	2220*	.143
11	- 2/	-	75	.264	1728	.144
12	-	-	144	.288	2076	.140
13	106	.153	90	.259	1896	.145
14	190	.162	120	.250	2244*	.139
17	132	.171	87	.243	1716	.148
18	207*	.162	93	.246	1704	.149
23	186	.176	99	.260	1776	.159
24	200*	.170	88	.247	2004	.147
27	240*	.193	124	.302*	1788	.144
28	204*	.215*	138	.301*	1944	.147
29	270*	.197	142	.329*	2196*	.140
30	364*	.192	130	.303*	2100*	.138
-----						
LSD (.05)	96	.034	66	.039	528	.026

1/ Fertilizer treatments are listed in Table 1.

2/ Dash indicates data not available.

\* Significant at the .05 level compared with treatment 3.

1969 and at an earlier stage of development than in 1968. The normal trend is for P percentage to be reduced with development of plant growth. More differences in %P were measured in 1969 early samples as a reflection of treatment, than for 1968 when stage of development was later. However, magnitude of differences was not enough to provide a reliable predictive tool of P availability in soils.

Observation of the data at Froid and Power indicated that during the very early stages of plant development, P percentage may be meaningful for evaluating plant use of P but after growth reaches a certain stage in the spring, Feekes stage 4-5 for winter wheat and later for spring wheat, P yield may be more meaningful.

The data for the second sample taken at heading at Froid, 1969, are shown in Table 18. At this stage of development, Feekes stage 10.2, P percentage values were non-significantly influenced by fertilizer treatments while dry matter yields were significantly influenced. Complete data are shown in Table 19 for P percentage at all locations for 1968 and 1969.

#### Phosphorus Yield For 1968 And 1969

P yield (dry weight x %P) data for mature plant samples at the three locations are listed in Tables 20 and 21 for 1968 and 1969. Samples for P yield were taken at Denton just prior to the hail that reduced yield for 1968. This sample was used for P yield in preference to the final sample at harvest as it gave a better indication of actual

Table 19. Precent P (mature sample) for all treatments, 1968 and 1969. Winter wheat at Power and Denton, spring wheat at Froid.

Treatment No. 1/	%P					
	1968			1969		
	Power	Denton	Froid	Power	Denton	Froid
1	.091	.130	.112	.131	.148	.088
2	.101	.132	.129	.128	.154	.092
3	.094	.115	.117	.111	.165	.112
4	.098	.097	.117	.106	.154	.097
5	.089	.108	.121	.130	.162	.095
6	.100	.101	.127	.124	.148	.094
7	.099	.115	.137	.135	.162	.091
8	.092	.109	.138	.125	.159	.096
9	.098	.128	.135	.142	.158	.101
10	.096	.126	.133	.144	.159	.108
11	.103	.104	.127	.119	.164	.092
12	.100	.111	.136	.120	.162	.089
13	.090	.130	.126	.117	.144	.082
14	.093	.119	.132	.169	.146	.094
15	.086	.113	.134	.123	.160	.097
16	.091	.088	.126	.124	.158	.108
17	.103	.120	.123	.107	.165	.093
18	.098	.110	.130	.120	.161	.103
19	.097	.121	.116	.130	.166	.091
20	.092	.114	.126	.153	.154	.086
21	.118	.131	.144	.136	.177	.097
22	.087	.119	.124	.125	.160	.099
23	.107	.107	.127	.152	.151	.095
24	.106	.120	.119	.148	.144	.097
25	.094	.118	.118	.138	.138	.101
26	.090	.111	.124	.138	.143	.106
27	.104	.117	.123	.146	.154	.117
28	.098	.095	.131	.155	.158	.121
29	.100	.135	.138	.138	.166	.099
30	.097	.126	.139	.163	.167	.104

Table continued. . .

Table 19. Continued. . .

Treatment No. 1/	%P					
	1968			1969		
	Power	Denton	Froid	Power	Denton	Froid
31	.096	.115	.121	.138	.156	.096
32	.088	.127	.121	.141	.159	.096
33	.100	.129	.118	.132	.140	.096
34	.096	.118	.127	.129	.153	.090
35	.099	.080	.120	.106	.156	.094
36	.095	.104	.114	.131	.158	.095
37	.100	.109	.116	.134	.150	.099
38	.092	.112	.122	.136	.158	.099
39	.101	.145	.129	.123	.141	.086
40	.106	.125	.128	.109	.141	.088
41	.100	.107	.108	.136	.158	.099
42	.095	.111	.117	.137	.167	.106
43	.099	.116	.118	.125	.154	.104
44	.092	.105	.124	.135	.164	.101
45	.089	.106	.119	.164	.158	.100
46	.097	.132	.125	.146	.154	.100
-----						
LSD (.05)	.022	.024	.026	.027	.024	.022

1/ Fertilizer treatments are listed in Table 1.

Table 20. P yield and grain yield for with-the-seed placement of fertilizer. Winter wheat at Power and Denton, spring wheat at Froid, 1968 and 1969.

Treatment No. 1/	1968					
	Power		Denton		Froid	
	P Yield lb/A	Gr Yield Bu/A	P Yield lb/A	Gr Yield Bu/A	P Yield lb/A	Gr Yield Bu/A
4	4.92	34.4	7.87	25.0	4.32	23.4
5	4.80	40.3	7.22	26.8	4.42	22.7
6	5.47	40.0	7.44	30.0*	4.59	24.4
7	5.32	41.9*	7.29	27.8	5.68	25.1
8	5.76	41.6*	7.89	26.8	5.96*	27.0*
9	6.01	41.5*	8.12	27.9	6.55*	26.6*
10	6.36*	43.1*	9.39*	28.4	6.71*	26.5*
LSD (.05)	1.34	6.6	1.27	4.9	1.42	3.1
	1969					
4	3.90	23.7	4.06	14.9	4.06	21.3
5	4.80	23.4	4.39	17.1	3.75	22.0
6	4.70	24.2	4.99	18.2*	3.44	21.1
7	6.23*	25.6	4.59	16.9	3.43	25.3
8	5.76*	28.1*	4.76	17.6	3.89	23.9
9	7.36*	25.6	4.77	18.2*	4.47	26.2*
10	7.49*	29.4*	5.48*	18.6*	4.59	24.2
LSD (.05)	1.57	3.9	1.39	3.0	1.09	4.7

1/ Fertilizer treatments are listed in Table 1.

\* Significant at the .05 level compared with treatment 4.

Table 21. P yield and grain yield for broadcast rates of P with and without starter (5N + 2.5P). Winter wheat at Power and Denton, spring wheat at Froid, 1968 and 1969.

Treatment	1968					
	Power		Denton		Froid	
	No.1/ P Yield lb/A.	Gr Yield Bu/A.	P Yield lb/A.	Gr Yield Bu/A.	P Yield lb/A.	Gr Yield Bu/A.
3	4.62	38.4	6.61	25.2	4.31	23.1
6	5.47	40.0	7.44	30.0*	4.59	24.4
13	4.90	38.5	8.07*	25.5	4.80	24.5
14	5.36	38.8	7.24	29.3	4.98	26.5*
17	5.63	38.3	8.28*	28.1	4.66	23.8
18	5.55	44.3	9.34*	31.0*	4.73	26.2*
23	5.63	40.1	7.58	29.9	4.76	24.5
24	5.88	43.2	8.29*	29.9	4.28	25.0
27	6.00*	43.9	8.76*	29.4	5.67	22.8
28	6.63*	44.3	7.80	29.0	5.97*	25.3
29	5.93	45.6*	9.29*	29.4	6.00*	25.2
30	6.73*	45.8*	9.47*	29.9	6.19*	26.8*
LSD (.05)	1.34	6.6	1.27	4.9	1.42	3.1
Treatment	1969					
	Power		Denton		Froid	
	No.1/ P Yield lb/A.	Gr Yield Bu/A.	P Yield lb/A.	Gr Yield Bu/A.	P Yield lb/A.	Gr Yield Bu/A.
3	4.09	23.6	3.57	14.1	3.79	20.9
6	4.70	24.2	4.99	18.2*	3.44	21.1
13	4.28	26.2	3.75	15.3	3.42	25.2
14	6.13*	26.8	4.33	16.8	3.79	28.7*
17	4.79	30.2*	3.89	14.7	3.82	21.4
18	5.89*	29.8*	3.56	17.0	3.77	22.4
23	7.11*	26.1	3.61	17.7*	3.75	24.2
24	7.11*	26.5	4.52	17.6*	3.66	27.2*
27	7.25*	28.9*	5.06*	17.0	4.73	24.5
28	7.41*	28.5*	5.19*	17.3*	5.40*	26.8*
29	7.65*	32.4*	4.03	16.3	4.02	28.8*
30	7.89*	31.0*	4.73	17.5*	4.71	29.2*
LSD (.05)	1.57	3.9	1.39	3.0	1.09	4.7

1/ Fertilizer treatments are listed in Table 1.

\* Significant at the .05 level compared with treatment 3.

P use. At the time of sampling, the wheat was in Feekes stage 10.4, and probably nearly maximum absorption of P had occurred.

Table 20 contains P yield and final grain yield for treatments 3-10, fertilizer placement with-the-seed. As shown by superscripts on the data, P yield was significantly increased compared with the check by 30 pounds P per acre (treatment 10) at all three locations plus treatment 8 and 9 at Froid. Significant grain yield increases occurred with the same treatments. Single degree of freedom comparisons were made at the Denton location between treatments 6, 7, 8, 9, and 10 and treatment 4 (5N + 0 P) to determine the significance of response to banded P and were found to be highly significant. This later comparison is not shown in the table.

Similar results of those in 1968 occurred in 1969 with increased P yield obtained with 30 lb. P per acre with-the-seed, treatment 10 at Power and Denton. Significant increased grain yields occurred with this treatment. At the Froid location increased P yields were not shown to be significant in 1969.

This same trend of increased P yields and significant yield increases with higher rates of broadcast P is shown in Table 21. In general, broadcast rates of 60 and 90 lb. P per acre applied for the 1967 crop with and without starter (treatments 27-30) significantly increased P uptake and grain yields. The most apparent exception was at Froid in 1969.

The data on P yield as influenced by starter fertilizer at different broadcast rates of P are included in graphic form for comparison purposes. Figure 10 for Power, 1968, shows that Starter increased P yield at all levels of broadcast P with greater influence at higher rates. This may be a luxury consumption under conditions of that experiment since grain yields were about equal at 90 lb/A of broadcast P regardless of starter or no starter fertilizer.

P yield data listed in Table 21 for Denton, 1968, showed variation with respect to starter. The same general trends existed with yields, also. Positive starter influence was greatest at 20 and 30 lb. P per acre broadcast and negative or no effect at higher rates.

Table 21 for Denton, 1969, shows increases in P yield due to starter at all levels of broadcast P except 20 lb/A. However, significance was noted only at the zero broadcast level.

P yield for 1969 as related to broadcast P and starter for the Power and Froid locations is plotted in Figures 11, and 12. The P yield for single broadcast treatments as shown in Figure 11 for Power indicated significant influence of starter on up to 20 lb. P, while at 30 P and above very little influence was evident. Grain yields did not respond in the same way as practically no response was noted due to starter for these same treatments. The data for grain yields are shown in Figure 5. A greater influence of starter on P yield resulted with two applications ( 20 P for 1967 plus 20 P for 1969) as shown by

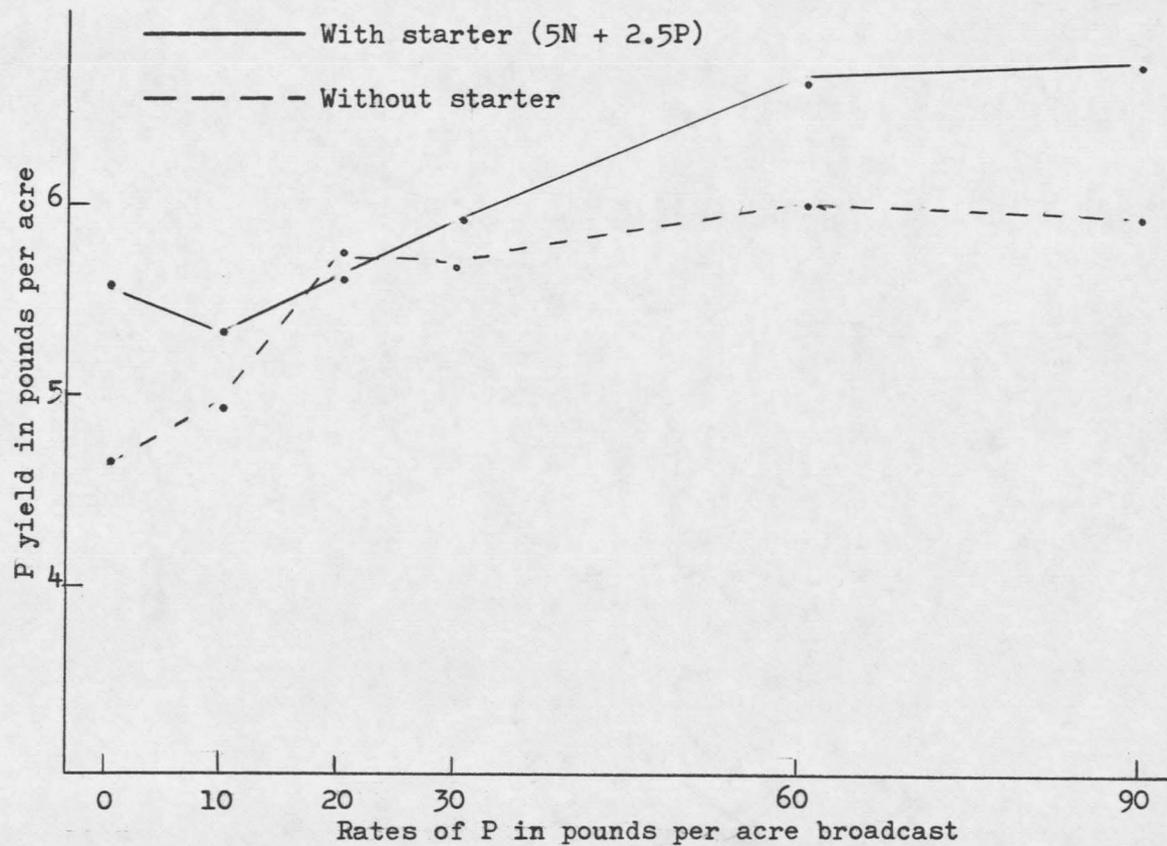


Figure 10. P yield comparisons with and without starter - Power, 1968; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

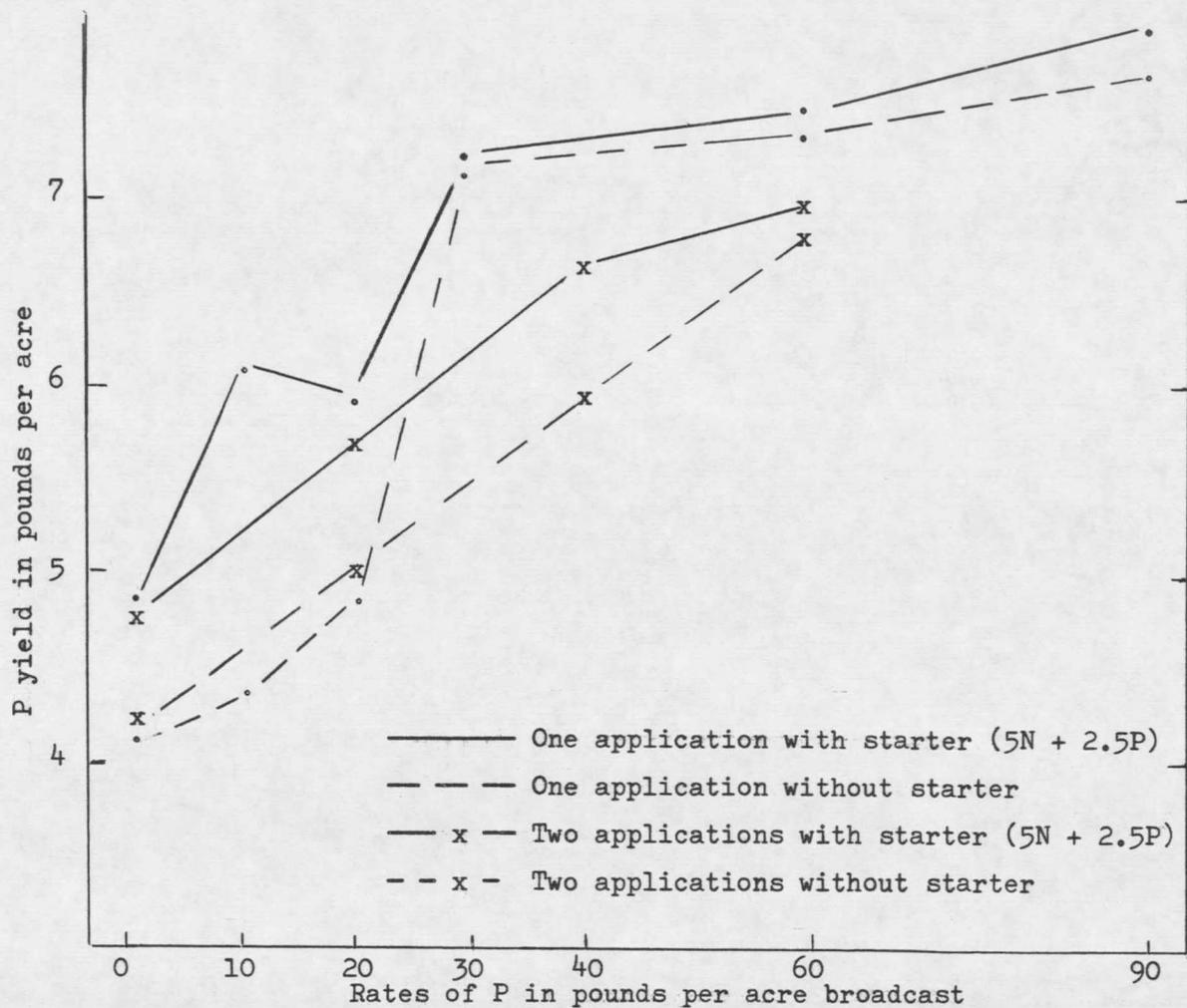


Figure 11. P yield comparisons for broadcast P for one application for 1967 and two applications (one for 1967 plus one for 1969) with and without starter fertilizer - Power, 1969; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

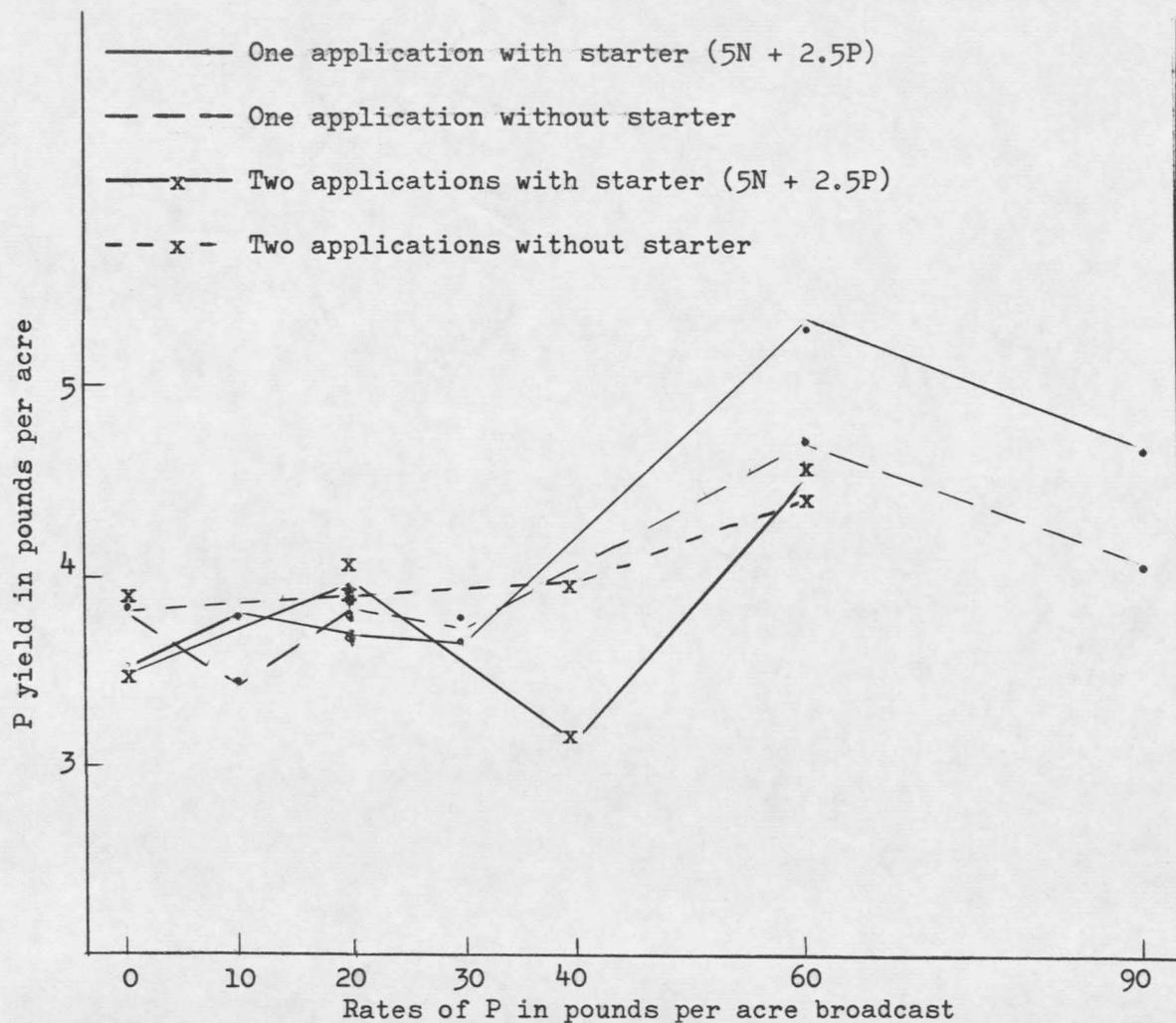


Figure 12. P yield comparisons for broadcast P for one application for 1967 and two applications (one for 1967 plus one for 1969) with and without starter fertilizer - Froid, 1969; spring wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

the imposed lines of Figure 11. However, P yields for the double application of 20 P and 30 P were considerably lower than single applications of 40 and 60 P.

Figure 12 for Froid, 1969, does not show response to starter at the low rates of broadcast P. At rates of 60 and 90 lb. P per acre, the P uptake did increase due to starter. The imposed figure of P yield with double broadcast applications of 10, 20, and 30 P totaling 20, 40, and 60 lb. P per acre, respectively, shows starter effect as practically zero or negative. This was not true with grain yields as a 3 bu/A increase was noted at 20 P plus 20 P due to starter. A complete listing of P yield for all treatments for 1968 and 1969 are in Tables 22, 23, and 24 for Power, Denton, and Froid, respectively.

The P absorption pattern for samples collected at Power throughout the growing season of 1968 is shown in Figures 13, and 14. Only this location was plotted as the absorption pattern with time was relatively the same at all locations and more frequent plant samplings were made for Power. The influence of broadcast P with and without starter was plotted in Figure 13 and the influence of placement with-the-seed was plotted in Figure 14.

It should also be pointed out that P yield increased at a constant rate throughout the season, dependent on the P treatment. This was shown by very little crossing of lines between sample dates. Also in nearly all cases, higher P yield resulted from higher P-rates. Because

Table 22. Culm, kernel count, and kernels/head for 1969 - P yield (final sample) for 1968 and 1969 for Power, winter wheat.

Treatment No. <u>1/</u>	P Yield 1968	P Yield 1969	Culm Count <u>2/</u> 8' of Row	Kernel Count 8' of Row	Kernels Per Head
1, 39	4.31	4.22	157	2335	14.9
2, 40	4.96	4.51	225	2870	12.8
3	4.62	4.09	197	2780	14.1
4	4.92	3.90	169	2690	15.9
5	4.80	4.80	185	3000	16.2
6	5.47	4.70	180	3040	16.9
7	5.32	6.23*	217	3260	15.0
8	5.76	5.76*	232	3500*	15.1
9	6.01*	7.36*	264*	3820*	14.5
10	6.36*	7.49*	250*	4040*	16.2
11	4.90	5.26	196	3320	16.9
12	5.63	5.16	194	3330	17.2
13	4.90	4.28	184	2910	15.8
14	5.36	6.13*	196	3040	15.5
15	4.90	4.97	182	3060	16.8
16	5.36	5.63	220	3470	15.8
17	5.63	4.79	212	3140	14.8
18	5.55	5.89*	221	3760*	17.0
19	5.63	5.98*	214	3080	14.4
20	5.55	6.60*	212	3320	15.7
21	5.63	5.36	194	3390	17.5
22	4.38	5.74*	195	3440	17.6
23	5.63	7.11*	236	3570*	15.1
24	5.88	7.11*	214	3580*	16.7
25	5.63	6.88*	229	3930*	17.2
26	5.88	6.68*	258*	3610*	14.0
27	6.00*	7.25*	222	3750*	16.9
28	6.63*	7.41*	220	3400	15.5
29	5.93	7.65*	246*	4090*	16.6
30	6.73*	7.89*	245*	4140*	16.9
31	5.67	5.47	195	3130	16.1
32	5.64	5.87*	181	3300	18.2
33	5.71	6.06*	210	3190	15.2
34	5.98*	6.03*	210	3450	16.4

Table continued. . .

Table 22. Continued. . .

Treatment No. <u>1</u> /	P Yield 1968	P Yield 1969	Culm count <u>2</u> / 8' of Row	Kernel Count 8' of Row	Kernels Per Head
35	5.41	4.75	174	2790	16.0
36	4.50	4.60	207	3160	15.3
37	6.43*	7.20*	214	3170	14.8
38	6.04	6.51*	270*	3850*	14.3
41	6.11*	5.59	227	3320	14.6
42	5.75	6.97*	249*	4030*	16.2
43	6.47*	5.21	196	3100	15.8
44	4.36	5.31	186	2910	15.7
45	4.79	7.04*	214	3360	15.7
46	5.75	6.87*	232	3870*	16.7

-----  
Analysis of Variance

Source of Var	df	MS	df	MS	df	MS	df	MS
Treatments	30	1.570*	30	5.534**	45	3240**	45	779571**
Exp Error	90	.920	90	1.253	135	1015	135	260050
LSD (.05)		1.34		1.57		45		714

1/ Fertilizer treatments are listed in Table 1.

2/ Includes culms with heads containing three or more kernels.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 23. Culm, kernel count, and kernels/head for 1969 - P yield (final sample) for 1968 and 1969 for Denton, winter wheat.

Treatment No. <u>1</u> / No. <u>2</u>	P Yield 1968	P Yield 1969	Culm Count <u>2</u> / 8' of Row	Kernel Count 8' of Row	Kernels Per Head
1, 39	4.11	2.35	129	1595	12.4
2, 40	2.98	2.25	115	1465	12.7
3	5.12	3.57	144	2010	14.0
4	4.61	4.06	173	2410	14.0
5	5.00	4.39	177	2690	15.2
6	4.87	4.99*	224*	3510*	15.7
7	4.94	4.59	198	2780	14.0
8	4.55	4.76	222*	2830	12.7
9	6.51	4.77	216*	3490*	11.5
10	5.70	5.48*	207*	4150*	20.0
11, 13, 15	4.68	3.75	167	3390*	20.3
14, 16	5.25	4.33	193	2680	13.9
12, 17, 19	5.31	3.89	149	2000	13.4
18, 20	5.04	3.56	158	1910	12.1
21	3.00	3.18	132	1670	12.7
22	4.15	3.23	149	1580	10.6
23, 25	5.04	3.61	182	2290	12.6
24, 26	4.96	4.52	219*	2820	12.9
27	4.60	5.06	222*	3250*	14.6
28	3.83	5.19	197	2980*	15.1
29	5.55	4.08	155	1960	12.6
30	6.38*	4.73	220*	2940*	13.4
31	4.68	3.99	169	2480	14.7
32	5.25	4.77	208*	2650	12.7
33	5.31	3.18	167	2200	13.2
34	5.04	3.52	166	2030	12.2
35	4.68	1.92	112	1200	10.7
36	4.84	3.07	133	1380	10.4
37	5.31	2.07	109	1130	10.4
38	4.83	1.67	106	930	8.8
41	5.01	4.96*	237*	3440*	14.5
42	5.83	5.37*	207*	3420*	18.8
43	5.66	5.43*	236*	2520	10.7
44	5.94	5.38*	225*	3020*	13.4
45	4.83	4.40	196	2830	14.4
46	5.49	3.50	163	2050	12.6

Table continued. . .

Table 23. Continued. . .

	P Yield 1968	P Yield 1969	Culm Count <u>2</u> / 8' of Row	Kernel Count 8' of Row
Analysis of Variance				
Source of Var	df MS	df MS	df MS	df MS
Treatments	26 2.589**	30 4.249**	45 5816**	45 2096241**
Exp Error	78 .828	70 .983	135 1754	135 437722
LSD (.05)	1.27	1.39	59	926

1/ Fertilizer treatments are listed in Table 1.

2/ Includes culms with heads containing three or more kernels.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

Table 24. Culm, kernel count, and kernels/head for 1969 = P yield (final sample) for 1968 and 1969 for Froid, spring wheat.

Treatment No. 1/	P Yield 1968	P Yield 1969	Culm Count 2/ 8' of Row	Kernel Count 8' of Row	Kernels Per Head
1, 39	4.19	3.55	241	3750	15.6
2, 40	4.41	3.46	206	3470	16.8
3	4.31	3.79	188	3200	17.0
4	4.32	4.06	186	3800	20.4
5	4.42	3.75	211	3830	18.2
6	4.59	3.44	2.4	3730	17.4
7	5.68	3.43	242*	4000	16.5
8	5.96*	3.89	241*	4260*	17.7
9	6.55*	4.47	257*	4230*	16.5
10	6.71*	4.59	250*	4670*	18.7
11	5.10	3.46	195	3860	19.8
12	5.25	3.89	218	4430*	20.3
13	4.83	3.42	198	3940	19.9
14	4.97	3.79	218	3840	17.6
15	4.83	3.93	215	3910	18.2
16	4.97	3.99	206	3550	17.2
17	4.67	3.82	227	4180*	18.4
18	4.73	3.77	225	3550	15.8
19	4.67	3.98	227	4520*	19.9
20	4.73	3.17	233	4290*	18.4
21	4.18	3.81	213	3690	17.3
22	5.33	3.86	250*	4140	16.6
23	4.70	3.75	254*	3710	14.6
24	4.27	3.66	255*	3950	15.5
25	4.70	4.47	215	3870	18.0
26	4.27	4.51	249*	4080	16.4
27	5.67	4.73	215	4170*	19.4
28	5.97*	5.40*	224	4400*	19.7
29	6.00*	4.02	233	4120	17.7
30	6.19*	4.71	252*	4660*	18.5
31	5.10	3.67	240*	3830	16.0
32	5.04	3.48	210	3360	16.0
33	4.73	3.88	224	3950	17.6
34	4.38	3.47	218	3600	16.5

Table continued. . .

Table 24. Continued. . .

Treatment No. <u>1</u> /	P Yield 1968	P Yield 1969	Culm Count <u>2</u> / 8' of Row	Kernel Count 8' of Row	Kernels Per Head
35	4.54	4.60	231	4180*	18.1
36	3.80	4.45	235	4690*	20.0
37	4.07	3.39	172	4020	23.4
38	4.53	4.24	240*	3610	15.0
41	4.92	4.52	242*	4300*	17.8
42	5.08	4.47	231	4280*	18.5
43	5.09	4.08	189	3350	17.7
44	5.09	3.76	234	3900	16.7
45	4.65	3.72	233	4040	17.3
46	5.39	4.00	225	4340*	19.3

Analysis of Variance

Source of Var	df	MS	df	MS	df	MS	df	MS
Treatments	32	2.148**	32	.983*	45	1819	45	663050
Exp Error	96	1.013	96	.602	135	1256	135	468867
LSD (.05)		1.42		1.09		50		959

1/ Fertilizer treatments are listed in Table 1.

2/ Includes culms with heads containing three or more kernels.

\*\* Significant at the .01 level.

\* Significant at the .05 level.

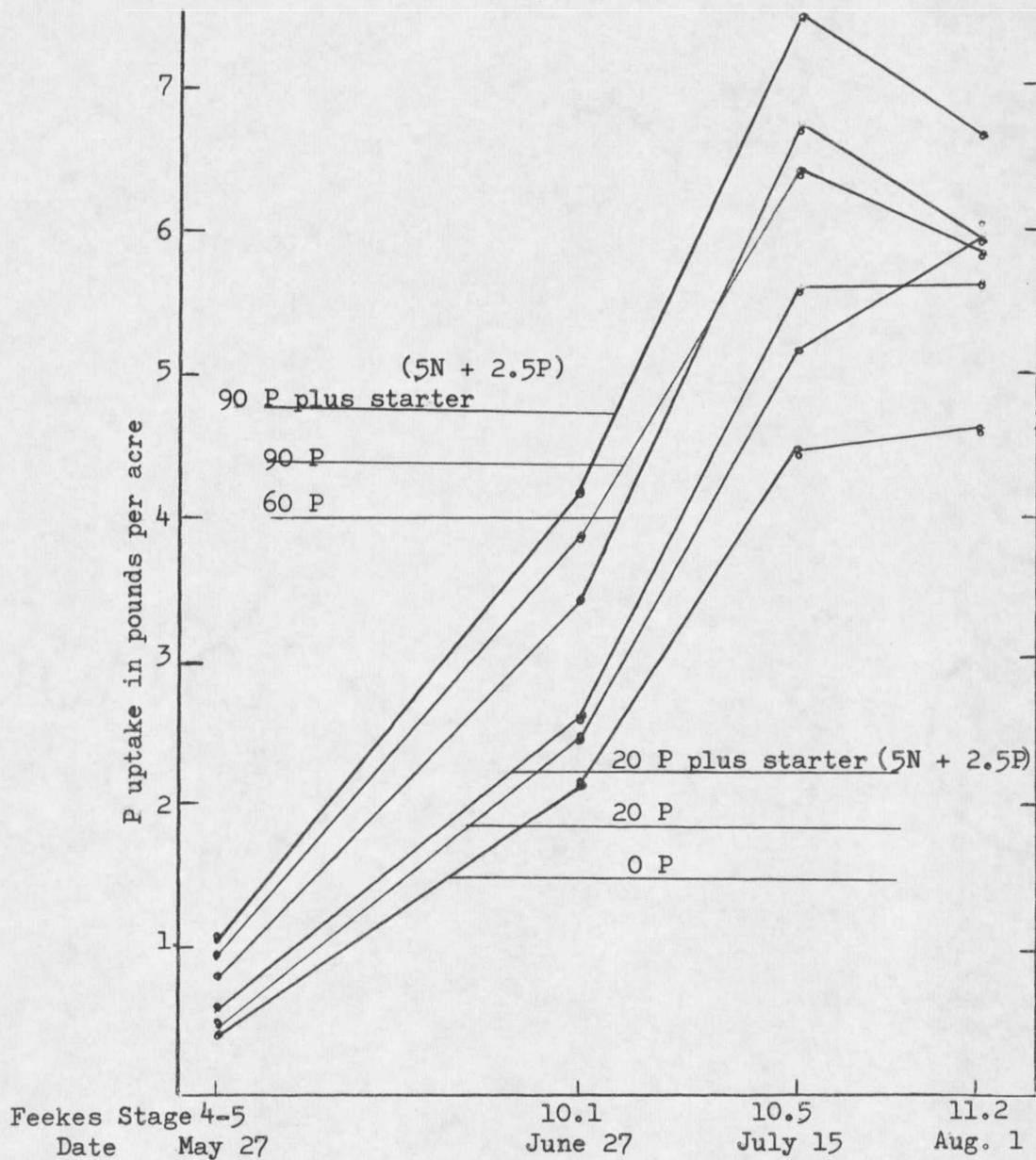


Figure 13. P uptake as related to broadcast P at four stages of plant development - Power, 1968; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

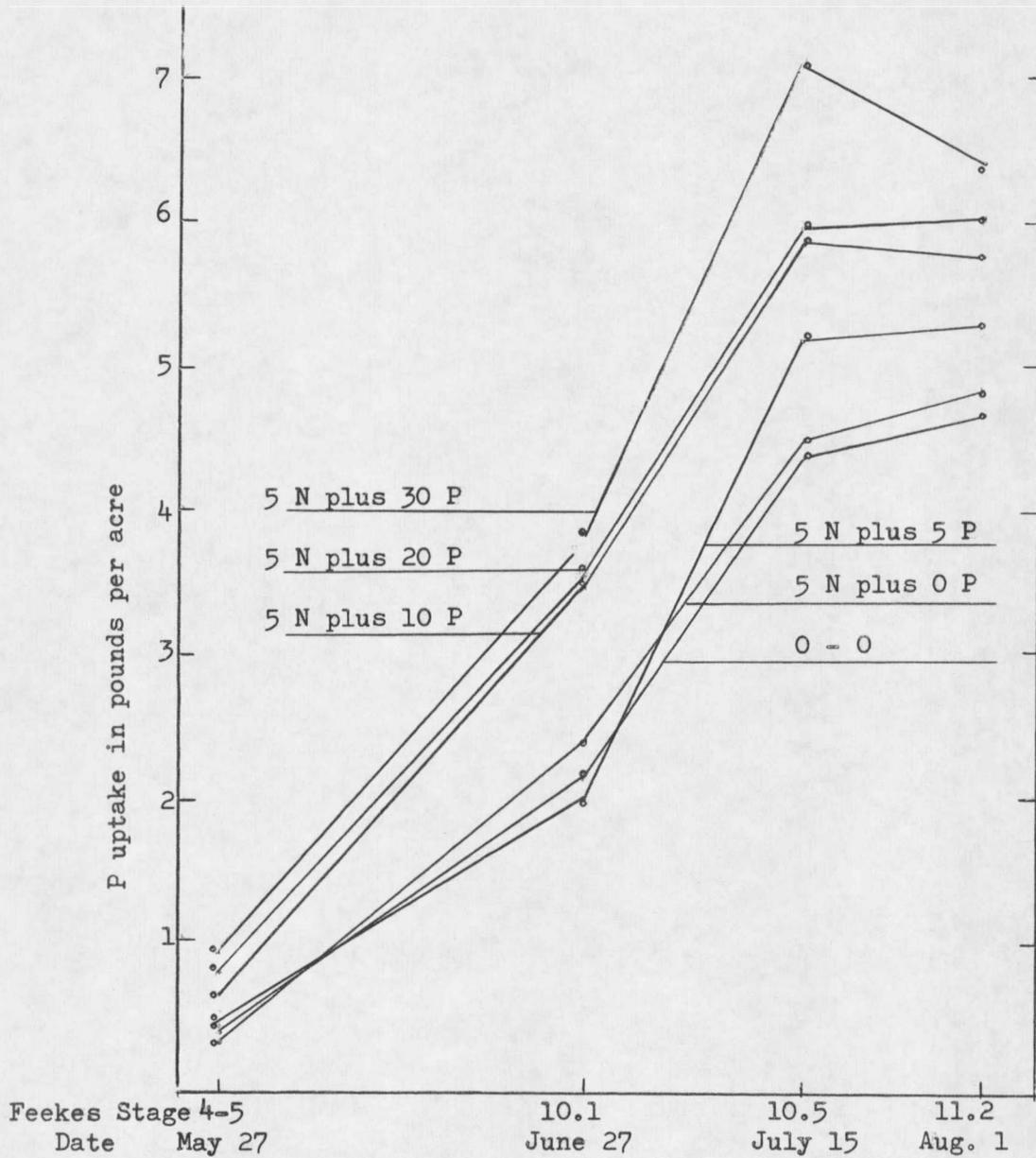


Figure 14. P uptake as related to with-the-seed placement of fertilizer at four stages of plant development - Power, 1968; winter wheat (all treatments had 40 lb. N and 25 lb. K/A, topdressed in the spring).

of the rapid increase in P yield with time, it would be difficult to use it as a predictive tool for final P absorption or yield.

A slight drop in P yield noted after heading, seemed more pronounced with higher rates of P fertilizer. A similar response can be observed in the data of Choriki (16) at the Central Montana Experiment Station with winter wheat. He found that with lower rates of P applications, the plants continued to absorb P after heading while those with adequate P reached maximum P uptake by heading. Possibly the small loss of dry matter or whatever causes the slight drop in P yield is partially offset by this continued uptake of P by the check treatment and lower rates of P application.

#### Culm And Kernel Count--1968 and 1969

The discussion for culm count will have more meaning if the 1969 data are referred to first. Culm count showed the same trends for both 1968 and 1969 but kernel counts were made only in 1969. Culms counted in 1969 contained heads with approximately three or more kernels. Kernel counts were determined for the same 8' section of row. There was very little difference between the number of culms with heads and total culms, probably less than three percent. In 1968, all culms were counted without checking for heads. Kernels per head were determined for each location but differences due to P treatments were inconsistent. However, there was a trend of 2-3 kernels per head more with higher rates of P with-the-seed or broadcast than check treatments

with no N or P fertilizer. Culm count, kernel count, and kernels per head for 1969 are listed for Power in Table 22, for Denton in Table 23, and for Froid in Table 24.

Significant increases in culms and kernel count were noted with respect to P applied with-the-seed, treatments 7, 8, 9, and 10, and P broadcast rates of 60 and 90 lb. P/A, treatments 27, 28, 29, and 30. At the Power location, treatments 7, 8, 9, and 10 with P rates of 5, 10, 20, and 30 P were significantly increased over the check treatment 4 with respect to culm count and similarly with kernel count for treatments 8, 9, and 10. Also there were significant increases noted with broadcast P for treatments 26, 29, and 30 with P-rates of 30, 60, and 90 P with respect to culm count over treatment 3 and treatments 26, 27, and 30 for kernel count.

Culm count values have been plotted with grain yields to show these relationships with broadcast rates of P. First, by checking Figure 7 for 1969 Denton data, a very similar pattern of culm count with final yields can be noted. Some difference existed at the 20 lb. P/A level as culm count did not show the variation as did grain yields due to starter fertilizer but both values were lower than zero P plus starter, as were yields. Notice also that at 60 and 90 lb. P broadcast, culm counts showed the same type of spread as did grain yields.

Figures 1, 2, and 4 pages 51, 52, and 55 show the culm count and grain yields for 1968. Figure 1 shows the Power data for starter and

no starter with culm count and final grain yield. By comparing curves for culm count and final grain yield, a very similar pattern resulted. Slight variation existed with starter at 20 lb. P per acre but all other points are almost identical. This trend was evident with the other locations in 1968, Denton--Figure 2, and Froid--Figure 4. The Froid data for 1968 probably show the best overall similarity between culm count and final grain yields with changes in P-rates.

These relationships, increased culm count and increased final grain yields, were also found with placement of fertilizer with-the-seed. Complete data are given in Tables 8, 9, and 10 for 1968 and 12, 13, and 14, for 1969.

A comparison of various combinations of N and P is plotted in Figure 15 showing the influence of broadcast P at zero and 20 lb/A on culm count at Denton, 1968. With zero N, there was little effect on culm counts with 20 lb. P per acre broadcast compared to zero P. Culms were increased with 40 lb. N per acre to 260 per 8' of row without broadcast P, but were increased to 309 per 8' of row with 20 lb. P per acre broadcast. An additional increase in culm count to 328 was noted with starter at zero P plus 40 lb. N/A with no added increase from 20 lb. P/A broadcast. At the Power location, starter fertilizer gave increased culms with 40 lb. N and zero and 20 lb. P broadcast and at Froid 40 N plus 20 P plus starter (5N + 2.5P) significantly increased count. These data indicated the need for both N and P for more culms.

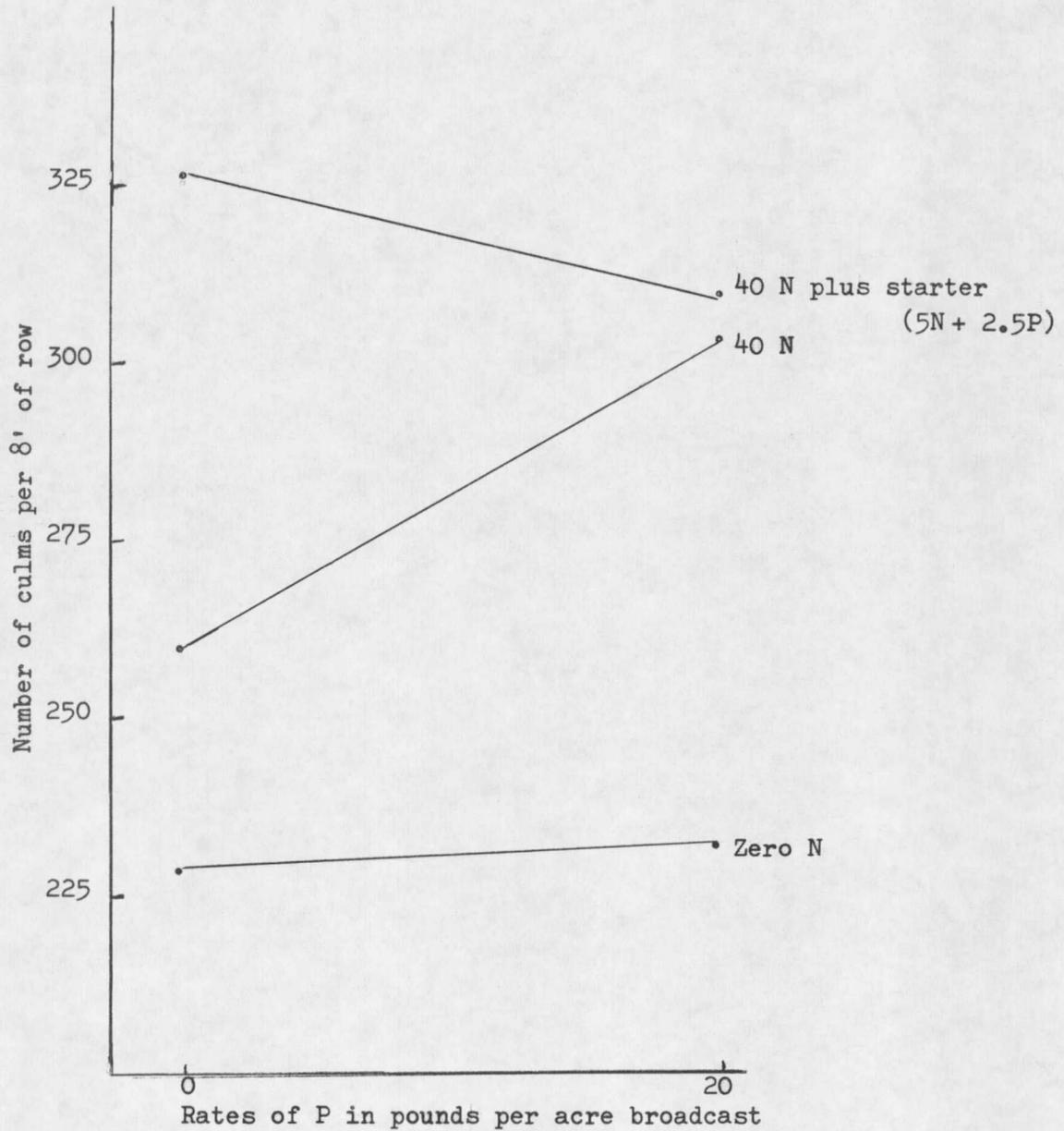


Figure 15. Culm count as influenced by 0 and 20 lb. P/A at Denton, 1968; winter wheat.

The data presented on culm count and grain yield show as the number of culms increased due to fertilizer treatments so did grain yields. This is in agreement with Black (7) in working with spring wheat at Sidney, Montana.

Comparison of 10, 20, and 30 lb. P per acre applied with-the-seed and 10, 20, and 30 lb. P per acre applied broadcast were made from the data in Tables 8 for Power, 9 for Denton, and 10 for Froid. Both the 1968 and 1969 results showed increased culm counts with-the-seed.

Culm counts were increased with 10 and 20 lb. P per acre with-the-seed compared with 10 and 20 lb. P broadcast in every case regardless of whether starter was or was not applied with fertilizer at all locations for 1968 and 1969. At Power for both years, and Froid in 1968, 30 lb. P with-the-seed increased culms compared with 30 lb. P broadcast, both with and without starter. At Denton in 1968 and 1969, and Froid in 1969, culm counts were about the same at 30 lb. P regardless of application method. It was also noticed that generally, culm counts were not substantially increased due to fertilizer treatments above the level reached at 30 lb. P per acre.

#### Comparisons Between Broadcast P And With-The-Seed Applications

Comparison was made between broadcast P and with-the-seed applications at the same rates; see Table 25. Higher yields, although not significant, were obtained at the 10 lb. P per acre rate with-the-seed compared with broadcast at all locations in 1968 and Denton for 1969.

Table 25. Grain yield comparisons with-the-seed and broadcast P at 10, 20, and 30 lb. P per acre. Winter wheat at Power and Denton, spring wheat at Froid, 1968 and 1969.

Location Year	10 P		One Application 1967 Gr Yield Bu/A
	With-the-Seed <u>1/</u> Gr Yield Bu/A	Broadcast Gr Yield Bu/A	
Power 1968	41.6	38.5	
Denton 1968	26.8	25.5	
Froid 1968	27.0	24.5	
Denton 1969	17.6	16.0	
<hr style="border-top: 1px dashed black;"/>			
	<u>10 P 1967 plus 10 P 1969</u>		<u>20 P</u>
Power 1969	28.1	28.3	30.2
Froid 1969	23.9*	21.4	19.1
<hr style="border-top: 1px dashed black;"/>			
	<u>20 P</u>		
Power 1968	41.5	38.3	
Denton 1968	27.9	28.1	
Froid 1968	26.6 <sup>⊙</sup>	23.8	
Denton 1969	18.2*	14.8	
<hr style="border-top: 1px dashed black;"/>			
	<u>20 P 1967 plus 20 P 1969</u>		
Power 1969	25.6	26.5	
Froid 1969	26.2 <sup>⊙</sup>	22.3	
<hr style="border-top: 1px dashed black;"/>			
	<u>30 P</u>		
Power 1968	43.1	40.1	
Denton 1968	28.4	29.9	
Froid 1968	26.5	24.5	
Denton 1969	18.6	17.3	
<hr style="border-top: 1px dashed black;"/>			
	<u>30 P 1967 plus 30 P 1969</u>		<u>60 P</u>
Power 1969	29.4	29.9	28.9
Froid 1969	24.2	24.2	21.9

1/ 5 lb. N/A applied with-the-seed and 40 lb. N and 25 lb. K/A, topdressed in the spring.

\* Significant at the .05 level.

<sup>⊙</sup> Significant at the .10 level.

Applications of 20 P (10 lb. P for 1967 plus 10 lb. P for 1969) were compared with 20 lb. P/A applied singly in 1967. At Power, one application of 20 lb. P appeared slightly better while at Froid, double applications of 10 P with-the-seed produced significantly increased yields.

At the 20 lb. P-rate, significant yield increases were noted with-the-seed compared with broadcast at Froid for 1968 and Denton for 1969. At 40 P (20 lb. P for 1967 plus 20 lb. P for 1969) grain yield from with-the-seed applications was significantly higher at Froid in 1969.

At the 30 lb. P/A rate, general increases occurred with-the-seed over broadcast rates but increases were not significant. At the rate of 30 lb. P for 1967 plus 30 lb. P for 1969 with-the-seed, there was no yield increase over the 1967 60 lb. P/A broadcast rate. This might indicate that soil P levels from applications in 1967 and 1969 were great enough that P applied close to the seed was no longer of much benefit.

The implications of the previously discussed data stress the importance of placement of P with-the-seed and/or the application of 5 lb. N/A in combination with the P placed with-the-seed.

#### Influence of Season of Application

Time of fertilizer application comparisons for a given crop were made. The separate application combinations are listed as follows: 1) P broadcast in the fall just prior to seeding plus N topdressed on the

crop in the spring, 2) P broadcast before fallow operations started plus N topdressed on the crop in the spring, and 3) N and P broadcast before fallow. At Froid a slight modification was made for spring wheat; two treatments were broadcast in the spring before seeding.

The above application methods were only made with two rates of P, 10 and 20 lb/A and the data for 1968 and 1969 are shown together. Information was not available for Denton in 1968 as this experiment was one year later than the other two caused by loss of the Stanford location because of soil variability. Table 26 lists grain yields for various applications with 10 and 20 lb. P per acre at Power and Froid for 1968 and for Power, Denton, and Froid for 1969.

No real trends were noted for either 1968 or 1969 with 10 lb. P per acre. The only significant value was a decrease in yield noted at Denton in 1969 when N and P was applied before fallow. The decreased yield with both 10 and 20 P plus N applied on the summer fallow resulted when the wet summer prevented the working of the fallow until after July 10. Weeds were two to three feet taller than untreated areas. The farmer was quoted as saying, "what did you put on the summer fallow, it sure does make the weeds grow." Evidently the N and P fertilizer was tied up in organic material and not available for the 1969 crop.

Precipitation data given in Appendix table 45 shows that over 10 inches of precipitation fell from May through September that year.

Table 26. Influence of time of fertilizer application (10 and 20 lb. P/A and 40 N) on 1968 and 1969 grain yields. Winter wheat at Power and Denton, spring wheat at Froid.

<u>Location and Year</u> P lb/A	<u>N+P Before Fallow</u> Bu/A	<u>P Before Fallow N Topdressed</u> Bu/A	<u>P Fall Prior to Seeding N Topdressed</u> Bu/A	
<u>10 P</u>				
Power 1968	38.9	40.2	38.5	
Froid 1968	24.6	24.3	24.5	23.7 <u>1/</u>
<u>20 P</u>				
Power 1968	42.9	44.00	38.3	
Froid 1968	24.5	21.4	23.8	24.9 <u>1/</u>
<u>10 P</u>				
Power 1969	30.1	27.3	28.3	
Denton 1969	6.8*	15.3	15.3	
Froid 1969 <u>2/</u>	24.5	19.1	21.4	21.6 <u>1/</u>
<u>20 P</u>				
Power 1969	28.8	25.5	26.5	
Denton 1969	8.2*	14.7	14.7	
Froid 1969 <u>2/</u>	24.6	22.2	22.3	22.8 <u>1/</u>

1/ Grain yields for P broadcast in the spring N topdressed - Froid only.

2/ N rates to 20 lb/A in 1969.

\* Significant at the .05 level.

0 Significant at the .10 level.

There may have been some N loss due to leaching, at least from the upper few inches of soil.

With the drastic reduction noted at Denton and some minor yield changes at the other location, it would appear that time of application of P fertilizer was not as important as the change in the time of N application. Phosphorus broadcast before the fallow compared with the P broadcast in the fall prior to seeding and N topdressed in the spring in both cases showed practically no difference in yields except at Power for 1968 at 20 lb. P per acre. This yield increase at 20 P before the fallow was significant at the 10% level compared with 20 P applied in the fall. In no case was there a significantly lower grain yield for P applied before fallow than for P applied just prior to seeding. Evidently the P availability was great enough with 10 and 20 lb. P/A to give maximum yields in 1969 with either application time. The fact that the soil at the Power location was calcareous to the surface and contained approximately 14%  $\text{CaCO}_3$  equivalent did not reduce P availability enough to lower yields.

#### Influence Of Starter On Time Of Fertilizer Application

Differences were non-significant at all locations and for all years. Most increases due to starter were obtained with P applied just prior to seeding in the fall. One exception was noted with Power in 1968 at 10 lb. P per acre. A greater yield, 5 bu/A, was recorded when

starter was placed with P applied before fallow. The data for this comparison is in Table 8 on pages 42 and 43, treatments 32 versus 14 and 16.

#### Low Rates Of N And P Fertilizer Applied With-The-Seed

Various low rates of N and P fertilizer applied with-the-seed have been evaluated as to influence on yields with broadcast fertilizer of 10, 20, and 30 lb. P/A. Yield response to the different fertilizers with-the-seed was low, but Table 27 indicates that as the rate of broadcast P increases, the rates of N and P needed for yield increases changed from 5 lb. N plus 2.5 lb. P to 5 lb. N plus 5 lb. P. At 10 lb. P/A, zero N plus 2.5 P or 5 N plus 2.5 P applied with-the-seed, were about equal in effectiveness. With rates of 10 P for 1967 plus 10 P for 1969 and likewise for 20 P, 5 N plus 2.5 P applied with-the-seed gave slightly higher grain yields. At broadcast 30 lb. P, 5 N plus 5 P showed slightly increased yields.

These data indicate that with increased broadcast rates of P, the rate of P with-the-seed may need to be increased. Additional research is needed to determine if the above differences are significant and why.

#### Source Of Fertilizer

Two sources of P fertilizer were compared using TVA ammonium polyphosphate (15-60-0) versus concentrated superphosphate (0-45-0).

Table 27. Grain yield as influenced by low rates of N and P with-the-seed in combination with 10, 20, and 30 lb. P per acre broadcast. Winter wheat at Power and Denton, spring wheat at Froid, 1968 and 1969.

Location Year	10 P Broadcast			
	N		P	
	0	2.5	5	2.5
	Gr Yield Bu/A		Gr Yield Bu/A	
Power 1968	41.1		38.8	
Denton 1968	27.5		29.3	
Froid 1968	26.7		26.5	
Denton 1969	16.0		16.7	
-----				
	<u>10 P 1967 plus 10 P 1969</u>			
Power 1969	26.3		29.4	
Froid 1969	22.1		22.1	
-----				
	20 P Broadcast			
	N		P	
	0	2.5	5	2.5
	Gr Yield Bu/A		Gr Yield Bu/A	
Power 1968	40.4		44.3	42.8
Denton 1968	28.1		31.0	26.9
Froid 1968	29.2		26.2	25.9
Denton 1969	14.6		16.6	17.0
-----				
	<u>20 P 1967 plus 20 P 1969</u>			
Power 1969	25.9		27.7	26.8
Froid 1969	22.7		24.9	25.6
-----				
	30 P Broadcast			
			P	
			5	2.5
			Gr Yield Bu/A	
Power 1968			43.2	44.4
Denton 1968			29.9	30.5
Froid 1968			25.0	25.8
Denton 1969			16.2	19.5
-----				
	<u>30 P 1967 plus 30 P 1969</u>			
Power 1969			28.7	28.1
Froid 1969			24.1	24.9

N (33.5-0-0) was used for the source of N to balance N rates. Treatments were applied before the fallow, and yield measurements were made for the following crop. These grain yields are shown in Table 28 for 1968 and 1969.

Although non-significant, the ammonium polyphosphate (15-60-0) yielded slightly more than concentrated superphosphate (0-45-0) at comparable rates.

A wide range of conditions has occurred as noted by the grain yields of 6.8 to 45 bu/A but as yet no significant differences due to P source are evident. These treatments should be watched closely in the next two years to see if differences develop.

Table 28. Grain yield as influenced by source of fertilizer (15-60-0) TVA ammonium polyphosphate, 0-45-0, and N (33.5-0-0): Power and Froid, 1968, and Power, Denton, and Froid, 1969. Winter wheat at Power and Denton, spring wheat at Froid.

Year Location	P lb/A	Applied on Fallow <sup>1/</sup>	
		15-60-0 <sup>2/</sup> Yield in Bu/A	0-45-0 Yield in Bu/A
<u>1968</u>			
Power	10	39.3	38.9
	20	45.0	42.9
Froid	10	24.0	24.6
	20	24.1	24.5
<u>1969</u>			
Power	10	28.2	30.1
	20	30.1	28.8
Denton	10	7.6	6.8
	20	8.3	8.2
Froid	10	25.7	24.5
	20	27.0	24.6

<sup>1/</sup> N (33.5-0-0) applied with 15-60-0 and 0-45-0 to balance N for treatments at 40 lb. and 25 lb. K/A, topdressed in the spring.

<sup>2/</sup> TVA ammonium polyphosphate.

## SUMMARY AND CONCLUSIONS

Placement of fertilizer with-the-seed at rates of 5 lb. N per acre plus 2.5 to 30 lb. P per acre showed significant grain yield increases. The range of increases in yields was up to 5.3 bu/A for 5 lb. N plus 2.5 lb. P per acre and 2.9 to 8.4 bu/A increases with 5 lb. N plus 30 lb. P per acre. The average increase of all P treatments compared with the check treatment at all locations for 1968 and 1969 was 2.51 bu/A and 4.53 bu/A, respectively.

Broadcast rates of P fertilizer showed significant grain yield increases from 10 to 90 lb. P per acre. Average yield increases for 10 and 30 lb. P per acre were 1.65 to 3.56 bu/A, respectively, compared with check treatment. All treatments except the zero check received 40 lb. N/A per crop year.

Starter fertilizer (5 lb. N plus 2.5 lb. P/A) placed in combination with all broadcast treatments showed yield increases at rates of 10, 20, and 30 lb. P/A at most locations as compared with broadcast P and no starter. There was a different response to starter fertilizer with spring wheat compared with winter wheat. In 1968, spring wheat yields showed significant increases in grain yield due to starter with up to 90 lb. P/A broadcast.

Significant yield increases due to starter on winter wheat seldom exceeded responses obtained from 30 lb. P/A broadcast, at the Denton location, and from 60 lb. P/A at the Power location. The differences

in response at the two winter wheat locations was a reflection of available P as shown in soil test information. The available soil P level at Denton was 32 ppm while Power was lower with 18 ppm.

A possible explanation of the added response of spring wheat to starter may be the less extensive root system compared with winter wheat. Spring wheat probably absorbs a higher percentage of its total P from the starter than does winter wheat. Also young plants require a higher concentration of P especially with lower soil temperatures. The starter may provide this added concentration of P in the spring necessary for increased yields.

Placement of fertilizer with-the-seed generally showed greater increased yields at lower rates of P than broadcast P. The average yield increase due to 5 lb. N plus 2.5 lb. P/A with-the-seed exceeded the average yield increase of 10 lb. P broadcast by about one bushel. Also at 30 lb. P/A, average increases were greater with-the-seed being 4.53 bu/A and 3.51 bu/A for broadcast. Or stating this another way, 10-15 lb. P per acre placed with-the-seed was approximately equivalent to 30 lb. P broadcast. Evidently, the placement of P fertilizer with-the-seed has advantages in being more available for early plant growth and development and this was important for increased yields.

It was further observed that adequate P was needed to significantly increase culm count even if N was applied. Significant increases were not observed with 40 lb. N/A unless P was applied at the Denton site in

1968. Comparisons of culm counts and final grain yields were made. Response to broadcast P at rates of 0, 10, 20, 30, 60, and 90 lb/A with and without starter as shown by culm count and grain yield were almost identical for the 1968 crop at all locations. The same trends were evident for the 1969 data.

Grain yields in 1969 reflected residual P from P fertilizers applied in 1967. The residual P increased yields as much as did two applications (one for 1967 plus one for 1969) for comparable rates. The data indicate the P availability after a 2-year period was still great enough to give maximum yields in 1969.

P percentage values reflected P treatment at the very early stages of development, Feekes stage 2 for winter wheat and Feekes stage 4 for spring wheat; but it was found that P percentage values of winter wheat by the six-leaf stage in the spring, Feekes stage 4-5, showed little influence of P fertilizer treatment. However, the important component of P yield at this time was dry matter weight which did reflect P treatment.

It was shown that if P percentage values are to have any meaning for predictive purposes on final yields, it must be at the early plant development stages. P yield, however, reflected P treatment throughout the growth of the plant. It appears that P fertilizer has a greater influence on final yields at the very early developmental stages than

any other time of growth. Seatz (70) concluded the time of critical P need was prior to the fourth week for corn.

With several sample dates throughout the growing season, the P yield increased at a constant rate dependent on P treatment. There was a tendency of treatments with low P-rates, 0-10 lb. P/A, to show continued P uptake after heading while treatments with 60-90 lb. P/A did not. There may have been a slightly sharper rate of increase in uptake at the early development stages with highest rates of P.

Test weight and protein percentage were not influenced to any measurable degree by P fertilizer treatments. Protein percentage did show response to N treatments, but N treatments were not evaluated in this thesis except as related to P absorption.

Season of fertilizer application was evaluated considering; 1) N and P applied broadcast before fallow, 2) broadcast P in the fall before seeding with N topdressed on the crop, 3) P broadcast before fallow with N topdressed on the crop in the spring. Very little difference was observed between time of applications 2) and 3). Application method 1) did not prove very satisfactory when grain yields were actually decreased by 50% at one location in 1969 due to a wet summer and extreme weed growth caused by early N applied before fallow.

Very little difference was noted between two P fertilizer sources TVA ammonium polyphosphate (15-60-0) and concentrated superphosphate (0-45-0) with 33.5-0-0 N used to balance the N rate. Applications were

made broadcast before fallow and grain yields determined the following year. This aspect of the experiment will need to be checked in the coming two years to determine if differences develop.

Conclusions Obtained From The Results Of This Study

1. Placement of fertilizer with-the-seed significantly increased grain yields at lower rates of P more than did broadcast fertilizer.
2. Starter fertilizer (5 lb. N plus 2.5 lb. P/A) significantly increased yields at 0, 10, 20, and 30 lb. P/A broadcast, consistently, and occasionally at 60 and 90 lb. P/A broadcast. Spring wheat showed a greater response due to the starter than did winter wheat.
3. If P percentage of wheat plants is to have any predictive meaning for P needs for increasing grain yields, it must be in the early developmental stages before Feekes stage 4, the five to six-leaf stage of winter wheat.
4. The number of culms (heads) was a function of P availability and was directly related to grain yields especially in the range of significant yield increases up to 30 lb. P/A.
5. P yield increased at a constant rate throughout the season, dependent on P treatment. Continued P uptake after heading was relatively greater with those treatments having low rates of broadcast P, 0 or 10 lb. P/A, compared with the higher rates of 60-90 lb. P/A.
6. There was no significant loss of grain yields in 1969 for broadcast P applications made for the 1967 crop. Evidently the P

availability was great enough with 10 and 20 lb. P/A to give maximum grain yields in 1969. The fact that the soil at the Power location was calcareous to the surface and contained approximately 14%  $\text{CaCO}_3$  equivalent did not reduce availability enough to lower yield response.

7. Soil test for P availability did relate to the pattern of P responses obtained as shown by grain yields, culm, and other measurements.

8. Additional time and study are needed on these experiments to adequately determine the relative effectiveness of broadcasting and of banding P fertilizers, and to determine the economic effects of the residual P.

APPENDIX

Table 29. Soils description--Power.

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The soils in and around the experimental area at the Power location are considered mainly as soils of the Cargill soil series. A shortened description of this soil has been included below. Complete soils series descriptions are available from the USDA, S.C.S.

<u>Soil Profile</u>	<u>Cargill Series</u>
A <sub>p</sub> 0-6"	Light brownish gray (10YR 5.5/2) silty clay loam-est. 30 to 38% clay, 10YR 4/2 moist; cloddy and moderate very fine crumb structure; hard, very friable, sticky, and plastic; strongly calcareous.
B <sub>2</sub> 6-13"	Silty clay loam-est. 30-33% clay; weak medium and coarse prismatic structure; strongly calcareous.
B <sub>3ca</sub> 13-17"	Silty clay loam differing from the B <sub>2</sub> above mainly in that it is very strongly calcareous.
C <sub>1ca</sub> 17-25"	Silty clay loam-est. 33% clay; very strongly calcareous with common lime splotches.
C <sub>2</sub> 25-30"	Silty clay loam; very strongly calcareous with a few lime splotches.
R. 30-50"	Clayey shales; strongly calcareous.

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Table 30. Soils description--Denton.

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The area is mapped as a soil complex of Coffeek and Ekah soil series at the Denton location. The plot area is predominantly Coffeek clay loam 95% plus. The soils description provided by the Soil Conservation Service of the Coffeek soil series is listed below.

<u>Soil Profile</u>	<u>Coffeek clay loam - cultivated</u>
Ap 0-5"	Dark grayish-brown (1OYR 4/2) dry; (1OYR 3/2) moist; clay loam; moderate fine crumb structure; soft, friable, sticky, and slightly plastic; noncalcareous.
A3 5-9"	Clay loam 1OYR 4/3 dry; 1OYR 3/3 moist; moderate medium subangular blocky structure; hard, friable, sticky, and plastic; weak effervescence in places only.
C1ca 9-18"	Clay loam weak medium and fine subangular blocky structure; violent effervescence; gravels partially coated with lime.
C2ca 18-44"	Clay loam, violent effervescence, pebbles undercoated with lime.
C3ca 44-51"	Very gravelly sandy clay loam; strong effervescence.
C4 51-79"	Very gravelly sand, moderate effervescence, some pebbles thinly undercoated.

These soils tend to grade into the Danvers type soils which are slightly deeper to the calcareous layer and have a better defined B horizon. The deeper type soils are also found in the area where the experimental plots are located. (Complete soils descriptions are available from the Soil Conservation Service.)

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Table 31. Soils description--Froid.

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The soils at the Froid location are best characterized by a soils description taken in the general area of the plots by the Soil Conservation Service. The soils description is listed below.

<u>Soil Profile</u>	<u>Williams loam</u>
A <sub>p</sub> 0-7"	Dark grayish-brown (10YR 3/2) loam; 10YR 3/2 moist; strong fine crumb structure; slightly hard; very friable, sticky, and plastic; noncalcareous.
B <sub>2t</sub> 7-15"	Same color as A <sub>p</sub> clay loam; moderate fine and medium prismatic structure; hard, friable, sticky, and very plastic; noncalcareous.
B <sub>3</sub> 15-20"	Clay loam; moderate medium prismatic structure; noncalcareous.
C <sub>ca</sub> 20-36"	Clay loam; violent effervescence; lime crusts on undersides of gravel.
C 36-60"	Clay loam; strong effervescence.

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Table 32. Soil pH, conductivity, and organic matter data for Power, Denton, and Froid. 1967.

Location	pH <u>1/</u>	Conductivity <u>2/</u> m. mhos/cm	O.M. <u>3/</u> %
<b>Power</b>			
A 1 <u>4/</u>	-	-	-
A 4	7.5	.19	2.5
B 1	7.4	.19	2.4
B 4	7.4	.19	2.6
C 1	7.6	.17	2.6
C 4	7.4	.20	2.6
D 1	7.4	.18	2.6
D 4	7.4	.18	2.4
<b>Denton</b>			
A 1	6.0	.10	1.9
A 4	6.2	.12	1.6
B 1	6.4	.10	1.9
B 4	6.2	.08	1.9
C 1	6.3	.14	1.9
C 4	6.1	.10	1.9
D 1	6.7	.26	2.0
D 4	6.2	.09	1.9
<b>Froid</b>			
A 1	6.6	.07	2.2
A 4	6.8	.09	2.5
B 1	6.7	.08	2.4
B 4	6.5	.09	2.5
C 1	6.6	.06	2.1
C 4	6.8	.08	2.6
D 1	7.0	.06	1.9
D 4	6.9	.10	2.2

1/ Soil pH determination procedure in Appendix table 38.

2/ Soil conductivity determination procedure in Appendix table 37.

3/ Organic matter determination procedure in Jackson (32) pp. 219-221.

4/ Sampled by grid pattern (see Table 2 in materials and methods).

Table 33. Soil phosphorus determined using the Bray 1/ and NaHCO<sub>3</sub> 2/ methods on soil samples from Power location.

Soil Depth	A <u>3</u> /		B		C		D	
	NaHCO <sub>3</sub> ppm	Bray ppm						
I. 0-6"	8.4	18	6.4	22	4.9	19	4.4	18
I. <u>3</u> / 6-12" <u>4</u> /	3.4	4	3.4	15	3.4	5	3.4	10
II. 0-6"	6.4	18	4.4	22	6.4	27	5.4	21
II. 6-12"	3.4	6	2.5	11	4.4	3	3.4	4
III. 0-6"	6.4	30	7.4	25	3.4	22	6.4	22
III. 6-12"	3.4	19	2.5	5	8.4	27	3.4	3
IV. 0-6"	4.4	21	4.4	16	3.9	13	3.4	13
IV. 6-12"	3.4	11	2.5	6	3.4	4	5.4	4

1/ Bray #1 method modified (78) (55).

2/ Extraction with sodium bicarbonate (54).

3/ Sampled by grid pattern (see Table 2 in materials and methods).

4/ 6-12" included B horizon.

Table 34. Soil phosphorus determined using the Bray 1/ and NaHCO<sub>3</sub> 2/ methods on soil samples from Denton location.

Soil Depth	A <u>3/</u>		B		C		D		
	NaHCO <sub>3</sub> ppm	Bray ppm							
I. <u>3/</u>	0-6"	9.9	30	9.9	33	8.9	30	9.4	31
	6-10" <u>4/</u>	.7	19	.7	19	.7	15	.7	12
II.	0-6"	8.4	34	9.4	28	8.4	33	8.4	28
	6-10"	1.6	19	.7	10	1.6	19	.7	12
III.	0-6"	8.4	38	10.4	31	9.4	41	8.4	33
	6-10"	2.5	14	.7	11	.7	18	.7	12
IV.	0-6"	11.9	34	10.4	34	9.9	31	9.4	35
	6-10"	1.6	15	1.6	11	.7	10	1.6	17

1/ Bray #1 method modified (78) (55).

2/ Extraction with sodium bicarbonate (54).

3/ Sampled by grid pattern (see Table 2 in materials and methods).

4/ 6-10" included B horizon.

Table 35. Soil phosphorus determined using the Bray 1/ and NaHCO<sub>3</sub> 2/ methods on soil samples from Froid location.

Soil Depth	A <u>3/</u>		B		C		D		
	NaHCO <sub>3</sub> ppm	Bray ppm							
I. <u>3/</u>	0-6" <u>4/</u>	5.4	17	5.4	25	9.4	28	5.4	16
	0-6" <u>5/</u>	8.4	18	9.9	22	9.4	17	7.4	13
II.	0-6" <u>4/</u>	5.9	16	6.4	22	10.4	30	5.4	16
	0-6" <u>5/</u>	6.9	19	7.9	21	6.4	18	5.4	14
III.	0-6" <u>4/</u>	3.9	16	6.4	20	10.9	24	3.9	13
	0-6" <u>5/</u>	6.4	14	6.4	20	8.9	25	5.9	16
IV.	0-6" <u>4/</u>	4.9	14	6.4	22	8.9	29	5.9	17
	0-6" <u>5/</u>	7.9	22	8.4	21	12.4	33	9.9	25

1/ Bray #1 method modified (78) (55).

2/ Extraction with sodium bicarbonate (54).

3/ Sampled by grid pattern (see Table 2 in materials and methods).

4/ Samples taken from west strip.

5/ Samples taken from east strip which was the stubble strip in 1967.

Table 36. Nitrate determination for soil samples from Power, Denton, and Froid locations.

Depth	<u>Power</u> ppm N	<u>Denton</u> ppm N	<u>Froid</u> ppm N
<u>Spring 1967</u>			
0-1'	6.0	- <u>1</u> /	-
1-2'	5.2	-	-
2-3'	2.5	-	-
3-4'	8.3	-	-
-----			
<u>Spring 1968</u>			
0-1'	16.8	1.7	1.7
1-2'	3.0	2.2	4.5
2-3'	3.8	1.6	2.5
3-4'	2.6	2.0	2.2
4-5'	2.8	.9	2.0
5-6'	4.5	-	1.5

1/ A dash indicates that information was not available.

Table 37. Procedure for determination of soil pH.

- 
1. Weigh 10 g soil into a 50 ml beaker.
  2. Add 20 ml distilled H<sub>2</sub>O to each soil sample.
  3. Stir with electric stirrer and let settle for 30 minutes.

Determine the temperature of the water added to the soil samples. Set the temperature dial (upper) of the pH meter to this temperature.

Place about 15 ml of pH buffer 7 1/ under the electrodes and punch down the read button. Allow about 30 seconds for the dial needle to stabilize, then using the standardize knob, adjust the needle to 7. Punch down the stand-by button. Rinse the electrodes thoroughly. Meter is now standardized and ready.

4. Place a soil sample under the electrodes (both electrodes must be in the sediment) and punch down the read button. Take the reading when the needle stops moving. Read conductivity on the next sample while waiting for the pH reading.
5. Set the meter back to "stand-by" and remove the soil samples, then rinse the electrodes thoroughly and repeat 4 and 5 with all samples.
6. When all samples are analyzed, place a 50 ml beaker of deionized water under the electrodes.

---

1/ pH buffer 7 is prepared by emptying the contents of a buffer 7 capsule into a 100 ml volumetric flask and adding distilled water to volume.

Table 38. Procedure for determination of soil conductivity.  
(using same samples analyzed for pH)

---

1. Turn the Solu-bridge on and allow it to warm up until the "eye" is green. Set the temperature dial on the temperature of the water added to the samples. (Same as for pH)
  2. Draw sufficient sample solution into the pipet to rinse it. Discard this first rinsing.
  3. Draw a second aliquot of sample solution into the pipet until it covers the electrodes. (Be certain there are no air bubbles in the electrode area.)
  4. Turn the center dial until the "green eye" (dark portion) is open to its widest point.
  5. Record the value pointed to by this dial.
  6. Repeat 2, 3, 4, and 5 for all samples. When complete, rinse the pipet and leave it full of distilled H<sub>2</sub>O. Turn Solu-bridge to "off" position.
  7. Convert the bridge reading to m. mhos in a saturated paste by use of the following equation  $Y = 3X + 0.7$ , where Y is the conductivity of the saturated paste and X is the solu-bridge reading. Below a conductivity of 0.7,  $Y = 4X$ .
-

Table 39. Soil temperature at Power location in 1968.

Day of Month	Degrees F										
	April		May		June		July		August		
	Low	High	Low	High	Low	High	Low	High	Low	High	
1			40-52		45-60		50-65		54-70		
2											
3					48-60						
4							55-70				
5									60-75		
6			35-50								
7											
8									60-73		
9											
10					48-61		60-74				
11	30-40										
12		<u>1/</u>								52-68	
13			40-52								
14					44-54						
15	28-40						54-70				
16					48-64						
17											
18					54-68						
19									51-62		
20			45-61								
21											
22	28-42						55-68				
23											
24					52-69				56-70		
25											
26									55-67		
27			43-60								
28	40-52										
29	43-55				45-55						
30							54-70		53-65		
31											

1/ All blank spaces indicate slight variation from temperature listed immediately above.

Table 40. Soil temperature at Power location in 1969.

Day of Month	Degrees F							
	May		June		July		August	
	Low	High	Low	High	Low	High	Low	High
1			60-83		64-80		72-86	
2								
3			53-69					
4					60-78			
5							66-85	
6			48-76		60-72			
7								
8								
9							70-90	
10	38-66		58-75		65-85			
11		1/						
12					68-84		65-87	
13	44-70							
14			58-78					
15					64-85			
16	44-61							
17							65-88	
18			50-68		68-86			
19								
20	48-60							
21			58-64					
22	45-67				70-88			
23								
24			55-68				70-90	
25	45-66							
26					66-88			
27	55-74	2/						
28								
29			58-72					
30	55-75				74-88		60-80	
31								

1/ All blank spaces indicate slight variation from temperature listed immediately above.

2/ See text p. 63 discussion of "high" temperature.

Table 41. Soil temperature at Denton location in 1968.

Day of Month	Degrees F											
	May		June		July		August		September		October	
	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
1					54-65							
2												
3	48-60		53-60						54-60			
4	50-60				60-70							
5												
6	42-52	<sup>1/</sup>							55-61			
7	40-48		55-62								43-49	
8	42-54				65-72							
9			55-62						60-64			
10	42-54		54-63									
11												
12							64-73					
13	50-60		52-60									
14											43-49	
15	46-52				65-75				53-58			
16							58-65					
17	52-58		58-66		60-70							
18			59-68									
19	54-63											
20	50-60				63-72		59-64		51-55			
21											40-45	
22												
23					63-72							
24			56-64									
25									47-50			
26			54-62				60-68					
27												
28	54-65				65-77							
29					68-76							
30	58-67						59-65		47-51			
31												

<sup>1/</sup> All blank spaces indicate slight variation from temperature listed immediately above.

Table 42. Soil temperature at Denton location in 1969.

Day of Month	Degrees F					
	May Low High	June Low High	July Low High	August Low High	September Low High	October Low High
1		38-49	48-62	60-80	55-74	45-57
2						40-50
3		44-62				
4			52-68			
5				60-78		
6						
7		40-56				
8			54-70			
9					55-72	
10		39-62				
11						
12				60-82		
13	48-60	48-66				
14	44-62 <sup>1/</sup>					
15			56-74		48-62	
16				56-74		
17	44-54		60-78			
18		55-68				
19						
20	42-60			62-80	45-57	
21						
22						
23			60-80			
24		53-66				
25						
26				56-74		
27		48-52				
28	50-68		60-80			
29						
30	50-62			55-74		
31	36-47					

<sup>1/</sup> All blank spaces indicate slight variation from temperature listed immediately above.

Table 43. Precipitation in inches and distribution for three locations for April - September, 1967.

Date	Power	Stanford	Froid
<b>April</b>			
20			1.62
26			.12
28			.07
29			<u>1.33</u>
Total			3.15
<b>May</b>			
2			.03
7			.05
15			.20
30	<u>.80</u>		<u>.02</u>
Total	.80		.30
<b>June</b>			
5-11	.32	.95	2.80
12-18	1.48	3.10	.22
19-25	2.53	1.59	.11
26-30	<u>.15</u>	<u>.00</u>	<u>.02</u>
Total	4.48	5.64	3.15
<b>July</b>			
3-9	.13	.20	.00
10-16	.00	.00	.09
17-23	.40	.15	.57
24-30	.06	.00	.00
31	<u>.11</u>	<u>.00</u>	<u>.00</u>
Total	.70	.35	.76
<b>August</b>			
7-13	<u>.23</u>	<u>.00</u>	<u>.31</u>
Total	.23	.00	.31
<b>September</b>			
12-19			<u>.67</u>
Total			.67
<b>Total for season 1/</b>			
	5.98	5.99	4.21

1/ Total precipitation for May through August 1.

Table 44. Precipitation in inches and distribution at Power for  
May - September, 1968.

Day of Month	May	June	July	August	September
1					
2					.65
3		.20			.10
4		trace			.15
5	.05	trace			
6					
7	.74	1.15			
8					
9		.25			
10		.15	.22		
11		.20		trace	
12	trace		trace		
13	trace	.15			
14	.20	.20	trace	trace	
15					
16				1.95	
17			trace	trace	.20
18				trace	
19		trace			
20		.05		trace	
21					
22	1.50				
23	.05				4.20
24	.05	.25			
25					
26	.05				
27					
28					
29	.45				
30			.04		
31					
Totals	3.09	2.60	.26	1.95	5.30
Total for season 1/ = 5.95					

1/ Total precipitation for May through August 1.

Table 45. Precipitation in inches and distribution at Denton for May - September, 1968.

Day of Month	May	June	July	August	September
1			.11		.20
2					
3					
4					
5					
6	.49				
7					.30
8	.59				
9					
10					.25
11					
12		1.12			
13	.04				
14		.20			.20
15					
16	.22	.06		2.10	
17			1.35		
18			.70		
19					
20					1.25
21		.50		.20	
22		.10			
23					
24		.50			
25					
26	1.60				
27					
28	.24			.40	
29					
30	.40				
31	.07				
Totals	3.65	2.48	2.16	2.70	2.20
Total for season $\frac{1}{2}$ = 8.29					

$\frac{1}{2}$  Total precipitation for May through August 1.

Table 46. Precipitation in inches and distribution at Froid for April - September, 1968.

Day of Month	April	May	June	July	August	September
1				.07		
2	.09					
3					trace	
4						
5			.10			.31
6			.48			.01
7			.01			.40
8		.61				
9		.02	1.08			.01
10						
11		.09	.30			
12				.01		
13				.02		
14						
15				.07	.62	.04
16				1.00	.91	
17					.16	.07
18		.12		.05		
19					.60	.04
20			.05			
21						.12
22					.05	
23				.01	1.18	
24			.95	.02	1.60	
25			.42			
26						
27		.05				
28			.05			
29						
30			.60	.06		
31				trace		
Totals	.09	.89	4.04	1.31	5.12	1.00
Total for season $\frac{1}{2}$ = 6.24						

$\frac{1}{2}$  Total precipitation for May through August 1.

Table 47. Precipitation in inches and distribution at Power for  
May - October, 1969.

Day of Month	May	June	July	August	September	October
1			.15			
2						
3						trace
4						
5						
6						.25
7		.10 <u>1/</u>	1.55 <u>1/</u>			
8						
9		trace				
10						
11						
12		.34		.12 <u>2/</u>		
13						
14						
15	.72					
16						
17	.04					
18						
19					.04	
20	.20	.28			.04	
21		.20				
22		trace				
23						
24	trace					
25						
26						
27						
28						
29		3.85 <u>3/</u>				
30	.10					
31	.10					
Totals	<u>1.16</u>	<u>4.77</u>	<u>1.70</u>	<u>.12</u>	<u>.08</u>	<u>.25</u>
Total for season	<u>4/ = 8.63</u>					

1/ Total for 5-7.

2/ Total for 10-12.

3/ Total for 24-29.

4/ Total precipitation for May through August 1.

Table 48. Precipitation in inches and distribution at Denton for May - October, 1969.

Day of Month	May	June	July	August	September	October
1						
2		.40				
3			.42			.60
4						
5						
6						
7						
8			1.00			
9						
10						
11						
12				.02		
13						
14		.35	.06			
15						
16	.38					
17						
18			.10			
19	.64					
20						
21						
22	.08	.13				
23		.04				
24						
25						
26	.08					
27						
28		2.60				
29	.03					
30						
31						
Totals	1.21	3.52	1.58	.02		.60
Total for season 1/ = 6.11						

1/ Total precipitation for May through August 1.

Table 49. Precipitation in inches and distribution at Froid for April - September, 1969.

Day of Month	April	May	June	July	August	September
1		.10				
2		.07		.02		
3		.27	trace			
4				.04		
5		.04		.06	.29	
6			.05	.14	.02	
7		.07	.43	.77		
8	.10		.03	.45		
9						
10			.17			
11						
12						
13				.01	.22	
14			trace	.34	.01	
15				.01		
16	1.16			.12		.04
17				.16		
18		.01		.02		
19		.08	.03			
20						
21			.12	.01	.32	1.08
22				.19		
23		.02	.04			
24				.02		
25	.11		.38			
26	.43		1.04			.02
27			.87	.10		
28	.01	.02	.05		.18	
29			.27			
30			.01			
31		.08				
Totals	1.81	.76	3.49	2.46	1.04	1.14
Total for season $\frac{1}{2}$ = 6.71						

$\frac{1}{2}$  Total precipitation for May through August 1.

Table 50. Soil moisture percentage - Power, 1967, 1968, and 1969 and Denton and Froid, 1969.

Depth Feet	Power 1967	Power 1968	
	% H <sub>2</sub> O	% H <sub>2</sub> O	% H <sub>2</sub> O (15 atm)
1	19.3	24.5	17.5
2	21.6	15.6	14.2
3	19.4	15.1	11.8
4	20.7	12.9	11.4
5	- <u>1/</u>	14.7	13.7
6	-	14.2	11.9
-----			
	1969		
	Power	Denton	Froid
	% H <sub>2</sub> O	% H <sub>2</sub> O	% H <sub>2</sub> O
1	20.1	22.8	12.5
2	19.1	20.5	13.7
3	14.1	18.4	13.5
4	10.4	15.4	12.9
5	15.1	11.4	14.1
6	17.4	-	11.5

1/ Data not available

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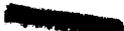
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