Phosphorus fertilization of newly cleared soils in interior Alaska
by Barbara Jean Pierson

A thesis submitted in partial fulfillment of the requirements for the degree of Master of Science in Soils
Montana State University

Abstract:
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Ongoing research of the University of Alaska evaluates conservation tillage systems in barley production. Newly cleared soils of Interior Alaska are highly susceptible to wind and water erosion and conservation tillage systems must be adapted for Alaskan agriculture.

Within the scope of conservation tillage research, fertilizer application is of major concern. A two year study was initiated to evaluate phosphorus fertilizer application on a newly cleared soil. Two methods of application and five rates of application were evaluated. Residual effects of the fertilizer application were examined during the second year of the study.

Based on two growing seasons, a minimal application of 10 kg P/ha is necessary to provide adequate phosphorus for normal crop production following land clearing operations. Application of fertilizer phosphorus in excess of 10 kg P/ha may be beneficial for higher yields. Application of phosphorus by using Broadcast or Banded methods provided adequate placement of fertilizer at the time of seeding. Soil phosphorus levels after the first growing season were significantly higher in soils that received higher rates of phosphorus fertilizer, however, these higher levels did not contribute to higher yields in the second growing season.

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of

Master of Science

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Soils

MONTANA STATE UNIVERISTY
Bozeman, Montana

June 1985

APPROVAL

of a thesis submitted by

Barbara Jean Pierson

This thesis has been read by each member of the thesis committee and has been found to be satisfactory regarding content, English usage, format, citations, bibliographic style, and consistency, and is ready for submission to the College of Graduate Studies.

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ACKNOWLEDGEMENTS

I would like to thank the faculty and staff of Agriculture and Forestry Experiment Station , University of Alaska for the opportunity to experience Interior Alaska.

Sincere appreciation is extended to my parents, friends and fellow graduate students of 8th floor Johnson Hall for their unending support during the past two years. Without this support, my academic acheivement would have been difficult.

I would like to especially thank the members of my graduate committee who supported my journeys to and from Alaska in the last two years.

Finally, the memory of Dr. Francis Siddoway has been a special inspiration for me as I complete degree requirements and plan for future endeavors.

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ABSTRACT

Agriculture in Interior Alaska has become more extensive since the mid 70's when land was released for development by the State of Alaska to stimulate the industry. Agricultural research in Interior Alaska has relied primarily on current technology and methodology of Canada, Scandinavia, and the "lower 48" of the United States.

Ongoing research of the University of Alaska evaluates conservation tillage systems in barley production. Newly cleared soils of Interior Alaska are highly susceptible to wind and water erosion and conservation tillage systems must be adapted for Alaskan agriculture.

Within the scope of conservation tillage research, fertilizer application is of major concern. A two year study was initiated to evaluate phosphorus fertilizer application on a newly cleared soil. Two methods of application and five rates of application were evaluated. Residual effects of the fertilizer application were examined during the second year of the study.

Based on two growing seasons, a minimal application of 10 kg P/ha is necessary to provide adequate phosphorus for normal crop production following land clearing operations. Application of fertilizer phosphorus in excess of 10 kg P/ha may be beneficial for higher yields. Application of phosphorus by using Broadcast or Banded methods provided adequate placement of fertilizer at the time of seeding. Soil phosphorus levels after the first growing season were significantly higher in soils that received higher rates of phosphorus fertilizer, however, these higher levels did not contribute to higher yields in the second growing season.

INTRODUCTION

Agricultural production has historically contributed little to Alaska's economic base and was not really a factor in statewide development. The 70's marked the beginning of the age of the Trans-Alaska pipeline. Oil revenues have provided financial means to encourage development in various sectors of the state's economy. In 1978, legislative mandate released 23,000 hectares (58,000 acres) of state land for purchase by qualified lottery applicants for agricultural development. This large scale "Agriculture Project" was the beginning of a state sponsored venture to establish a successful agricultural economy. Since this initial project was started, 10,000 additional hectares (24,000 acres) of state land have been released for agriculture purposes.

Small-scale agricultural operations existed before this recent push toward a stable Alaskan agricultural economy. These small farms became the stepping stones toward larger, more intensive methods of production. Cereal grain production on large farms (1000-1200 ha) involves assessment of 1)crop nutrition requirements, 2)availability of cost effective fertilizers, 3)proper application rates, and 4)timeliness of fertilizer application. Prior knowledge of grain production from the Midwestern and Great Plain states and Canadian provinces has proven to be helpful for Alaskan conditions, but Alaskan agriculture has unique conditions deserving additional attention and research.

Growing seasons in Interior Alaska are typically shorter and cooler than areas of small grain production in the "lower 48". Soils identified as those of agricultural potential are relatively colder and wetter than most soils of dryland agriculture. Field research with Alaskan soils is gradually beginning to provide fertilizer response data which may provide a basis for fertilizer recommendations for Alaskan soils.

A critical problem of high erodibility exists with the majority of Alaskan soils cleared for agriculture production. Newly cleared soils are silty, poorly aggregated and lack surface roughness. Plant residues remaining after clearing operations are not sufficient to reduce erosion damage during seasonal high prevailing winds. Conservation tillage systems are encouraged by state and federal agricultural agencies to reduce erosion losses. Research priority is given to fertilizer management appropriate for conservation tillage and the unique conditions of Interior Alaska.

The objectives of this study were to address phosphorus fertilization in barley production on soils which have been recently cleared of native vegetation and are destined for small grain production. The affect of phosphorus fertilizer in barley production was evaluated with two different methods of application and five rates of application. The second year of the study examined the possible residual effect of the fertilizer application from the previous year.

LITERATURE REVIEW

Soil Phosphorus Essentiality and Availability

Phosphorus is a nutrient indispensable for all forms of life and often becomes a life-limiting factor in natural systems due to low availability (Ozanne, 1980). Phosphorus functions as a key element in energy transfers via adenosinetriphosphate (ATP) and in genetic transformations associated with ribonucleic acid (RNA). The majority of phosphorus in the natural system is present in the soil. Soil phosphorus (P) can be described by the following equilibria:

$$\text{Soil solution P} \rightleftharpoons \text{Labile soil P} \rightleftharpoons \text{Nonlabile soil P}$$

True equilibrium rarely is established between nonlabile P and labile soil P, yet equilibrium is rapidly established between soil solution P and labile soil P (Olsen and Khasawneh, 1980). Soil solution P is the medium from which the plant obtains phosphorus. Researchers have described the relationship between plant uptake and soil solution phosphorus as an intensity factor. (Tisdale et al.,1985; Kamprath and Watson, 1980; Olsen and Khasawneh, 1980). The intensity factor describes the amount of phosphorus in soil solution available for plant uptake. Labile soil P, from which the soil solution is replenished, is described as the quantity factor. The quantity factor can be used as an indication of how much phosphorus is available to move from the labile phase to soil solution.

Besides attempting to measure quantity and intensity of soil phosphorus, it is important to understand the movement of phosphorus to the root surface. Plant phosphorus uptake by roots removes phosphorus from soil solution immediately surrounding the root. Phosphorus concentrations are greater away from this zone of depletion and a concentration gradient is established at the root surface. Diffusion becomes the primary mechanism moving phosphorus to the root. (Barber, 1980). The replenishment of phosphorus in solution is regulated by the equilibria between labile soil P and solution phosphorus (Holford, 1980).

The equilibria of soil phosphorus are affected by depletion of soil solution phosphorus by 1) uptake of the growing plant, 2) adsorption of phosphorus in solid phase, and 3) factors changing or maintaining diffusion mechanisms.

Plant uptake of phosphorus is primarily in the form of primary ($H_2PO_4^-$) or secondary ($HPO_4^=$) orthophosphate ions present in soil solution (Olsen and Khasawneh, 1980). Bieleski (1973) has shown primary orthophosphate is taken up faster than secondary orthophosphate. This work proves a large concentration gradient exists between root xylem tissue and soil solution and phosphorus is accumulated in plant tissue. Inorganic phosphorus is 20-100 times more concentrated in xylem tissue than in soil solution.

Research with hydroponically grown barley (Green et al., 1973) proved that transpirational uptake and accumulation occurs across the concentration gradient between the root tissue and soil solution. Unless there is active movement across this concentration gradient, plant uptake is explained by nutrient transport in water associated with the transpirational demands of the plant.

Barber (1980) outlined conditions affecting phosphorus uptake by plant roots as follows: 1) change of phosphorus absorption with the age of plant, 2) age and morphology of lateral and seminal roots, and 3) soil depth, i.e. anything affecting root penetration such as soil structure, soil, soil temperature, fertility and water relations.

Adsorption of phosphorus in the solid or labile phases of soils has often been referred to as "fixation". The definition of fixation includes precipitation reactions of phosphorus as well as adsorption reactions (Tisdale et al., 1985). In slightly acid soils, adsorption reactions involve primarily iron and aluminum hydrous oxides. These reactions affect the overall equilibrium of soil phosphorus in varying degrees depending on: 1) length of time for reaction to take place, 2) temperature, 3) pH, and 4) concentration of phosphorus in solution. These reactions with iron and aluminum are relatively fast when taking place on the surface of hydrous oxides (Ibrahim and Pratt, 1982). Adsorption of phosphorus on other soil surfaces is relatively slower and subject to other cation and anion competition.

Fixation and retention are frequently used synonymously in regard to soil phosphorus reactions. Fixation collectively includes retention reactions at soil surfaces (adsorption) and chemical precipitation of phosphorus from soil solution. Phosphorus retention has been explained by many researchers by using an either/or approach toward adsorption reactions or precipitation reactions (Sample et al., 1980). Regardless of precise mechanism, retention will affect phosphorus availability.

Soil organic matter plays a significant part in phosphorus equilibria reactions. Bloom (1981) has shown that organic matter has a high affinity for phosphorus in low pH environments. Work by Black and Reitz (1972) has proven wheat straw incorporated in the soil immobilizes phosphorus. Mineralization of organic phosphorus may benefit subsequent crop production. Organic matter and the association with calcium, iron, and aluminum ions will definitely have an impact in equilibria reactions (Sample et al., 1980).

Soil texture is a major factor affecting water holding capacity of soils. At a specfic water content, the thickness of water films and total amount of water for solution is generally controlled by soil texture. Phosphorus diffusion in soils of differing texture depend on 1) concentration gradients between soil solution and root surfaces, 2) equilibria reactions between solution phosphorus and solid phase phosphorus and, 3) diffusion coefficients. (Olsen and Watanabe, 1970). Subsequent work by Mahtab et al., (1972) confirmed the influence that soil water content of different soil textures affects diffusion of phosphorus. Their work also recognizes the movement of phosphorus from the labile solid phase to replenish soil solution. This work further indicates the importance of proper fertilization on dry or droughty soils. Clayey soils have less tendency towards phosphorus deficiency in dry conditions than sandy soils.

Additional work has been done relating phosphorus nutrition and plant water requirements (Follett and Reichman, 1972; Matar, 1977; Sharpley and Reed, 1982). Their work indicates low soil water content becomes a very important factor influencing plant growth and subsequently phosphorus uptake. Movement of phosphorus through soil solution under these conditions may not be due to diffusion, but rather plant transpirational demands. Boatwright and Viets (1966) linked adequate phosphorus nutrition and soil water during the early stages of growth as a critical period in order to realize optimal yield. Phosphorus availabiltiy early in the season may be sufficient for plant growth and adequate development. Phosphorus fertilizer recommendations for phosphorus deficient soils in areas of inadequate soil moisture may require adjustment.

Phosphorus available to the root via diffusion is not only affected by soil moisture, but also tortuosity, and temperature. The tortuosity of the diffusion path depends on the thickness of the water films and the fineness of the soil particles (Barber, 1980). The supply of phosphorus to the root by diffusion will be affected by temperature related factors of solution viscosity and solubilization. Power et al., (1970) have provided evidence of reduced growth rate of barley at lower temperatures with phosphorus solubility unaffected. This is not directly affecting diffusion, but reflecting changes in the concentration gradient created by the growing plant responding to temperature. Their work suggests that increased levels of phosphorus fertilizer provides greater flexibility in cool temperature regimes of the Northern Great Plains. This implies adequate phosphorus nutrition allows the plant greater tolerance in regions of cool soils. Research by Michaelson et al., (1984) supports the conclusion that low soil temperatures of Interior Alaska may reduce phosphorus availability.

Another factor affecting phosphorus availability is the transformations of organic soil phosphorus to available inorganic ions. Characterization of soil phosphorus is a difficult process primarily due to the readsorption reactions taking place during extraction procedures for organic and inorganic phosphorus (Tiessen et al., 1984).

Their research involved soils of differing pedogenesis. One soil order they studied was an Ultisol, which is highly developed, with low organic matter, and delivers available phosphorus mostly from the labile inorganic phase. Their study indicates moderately developed soils, such as Mollisols, have stable reservoirs of organic matter from which organic phosphorus may be mineralized. The study of soils with little or no development and various levels of organic matter may introduce unique questions of phosphorus availability.

A summary of phosphorus use in the soil-plant system is found in a model projected by Scaife and Smith (1973). (Figure 1). Although their work was on phosphorus requirements of lettuce, it provides an excellent illustration of the path of phosphorus utilization in plants.

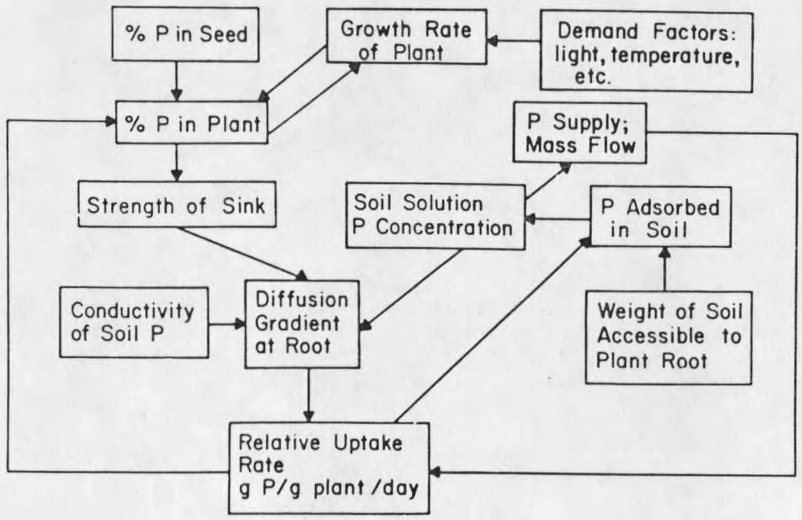

Figure 1. Diagram of a model indicating relationships of the different processes involved in plant growth and phosphorus utilization. (Scaife and Smith, 1973)

In using this model for other plant species, it is important to realize differences come from seed size, root morphology, growth rate, tolerance to low phosphorus concentrations, yield potentials and crop requirements.

Phosphorus Fertilization

Phosphorus requirements for small grain cereal production vary slightly depending on local conditions. Crop requirements for average yields from the Northern Great Plains, Northern Scandinavia, and England range from 11 kg P/ha (27 kg P_2O_5/ha) to 15 kg P/ha (34 kg P_2O_5/ha)(Greenwood et al., 1980; Anon., 1981; Russell, 1973; Lyngstand and Stabbetorp, 1981). These requirements are based on the amount removed by the plant during the period of growth. Recommendations for phosphorus fertilization should consider these basic requirements in addition to local factors affecting availability.

Fertilizer recommendations must be made with consideration of cropping systems. In conservation tillage systems, as well as conventional systems, nutrient cycling has been of specific importance in development of fertilizer recommendations (Ritchie and Follett, 1983). Plant residue accumulation in conservation tillage systems may have significant impact on nutrient cycling (Black and Reitz, 1983; Holt, 1979; and Larson, 1979). Several researchers have identified nutrient cycling of essential nutrients, including phosphorus, as foremost in assessing fertilizer management recommendations in reduced tillage and conservation tillage systems (Carter and Rennie, 1982; Parr et al., 1983; and Ritchie and Follett, 1983).

Conventional fertilization methods in small grain production have generally included phosphorus fertilization in the same operation as seeding. This process places fertilizer in close proximity to the seed during seeding operations. Localized placement of phosphorus may have advantages for early growth following germination. Phosphorus placed in a restricted band at the time of seeding will reduce soil-fertilizer contact and retention reactions (Tisdale et al., 1985). In greenhouse studies, phosphorus was placed in a band and contrasted with a broadcasted treatment (Sleight et al., 1984). These researchers contend placement of phosphorus near the growing plant root has advantages due to improved root-fertilizer contact and not due to improved availability obtained from decreased soil-fertilizer contact and reduced retention. In contrast to these observations, it has been noted that root growth and root proliferation might be suppressed by the restricted placement of nitrogen and phosphorus placement (Drew, 1975; Barrow, 1980). Plants growing in this restricted zone may not be required to explore beyond the zone of fertilizer placement.

Placement of phosphorus fertilizer is especially important in conservation tillage systems. Plant access to fertilizer amendments may vary due to changes in moisture and temperature regimes due to crop residue accumulation (Klepper et al., 1983; Murphy, 1983). Current research strongly suggests placement of fertilizers with or below the seed or incorporation of fertilizer with limited tillage (Fenster, 1977). New developments in fertilizer placement are forthcoming as conservation tillage systems become common.

Evaluation of Residual Soil Phosphorus

The previous discussion of equilibria affecting phosphorus availability introduced the nonlabile, labile, and solution phases of soil phosphorus. Reactions affecting these solid and solution phases are of key importance in assessing the amount of residual phosphorus remaining from previous fertilization. Fractionation of all soil phosphorus is essential to begin to estimate the effect of residual soil phosphorus (Hedley et al., 1982). The buffer capacity of individual soils is also necessary to evaluate labile soil phosphorus (Probett and Willett, 1983; McIntosh, 1968; Holford, 1979, 1980b). These researchers studied the sensitivity of extractants in measuring labile soil phosphorus. Extractants of the Bray-I (NH_4F and HCl) test used in slightly acid soils do not accurately remove phosphorus from the labile pool. Measurement of labile soil phosphorus reflects the "sink" for residual phosphorus and accurate measurement of this labile pool would indicate soil phosphorus equilibria changes.

In addition to accurate measurement of the labile phosphorus, it is necessary to estimate the buffer capacity of the soil to completely evaluate residual phosphorus. Soil buffer capacity characterizes the dynamic relationship between soil phosphorus in solution and the labile solid phase (Holford, 1979; Holford, 1980b). Buffer capacity refers to the ability of the phosphorus concentration or intensity of soil solution to resist change when phosphorus is added or removed from solution. The equilibria reactions of soil solution phosphorus and labile phosphorus proceed according to the degree of buffering. Holford has shown a measure of labile soil phosphorus and buffer capacity provides explanation for the wide variance in plant uptake in various soils. Changes in phosphorus uptake by plants was attributed to buffer capacity and diffusion characteristics (Olsen, et al., 1983).

Several years of experimentation are essential to make recommendations for phosphorus fertilization based on residual phosphorus. Several researchers have found response to phosphorus fertilization based on residual effects (Alessi and Power, 1980; Ridley and Tayakepisuthe, 1974; and Spratt et al., 1980; Nosko, 1983). Research of several years of production indicates reduced phosphorus recovery by the plant as soil phosphorus levels increased. Phosphorus recovery was calculated from phosphorus content of grain from fertilized plots of known fertilizer input. The levels of soil phosphorus increased with applied fertilizer, but apparently plant availability did not. It may be important to apply a critical phosphorus level each year for greatest efficiency. Luxurious consumption by wheat, in excess of a critical level may have been observed on soils studied by Alessi and Power (1980). A critical level is reached when no response is obtained from additional application of fertilizer. McLean et al., (1982) support fertilizer recommendations based on a critical level indicated by the appropriate soil test method for independant locations.

Soil test values for extractable phosphorus and labile phosphorus are dependant upon local environments. Recent innovations have improved correlations between plant available soil phosphorus and soil test values. Flow injection analysis is a technique developed in Europe which avoids a mechanical disturbance which affects duration of adsorption reactions. Electroultrafiltration (EUF) may also prove important in assessing conventional soil phosphorus tests (Nemeth and Recke, 1982). Anion exchange resins (AER) have been used successfully in correlating phosphorus uptake on previous highly fertilized soils (Adepoju et al., 1982).

Models have been developed to evaluate residual soil placed in each facet of a mathematical model to understand synergistic effects. Reactions of residual soil phosphorus take place over several years and sophisticated models must include this essential time factor.

Soil Phosphorus Availability as Affected by Vesicular Arbuscular Mycorrhiza

Nutrient availabilitiy has been enhanced in natural and agricultural systems by the presence of mycorrhizal populations (Molina et al., 1978). Several species of endotrophic and ectotrophic mycorrhizal fungi exist symbiotically within several host species. Endotrophic mycorrhiza are distinguished from ectotrophic by the location of threadlike hyphae. Endotrophic hyphae penetrate epidermal and cortex cells of the living root (Alexander, 1977). Endotrophic mycorrhiza are frequently referred as vesicular arbuscular mycorrhiza (VAM) because of the presence of vesicles and arbuscles in the hyphal structure.

Most research with VAM and nutrient uptake enhancement has specifically dealt with phosphorus. Hyphae extending from the root is capable of exploring a greater volume of soil. Phosphorus in the soil may be reached by VAM which was unavailable to the root without VAM association. Phosphorus fertililization studies have evaluated the effectiveness of VAM in aiding phosphorus uptake (Gray and Gerdeman, 1969; Daft and Nicolson, 1969). These studies have shown existing mycorrhizal populations promoted plant growth when less soluble forms of phosphorus are applied, e.g. rock phosphate and tricalcium phosphate. More soluble forms of phosphorus seem to reduce hyphae penetration in the root.

Research by Black and Tinker (1977) suggest VAM infections in soil are affected in various degrees in continuous barley production. Maintenance of existing mycorrhizal population may provide greater uptake efficiency of soil phosphorus (Hall et al., 1977). Maintenance or inoculation of those plants with a confirmed VAM association may be considered important when assessing soils of high phosphorus retention capacities (Jackson et al., 1972).

The ultimate productivity of any ecosystem involves a dynamic relationship of all factors affecting biological functions. Within the soil ecosystem, microorganism populations are present in recognizable quantities. Attempting to understand a segment of this population, vesicular arbuscular mycorrhiza, may prove fruitful in soil phosphorus availability.

MATERIALS AND METHODS

Soils of the study area are classified in the Beales series. They are mixed, Typic Cryochrepts (SCS, 1973). They are located on stabilized deposits of loess on large glacial outwash plains. Surface horizons of cleared areas are silt loam ranging in thickness from 8 cm to 25 cm (3 - 10 in). Subsurface horizons vary from loamy fine sand to fine sand and are underlain by stratified coarse sand and gravel at a depth of 90 cm to 120 cm. All horizons are micaceous and the pH ranges from moderately acid (pH 5) in surface horizons to less acid (pH 6) in subsurface horizons. Mottling is present in lower horizons. Other series associated with Beales soils are Nenana, Chena, and Volkmar. These differ in depth of silt loam and fine sand horizons, depth to gravel, and degree of mottling. They are all highly susceptible to wind erosion when cleared of native vegetation.

In this study, two methods of fertilizer application were implemented by use of grain seeding equipment specifically designed for conservation tillage applications. Two growing seasons were evaluated. During the 1983 growing season, barley growth was the indicator of the effects of different phosphorus fertilizer rates and method of application. During the 1984 growing season, the effects of the prior year's fertilization were evaluated to determine if residual soil phosphorus is effective for subsequent crop growth. This study placed emphasis upon evaluation of "no-till" seeding equipment in barley production.

The study area for this project is approximately 170 km southeast of Fairbanks, Alaska (Figure 2.) and lies adjacent to the Delta Agricultural Project. The area was initially cleared in December, 1978. Native vegetation consisted primarily of black spruce [Picea mariana (Mill.) Britt., Sterns and Pogg], aspen [Alnus crispa (Ait.) Pursh.], and understory species of crowberry (Empetrum nigrun L.), sedges (Carex spp.), grasses [Agrostis spp. and Calamagrostis canadensis (Michx.) Nutt.] and mosses (Sphagnum spp.). The overstory vegetation was "chained" by means of a heavy length of chain connecting heavy track equipment moving parallel. The debris which had been chained was pushed into debris piles. This entire chaining operation was usually accomplished during the winter months and before spring thaw of subsurface soil horizons. While the mineral horizons are frozen, the organic horizons and understory vegetation was easily pushed into the large piles of debris. In 1980 , the site was root raked twice. Loose debris was raked together and placed in debris piles to allow normal cultivation practices on cleared areas. Prior to the first season of this study, the entire area was lightly tilled with a disc to prepare an adequate seedbed. Spring 1983 marked the beginning of the first cropping season for this area.

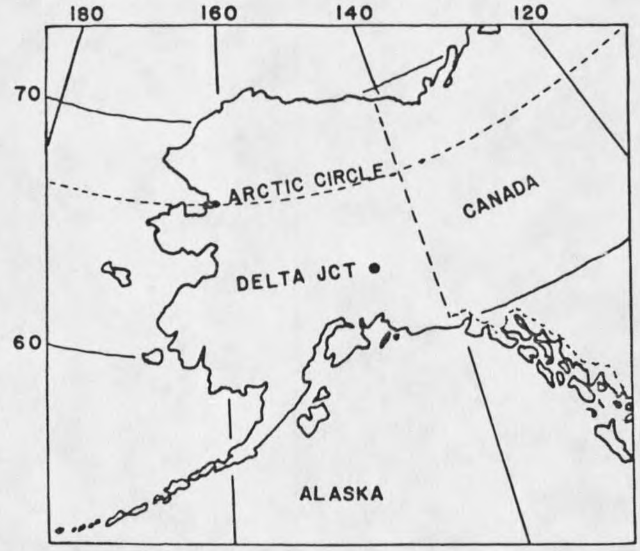

Figure 2. Location of the Delta Agricultural project near Delta Junction, Alaska.

1983 Growing Season

Before fertilization, soil samples were taken randomly across the study area. A Oakfield soil probe was used to sample to a depth of 0-15cm (0-6in). Eight cores per sample were composited and analyzed for NO_3-N, NH_4-N, P, K, Ca, Mg, Fe, CEC, % clay, % organic matter, and soil pH. Nitrogen (nitrate-N and ammonium) was extracted by 2N KCl (Bremner, J.M., 1979); phosphorus determined by Bray P-I(Olsen and Dean, 1979); potassium, calcium and magnesium by 1N NH_4OAc extraction (Pratt, P.F., 1979); iron by EDTA extraction (Olsen, 1979); CEC by NaOAc (Chapman, 1979); texture by Bouyoucous hydrometer (Day, 1979); % organic matter by Walkley-Black (Allison et al., 1979) and; pH of 1:1 soil-water.

On 5 May, a fertilizer blend of urea, muriate of potash, and ammonium sulfate was uniformly broadcast over the study area. The blend was applied to deliver 34 kg N/ha, 0 kg P/ha, 23 kg K/ha and 11 kg S/ha (75 lbs N/ac, 0 lbs P_2O_5/ac, 60 lbs K_2O/ac, and 24 lbs S/ac). Following this application, the entire study area was lightly disced.

Two grain seeding implements were calibrated to deliver 90 kg/ha (80 lbs/ac) of pure live seed. The variety of barley was "Lidal", a variety developed from the barley breeding program in Alaska. The grain seeding implements were calibrated to deliver five different levels of fertilizer at the time of seeding. Five fertilizer treatments included ammonium nitrate and triple superphosphate which delivered the following levels of nitrogen and phosphorus:

kg N/ha	(lbs N/ac)	kg P/ha	(lbs P_2O_5/ac)
10	(8.9)	0	(0)
10	(8.9)	10	(20)
10	(8.9)	20	(41)
10	(8.9)	40	(82)
10	(8.9)	80	(164)

One seeding implement placed the fertilizer directly with the seed (Banded treatment) via double-disc openers immediately followed by heavy press wheels. The other seeding implement broadcasted the seed and the fertilizer after a gang of one-way discs turned the soil (Broadcast treatment). This treatment resulted in random distribution of seed and fertilizer instead of distinct rows. The operation was followed by a "Brillion" packer which firmed the seedbed. Seeding the plot area was complete 18 May. Each plot measured 3.6m X 22.2m (12' X 72'). Four replications were seeded in a randomized block design.

On 15 June, a plant count was taken of each plot to compare plant establishment. It was noted during this measurement that the Broadcast treatments tended to have seed placed deeper than the desired 4 cm depth.

On 21 June, access tubes for neutron probe moisture measurements were placed in four plots of one replication. Earlier installation of these access tubes was prohibited by shallow depth of frost. The frost depth averaged 90 cm (3 ft) during the last week of June.

Broadleaf weeds were sprayed on 22 June with 24 ml/ha of bromoxynil. Good control of annual weed species was obtained. Perennial species were slightly affected.

Plant tissue samples were taken at late tillering (Stage 5 - Feekes scale) on 28 June. Samples were cut at ground level from a 625 cm^2 area. A frame measuring 25cm X 25cm was placed over two drill rows in random locations in the Banded treatments. The frame was placed randomly in the Broadcasted treatments. Three samples were cut from each plot on every replication. The samples were oven dried at 60°C, weighed and analyzed for total phosphorus content by using an acid digest method (Steckel and Flannery, 1971).

At the same growth stage, an additional sampling of plots was made to determine plants per plot and tillers per plant. An assessment of root development and vigor was also made at this time. On one replication, five samples were taken. Each sample area measureda 625 cm^2. Plants and tillers were counted. Assesment of roots was made by giving each root sample a rating based on a scale of 1 to 5. A rating of 1 was given to few roots easily separated from soil. A rating of 5 was given to a sample with many fibrous roots difficultly separated from soil. Intermediate ratings were given based on their appearance relative to a 1 or 5 rating.

Soil samples were taken at this growth stage over all plots. Eight cores were randomly taken from each Broadcast treatment application to a depth of 15 cm. These eight samples were composited. Core samples were taken within the barley row and also between the row on the Banded treatment plots. Samples were analyzed for available phosphorus using the Bray-I method.

Plots on one replication were sampled for dry matter production on 20 July. Five samples were cut from each plot. The sample area measured 625 cm^2. Samples were oven dried at 60° C and weighed.

Barley inflorescences were cut on 5 Aug and percent moisture was determined. Awns were removed before samples were weighed and dried. Identical samples were taken on 11 August, 19 August, 3 September, and 14 September. This procedure was used to measure percent moisture as an indication of degree of maturity.

Plots were harvested on 1 September by clipping three one square meter samples per plot. Samples were clipped at the soil surface, bagged and transported to Fairbanks where each sample was weighed and threshed. Grain and straw subsamples were taken from harvest samples and analyzed for percent total phosphorus and percent total nitrogen.

1984 Growing Season

Soil samples were taken on 9 May from each of the plots established in 1983. Eight cores per plot were composited. Soil at 0-7 cm (0-3 in) and 7-15 cm (3-6 in) depths were sampled and analyzed for available phosphorous.

A uniform broadcast fertilizer application of 27 kg N/ha, 29 kg P/ha, and 56 kg K/ha (80 lbs N/ac, 60 lbs P_2O_5/ac, and 60 lbs K_2O/ac) was inadvertently applied over the entire plot area prior to seeding.

The seeding design for the second year of this study included direct no-till seeding into the stubble remaining over winter after the 1983 crop. The plots were seeded by the double disc no-till drill with two different fertilizer blends. Both blends included 10 kg N/ha (8.9 lbs N/ac). In one blend, 10 kg P/ha (8.9 lbs P/ac) was included. No phosphorus was included in the second blend. One half of each plot from the 1983 design received fertilizer without P and the remainder received fertilizer with P at the time of seeding. Seeding rates and barley variety remained identical to 1983 season. Seeding operations were complete 10 May and barley emerged 12 days later.

On 30 May, isolated grassy areas within plots were sprayed with glysophate at a rate of 40 ml/ha. Care was taken to avoid healthy barley plants by using a hand held sprayer and walking across the entire plot area.

Plant samples were collected at tillering (Stage 5-Feekes scale, 20 June) by cutting 1m of row at the soil surface. These were oven-dried at 60^{o} C, weighed and analyzed for percent phosphorous. Soil samples were taken adjacent to the plant sample at depths of 0-7 cm and 7-15 cm (0-3 in and 3-6 in). Soil samples were analyzed for available phosphorous.

On 13 July, a sample was made of each plot similar to the sample taken during tillering on 20 June. The barley was at Stage 10.2-Feekes scale, flowering. Percent total phosphorus was determined from these plant samples.

On 11 August, barley roots were collected on three treatments on one replication. These treatments represented high, medium, and low phosphorus application levels. Soil samples were collected from the same treatments. Soil was collected from a 225 cm^2 area of soil to a depth of 7 cm.

The root samples were examined for vesicular-arbuscular mycorrhizal infection.

All plots were harvested on 30 August by cutting one square meter per plot. These harvest samples were cut at the soil surface, bagged and transported to Fairbanks. The samples were air-dried, weighed, and sub-sampled for straw and grain. Percent total phosphorus and total nitrogen were determined by the acid digest method.

Soil samples were taken from each plot immediately after harvest. Each plot was sampled to depths of 0-7 cm and 7-15 cm (0-3 in and 3-6 in). Eight cores were taken at each depth and composited on each plot. In addition, on one replication, soil samples were taken at 2.5 cm (1 in) increments to a depth of 7.5 cm (3 in). All samples were analyzed for available soil phosphorus.

RESULTS AND DISCUSSION

Table 1 shows general chemical and physical characteristics of the plot area before fertilization. The phosphorus level extracted by the Bray-I procedure indicates a phosphorus deficient soil.

Table 1. Initial soil status

pH	O.M. %	Total N	P	K	Ca	Mg	Al	Fe	clay %	sand %
		ug/g								
5.5	4.8	22.6	5.8	91	832	127	1.2	201	10.8	31.7

1983 Growing Season

Stand establishment counts on 15 June showed differences between treatment at emergence. Plots of the Broadcasted treatments had been observed to have been seeded to a depth of approximately 6.4 cm (2.5 in) and the Banded treatments approximately 3.8 cm (1.5 in) deep. The deep-seeded plants of the Broadcasted treatments were slightly delayed in emerging due to depth of seeding, but there were no significant differences in emergence between phosphorus treatments and method of phosphorus application.

Plots of two phosphorus levels and both methods of application contained access tubes for moisture measurements. Neutron probe measurements beginning in early July indicated no differences in soil moisture content across treatments. During the time of access tube installation, texture variation between horizons at each access tube installation site was observed. Soil textural differences may be so great that soil moisture use by the crop may be difficult to measure.

The first soil samples after fertilization were taken on 6 July (late tillering) and showed that the treated plots contained more phosphorus than the untreated plots(Table 2).

Table 2. Soil phosphorus levels at tillering, 6 July 1983.

Phosphorus Treatment	Banded	Broadcasted
kg P/ha	ug/g P	
0	7.4	7.2
10	8.1	8.9
20	9.1	8.9
40	11.8	9.2
80	17.2	9.3
Phosphorus Treatment	$LSD_{.05} = 2.9$	
Method of Application	$LSD_{.05} = 1.3$	

These samples also indicated that the Banded plots contained significantly more phosphorus than the Broadcast plots, especially at the higher rates of application. This occured inspite of identical application rates in the two methods of application. Two explanations are possible: 1) soil phosphorus levels from the Banded treatment plots were averaged between samples taken between the row and within the row and may have been skewed toward higher values or 2) the dilution and mixing of fertilizer phosphorus in the Broadcast treatments resulted in lower values. A greater difference between phosphorus rates was certainly expected in the Broadcast treatments as was seen in the Banded treatments.

On the one replication sampled, root rating and tiller count provides evidence of phosphorus levels effecting differences in plant growth. Table 3 illustrates these differences. The most notable change across phosphorus levels is the average number of tillers per plant. With Banded treatments, the first increment of applied phosphorus (10 kg P/ha) resulted in the largest difference in tiller development. The Broadcast treatments showed this reponse at 20 kg P/ha and as levels of applied phosphorus increased, tiller count generally increased. This count was made before fertile and nonfertile tillers could be distinguished. Even though high phosphorus treatments may influence tiller production, yield increases at harvest due to tiller numbers were not evident in this study. Differences in root ratings are obvious at the 10 kg P/ha phosphorus application rate in the Banded treatments and both 10 kg P/ha and 20 kg P/ha application rates of the

Broadcast treatments.

Table 3. Tillers per plant and root rating at tillering.

Phosphorus Treatment	Tillers/plant *		Root Rating **	
	Banded	Broadcast	Banded	Broadcast
kg P/ha				
0	.57	.53	2.4	1.4
10	1.05	.47	3.8	2.8
20	1.60	1.05	3.8	4.2
40	1.40	1.33	3.8	3.2
80	1.45	1.58	4.4	4.4

* - Tillers per plant is an average of five samples per plot.

** - Root rating is given relative to root vigor and development.

1 - few; easy to separate primary and secondary roots from soil.

5 - many; difficult to separate mass of root and soil.

Based on samples from one replication on two dates, 1 July and 20 July, (Table 4) dry matter yields generally increased with increasing levels of phosphorus. In comparing method of application, Broadcast plots generally yielded more than Banded plots. Growth in early July was stimulated by precipitation which had been preceded by unseasonably warm and dry conditions. The Broadcast treatments may have benefited more than the Banded treatments because of delayed emergence early in the growing season. The Banded treatments may have progressed past a point where it could benefit from the July precipitation.

Table 4. Dry matter production and plant phosphorus content at two growth stages.

	Phosphorus Treatment	Banded	Broadcast	Banded	Broadcast
	kg P/ha	----- g/m^2 -----		------ % P ------	
1 July	0	45.4	61.4	.23	.23
	10	61.4	101.7	.28	.22
	20	92.8	143.0	.24	.26
	40	143.0	123.0	.30	.34
	80	118.7	164.5	.35	.27
20 July	0	165.9	313.3	.24	.27
	10	286.7	373.1	.23	.21
	20	294.7	373.1	.23	.21
	40	318.7	457.9	.28	.21
	80	440.6	394.2	.31	.34

There was not an obvious correlation between dry matter production, tiller and root growth. Since these samples were taken at approximately the same stage of growth, some correlation would be expected. Increased tillers and vigorous root growth would normally predict increased dry matter production. Sampling at the exact stage of growth for tillers, roots and dry matter production might have alleviated this discrepancy. Sampling more than one replication would have provided the ability to make statistical comparisons.

At tillering, plant tissue phosphorus generally increased with increased levels of applied phosphorus. Alessi and Power (1980) showed similar results with spring wheat. Plant tissue phosphorus levels of spring wheat at tillering were significantly different between high and low levels of applied phosphorus. At later stages, they reported no significant differences between high and low phosphorus treatments.

As maturity approached, percent moisture in the barley heads decreased. Figure 3 illustrates the gradual decline in moisture content with time. On each date, the control treatment (0 kg P/ha) was significantly wetter than the two phosphorus treatments. These data support the general observation that adequate phosphorus nutrition may speed barley maturity. Moisture percentages were calculated on the complete unthreshed barley head and are considerably higher than threshed grain moisture content.

The 1983 grain and straw yields are shown in Figures 4 and 5. In the Broadcast treatments, grain yield was significantly increased by the first two increments (10 kg P/ha and 20 kg P/ha) of applied phosphorus. In Banded treatments, no significant yield increase was obtained after

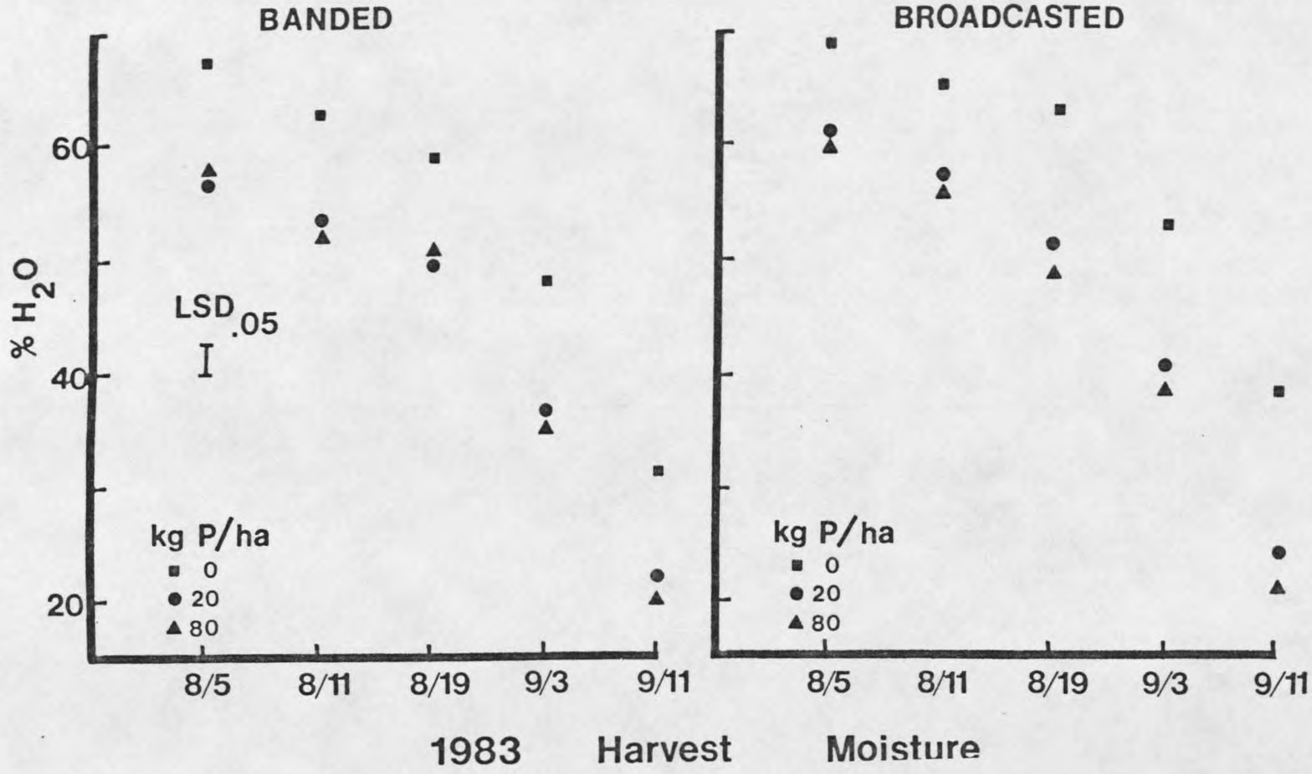

Figure 3. 1983 moisture content of barley heads on five dates.

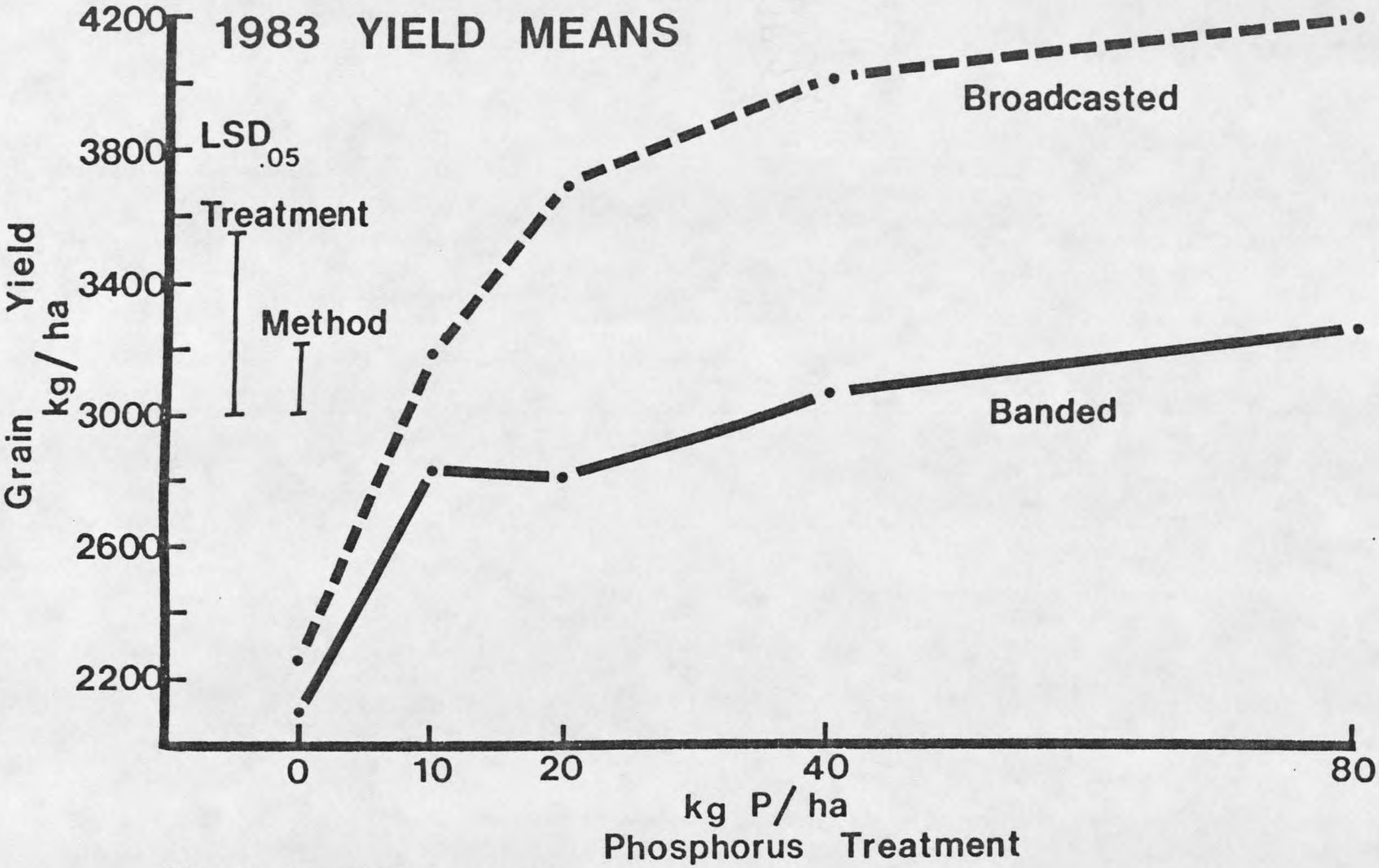

Figure 4. 1983 harvest grain yields.

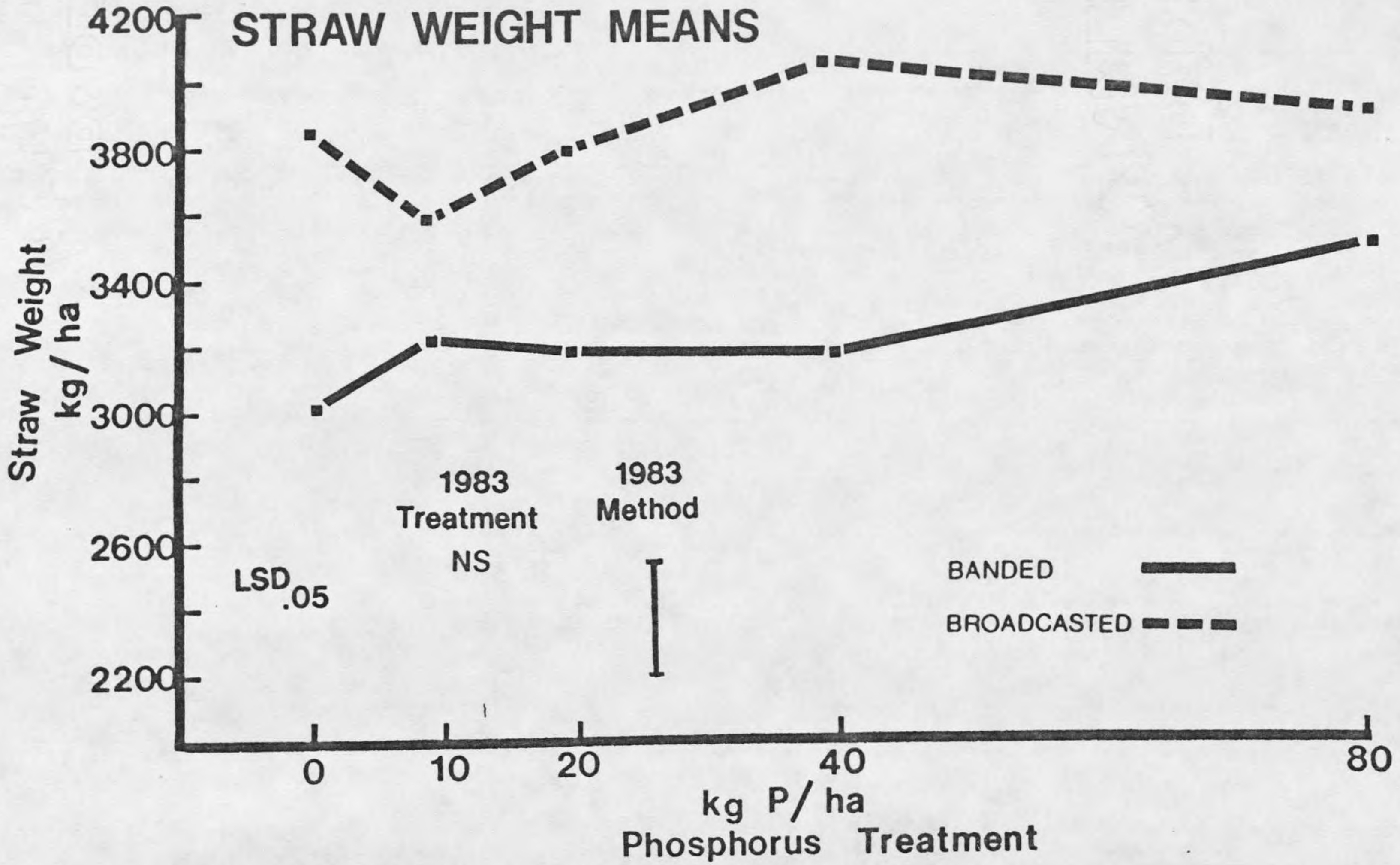

Figure 5. 1983 harvest straw weight means.

the first 10 kg P/ha application. Straw production was not significantly increased by phosphorus, although there is a trend toward higher straw production at higher phosphorus application rates. Broadcast tratments yield more grain and straw than Banded treatments. Due to delayed emergence and subsequent development, the Broadcast plots were able to take advantage of late precipitation. The difference in late growth in the Broadcast plots highlights the efficiency of phosphorus utilization in the Banded plots. Beyond the application of 10 kg P/ha, no yield increase was attributed to phosphorus fertilizer, i.e. grain production from treatments above 10 kg P/ha was not limited by phosphorus.

Differences in test weights and straw-grain ratios for 1983 (Table 5) were not attributed to methods of application. The first increment of applied phosphorus (10 kg P/ha) did, however, significantly increase test weight. The straw-grain ratio was significantly reduced by application of 10 kg P/ha in the Broadcast treatments and by application of 20 kg P/ha in the Banded treatments. This would be expected in examinination of the grain and straw production in Figures 4 and 5.

Phosphorus content of grain (Table 6) tended to increase with increasing phosphorus application. In the Broadcast treatments, the first 10 kg P/ha resulted in a significant increase in grain phosphorus. The Banded treatments required 20 kg P/ha to cause a significant

Table 5. 1983 harvest test weights and straw-grain ratios.

Phosphorus Treatment	Test Weight Banded	Test Weight Broadcast	Straw-Grain Ratio Banded	Straw-Grain Ratio Broadcast
kg P/ha	----lbs/bu----			
0	45.9	43.8	1.50	1.85
10	50.8	50.1	1.50	1.12
20	51.5	52.0	1.11	1.01
40	51.6	51.3	1.03	1.03
80	51.5	51.7	1.05	1.00

		Test Weight	Straw-Grain Ratio
Phosphorus Treatment	$LSD_{.05}$	2.21	.25
Method of Application		NS	NS

Table 6. 1983 harvest grain and straw phosphorus content.

Phosphorus Treatment	Grain Banded	Grain Broadcast	Straw Banded	Straw Broadcast
kg P/ha	-----------------% P-----------------------			
0	.28	.27	.035	.037
10	.29	.30	.035	.037
20	.31	.31	.042	.037
40	.31	.35	.037	.035
80	.37	.36	.055	.040

		Grain	Straw
Phosphorus Treatment	$LSD_{.05}$	.03	NS
Method of Application		NS	NS

increase. The 80 kg P/ha treatment resulted in a 9% increase in grain phosphorus over the control treatments with both methods of application. Straw phosphorus was not affected by phosphorus treatment or method of application.

<u>1984 Growing Season</u>

Residual phosphorus available in the spring of 1984 as a result of 1983 fertilization is shown in Figure 6. The 40 and 80 kg P/ha treatments contain significantly more soil phosphorus than other treatments. They are also significantly different from each other. There is no significant difference in soil phosphorus as affected by method of application. The sampling technique for these soil samples was identical over both Broadcast and Banded plots. All plots were randomly sampled with no separation between and within the rows.

Good seed placement was obtained when the double disc no-till drill penetrated the surface where stubble had been left standing, but due to 1983 harvest operations, traffic across the plots left residue lying flat in some plot areas. Penetration by the no-till drill was restricted through the flattened residue. Germination was either perhaps prohibited or delayed because of inadequate soil-seed contact.

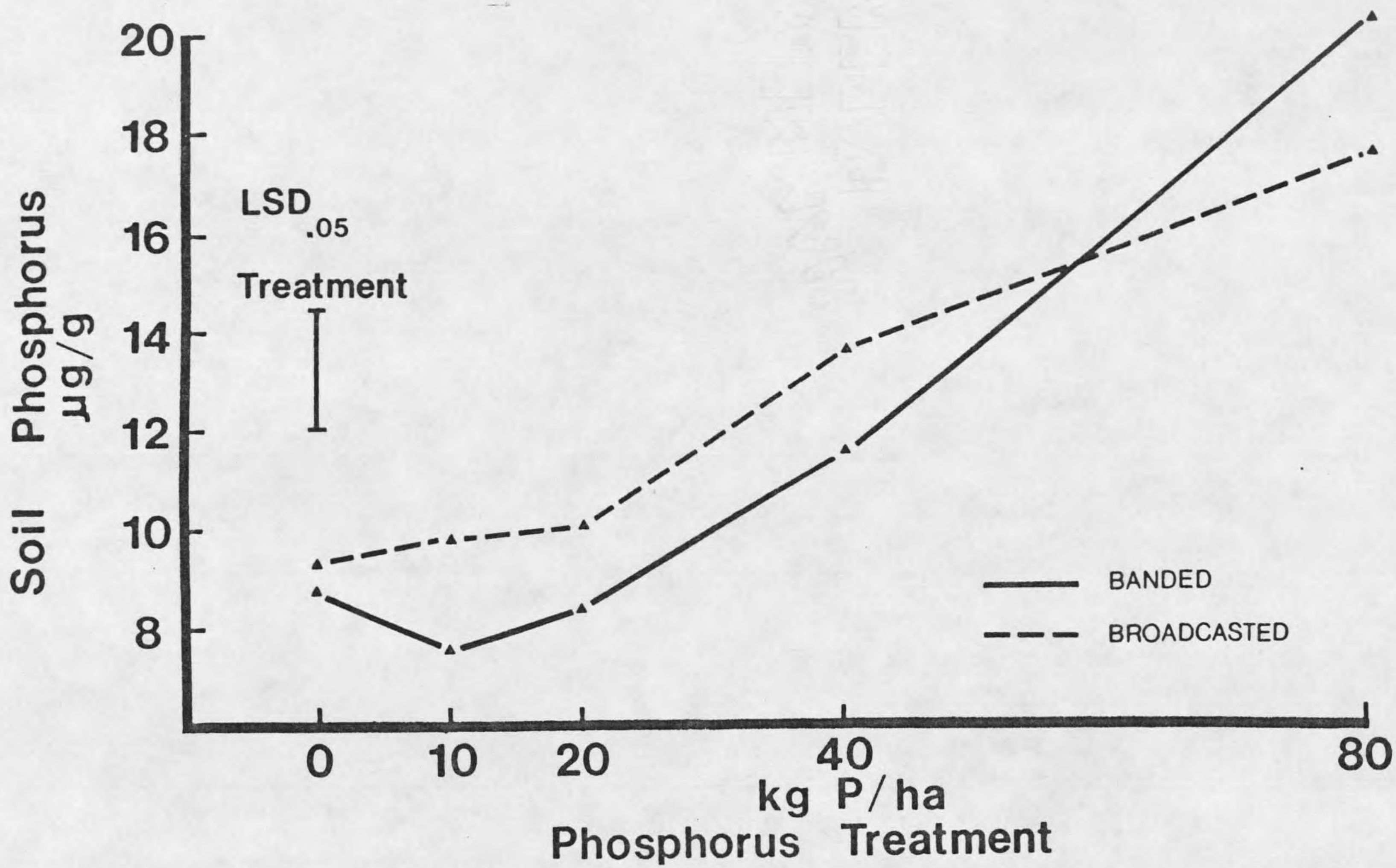

Figure 6. 1984 spring soil phosphorus levels prior to fertilization.

Competition by perennial grass was unforseen at the time of seeding and control measures failed to adequately eliminate grassy weeds from the plot area. Timely cultivation may provide the most efficient control of perennial grasses. Seeding directly into crop residues in conservation tillage systems avoids cultivation which has been used for weed control in conventional systems. Replacing this cultivation operation with herbicide control was not effective under our conditions.

Plant tissue phosphorus was sampled twice during the 1984 growing season. These samples were taken on 20 June and 13 July to examine changes in phosphorus content at two growth stages. Figure 7 and Figure 8 illustrate plant phosphorus as affected by 1983 phosphorus treatment levels, method of 1983 application, and 1984 placement of phosphorus at the time seeding. In examining the results, it is important to recognize the possible influence of the inadvertant application of phosphorus prior to seeding in 1984. At tillering, there is significant difference between plant phosphorus content across 1983 phosphorus treatments and 1984 placement of phosphorus. No significant difference exists between 1983 application methods. Sharp decreases in plant phosphorus content are observed between 0 and 10 kg P/ha treatments. The decreases are greater in the treatments where no additional phosphorus was applied at the time of seeding in 1984. An explanation for these

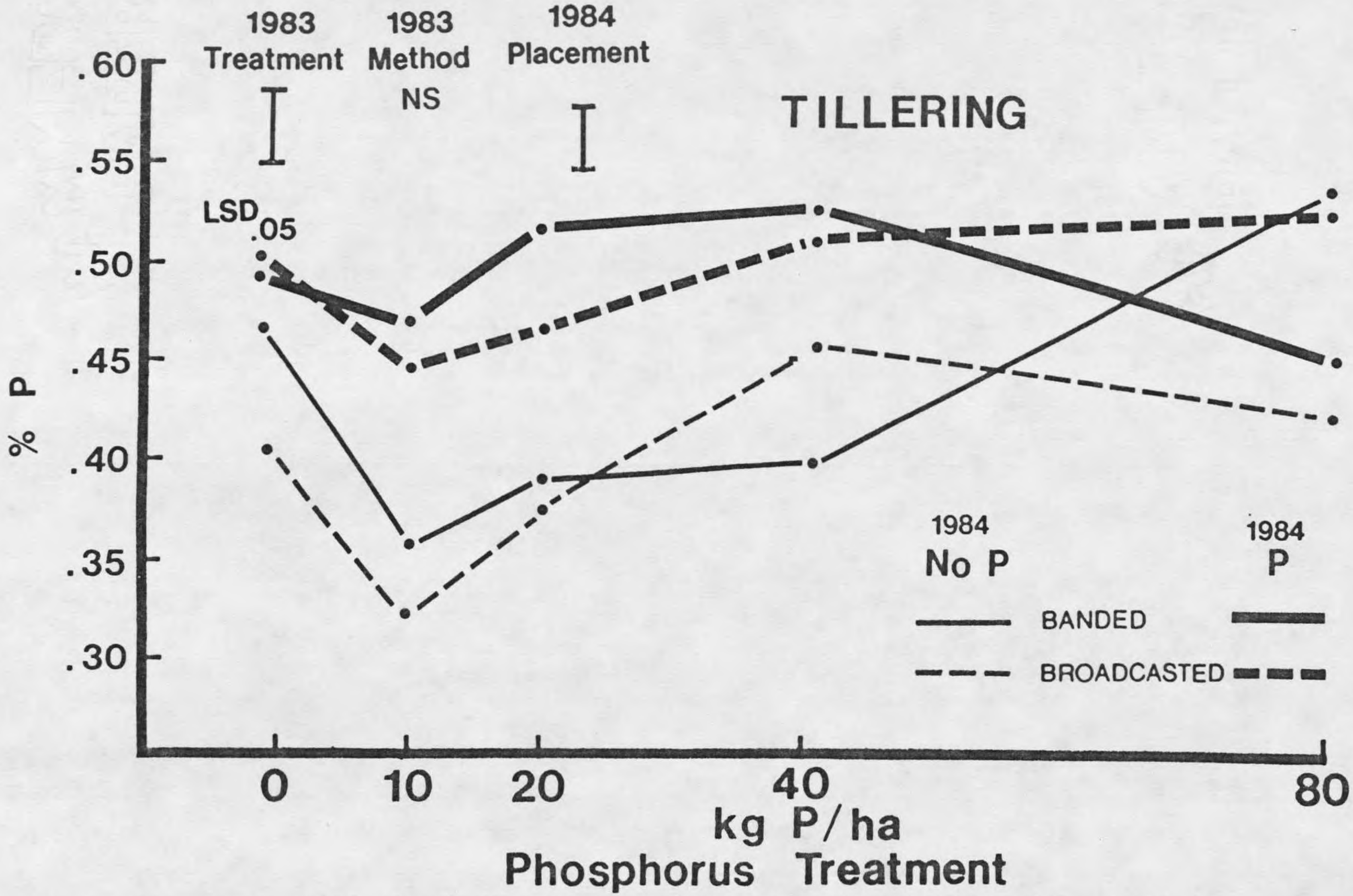

Figure 7. 1984 plant tissue phosphorus levels at tillering. Methods of application in 1983 were Banded and Broadcast. Placement of phosphorus at seeding in 1984 was Banded and compared with no additional phosphorus at seeding.

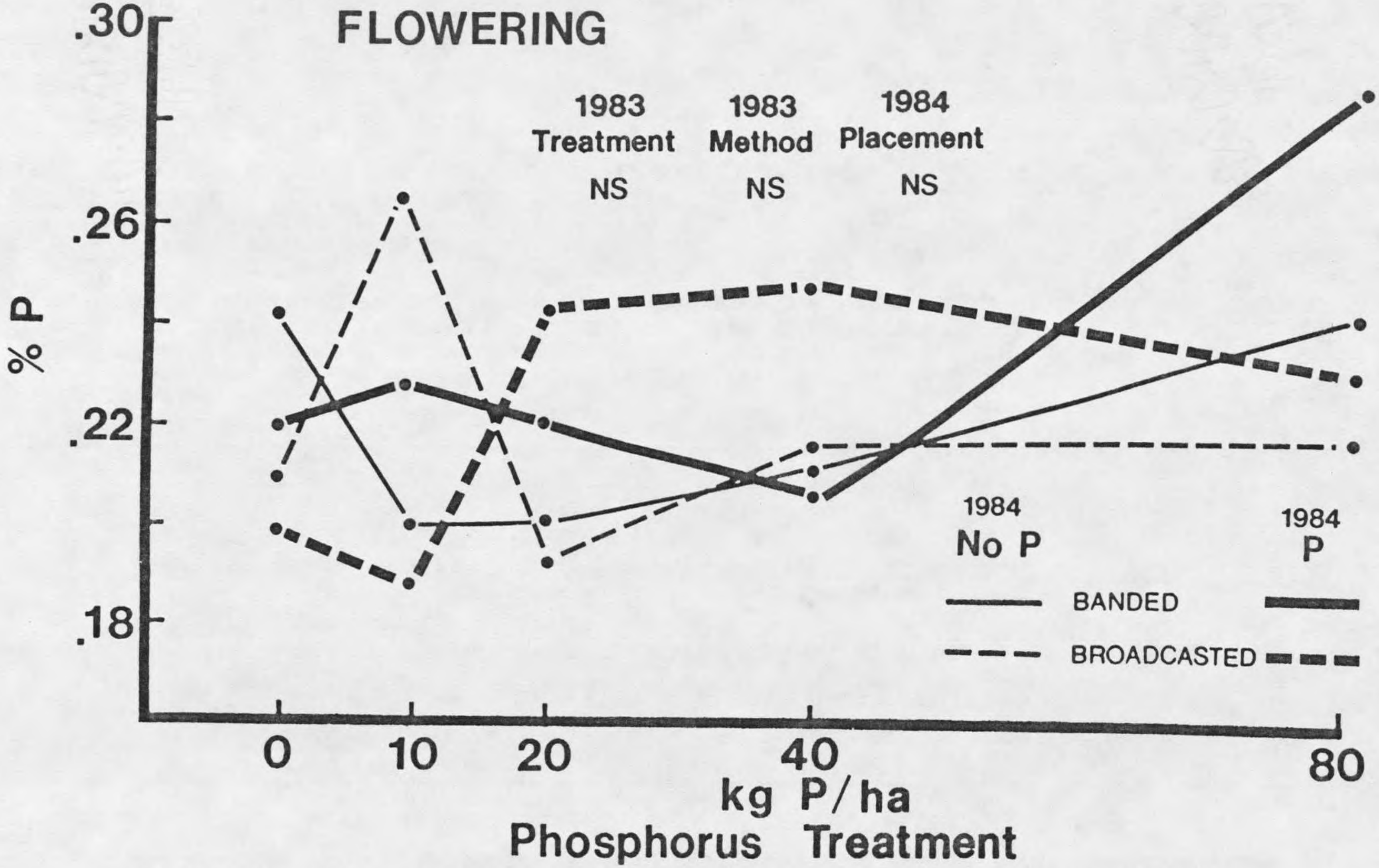

Figure 8. 1984 plant tissue phosphorus levels at flowering. Methods of application in 1983 were Banded and Broadcast. Placement of phosphorus at seeding in 1984 was Banded and compared with no additional phosphorus at seeding.

phosphorus levels in control treatments may be attributed to mycorrhizal activity. Application of phosphorus at the time of seeding may have compensated for the reduced activity of mycorrhiza. This may explain why the decline in plant phosphorus content is less in the treatments receiving additional phosphorus at seeding. Phosphorus uptake by mycorrhiza may be enhanced by the absence of soluble phosphorus fertilizers (Black and Tinker, 1977). Low rates of soluble phosphorus fertilizer reduces VAM activity and thereby phosphorus uptake by mycorrhizal hyphae. This response at this stage of crop growth may be complicated by the inadvertant broadcast application of phosphorus before seeding although this application of phosphorus was not incorporated into the soil surface and movement to the active root zone may have been minimal.

At flowering, plant phosphorus content is not different across any treatments, however, levels of tissue phosphorus are lower than at tillering. This indicates greater phosphorus uptake earlier in the growth of the plant and possible dilution of phosphorus in plant tissue due to increased biomass production at later stages of growth. Data reported by Alessi and Power (1980) show significant differences with plant phosphorus content between low phosphorus treatments and high phosphorus treatments at tillering of spring wheat, but plant phosphorus content at later growth stages in their study was not significantly different.

Soil phosphorus levels at tillering (Figure 9) were not significantly different due to treatments. Soil samples taken at this time included the surface application of phosphorus which had been inadvertantly broadcast over all plots. Soil phosphorus differences attributed to treatments may have been negated.

Examination of barley root samples taken on 11 August disclosed the presence of mycorrhizal fungi. This examination proved the existence of mycorrhiza, but differences in fungal populations as affected by phosphorus treatments were difficult to establish without extensive sampling. Sampling earlier in the growing season would be advisable for future study of mycorrhizae in agronomic crops.

Soil phosphorus levels at harvest in 1984 (Figure 10) are signficantly different between 1983 phosphorus treatments and 1984 phosphorus application, but not different when comparing 1983 method of application. Soil phosphorus levels are generally higher on the 80 kg P/ha treatments than the lower rates of phosphorus application with the exception of the plots receiving phosphorus at the time of seeding in 1984 on the 1983 Broadcast treatments. Soil phosphorus levels are lower in samples taken at harvest than those at tillering. This is a result of plant consumption as well as possible movement of soil solution phosphorus to the labile soil phosphorus pool. The Bray-I

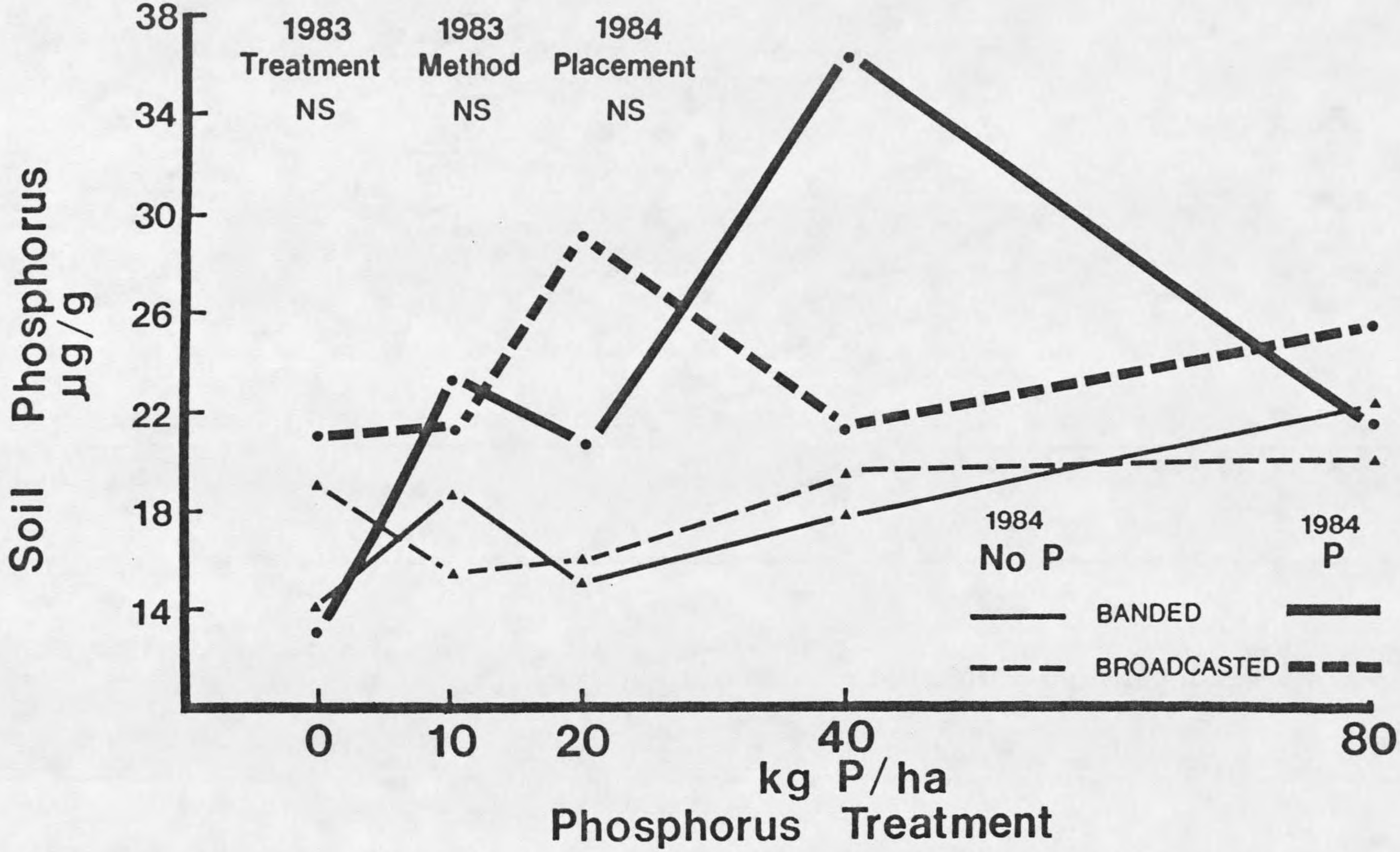

Figure 9. 1984 soil phosphorus levels at tillering. Methods of application in 1983 were Banded and Broadcast. Placement of phosphorus at seeding in 1984 was Banded and compared with no additional phosphorus at seeding.

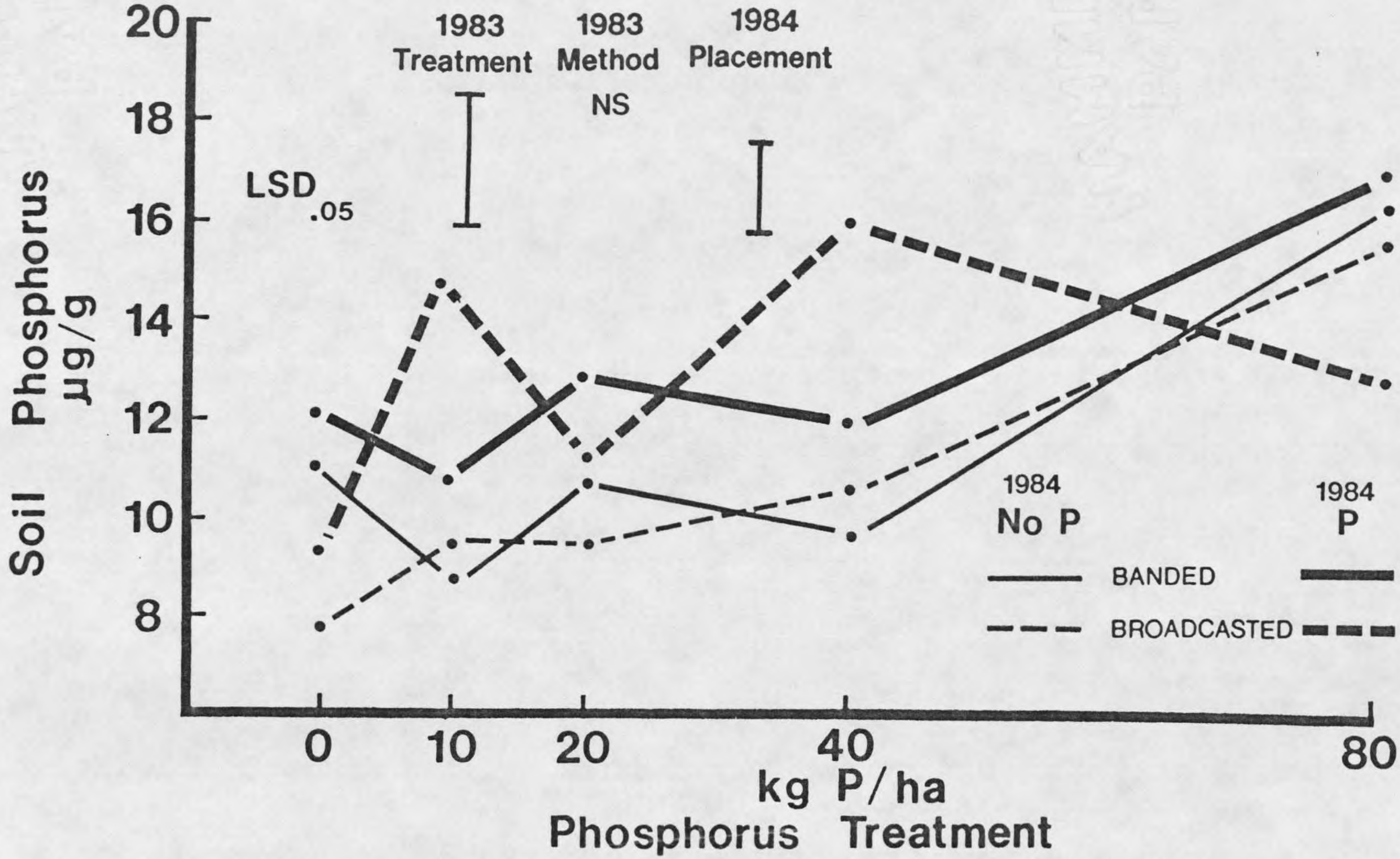

Figure 10. 1984 soil phosphorus levels at harvest. Methods of application in 1983 were Banded and Broadcast. Placement of phosphorus at seeding in 1984 was Banded and compared with no additional phosphorus at seeding.

procedure used in this study does not accurately measure labile phosphorus (Holford, 1980).

Soil samples taken at three 2.5 cm (1 in) increments are compared with the 0-7.5 cm sample in Table 7.

Table 7. Soil phosphorus levels at 2.5 cm increments and 0-7.5 cm increments.

Phosphorus Treatment	Depth	P Application in 1984* Banded	P Application in 1984* Broadcast**	No P Application in 1984 Banded	No P Application in 1984 Broadcast
kg P/ha	cm	ug/g P			
0	2.5	68.4	58.5	58.0	40.1
	5.0	19.6	12.1	32.0	15.5
	7.5	17.1	9.6	14.7	9.8
	0-7.5	10.2	7.1	9.0	6.8
10	2.5	48.1	18.8	35.8	51.2
	5.0	8.2	7.2	18.9	13.2
	7.5	6.8	7.2	12.7	11.3
	0-7.5	10.6	8.6	9.1	7.4
20	2.5	69.6	54.9	44.7	31.2
	5.0	29.0	17.9	30.9	17.4
	7.5	8.3	14.4	20.4	14.6
	0-7.5	14.5	11.2	14.8	10.6
40	2.5	32.0	51.7	116.0	56.1
	5.0	7.7	25.0	70.0	24.4
	7.5	5.5	27.4	28.0	56.4
	0-7.5	9.9	17.5	9.0	18.0
80	2.5	62.9	49.9	90.7	62.9
	5.0	52.4	25.7	59.1	19.8
	7.5	20.7	31.0	33.6	14.2
	0-7.5	19.9	13.2	16.2	13.7

* Phosphorus application in 1984 was placed at the time of seeding and compared with no additional phosphorus applied at seeding.

** Banded and Broadcast were methods of phosphorus application in 1983.

The samples taken at 2.5 increments indicate high phosphorus levels near the soil surface which shoul be expected when considering the inadvertant addition of 29 kg P/ha over the entire area. Below the surface, phosphorus levels are generally higher in the Banded treatments than the Broadcast treatments. Analysis of soil samples taken at 7-15 cm (Table 8) indicate no significant differences in levels of soil phosphorus at these lower depths between the 1983 phosphorus treatments.

Table 8. 1984 Soil phosphorus levels at harvest at 7-15 cm increment.

Phosphorus Treatment	P Application in 1984*		No P Application in 1984	
	Banded	Broadcast**	Banded	Broadcast
kg P/ha	---------------ug/g P---------------			
0	5.4	7.4	5.5	6.5
10	7.1	6.3	5.8	7.2
20	4.9	7.0	5.7	5.2
40	4.4	6.1	5.4	5.2
80	4.3	6.8	5.7	5.3

1983 Phosphorus Application --- NS

1983 Method of Application --- $LSD_{.05} = 2.51$

1984 Phosphorus Application --- NS

* Phosphorus application in 1984 was Banded at the time of seeding and compared with no additional phosphorus applied at seeding.

** Banded and Broadcast were methods of phosphorus application in 1983.

The 1983 method of application proved significantly different only at the 80 kg P/ha application rate on the plots receiving additional phosphorus at the time of seeding in 1984. At the time of initial application in 1983, fertilizer was placed deeper and possibly mixed in a greater volume of soil in Broadcast treatments than Banded. This resulted in higher initial levels in Broadcast treatments than Banded.

Harvest grain yield in 1984 (Figure 11) is not significant between 1983 phosphorus treatments, 1983 method of application or 1984 application. Three replications were used in analyzing harvest data because of flood damage received to the fourth replication during a heavy runoff event in July. Grain yields in 1984 on phosphorus treatments are lower than 1983 yields except the control treatments (0 kg P/ha). All 1984 control plots may have benefited from the inadvertant application of phosphorus prior to seeding and are higher than 1983 control treatments. Stand establishment hampered by excessive crop residues and inadequate weed control were serious factors of yield reduction.

Even though the harvest yields lack significance, the placement of phosphorus with the seed at the time of seeding has an effect on overall phosphorus availability and plant uptake during the season of application. This was apparent in examining straw-grain ratios, grain and straw phosphorus content.

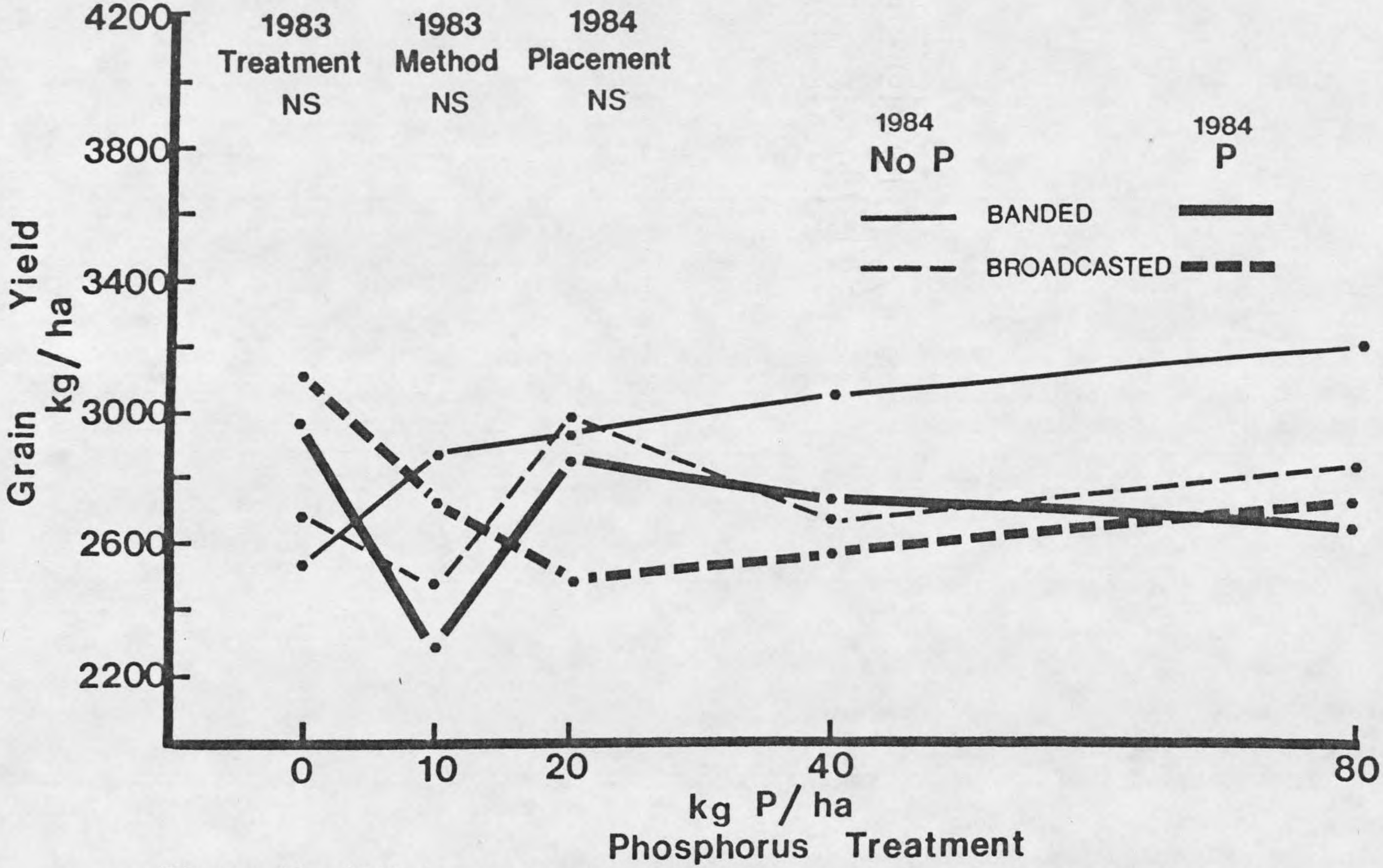

Figure 11. 1984 harvest grain yield means. Methods of application in 1983 were Banded and Broadcast. Placement of phosphorus at seeding in 1984 was Banded and compared with no additional phosphorus at seeding.

The straw-grain ratio and phosphorus content of grain at harvest (Table 9 and 10) are significantly different when comparing 1984 phosphorus applications. The plots receiving additional phosphorus at seeding in 1984 have higher straw-grain ratios and higher grain phosphorus contents. There is no significant difference in straw-grain ratios or grain phosphorus content when comparing 1983 phosphorus treatments or 1983 method of application.

Table 9. 1984 harvest straw-grain ratios.

Phosphorus Treatment	P Application in 1984*		No P Application in 1984	
	Banded	Broadcast**	Banded	Broadcast
kg P/ha				
0	1.03	1.00	.89	.84
10	1.17	1.21	.88	.97
20	1.21	1.02	.88	.85
40	1.11	.99	1.02	.87
80	1.11	1.09	1.01	.96

1983 Phosphorus Application --- NS

1983 Method of Application --- NS

1984 Phosphorus Application --- $LSD_{.05}$= .07

* Phosphorus application in 1984 was Banded at the time of seeding and compared with no additional phosphorus applied at seeding.

** Banded and Broadcast were methods of phosphorus application in 1983.

Table 10. 1984 harvest grain phosphorus content.

Phosphorus Treatment	P Application in 1984*		No P Application in 1984	
	Banded	Broadcast**	Banded	Broadcast
kg P/ha	% P			
0	.41	.40	.40	.41
10	.41	.43	.36	.36
20	.39	.39	.37	.38
40	.40	.40	.40	.39
80	.43	.42	.42	.40

1983 Phosphorus Application --- NS

1983 Method of Application --- NS

1984 Phosphorus Application --- $LSD_{.05} = .01$

* Phosphorus application in 1984 was Banded at the time of seeding and compared with no additional phosphorus applied at seeding.

** Banded and Broadcast were methods of phosphorus application in 1983.

The phosphorus content of straw (Table 11) in control treatments is significantly higher than all treatments of applied phosphorus. The phosphorus content of straw from plots receiving no additional phosphorus at seeding was significantly higher than straw from plots receiving additional phosphorus at seeding in 1984. This corresponds to lower straw-grain ratios in control treatments and possibly less dilution of phosphorus due to decreased dry matter production.

Table 11. 1984 harvest straw phosphorus content.

Phosphorus Treatment	P Application in 1984*		No P Application in 1984	
	Banded	Broadcast**	Banded	Broadcast
kg P/ha	% P			
0	.093	.093	.106	.130
10	.080	.086	.093	.090
20	.086	.076	.086	.090
40	.080	.076	.083	.086
80	.083	.080	.086	.086

1983 Phosphorus Application --- $LSD_{.05}$= .011

1983 Method of Application --- NS

1984 Phosphorus Application --- $LSD_{.05}$= .007

* Phosphorus application in 1984 was Banded at the time of seeding and compared with no additional phosphorus applied at seeding.

** Banded and Broadcast were methods of phosphorus application in 1983.

Plant uptake of phosphorus during the season as indicated by tissue phosphorus levels at tillering, flowering and harvest is not reflected in significant yield differences. It should be noted that phosphorus concentrations in plant tissue (excluding grain) is generally higher from plots which received lower rates of applied phosphorus.

CONCLUSIONS

Two seasons of study of phosphorus fertilizer rates and method of application have resulted in the following conclusions:

--Following initial land clearing operations, the soil is deficient in phosphorus for small grain production. An application of at least 10 kg P/ha at the time of seeding is necessary to compensate for this deficiency for average crop production on soils in this study.

--Application of phosphorus fertilizer at the time of seeding may be accomplished by an implement which bands or broadcasts the seed and fertilizer. The results of this study do not favor one method over the other.

--Effects of phosphorus applied during the first season were not evident during the second season of growth. Due to the inadvertant broadcast application of phosphorus uniformly applied prior to seeding operations, complete evaluation of residual phosphorus levels was prohibited.

Continued evaluation of the initial application of phosphorus following clearing operations should be considered. In continuing this study, care should be taken to adequately sample the plots to determine the location of soil phosphorus. Samples should be taken of a representative volume of soil which has been fertilized in previous operations. This takes into consideration all applications of phosphorus fertilizer before and after seeding operations. Soil sampling during the growing season may be helpful in explaining plant tissue nutrient analysis at crucial stages of the growing plant. These midseason samples would help prescribe changes in fertilizer recommendations for following years. Complete fractionation of soil phosphorus of Interior Alaskan soils would help determine the role of organic phosphorus in providing plant available phosphorus. Fractionation would also indicate the occurance of phosphorus retention.

Evidence of mycorrhiza populations existing prior to fertilization warrants further study of the use of commercial fertilizers in agricultural production and the effects on microbial populations.

Soil fertility research should continue to address the conditions of plant-soil-water relations in conservation tillage systems. Balanced plant nutrition is especially important when plant residues remain in the system and affect nutrient availability. Plant-soil-water relations in Alaskan agriculture require continued research to provide realistic fertilizer recommendations.

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