RELATIONSHIPS BETWEEN SEEDBED PREPARATION AND GROWTH OF CORN AND TOBACCO PLANTS

by

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INTRODUCTION

During the past few decades efforts have been directed toward devising methods of growing corn which are less costly as well as more efficient than conventional methods from the standpoint of soil and water conservation. The most recent of these methods is "no tillage" which involves planting corn in soil treated with chemicals to control weeds. Provided that weeds are effectively controlled, the "no tillage" method has given equal or higher corn yields than the conventional method.

Several problems must be solved before the "no tillage" method of growing corn can be routinely used by farmers. Among the more difficult of these problems are devising machinery for planting corn, establishing a suitable cover crop after corn is harvested, and placing fertilizer in a manner which results in efficient usage by corn plants. At the present time research is underway to solve each of these problems. One of these problems, method of fertilizer placement, was dealt with in the present investigation. Emphasis was directed toward uptake of applied P by corn plants grown by conventional and "no tillage" methods.

Specific objectives of experiments reported in this manuscript include:

1. to compare uptake of P by corn plants from fertilizer applied to the soil surface with that mixed with the soil;
2. to compare the conventional and "no tillage" methods of growing corn with respect to yield of corn, soil temperature, and soil moisture content;
3. to compare the conventional and "no tillage" methods of growing tobacco with respect to yield and nutrient composition; and
4. to determine the plant availability of the Ca-P, Fe-P, and Al-P fractions of soil which received varying amounts of superphosphate.

REVIEW OF LITERATURE

Investigations are continually being undertaken to increase corn yields and lower production costs. Among the more important factors considered in these investigations are seedbed preparation and fertilization practice. Seedbed preparation must provide measures for adequate weed control and conditions for suitable seed germination, whereas the fertilization practice must provide proper amounts of nutrients placed in a manner which allows efficient usuage by plants. Method of application is especially important for an element such as P which can be fixed by soil in forms which are relatively unavailable to plants. Information concerning the effect of seedbed preparation on corn growth and the effect of the method of P application on plant availability of applied P will be reviewed in the following sections.

Relationship Between Tillage Practice and Corn Growth

Plowing with subsequent disking or dragging (conventional tillage method) is at present the most widely used method of seedbed preparation for corn. It provides adequate weed control during the early portion of the growing season as well as a favorable seedbed with respect to seed germination. The main disadvantages of the conventional tillage method are that it does not provide adequate erosion control and that it is an expensive procedure due to high fuel, machinery, and labor costs. Consequently, less expensive tillage methods, which provide suitable seedbed preparation and erosion control, have been devised. These methods include "mulch tillage", "reduced tillage", and "no tillage".

Mulch tillage. Mulching is defined as the use of crop residues, manure, leaves, peat and other litter as well as paper, glass, wool, metal foil, cellophane and other convenient manufactured materials as mulches with or without shallow tillage, for the purpose of increasing soil productivity (Jacks et al., 1955).

Field investigations have been conducted to determine the effect of mulching on yield of corn. Nutt and Peele (1947) found that a corn stalk mulch increased the yield of corn on Cecil sandy loam. The increase in corn yield was attributed to the increase in soil moisture content. In contrast, Baugh et al. (1950) found that timothy mulch decreased yield of corn grown on Carrington and Miami silt loams. The decrease in yield was ascribed to plant damage caused by covering of plants with clumps of mulch during cultivation. An investigation on Canfield silt loam by Borst and Mederski (1957) showed that mulch tillage (2 tons straw/A.) decreased yield of corn and K uptake by corn plants, and increased bulk density of the soil. It was proposed that soil O_2 content was decreased by the high bulk density of soil to a level which decreased K uptake and that the decrease in yield was caused by K deficiency of plants.

Although mulch tillage may not result in higher yields, it is a desirable practice from the standpoint of soil and water conservation. Runoff experiments on Marshall silt loam conducted by Duley and Russell (1939) showed 15 times more erosion of bare soil than soil covered with a straw mulch (3500 lbs./A.). A decrease in soil erosion due to mulch tillage has also been shown by experiments on Cecil sandy loam (Nutt and Peele, 1947) and on Carrington and Miami silt loams (Baugh et al., 1950).

The decrease in erosion of mulched soils was attributed to an increase in infiltration rate of rain water (Duley, 1943) and to a decrease in size and velocity of raindrops which contacted the soil surface beneath the mulch (Laws, 1940; Borst and Woodburn, 1942).

Reduced tillage. Reduced tillage refers to seedbed preparation in which one or more of the conventionally used tillage practices is eliminated or performed a lesser number of times. The most thoroughly investigated methods of reduced tillage (Moody *et al.*, 1964) are given below:

1. shallow plow-planting, a two step process in which corn is planted immediately after shallow plowing of soil;
2. wheel-track planting, a two step process of plowing and then planting corn in tractor tire tracks;
3. strip-till planting, a two step process in which soil is plowed and corn is planted in a narrow area tilled by either a rotary sweep or chisel; and
4. plow-planting, a one step process consisting of plowing and planting corn at the same time.

Investigations have been conducted to determine the effect of reduced tillage on corn yields. Browning and Norton (1945) found that shallow plow-planting resulted in lower corn yields than conventional tillage for fine textured poorly drained soils (Clarion, Webster, Carrington, and Fayette silt loams). On the other hand, Bowers and Bateman (1960) obtained higher yields on reduced tillage than conventional tillage treatments for clayey soils. Conventional and reduced tillage did not result in significantly different corn yields in the following investigations: strip-till planting on Groseclose silt loam and silty clay loam (Moody *et al.*, 1955); wheel-track planting on Groseclose silt loam, Federick silt loam, Cecil loam and

and Woodston loam (Moschler *et al*., 1960); and plow-planting on poorly drained Mardin silt loam (Musgrave *et al*., 1955).

Mechanisms have been proposed to explain decreases in corn yields due to reduced tillage. Cloddy seedbed preparation by the plow-plant method resulted in poor germination and, consequently, low corn yields on Miami silt loam (Page *et al*., 1946). A similar explanation was given by Cook *et al*. (1953) who found that reduced tillage methods decreased yield of corn grown on Brookston clay loam, Brookston loam, Hillsdale sandy loam, and Fox sandy loam. Low corn yields on Tama and Fayette silt loams which received shallow plow-planting tillage were attributed to K deficiency (Bowers *et al*., 1944). It was proposed that the high bulk density of the plow-plant tilled soil reduced the soil O_2 content to a level which decreased K uptake by corn plants.

Higher corn yields on reduced tillage than conventional tillage treatments have been explained on the basis of soil moisture and aeration relationships. Rao, *et al*. (1960) attributed the increase in yield of wheel track planted corn on Drummer clay loam and Brenton silt loam to an increase in amount of available soil water. It was concluded that the lower bulk density of the wheel track as compared to conventionally tilled soil resulted in a higher rate of infiltration and, therefore, a higher amount of available water. Fanning and Brady (1963) concluded that plow-plant tillage improved aeration and, consequently, increased yield of corn grown on a poorly drained soil.

No tillage. "No tillage", the most recently devised method of seedbed preparation, is a two step process in which vegetation is killed by chemical methods and corn is planted in the chemically treated soil.

Investigations have been conducted to determine the effect of no tillage on corn yields. Yields of corn were not significantly different due to conventional tillage and no tillage on Honeoye silt loam (Free *et al*., 1963) and on Greendale silt loam (Moody *et al*., 1961). In a subsequent study on Groseclose and Lodi silt loams, and Davidson clay, Moody *et al*. (1964) found that no tillage resulted in either similar or higher corn yields compared to conventional tillage.

It is evident that seedbed preparation is less expensive for no tillage than conventional, mulch, and most reduced tillage methods. Equal or higher yields due to no tillage as compared to conventional tillage indicate that a reduction in cost of seedbed preparation can be obtained without a decrease in acre-value of the corn crop. These data imply that no tillage is a more efficient method of seedbed preparation than conventional tillage. It is apparent, however, that the no tillage method may not be used for all soils. For example, it would most probably result in decreased yields on soils where weeds can not be controlled by herbicide treatment.

Similar to the mulch tillage procedure, plant residues on the soil surface of a seedbed prepared by the no tillage method increases the rate of infiltration of rain water into soil and, thereby, decreases erosion of soil by runoff waters and increases the amount of plant available soil water. At present, many sloping soils of Virginia are not considered suitable for corn production because of soil erosion and low soil water content. It is anticipated that the no tillage method of growing corn could be effectively used on soils occurring on steep slopes.

Relationship Between P Placement and Corn Growth

One of the most difficult problems encountered in soil management is supplying optimum amounts of available P for normal plant growth. It is necessary to place P in a manner which provides efficient usuage by plants as well as to apply the proper amount and kind of P fertilizer. Data are not available in the literature relating P placement to yield of corn for any of the methods of seedbed preparation except conventional tillage. Three methods of P application have been investigated, mainly contact, band, and broadcast-mixed (mixed) placement.

Contact placement. Several investigations have been conducted to determine the effect of applying P fertilizer in contact with seed on corn growth. Coe (1926) found that contact placement of superphosphate (60 lbs./A.) gave lower corn yields than mixed placement of fertilizer. The lower yield was attributed to reduction in number of plants due to salt injury of germinating seeds. Collier (1954) found that contact placement of superphosphate (200 lbs./A.) did not decrease corn yields; as compared to the check, contact placement resulted in similar corn yield on Austin clay and higher corn yield on Houston black clay. The favorable effects of contact placement of P fertilization was attributed to alleviation of P deficiency of corn plants.

It has been shown that contact placement of N results in greater damage to germinating seeds than P. An investigation during 1959 on Davidson clay loam, Sassafras sandy loam, Groseclose silt loam, and Norfolk fine sandy loam showed that the number of corn plants per acre was not significantly different when 12-12-12 fertilizer (1000 lbs./A.)

was mixed with soil, or when N and K were mixed and P was placed in contact with seed (Lutz, 1964). However, stand counts were in all cases significantly lower than the mixed treatment when P and K were mixed and N was placed in contact with seed. Subsequent studies by Lutz (1964) showed that stand counts were not decreased by contact placement of concentrated superphosphate except under conditions of extreme moisture stress during seed germination.

Band and mixed placement. Yield response of corn to mixed and band application of superphosphate varies with different soils. Nelson et al. (1949) found that banding superphosphate (50 lbs. P_2O_5/A.), 3 in. to each side and 2 in. below corn seeds, gave higher corn yields than a mixed application on Norfolk sandy loam. Similar results were obtained on Canfield and Miami silt loams by Salter et al. (1931), who banded superphosphate at the seed depth in two areas separated 3 in. laterally and 3/4 in. horizontally. In contrast, Coe (1926), found that yield of corn grown on Carrington silt loam was significantly increased by either banding or mixed superphosphate (60 lbs. /A.) and that the placement methods did not result in significantly different corn yields. An investigation on Raub silt loam by Barber (1958) showed that mixed superphosphate (130 lbs. /A.) resulted in higher corn yields than band placement of the P fertilizer.

Improved yields due to banding superphosphate have been explained on the basis of less fixation. Webb and Pesek (1958) pointed out that in the case of superphosphate, which is highly water soluble, band placement results in a high concentration of P in a small volume of soil whereas mixed placement results in a lower concentration of P in a large volume of soil. The higher contact with soil due to mixed treatment leads to greater fixation of applied P and, consequently, lower availability of fertilizer P to corn plants. Webb and Pesek (1958) also observed that the effect of banding is apparent early in the growing season and that when plants obtain enough native soil P for their early needs band placement is not superior to mixed placement from the standpoint of corn yield. From these observations it was concluded (Webb and Pesek, 1958) that differences in yield due to placement would not be expected to be as great for soils having nearly adequate amounts of available P.

Mechanisms of P Fixation by Soils

The fact that P is sorbed from solution by the soil upon application of soluble P compounds has been well established. However, the exact mechanism by which removal of P from solution occurs is not well understood. Mechanisms to explain P fixation include adsorption involving hydroxylic surfaces and anion exchange sites, and precipitation reactions involving primarily Fe, Al, and Ca ions.

Acid soils. Approximately four decades ago, Roszman (1927) demonstrated that phosphate sorption by Putnam clay varied inversely with pH and that the maximum rate of sorption was attained at soil pH values of 3 to 4. Roszman attributed the fixation to surface adsorption of phosphate ions by Fe- and Al-oxides. Oxides of Fe and Al were implicated as components of fixation reaction by Chandler (1941) who found that removal of the two oxides from the clay fraction of soil (Decatur, Hartsells, Houston, Norfolk, and Cecil soils) decreased the amount of phosphate retained. Recently, Hsu (1964) characterized two reactions in sorption of P by Estlow clay loam; a rapid reaction was attributed to adsorption by native reactive amorphous Fe_2O_3 and Al_2O_3, and a slow reaction was attributed to adsorption by similar reactive components developed during the aging process.

Studies involving removal of P from solution by soil, which are very similar to those explained as adsorption reactions, have been explained as precipitation reactions. Bradfield _et al_. (1935) attributed phosphate retention by the $<$ 100 mu fraction of Wyoming Bentonite, Miami, and Upshur clay to precipitation of Al- and Fe-phosphates. Coleman (1944) showed that removal of free Fe- and Al-oxides from the coarse and fine clay fraction of Susquehanna clay loam and Orangeburg sand decreased phosphate retention by the two fractions at pH 3.2. Coleman proposed that the decrease in phosphate retention resulted from a decrease in precipitation of phosphate as Fe- and Al-compounds. Fixation of added P by Kaolinite was shown (Haseman _et al_., 1950) to occur in two stages, a rapid reaction was attributed to precipitation of phosphate by free Fe and Al, and a slow reaction was attributed to further precipitation by Al dissociated from the crystal lattice of clay.

A series of reactions presented by Hemwall (1957), given below, illustrate a mechanism by which adsorption and precipitation of P may occur simultaneously in soils.

$$(M(H_2O)_xA_y)^{+3 \text{ to } +1} + A + H_2PO_4^- \rightleftarrows (M(H_2O)_xA_zH_2PO_4)$$
$$\downarrow\uparrow$$
$$M_2O_3,\ M(OH)_3,$$

Clay Minerals, and Exchange Sites	Precipitated or Adsorbed

The symbol M represents cations of Fe and Al and A represents oxide or hydroxide. Hemwall points out that P fixation in acid soils is primarily due to the formation of Fe and Al compounds of the nature $M(H_2O)_3(OH)_2H_2PO_4$ and that soil minerals including the clay minerals are the source of Fe and Al; furthermore, the formation of these compounds is governed by the common ion principle, solubility product principle and the salt effect principle and, therefore, under certain conditions the compounds form a precipitate, whereas under other conditions they are adsorbed. Regardless of whether the compounds are adsorbed on the surface of soil minerals or precipitated, the compounds formed and the mechanism of reaction seem to be essentially the same (Hemwall, 1957).

Ravikovitch (1934) noted that concentration of P in solution varied directly with soil pH and assumed that P replaced hydroxyl ions by anion exchange reactions. In contrast, Olphen (1950, 1951) hypothesized the existence of a positive layer with negative diffuse ions at the edges of clay minerals which is responsible for phosphate adsorption. Although included in the above series of reactions, Hemwall (1957) proposed that P fixation by anion exchange is insignificant as compared to precipitation and adsorption of P by most acid soils.

Neutral soils. Fixation of P by near neutral soils has been ascribed to formation of insoluble Ca-, Al-, and Fe-phosphates. Hsu and Jackson (1960) presented a solubility diagram by which the relative concentration of ferric Fe, Al, and P in solution could be inferred as a function of pH, assuming strengite ($Fe(OH)_2H_2PO_4$), variscite ($Al(OH)_2H_2PO_4$) and calcium hydroxyapatite ($Ca_{10}(OH)_2(PO_4)_6$) to be the Fe-, Al-, and Ca-phosphates in the system. The solubilities of Al-, Fe-, and Ca-phosphates are approximately equal in the range of pH 6.0 to 7.0; thus, in this pH range, all three forms of phosphate may occur in varying proportions depending on the magnitude of the respective cation activities derived from the solubility of the various solid phases.

Calcareous soils. Fixation of P in calcareous soils has been attributed to precipitation reactions. Buehrer (1932) found that the equilibrium phosphate concentration of the $CaHPO_4$-$CaCO_3$-H_2CO_3 system is inversely proportional to the Ca ion concentration and pH, and pointed out that dicalcium phosphate resulting from surface hydrolysis of carbonate apatite supplies the P in solution. Later, Olsen (1953) related this system to soil and noted that Ca phosphates predominate in calcareous soils because Ca released from calcium carbonate in the soil, controls the phosphate solubility.

Plant Availability of Fixed P Compounds

Shortly after monocalcium phosphate is applied to soil, it hydrolyzes to dicalcium phosphate dihydrate which supplies most of the fertilizer P to plants in their initial stages of growth. Later, however, dicalcium phosphate dihydrate changes to complex Al- and Fe-phosphates in acid soils and mainly Ca phosphates in calcareous soils. Investigations have been carried out to determine the availability of these compounds to plants.

Al- and Fe-phosphates. An investigation by Lindsay and Stephenson (1959) showed that monocalcium phosphate added to Hartsells fine sandy loam (pH 5.5) converts to calcium ferric phosphate-$H_4CaFe_2(PO_4)_4 \cdot 5H_2O$, potassium taranakite-$H_6K_3Al_5(PO_4)_8 \cdot 18H_2O$, colloidal aluminum phosphate and colloidal iron phosphate. Taylor et al. (1960) determined the availability of these compounds to corn plants grown on Hartsells silt loam (pH 4.8) in the greenhouse; six corn plants were grown on the soil (3 Kg.) fertilized with P compounds (200 mg. P) for 62 days. Total P in corn shoots indicated the following P supplying power of the various sources; monocalcium phosphate (11.9 mg. P) $>$ colloidal aluminum phosphate (6.8 mg. P) $>$ potassium taranakite (5.8 mg. P) $>$ colloidal iron phosphate (4.0 mg. P) $>$ potassium hydrogen phosphate-$H_8KFe_3(PO_4)_6 \cdot 6H_2O$ (3.5 mg. P) $>$ potassium aluminum leucophosphate-$KAl_2(PO_4)_2OH \cdot 2H_2O$ (2.7 mg. P) $>$ potassium iron leucophosphate-$KFe_2(PO_4)_2OH.2H_2O$ (2.6 mg. P). Using the same procedure on Hartsells silt loam limed to pH 6.3, Taylor et al. (1960) found the following P supplying power for the various sources; monocalcium phosphate (24.9 mg. P) $>$ calcium ferric phosphate (24.4 mg. P) $>$ colloidal aluminum phosphate (21.9 mg. P) $>$ potassium taranakite (19.4 mg. P) $>$ colloidal iron phosphate (17.8 mg. P) $>$ potassium iron leucophosphate (3.5 mg. P) $>$ potassium aluminum leucophosphate (3.3 mg. P).

Ca phosphates. An investigation was conducted by Terman et al. 1958) to determine plant availability of dicalcium phosphate dihydrate, anhydrous dicalcium phosphate, and monocalcium phosphate; three acid soils (Clarksville silt loam-pH 6.0, Hartsells fine sandy loam-pH 4.8, and Edina silt loam-pH 5.5) and two alkaline soils (Rosebud loam - pH 8.0, Webster silty clay loam-pH 8.3) were used in the study. On the basis of total P in ryegrass and sudangrass, it was shown that P was more available from monocalcium phosphate than anhydrous dicalcium phosphate for all soils and that P from monocalcium phosphate was more available than dicalcium phosphate in alkaline soils and less available in acid soils. In another experiment (Terman et al., 1958) with Hartsells fine sandy loam limed to pH 7.5, yield of plant tissue (a sudangrass - ryegrass mixture) was used to indicate relative plant availability of P from various calcium phosphate compounds. Yields as related to P source were as follows: Ca phosphate dihydrate (11.4 g.) $>$ anhydrous dicalcium phosphate (9.1 g.) $>$ monocalcium phosphate (7.9 g.) $>$ octacalcium phosphate (5.3 g.) $>$ hydroxyapatite (4.1 g.) $>$ no phosphate (3.6 g.).

In summary, the greenhouse investigations indicate that when a similar amount of P is present in soil as complex Fe- or Al-P compounds

P from the Al-P compounds is more available to plants. However, if P as Fe-P predominates in soil, it would most probably supply a higher amount of P to plants than Al-P compounds. Data comparing the plant availability of complex Ca-P compounds with complex Al- or Fe-P compounds are not available in the literature.

EFFECT OF SEEDBED PREPARATION AND FERTILIZER PLACEMENT OF P UPTAKE BY CORN PLANTS

It has been shown that the no tillage method of growing corn is superior to the conventional method from the standpoint of erosion control and that the two methods result in approximately equal yields. In investigations reported in the literature, P fertilization of no tillage treatments was accomplished by hand placement of fertilizer in bands near the seed. This method of P fertilization is not readily applicable for routine usuage. Therefore, a reliable method of P application must be devised before the no tillage method of growing corn can be used routinely. The present investigation was undertaken to determine the ability of surface applied P to supply P to corn plants grown by the no tillage method.

Methods and Materials

Wellston loam, a Gray-Brown Podzolic soil developed from non-calcareous sandstone and shale (Robinson _et al_., 1961) was selected for this investigation. Laboratory and field procedures used during the course of the investigation are outlined below.

Field investigation conducted in 1963. The area of soil selected for the field experiment most probably did not receive fertilizer during modern times and certainly did not receive P fertilizer during the 12 year period from 1950-1962. Soil test values determined from a composite sample of the area by procedures outlined by Rich (1955) indicated that the soil had a pH value of 5.4, and contained a low amount of available P (5 lbs. P_2O_5/A.) and a high amount of available K (336 lbs. K_2O/A.). The experimental area was treated with Atrazine

(4 lbs./A.) to control weeds; no other weed control measures were used during the investigation.

A randomized complete block design, consisting of 4 treatments replicated 4 times, was used. Each plot was 10 by 6 ft. The following 4 treatments were used:

1. plowed-P fertilized, superphosphate (21.7% P_2O_5) tagged* with P^{32} was distributed evenly on the soil surface at the rate of 50 lbs. $P_2O_{5/A.}$ (144g./plot), and the fertilizer was mixed with the soil to a depth of 5" by means of a rotorator plow;

2. plowed-check, the soil was tilled to a depth of 5" by means of a rotorator plow;

3. no tillage-P fertilized, superphosphate (21.7% P_2O_5) tagged* with P^{32} was distributed evenly on the soil surface at a rate of 50 lbs. $P_2O_{5/A.}$ (144g./plot), and the soil was not tilled; and

4. no tillage-check, superphosphate was not applied and the soil was not tilled.

All plots received a broadcast treatment of NH_4NO_3 (50 lbs. N/A.) and KCl (50 lbs. K_2O/A.) which was thoroughly mixed with soil of the plowed treatments and was not mixed with soil of no tillage treatments. Corn (V.P.I. 648) was planted at a depth of 3 in. on May 7. The seeds were planted 10 in. apart in rows which were 36 in. apart.

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* The radioactive P fertilizer was provided by the U. S. Fertilizer Laboratory, USDA, Beltsville, Maryland.

<u>Field investigation conducted in 1964.</u> The area of soil selected for the field experiment received P fertilizer (10 lbs. P_2O_5/A.) during the 13 year period from 1950-1963. Prior to 1950 the area most probably did not receive any P fertilization. Soil test values were determined on a composite sample of the area by procedures outlined by Rich (1955). The results showed that the soil had a pH value of 5.0, and contained a low amount of available P (3.5 lbs. P_2O_5/A.) and a high amount of available K (323 lbs. K_2O/A.).

Plowed-P fertilized and no tillage-P fertilized treatment similar to those of the 1963 study, except that superphosphate tagged with P^{32} was applied at the rate of 100 lbs. P_2O_5/A., were arranged in a randomized complete block design consisting of 4 blocks. Each plot was 6 1/2 by 10 ft. Weed control, N and K fertilization and planting of corn (Pioneer 345A) were achieved by the methods used in the 1963 field study.

<u>Determination of P uptake by corn plants.</u> Total P content of newly developed corn leaves was determined by the following procedure: samples were oven-dried (24 hrs.) at 85°C. and ground in a Wiley mill to pass a 60 mesh screen; a sub-sample (1 g.) was ashed (2 hrs.) at 450°C., dissolved in 0.3 <u>N</u> HNO_3 (100 ml.), and the content of P in solution was determined by the ammonium vanadate procedure outlined by Jackson (1958).

The amount of P^{32} was determined on an aliquot of the dissolved leaf samples which was prepared for the total P determination; counter solvent (10 ml.) was added to a representative aliquot of dissolved leaf sample and counts were made on a Tricarb Liquid Scintillation Spectrometer (Packard Instrument Co., La Grange, Illinois). The counter solvent consisted of 2,5-Diphenyloxazole (7g.), 1,4-bis-2 (4 Methyl-5

Phenyl-oxazolyl) Benzene (50 mg.), and napthalene recrystallized from ethanol (50 g.) diluted to one liter with 1,4-dioxane.

Leaf samples were collected on June 19, July 5, August 1, and August 16 in 1963, and on June 7, June 23, July 7, and July 14 in 1964.

Measurement of corn plant height and yield. Plant height was measured at approximately weekly intervals during June, July, and August of 1963. Three plants were randomly selected from each plot for the plant height determination.

Corn ears and stover were harvested on October 22 in 1963, and on October 23 in 1964. After drying (96 hours) at 75°C. corn ears were shelled and dry weights of corn grain and stover were determined. Yield of grain was reported as bu./A. of corn grain at 15.5% moisture whereas yield of stover was reported as lbs. dry weight/A.

Determination of soil temperature and soil moisture content. Maximum and minimum temperatures of one plot of the plowed-check and no tillage-check treatments were recorded once a week during May, June, and July of 1963. The temperature was determined at a depth of 2 in. with a maximum and minimum temperature recording thermometer.

Soil moisture content of plowed-check and no tillage-check treatments at 0-6 and 6-12 in. depths was determined once a week during May, June, July and August of 1963. The moisture content of soil was determined gravimetrically after oven-drying samples (24 hrs.) at 110°C. and was reported as % moisture of oven-dried soil.

Determination of movement and fixation of P. The extent of P movement in soil was determined by the following procedure: soil samples were collected at 0-2, 2-4, 4-6, and 6-8 in. depths from plowed-P fertilized and no tillage-P fertilized treatments 13 days after superphosphate application; samples were air-dried, passed through a sieve (60 mesh), and the relative amount of P^{32} in soil (1 g.) was determined with a GM scaler (Nuclear Chicago Corp., Des Plaines, Illinois).

The amount of P fixation was determined by the following procedure: soil samples were collected at depths of 0-1, 1-2, 2-3, and 3-6 in. from plowed-P fertilized and no tillage-P fertilized treatments 49 days after superphosphate application; samples were oven-dried (24 hrs.), passed through a sieve (60 mesh), and inorganic P fractions were determined by the method devised by Chang and Jackson (1957).

Results and Discussion

A field investigation was conducted on Wellston loam to compare no tillage and conventional tillage with respect to yield of corn and uptake of applied P. During the course of the investigation, studies were also undertaken to determine the effect of the two tillage practices on soil temperature and moisture content, movement of P in soil, and fixation of P by soil.

Growth and yield of corn plants. The relationship between corn plant height, tillage practice and method of P fertilization is shown in table 1. Heights of corn plants up to 50 days after planting for the no tillage-P fertilized, no tillage-check, plowed-P fertilized, and plowed-check were 73, 60, 48, and 38 cm., respectively. As shown by Duncan's New Multiple Range Test, height of plants from each treatment was significantly different. The taller plants of the P fertilized treatments as compared to their respective checks indicate that growth of corn plants was improved by either surface or mixed application of superphosphate. However, later in the growing season, 88 to 104 days

Table 1 - Height of corn plants as affected by tillage and fertilization practice (1963 field investigation).

Days after Planting	Soil Treatment# Plowed Check	Plowed P Fertilized	No tillage Check	No tillage P Fertilized	F-value
	cm.				
40	25	34	42	52+	22.02**
45	30	40	46	66	25.7 **
50	38	48	60	73	22.4 **
56	48	61	75	92	17.7 **
62	60	74	88	108	15.3 **
69	75	89	104	128	15.6 **
77	95	108	127	155	11.7 **
88	118	133	153	179	9.9 **
95	133	148	166	196	6.7 *
104	153	167	180	208	6.3 *

* F-value is significant at the 5% level of probability.

** F-value is significant at the 1% level of probability.

+ Means underlined by a continuous line are not significantly different as determined by Duncan's New Multiple Range Test.

Superphosphate (50 lbs./A) was applied to the surface of the no tillage-P fertilized treatment, and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

after planting, height of corn plants was not affected by P fertilization, i.e., height of corn plants for the P fertilization treatments was not significantly different than corresponding checks. From these data, it is apparent that the early growth stimulation of P fertilization did not result in difference in height of mature corn plants.

During 1963, yield of corn stover for the various treatments (table 2) coincided closely to differences in height of mature corn plants (table 1). Corn stover yields for the no tillage-P fertilized, no tillage-check, plowed-P fertilized, and plowed-check were 2907.6, 2225.1, 1997.0, and 1757.6 lbs./A., respectively. Duncan's New Multiple Range Test indicated that stover yield from the plowed- and no tillage-P fertilized treatments were not significantly different than their corresponding checks. These relationships indicate that P fertilization did not influence stover yields of corn grown by either plowed or no tillage methods. It is apparent from these data that the early growth stimulation of corn plants due to P fertilization (table 1) did not result in differences in yield of corn stover.

Neither height of mature corn plants (table 1) nor yield of corn stover (table 2) gave a good indication of yield of corn grain (table 2) for the various treatments of the 1963 field investigation. Yield of corn grain for the no tillage-P fertilized, no tillage-check, plowed-P fertilized and plowed-check were 31.1, 19.9, 16.7, and 9.9 bu./A., respectively. As shown by Duncan's New Multiple Range Test, yield of corn grain was significantly higher for the no tillage-P fertilized treatment than the no tillage-check whereas yield from the plowed-P fertilized and plowed-check were not significantly different. The relationships show that P fertilization increased yield of corn grain

Table 2 - Yield of corn grain and stover as affected by tillage and fertilization practice.

Year	Plowed		No tillage		F-value
	Check	P Fertilized	Check	P Fertilized	
	Bu./A. of corn grain (15.5% moisture)				
1963	9.9	16.7	19.9	31.1+	13.1 **
1964		65.2		59.0	n.s.
	Lbs./A. of dry corn stover				
1963	1757.6	1977.0	2225.1	2907.6	4.3 *
1964		1444.0		1213.5	10.4 **

* F-value is significant at the 5% level of probability.

** F-value is significant at the 1% level of probability.

\+ Means underlined by a continuous line are not significantly different as determined by Duncan's New Multiple Range Test.

\# Superphosphate (50 lbs./A. in 1963 and 100 lbs./A. in 1964) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

on the no tillage treatment but not on the plowed treatment.

Corn plants grown on the no tillage-P fertilized treatment were significantly taller than those grown on the plowed-P fertilized treatment throughout the 1963 growing season (table 1). Likewise, the yield of stover and grain was higher for the no tillage-P than plowed-P fertilized treatment and the yield of grain was higher for the no tillage- than plowed-check (table 2). The relationships indicate that the no tillage treatment provides a more favorable environment for corn plant growth than the plowed treatment. Factors affecting growth of corn plants by plowed and no tillage methods are considered in subsequent sections.

Comparison of data from the 1963 and 1964 field experiment (table 2) shows that yield of corn grain and stover for the two seasons differ in two respects. Firstly, the no tillage-P fertilized treatment gave higher grain yields than the plowed-P fertilized treatment in 1963 whereas grain yields from the two treatments were not significantly different in 1964. Secondly, the no tillage-P fertilized treatment resulted in higher stover yields than the plowed-P fertilized treatment in 1963 whereas the latter treatment gave higher stover yields in 1964. In the review of literature, it was noted that no tillage and conventional tillage usually give equal yield of corn grain. From this standpoint the similar yield of corn grain obtained in 1964 for the two treatments are in close agreement with other investigations. However, the 1963 data show that under certain conditions no tillage results in superior yield of corn grain and fodder than conventional tillage.

Comparison of conditions give little insight regarding the differences in yield of corn grain and stover during 1963 and 1964. These differences may be a reflection of the rate of P fertilization, amount and distribution of rainfall, or variety of corn grown. In 1963 superphosphate was applied at the rate of 50 lbs. P_2O_5/A. whereas a higher rate (100 lbs. P_2O_5/A.) was applied in 1964. Rainfall was higher during July and August of 1964 than 1963 (table 3); the higher amount of rainfall corresponds to the period when corn plants were growing most rapidly. In 1963, V.P.I. 648 was grown whereas Pioneer 345A was grown in 1964. V.P.I. 648, the earlier maturing of the two varieties, generally results in similar grain and higher stover yields than Pioneer 345A (Shulkcum and Genter, 1964). It is apparent from these data that further experimentation is necessary before conditions under which no tillage gives higher corn yields than conventional tillage can be accurately described.

<u>Soil temperature and moisture content.</u> It has been shown in several investigations that under normal conditions P uptake varies inversely with soil moisture tension (Olsen *et al*., 1961; Hinman *et al*., 1962) and directly with soil temperature (Hinman *et al*. 1962; Power *et al*., 1963). It was therefore deemed desirable to determine the effect of the no tillage- and plowed-checks on soil temperature and moisture content.

Relationships between soil moisture content at two depths (0-6 and 6-12 in.) as related to the tillage methods of the 1963 field study are shown in table 4. Soil moisture contents of the 0-6 in. depth ranged from 8.3 to 18.7% for the plowed-check and from 6.6 to 18.7% for the no tillage-check. At the 6-12 in. depth, soil moisture content ranged from 11.1 to 18.4% for the plowed-check and from 9.5 to 18.6% for the no tillage-check. The analysis of variance (table 5) shows that the two tillage treatments did not significantly influence the

Table 3 - Amount of rainfall during the growing season of 1963 and 1964.

Month	Amount of rainfall during	
	1963	1964
	in.	
May	2.6	2.1
June	2.1	1.2
July	2.4	4.0
August	1.3	3.7
September	3.4	2.9
Total	11.8	13.9

soil moisture content of either the 0-6 or 6-12 in. depth on any of the sampling dates. Consequently, the higher yield of corn grain from the no tillage-check as compared to the plowed-check can not be attributed to differences in soil moisture content.

Temperature for the 0-2 in. soil depth of the plowed and no tillage checks during the 1963 field study are shown in table 6. Averages of maximum temperature were 87 and 88°C. and of minimum temperature were 58 and 59°C. for the plowed and no tillage-checks, respectively. Because the maximum and minimum soil temperature for the two treatments were not significantly different, the higher yield of corn grain on the no tillage-check as compared to the plowed-check (table 2) can not be ascribed to differences in either maximum or minimum soil temperature.

Movement and fixation of applied P. It has been shown that mixed application of highly water soluble P fertilizer most often results in more fixation and, consequently, lower availability of P to plants than band application. The greater amount of fixation due to mixing P fertilizer is generally attributed to a greater amount of soil-fertilizer contact (Webb and Pesek, 1958; Bhure, 1960). Investigations regarding the inorganic P transformations in acid soil during the fixation process indicate that superphosphate dissolves Al ions from soil and reacts with these ions to form Al-P compounds and that Al-P compounds gradually react with Fe ions to form Fe-P compounds (Chang and Jackson, 1958; Ensminger, 1960; Welch *et al*., 1957).

The present investigation was undertaken to compare movement and fixation of surface and mixed application of P as superphosphate. Results from the study were expected to provide information regarding differential plant uptake of surface and mixed P.

Table 4 - Soil moisture content (% by weight) at two depths as related to tillage practice and sampling date (1963 field investigation).

Sampling		Soil Moisture Content	
Date	Depth in.	Plowed-check	No tillage-check
		%	
May 20	0-6	18.7	18.7
	6-12	18.4	16.7
June 11	0-6	15.3	18.6
	6-12	16.9	17.1
June 21	0-6	15.8	16.5
	6-12	15.3	15.7
June 29	0-6	12.2	12.5
	6-12	14.2	14.4
July 1	0-6	13.5	16.2
	6-12	14.8	15.4
July 11	0-6	12.0	12.8
	6-12	13.8	15.0
July 18	0-6	13.2	13.8
	6-12	15.4	15.1
July 26	0-6	14.0	13.7
	6-12	14.8	13.8
August 5	0-6	11.1	11.5
	6-12	13.9	12.5
August 12	0-6	11.3	9.5
	6-12	14.0	13.2
August 21	0-6	8.3	6.6
	6-12	12.4	9.9

Table 5 - Analysis of variance for the relationship between soil moisture at two depths as related to tillage practice and sampling date (1963 field investigation).

Source	df	SS	MS	F-value[a]
Replications	3	295.25	98.42	2.28
Treatment combinations	43	1668.86	38.81	0.89
Treatment	1	42.51	12.51	0.29
Dates	10	567.62	56.76	1.31
Depths	1	4.42	4.42	0.10
Treatment x Dates	10	201.96	20.20	0.46
Treatment x Depths	1	91.50	91.50	2.12
Date x Depth	10	286.45	28.64	0.66
Treatment x Date x Depth	10	474.40	47.44	1.10
Error	129	5570.69	43.18	
Total	175	7534.20		

a. F-value is not significant at the 5% level of probability.

Table 6 - Maximum and minimum soil temperature (0-2 in. depth) as related to tillage practice and sampling date (1963 field investigation).

Sampling date	Maximum soil temperature		Minimum soil temperature	
	Plowed-check	No tillage-check	Plowed-check	No tillage-check
	°C.			
May 21	78	78	60	60
May 24	71	75	48	48
May 31	76	77	54	54
June 6	75	77	54	54
June 11	86	88	61	54
June 13	84	87	56	48
June 19	87	89	60	60
June 21	84	92	66	67
June 25	94	95	55	61
June 30	102	106	62	62
July 1	101	98	62	67
July 6	98	95	58	69
July 11	96	96	67	63
Average *	87	88	58	59

* A two way classification statistical analysis showed that the differences in either maximum or minimum temperature due to tillage treatments were not significant at the 5% level of probability.

The relationship between movement of surface (no tillage-P fertilized) and mixed (plowed-P fertilized) P, 13 days after application of superphosphate, is given in table 7. The statistical analysis of these data is shown in table 8. Difference in total cpm (counts per minute) from P^{32} for the mixed application (1023 cpm) and surface application (690 cpm) most probably resulted from the soil sampling procedure. Fertilizer granules present on the soil surface of the surface P treatment were not included in the soil sample and consequently, cpm of P^{32} of the sample underestimated the amount of P^{32} in the 0-2 in. depth. It was expected that inclusion of fertilizer granules which had not reacted with soil would overestimate the amount of fertilizer in the 0-2 in. depth and for this reason the above sampling procedure was followed.

Although the rotorator plow was adjusted to till soil to a depth of 5 in., the major portion of the fertilizer was mixed with soil to a depth of 4 in., i.e., number of cpm/g. soil from fertilizer P^{32} were 400, 528, 61 and 34 for the 0-2, 2-4, 4-6, and 6-8 in. depths of the mixed treatment (table 7), respectively. From these data it can be assumed that more than 90% of the fertilizer remained in the 0-4 in. layer 13 days after application. The cpm from surface applied P^{32} fertilizer were 608, 44, 29, and 9 per g. of soil for the 0-2, 2-4, 4-6, and 6-8 in. depths, respectively (table 7). These data show that less than 15% of the surface applied P moved downward to the 2-8 in. soil layer during 13 days. Since very little movement of surface applied P occurred, mixed application of P would most probably result in a higher amount of soil-fertilizer contact and thereby a faster rate of P fixation than the surface application.

Table 7 - Movement of p32 during a 13 day period as related to tillage and fertilization practice (1963 field investigation).

Treatment#	Soil depth (in.)				Total
	0-2	2-4	4-6	6-8	cpm
	p^{32} cpm/g. soil				
Plowed - P fertilized	400+	528	61	34	1,023
No tillage - P fertilized	608	44	29	9	690

\+ Means underlined by a continuous line are not significantly different as determined by Duncan's New Multiple Range Test.

\# Superphosphate (50 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

Table 8 - Analysis of variance for the relationship between movement of P^{32} in soil after an equilibration period of 13 days as related to tillage and fertilization practice (1963 field investigation).

Source	df	SS	MS	F-value
Replications	3	67,244.35	22,414.78	
Treatment combinations	7	1,800,009.72	257,144.25	7.90**
Treatment	1	55,361.28	55,361.28	1.70
Depth	3	1,240,318.59	413,439.53	12.70**
Treatment x Depth	3	504,329.85	168,109.95	5.16**
Error	21	683,736.90	32,558.90	
Total	31	2,550,990.70		

** F-value is significant at the 1% level of probability.

Superphosphate (50 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

Indication that the mixed application results in a higher rate of P fixation is shown by the P fractionation study (table 9) and the analysis of variance for the data (table 10). The significant F-value of 5.74 (table 10) shows that the mixed and surface applied P treatments result in significantly different amounts of difficulty soluble Al-, Fe-, and Ca-P compounds at the various soil depths. Comparison of data (table 9) shows that the amount of these fractions is higher for the mixed P application.

P content of corn leaves. Content of P and P^{32} cpm of fertilizer of corn leaves from the plowed and no tillage treatments of the 1963 field experiment are shown in table 11. The significantly higher P content of corn leaves for the surface as compared to the mixed P application, 49 and 61 days after fertilization, indicates that the former treatment was superior in supplying P to corn plants during the early portion of the growing season. Later in the growing season, 84 and 99 days after planting, the two treatments did not result in different P contents of corn leaves.

Differences in cpm of P^{32} of leaf tissue from mixed and surface P applications were not significant at any sampling date (table 11). These data imply that the two treatments were not significantly different in supplying P to corn plants. However, it should be pointed out that corn plants were taller on the surface P than mixed P treatment (table 1) and, therefore, the former treatment most probably resulted in higher uptake of fertilizer P.

Since the percentage of P in corn leaves was low throughout the growing season and was higher for the surface than mixed application early in the growing season (table 11), faster corn plant growth of

Table 9 - Effect of tillage and fertilization practice on P fractions at various soil depths 48 days after application of superphosphate to Wellston loam (1963 field investigation).

Sampling Depth	Treatment#	Fraction of Soil P Al-P	Fe-P	Ca-P
in.		ppm.		
0-1	Plowed-P fertilized	60	39	22
	No tillage-P fertilized	44	36	22
1-2	Plowed-P fertilized	51	32	23
	No tillage-P fertilized	23	20	11
2-3	Plowed-P fertilized	40	45	25
	No tillage-P fertilized	28	38	22
3-6	Plowed-P fertilized	26	29	31
	No tillage-P fertilized	27	40	18

Superphosphate (50 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

Table 10 - Analysis of variance for the relationship between P fractions, sampling depths and tillage practice 48 days after application of superphosphate # (1963 field investigation).

Source	df	SS	MS	F-value
Reps.	3	1,372.53	457.51	2.30
Treatment combinations	23	11,842.24	514.88	2.59**
Treatments	1	1,141.26	1,141.26	5.74**
Depths	3	1,827.78	609.26	3.06*
Fractions	2	3,882.27	1,941.14	9.76**
Treatment x Depths	3	919.20	306.40	1.54
Treatment x Fractions	2	522.52	261.26	1.31
Depths x Fractions	6	2,535.32	422.55	2.12
Treatment x Depths x Fractions	6	1,013.89	168.98	0.85
Error	69	13,719.22	198.83	
Total	95	26,933.99		

* F-value is significant at the 5% level of probability.

** F-value is significant at the 1% level of probability.

Superphosphate (50 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

the former treatment can be explained on the basis of higher P uptake. Apparently, this early growth stimulation was responsible for the higher yield of corn grain and stover due to the surface P application (table 3).

An investigation, similar to the 1963 field experiment, was conducted in 1964. Because the 1963 data indicated that difference in P uptake due to surface and mixed P application occurred early in the growing season, tissue samples were obtained at earlier dates in 1964 than 1963. Data obtained from the 1964 field study are given in table 12. The percentage of fertilizer P in corn plants grown on surface and mixed P treatments 30 days after application was 54.0 and 16.0, respectively. The highly significant F-value of 285.3 indicates that a higher amount of fertilizer P was absorbed by plants from the surface P treatment. As indicated by the nonsignificant F-values, the two treatments supplied approximately equal amounts of fertilizer P to corn plants later in the growing season (46, 60, and 67 days after fertilizer application).

The higher uptake of fertilizer P from surface than mixed P application early in the growing season corresponds closely to higher uptake of banded than mixed P fertilization. Similar to the band application, there is less fertilizer P-soil contact with the surface than mixed application and consequently surface application, like the band application, would result in less fixation of P than the mixed application. Less fixation of fertilizer and phosphate would increase its availability to plants provided that it is in a zone which is penetrated by plant roots. Uptake data for surface applied P (table 11 and 12) indicate that corn plants can absorb P from near the soil surface.

It is envisioned that small showers and dew which do not supply sufficient amounts of water to penetrate deeply into soil would favor

Table 11 - Relationship between P content of corn leaves and tillage practice during early stages of plant growth (1963 field investigation).

Days after Planting	Treatment#	P^{32} Counts of leaves			P content of leaves	
		Sample size (mg.)	cpm	F-value	%	F-value
49	Plowed-P fertilized	10	119	n.s.	.140	16.67*
	No tillage-P fertilized		190		.187	
61	Plowed-P fertilized	100	661	n.s.	.137	19.19*
	No tillage-P fertilized		779		.154	
84	Plowed-P fertilized	200	742	n.s.	.101	n.s.
	No tillage-P fertilized		813		.104	
99	Plowed-P fertilized	500	187	n.s.	.102	n.s.
	No tillage-P fertilized		170		.098	

* F-value is significant at the 5% level of probability.

Superphosphate (50 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

uptake of surface applied P. The concentration of P in water from dew and small showers would most probably be higher for the surface than P application. This higher concentration of P in solution would result in a higher uptake of surface applied P as water is absorbed by plants.

The percentage of P present in plant leaves from the mixed P application increases in the later portion of the growing season. For example, the fertilizer P content in corn leaves 30 and 67 days after planting was 16.0 and 37.0% (table 12) of total P, respectively. From these data, it is apparent that a higher amount of fertilizer P is absorbed by the plants as root proliferation increases in the volume of fertilized soil. In contrast, the portion of native soil P absorbed by plants which received the surface application increases later in the growing season, i. e. fertilizer P content of corn leaves 30 and 67 days after planting was 54.0 and 35.9% of the total P (table 12), respectively. The increase in absorption of native soil P may result from an increase in soil volume penetrated by plant roots.

Table 12 - Relationship P content of corn leaves and tillage practice during early stages of plant growth (1964 field investigation).

Days after Planting	Treatment#	Fertilizer P Content of leaves %	Fertilizer P Content of leaves F-value	Total P content of leaves %	Total P content of leaves F-value
30	Plowed-P fertilized	16.03	285.30**	0.044	n.s.
	No tillage-P fertilized	54.03		0.066	
46	Plowed-P fertilized	31.76	n.s.	0.182	n.s.
	No tillage-P fertilized	42.73		0.182	
60	Plowed-P fertilized	21.03	n.s.	.132	n.s.
	No tillage-P fertilized	25.45		.159	
67	Plowed-P fertilized	37.14	n.s.	.148	n.s.
	No tillage-P fertilized	35.85		.150	

** F-value is significant at the 1% level of probability.

Superphosphate (100 lbs./A.) was applied to the surface of the no tillage-P fertilized treatment and mixed to a depth of 5 in. for the plowed-P fertilized treatment.

EFFECT OF SEEDBED PREPARATION ON BURLEY TOBACCO YIELDS

Cost of tobacco production could be reduced by using no tillage method of seedbed preparation. However, the no tillage method would not be beneficial unless higher or comparable profit per acre would be obtained as compared to conventional seedbed preparation. Before the no tillage method of growing tobacco can be either recommended or discouraged, studies are necessary to compare no tillage and conventional tillage with respect to yield and quality of tobacco and to develop a reliable inexpensive method of chemically controlling weeds. One aspect of these studies was considered in the present investigation which was conducted to compare yield and nutrient composition of Burley tobacco plants grown by no tillage and conventional methods of seedbed preparation.

Methods and Materials

The soil selected for the investigation is classified as Wellston loam, a Gray-Brown Podzolic soil developed from noncalcareous sandstone and shale. The area selected most probably did not receive fertilizer during modern times and certainly did not receive fertilizer during the 12 year period from 1951 to 1963. The following procedures were performed during the investigation which was conducted in 1963:

Experimental design. Two treatments, given below, were used in the investigation:

1. plowed tillage, fertilizer (1000 lbs. 5-10-5/A.) was mixed with the soil to a depth of 5 in. with a rotorator plow, and
2. no tillage, fertilizer (1000 lbs. 5-10-5/A.) was spread evenly on the soil surface.

The treatments were arranged in a randomized complete block design with two blocks. Each plot was 10 by 10 ft. Burley tobacco plants (18 plants/plot) were planted (June 20) 20 in. apart in rows which were 40 in. apart. Weed control prior to seedbed preparation was achieved by covering the experimental area (May 5) with a black plastic sheet. The plastic was removed when fertilizer was applied (June 19) and, thereafter, weeds were controlled by clipping with a hoe.

Determination of soil moisture content. Soil moisture content of the plowed and no tillage treatments was determined once a week during July and August. Soil samples were placed in tin containers, oven-dried (24 hrs.) at 110°C., and moisture content was reported as % moisture of oven-dried soil.

Measurement of tobacco height and yield. Plant height was measured on July 26, August 5, August 12, and August 21. The plants from the center row of each plot were measured.

Yield of tobacco was measured by the following procedure: The fresh weight of plants (stem and leaves) was determined in the field, a subsample (5 plants) was oven-dried (72 hrs.) at 75°C., and the yield per acre was reported as lbs. dry weight/A.

Determination of content of N, P, and K of tobacco plants. A representative sample of tobacco leaves (20 g.) was ground to pass a 60 mesh screen and thoroughly mixed. A subsample (1 g.) was ashed (2 hrs.) at 450°C., dissolved in 0.3 N HNO_3 (100 ml.), and the content of P in solution was determined by the method outlined by Jackson (1958). Potassium content of the dissolved sample was determined with a Beckman model DU flame photometer. Nitrogen was determined by the Micro-Dumas method which employs a Coleman Nitrogen Analyzer (Stewart et al., 1963).

Results and Discussion

The investigation reported herein was undertaken to determine the effect of no tillage and plowed treatments on soil moisture content, and nutrient composition, yield, and height of Burley tobacco plants. Since the fertilizer was mixed with soil of the plowed treatment whereas it was applied to the soil surface of the no tillage treatment, each treatment consisted of two variables. In the remaining portion of this section, attempts will be made to attribute experimental results to the tillage or fertilization variable of the two treatments.

Height of plants. Relationships between the height of tobacco plants and tillage practice are given in table 13. It can be seen that tobacco plants of the no tillage treatment were taller earlier in the growing season (36 and 46 days after planting) and, thereafter (53 and 62 days after planting), plants of the plowed treatment were taller. The greatest difference in plant height occurred early in the growing season (July 26). At this time, the height of tobacco plants for the no tillage and plowed treatments were 61.6 and 51.0 cm., respectively.

Soil moisture content. The total percentage moisture of the 0-6 and 6-12 in. depths was higher for the no tillage than plowed treatment in July but was approximately the same in August (table 14).

The differences in plant height (table 13) correspond to the differences in percentage of moisture (table 14) for the two treatments, i.e., plant heights and % moisture were higher for the no tillage treatment during July. Since the soil moisture was inadequate for optimum plant growth as evidenced by the fact that moisture content of both treatments was below field moisture capacity of the Wellston loam (24%) the more rapid growth of plants on the no tillage treatment was most probably a reflection

Table 13 - Relationship between height of tobacco plants and tillage practice.

Days after transplanting	Date	Treatment#	Height of tobacco plants
			cm
36	July 26	Plowed	51.0
		No tillage	61.6
46	August 5	Plowed	74.3
		No tillage	77.4
53	August 12	Plowed	88.6
		No tillage	86.6
62	August 21	Plowed	118.4
		No tillage	113.6

Fertilizer (1000 lbs. 5-10-5/A.) was applied to the soil surface of the no tillage treatment and was mixed to a depth of 5 in. with soil of the plowed treatment.

Table 14 - Relationship between soil moisture content and tillage practice for Burley tobacco.

Month	Sampling depth	Treatment#	Moisture content
	in.		%
July	0-6	Plowed	16.87
		No tillage	20.72
	6-12	Plowed	18.12
		No tillage	18.76
August	0-6	Plowed	10.25
		No tillage	12.70
	6-12	Plowed	15.57
		No tillage	13.89

Fertilizer (1000 lbs. 5-10-5/A.) was applied to the soil surface of the no tillage treatment and was mixed to a depth of 5 in. with soil of the plowed treatment.

of the higher amount of available water.

Yield and nutrient composition of plants. Relationships between tillage practice, and yield and nutrient composition of tobacco leaves are shown in table 15. Yield of tobacco plants was much greater from plowed tillage (6124 lbs./A.) than no tillage (3481 lbs./A.) treatment. Phosphorus and K contents of plant leaves from the two treatments were similar. However, the N content of the leaves was much higher for the plowed tillage (3.1%) than no tillage (2.0%) treatment. Since the % N of tobacco leaves was closely related to yield of dry leaves and, in general, the % N of leaves was in the range in which plants would respond to N fertilizer, it appears that utilization of N was less efficient by plants grown on the no tillage treatment.

From the standpoint of Burley tobacco yields, the no tillage method used in this investigation was not as suitable as the plowed treatment. However, a favorable effect due to no tillage, higher soil moisture content was noted in the early portion of the growing season. Because the higher moisture content resulted in more rapid growth of plants, it is recognized that water conservation provided by no tillage may be beneficial during a droughty season. The rapid growth early in the growing season on the no tillage treatment did not result in increased tobacco yields, an affect attributed to N shortage. These data indicate that, before no tillage and plowed methods of growing tobacco plants can be validly compared, the optimum amount of N fertilization must be determined for the no tillage method.

Table 15 - Yield and nutrient composition of Burley tobacco as affected by tillage practice.

Plant variable	Tillage Practice#					
	No tillage			Plowed		
	Rep I	Rep II	Ave.	Rep I	Rep II	Ave.
N,%	2.0	2.0	2.0	2.7	3.4	3.1
P,%	0.28	0.29	0.29	0.27	0.25	0.26
K,%	2.6	2.7	2.7	3.1	2.8	3.0
Yield Lbs./A.	3600	3361	3481	5713	6535	6124

Fertilizer (1000 lbs. 5-10-5/A.) was applied to the soil surface of the no tillage treatment and was mixed to a depth of 5 in. with soil of the plowed treatment.

RELATIONSHIP BETWEEN SOIL INORGANIC PHOSPHORUS FRACTIONS AND OAT PLANT GROWTH

In the review of literature, it was pointed out that when monocalcium phosphate is added to soil it hydrolyzes to dicalcium phosphate dihydrate which reacts with Ca, Fe, Al, and Mn ions to form their respective phosphate compounds. The predominace of one of these cations in a form capable of reacting with dicalcium phosphate dihydrate determines the amount of the phosphate compound which forms in soil. The present study was undertaken to determine the plant availability of compounds formed in soil after fertilization with superphosphate.

Methods and Materials

Soils from the Ap horizon of two Lloyd clay loams and Huntington silt loam were selected for the investigation. The procedures outlined below were used in greenhouse and laboratory studies.

Greenhouse procedure. Soils were passed through a 4 mesh screen and N and K (150 mg.) as ammonium nitrate and potassium chloride were mixed with portions (1500 g.) of the screened soils. Phosphorus as monocalcium phosphate monohydrate was mixed with the soils at the rate of 0, 25, 50 and 200 ppm. The soils were then placed in tin cans (no. 10) and 20 oat seeds were planted in each can. The cans were arranged in a randomized complete block design with two replicates for Huntington silt loam and three replicates for the Lloyd soils. Plant cultures were watered to approximately field moisture capacity and rotated daily. After 28 days oat plants were harvested, oven-dried (24 hrs.) at 85°C., weighed and ground to pass a 40 mesh screen.

Laboratory prodecures. Total P content of the plant tissue was determined by the following method; dry tissue (1 g.) was ashed (2 hrs.) at 450°C., dissolved in 0.3 N HNO_3 (100 ml.) and the content of P in solution was determined by the ammonium vanadate procedure outlined by Jackson (1958).

Available soil P was determined by the method of Mehlich (1953). The procedure involves shaking soil (5 g.) with a 0.05 N HCl and 0.025 N H_2SO_4 mixture (20 ml.) for 5 min., filtering and determining the P content of the extract by the ammonium vanadate procedure. Soil inorganic P fractions were determined by the method of Chang and Jackson (1957); 0.5 N NH_4F extractable P (Al-P) was determined on all treatments whereas 0.5 N H_2SO_4 extractable P (Ca-P) and 0.1 N NaOH extractable P (Fe-P) were determined on 0 and 200 ppm. P treatments.

Results and Discussion

Soil test P vs. P uptake by oat plants. Data relating P uptake by oat plants to P fertilization of three soils are given in table 16. As indicated by the F-value, P fertilization did not significantly affect P uptake by oat plants grown on Lloyd clay loam no. 1 but significantly increased P uptake from Huntington silt loam and Lloyd clay loam no. 2. Soil test data (table 17) shows that the Lloyd soil no. 1 contained a considerably higher amount of available P than the other two soils. The high amount of available soil P (96 ppm.) may account for the lack of response to P fertilization of oat plants grown on Lloyd soil no. 1.

Duncan's New Multiple Range Test (table 16) showed that P uptake was higher at the 100 ppm. P treatment than the check and that the 200 ppm. treatment was not significantly higher than the 100 ppm. treatment for the Huntington soil. On the other hand, P uptake at the 200 ppm.

Table 16 - Relationship between P fertilization and uptake of P by oat plants grown on Huntington silt loam and two Lloyd clay loams.

Soil Type	Rate of P fertilization (ppm. of soil) 0	25	50	100	200	F-value
	mg. P/1500 g. soil					
Huntington silt loam	2.3[+]	3.9	5.3	5.6	8.0	9.47*
Lloyd clay loam no. 1	6.4	7.4	7.8	10.0	10.5	n.s.
Lloyd clay loam no. 2	2.1	2.5	3.2	4.4	7.4	38.86*

* F-value is significant at the 5% level of probability.

\+ Means underlined by a continuous line are not significantly different as determined by Duncan's New Multiple Range Test.

Table 17 - Contents of Al-P, Fe-P, Ca-P, soil test P, and P uptake by oat plants for three soils fertilized with several amounts of superphosphate.

Soil type	pH	P uptake by oat plants	P applied to soil	Soil[+] test P	P fraction Al-P	Fe-P	Ca-P
		mg./1500g.soil	ppm. of soil				
Huntington silt loam	7.8	2.27	0	8	34	67	38
		3.85	25	11	43	-	-
		5.30	50	19	63	-	-
		5.64	100	24	67	-	-
		8.00	200	55	134	99	47
Lloyd clay loam no. 1	6.9	6.42	0	96	75	262	82
		7.38	25	106	85	-	-
		7.77	50	115	97	-	-
		9.97	100	135	116	-	-
		10.52	200	154	141	330	84
Lloyd clay loam no. 2	7.0	2.08	0	26	38	276	85
		2.54	25	31	48	-	-
		3.15	50	38	57	-	-
		4.35	100	45	78	-	-
		7.41	200	75	111	358	98

+ Soil test P determined by using a mixture of .025 N H_2SO_4+.05 N Hcl as an extractant (Mehlich, 1953).

P treatment was significantly higher than at the 100 ppm. P treatment for the Lloyd soil no. 2. These statistical data as well as the higher uptake at each level of applied P for Huntington soil indicate that uptake of applied P was more efficient from the Huntington silt loam than Lloyd clay loam no. 2. However, the available P test values for each treatment indicate a higher available P status for the Lloyd soil (no. 2). Since the Huntington soil had a pH value of 7.8 whereas the Lloyd soil no. 2 had a pH value of 7.0, the soil test may have underestimated the available P status of the Huntington soil due to neutralization of the extracting solution.

Soil inorganic P fractions vs. P uptake by oat plants. Relationships between applied P, P uptake by oat plants, soil test P and inorganic soil P fractions are shown in table 17. Although all the soils had an available CaO content of greater than 4500 lbs./A., addition of superphosphate (200 ppm. P) resulted in little increase in the Ca-P fraction of the soils (2-13 ppm.) during the 28 day equilibration period. The 200 ppm. P treatment substantially increased the Fe- and Al-P fractions of the soils. The Fe-P fraction of the Lloyd no. 1 and no. 2 soils, which are known to contain high amounts of Fe, increased by 68 and 92 ppm., respectively. The Fe-P fraction of the Huntington soil, which contains less iron than the Lloyd soils, increased by 32 ppm. The increase in Al-P was higher for the Huntington soil (100 ppm.) than either Lloyd no. 1 (66 ppm.) or Lloyd no. 2 (73 ppm.) soils. In general, the above data show that the Fe- and Al-P fractions of these three soils increased to a greater extent than the Ca-P. These data concur with results obtained in several investigations (Lindsay et al., 1959; Baldovinos, 1964), which show that a considerable amount of Al- and Fe-P is formed in alkaline as well as acid soils.

In a greenhouse investigation, Baldovinos (1964) found that Al-P formed on addition of superphosphate to soil was more closely related to P uptake by plants than the amount of Fe- or Ca-P formed. Statistical data (table 18) also show that Al-P formed on addition of various amounts of monocalcium phosphate to three soils correlates closely (r=0.93**) with P uptake by oat plants grown for 28 days. These data indicate that, shortly after P fertilization, Al-P fraction of soil supplies the P requirements of plants. This observation supports the hypothesis of Baldovinos (1964) that Al-P fraction of soil supplies P in soil solution shortly after fertilization with superphosphate.

Table 18 - Coefficients of simple correlation for the relationship of P uptake by oat plants with soil test P and Al-P for three soils fertilized with several amounts of superphosphate.

Soil	No. of observations	Variable correlated with P uptake	
		Al-P	Soil test P
Huntington silt loam	5	0.94*	0.94*
Lloyd clay loam no. 1	5	0.97**	0.98**
Lloyd clay loam no. 2	5	0.99**	0.99**
All soils	15	0.93**	0.87**

* Significant at the 5% level of probability.

** Significant at the 1% level of probability.

SUMMARY

The present investigation was initiated a) to compare plowed and "no tillage" with respect to yield of corn and tobacco grown on Wellston loam, b) to determine the availability of surface applied and mixed P fertilizer to corn plants, and c) to evaluate the plant availability of Ca-, Fe-, and Al-P fractions of soils fertilized with superphosphate.

The principal conclusions reached in the course of this study are summarized as follows:

1. During 1963 corn plants were taller on no tillage- and plowed-P fertilized plots than their respective checks, 50 days after planting. Later in the season, 88 to 104 days after planting, height of corn plants on no tillage- and plowed-P fertilized plots were not significantly different than their corresponding checks. From these data it was concluded that P fertilizer applied to the surface of the no tillage treatment and mixed with soil of the plowed treatment increased growth of corn plants early in the season.

2. Yield of corn stover in 1963 corresponded closely to height of corn plants, 88 to 104 days after planting, i.e., no tillage- and plowed-P fertilized treatments did not give higher yields than their respective checks. Neither plant height nor yield of stover was reflected in yield of corn grain. Duncan's New Multiple Range Test showed that P fertilization increased yield of corn grain on no tillage but not on the plowed plots.

3. Soil moisture content and temperature were not significantly different for no tillage- and plowed-checks of the 1963 field experiment. Consequently, the higher yield of corn grain from the no tillage-check as compared to the plowed-check could not be attributed to different soil temperature or moisture content.

4. Phosphorus movement studies showed neglibible downward movement of surface applied P of 1963 no tillage plots. These results indicate that surface application of P results in less fixation of P than mixed application of P due to less soil-P fertilizer contact. Further evidence that surface P application results in less fixation of P was shown by a soil inorganic P fractionation study; the amount of difficulty soluble Ca-, Fe-, and Al-P compounds was higher for the mixed than surface application. Higher yield of no tillage P fertilized as compared to plowed-P fertilized treatments was explained on the basis of less fixation and, consequently, higher uptake of surface than mixed application of P.

5. An amount of moisture which does not penetrate deeply into soil would contain a higher concentration of P in soil solution from surface than mixed P application. Therefore, it was concluded that small showers and dew favor plant uptake of surface applied P.

6. The amount of P in corn leaves from mixed P application increased in the later portion of the growing season. These data were explained on the basis of higher uptake of fertilizer P as root proliferation occurred in the volume of soil containing fertilizer. The content of P in corn leaves from surface application decreased in the later portion of the growing season. This decrease was explained by increased uptake of native soil P as root proliferation increased.

7. Tobacco plants were taller on no tillage than plowed plots early in the growing season. Since the difference in height occurred during a droughty period, the increase in height was attributed to the higher amount of available water of the no tillage treatment. Content of N in tobacco leaves was lower for the no tillage than plowed treatment

whereas contents of P and K were similar for the two treatments. Lower yield of tobacco from the no tillage treatment was attributed to N deficiency. Apparently surface applied N of the no tillage treatment was not as efficient in supplying N to tobacco plants as the mixed application of the plowed treatment.

8. Phosphorus fertilization increased yield of oat plants grown in the greenhouse on Lloyd clay loam and Huntington silt loam which contained 26 and 8 ppm. available P by the Mehlich soil test, respectively, but not on Lloyd clay loam which contained a higher amount of available P (96 ppm.). For the two soils on which oat plants showed growth response to P fertilization, uptake of applied P was greater for the Huntington than Lloyd soil whereas the soil test indicated a higher amount of available P at each level of P fertilization for the Lloyd soil. It was concluded that the available P content of the Huntington soil was underestimated due to neutralization of the extracting solution.

9. Fractionation studies showed that higher amounts of Al-P and Fe-P than Ca-P were formed in Huntington silt loam and two Lloyd clay loams 28 days after fertilization with superphosphate. The Huntington soil had a pH of 7.8 whereas the Lloyd soils had pH values of 6.9 and 7.0. These data show that considerable amounts of Fe- and Al-P compounds may form in alkaline and neutral soils.

10. The amount of Al-P formed in Huntington silt loam and two Lloyd clay loams which received 5 rates of P fertilization correlated significantly ($r = 0.93^{**}$) with P uptake by oat plants. It was concluded that the Al-P formed, shortly after fertilization with superphosphate, supplied the major portion of P absorbed by oat plants.

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ABSTRACT

RELATIONSHIPS BETWEEN SEEDBED PREPARATION
AND GROWTH OF CORN AND TOBACCO PLANTS

THAKUR AMAR SINGH

The objectives of the investigation were to evaluate no tillage and tillage by plowing with respect to yield of tobacco and corn plants and to compare uptake of P by corn plants from surface and mixed applications of superphosphate. A further aim was to determine the relationship between P uptake by oat plants and inorganic P fractions of three Virginia soils which received varying amounts of superphosphate.

During 1963 corn plants were taller on no tillage- and plowed-P fertilized plots than their respective checks, 50 days after planting. Later in the season, 88 to 104 days after planting, height of corn plants on no tillage- and plowed-P fertilized plots were not significantly different than their corresponding checks. From these data it was concluded that P fertilizer applied to the surface of the no tillage treatment and mixed with soil of the plowed treatment increased growth of corn plants early in the season.

Studies with P^{32} indicated that surface applied P was more available to corn plants than broadcast-mixed P during the early portion of the 1963 and 1964 growing seasons. Higher yield of corn grain in 1963 from the no tillage treatment was attributed to the higher uptake of surface applied P. During the middle and later portions of the two seasons, surface and mixed applied superphosphate were equally available to corn plants. Because soil temperature and moisture content were not significantly different for the plowed and no tillage treatment it was concluded that

these two variables did not influence corn yield.

Higher uptake of surface applied P was explained on the basis of less fixation due to less soil-fertilizer contact. This explanation was supported by investigations which showed negligible downward movement of surface applied P and a higher amount of difficulty soluble P compounds in soil of the broadcast-mixed P treatment. It was pointed out that moisture, which does not penetrate deeply into soil, favors plant uptake of surface applied P due to a higher amount of P in solution from surface applied P than broadcast-mixed P.

Burley tobacco plants grown on Wellston loam were taller on no tillage than plowed plots early in the growing season. The difference in height was attributed to the higher available water content of the no tillage treatment. Content of N in tobacco leaves at harvest time was lower for plants grown by no tillage. Smaller plants late in the growing season and lower yield for the no tillage treatment were attributed to N deficiency. Presumably, surface applied N (no tillage treatment) supplied less N to plants than mixed N (plowed treatment). The two methods of fertilizer application resulted in equal contents of P and K in tobacco leaves.

In a greenhouse investigation, P fertilization increased yield of oat plants on Huntington silt loam and Lloyd clay loam which contained 8 and 26 ppm. of available P (Mehlich test), respectively, but not on Lloyd clay loam which contained 96 ppm. For the soils on which oat plants responded to P fertilizer, uptake of applied P was higher from the Huntington than Lloyd soil whereas the soil test indicated higher amounts of available P for the Lloyd soil. It was concluded that the available P content of the Huntington soil (pH 7.8) was underestimated due to neutralization of the extracting solution.

Higher amounts of Al-P and Fe-P than Ca-P were present in the Huntington (pH 7.8) than two Lloyd soils (pH 6.9 and 7.0), 28 days after application of 5 amounts of superphosphate. These data show that considerable amounts of Al-P and Fe-P may form in alkaline and neutral soils. Amounts of Al-P present in the fertilized soils correlated significantly ($r = 0.93^{**}$) with P uptake by oat plants. From these data it was concluded that Al-P compounds, formed shortly after application of superphosphate, supplied the major portion of P absorbed by oat plants.