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The relationship among soil manipulation, seedling environment and plant growth

by

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TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

METRIC CONVERSION FACTORS

The metric units of measure were used throughout this thesis. As an aid for the reader the following list of conversion factors is provided:

LENGTH

1 inch = 2.54 centimeters = 2.5 x 10^4 microns

1 foot = 0.3048 meters

AREA

1 square inch = 6.452 square centimeters

1 square foot = 0.092 square meters

1 acre = 0.405 hectares

MASS

1 pound mass = 452 grams = 0.452 kilograms = 4.52 x 10^{-3} quintals

PRESSURE

14.7 pounds per square inch = 1 atmosphere = 1.013 bars

1 pound per square inch = 0.0689 bars = 0.689 newtons per square centimeter

RATE AND YIELD

1 pound per acre = 1.12 kilograms per hectare

1 bushel per acre (56 pounds per bushel) = 0.627 quintals/hectare

INTRODUCTION

"When tillage begins, other arts follow. Farmers therefore are the founders of human civilization." Daniel Webster (1782-1852). Over a century later, tillage (defined as mechanical manipulation of soil for changing soil conditions to increase crop production) is still more of an art than a science.

With society demanding a quality environment while pointing an accusing finger at soil erosion and with the development of herbicides, farmers are asking the question, "why is tillage necessary, and if so, how much is required?" If one attempts to answer the question, "Why till?", it becomes obvious that tillage is still an art and not a science. Farmers speak in qualitative terms - "Good tilth," "Fine seedbed." Machinery manufacturers have little or no design criteria upon which to base modification and development of new and existing tillage systems. Researchers have not been able to quantify an optimum seedbed. One does not have to wonder why the condition exists. Our present crop production systems were developed primarily through trial and error by farmers with an urge to experiment and an ability to fabricate.

One of the primary reasons for tillage is to create an optimum seedbed for promoting germination and seedling emergence. Conventional cultural practice systems for corn (*Zea mays* L.) and soybean (*Glycine max* (L.) Merrill) production rarely emerge more than 85% of the seeds. Conservation tillage systems, of which Iowa has approximately 3,000,000 acres often emerges less than 60% of the planted seed. There definitely is a need for improving emergence for both conventional and conservation tillage systems.

A voluminous amount of research results exists concerning specific soil physical factors and their effects on seed germination and seedling emergence, such as temperature and moisture. A limited amount of research has studied the interactions of soil physical factors and their effects on germination and emergence.

Basic to the problem of plant growth, and specifically seedling emergence, is soil structure (soil structure is defined as the arrangement of solid particles and their bonding forces). Soil acts as a support for plant growth and acts as a medium for the storage and transport of water, heat, air and nutrients which are necessary for plant production.

Man has attempted to optimize soil structure for plant growth through tillage and tillage systems. Progress has been slow. The main reason tillage is still an art and not a science is that soil structure has not been quantified. If soil structure could be quantified, then tillage and tillage systems could be optimized.

Indirect methods, for example moisture desorption have been developed for measuring soil pores and pore distribution.

These methods do not provide any means for measuring pore orientation such as results from the flow of soils under load (compaction by a wheel).

There is a definite need to quantify soil structure so that present tillage systems and especially conservation tillage systems can be modified or changed so that emergence of seedlings can be improved or at least predicted. If soil structure were quantified, the benefits would be broader and encompass more than seedling emergence. Root growth, drainage, infiltration, tillage energy, aeration, mechanical impedance and drying rate are all influenced by the arrangement and bonding of soil particles. This research was designed to provide information for quantifying soil structure and for establishing the effects of soil structure on seedling emergence.

OBJECTIVES

Broad Objectives

The objectives of this research were to gain knowledge and insight into the effect of soil physical environment on corn and soybean seedling emergence. This knowledge will be used to establish design criteria for tillage and planting equipment.

Specific Objectives

1. Develop a technique for direct measurement of soil structure, and in particular, the geometry of soil pores.

2. Evaluate the effect of tillage systems, soil moisture, soil temperature, soil structure (as measured with the technique developed in objective 1) and planting depth on corn seedling emergence under field conditions.

3. Establish the relationships among soil moisture, soil temperature, soil structure, and planting depth on corn and soybean seedling emergence under controlled conditions.

REVIEW OF LITERATURE

There are many physical, chemical, and biological factors that affect corn and soybean seed germination and seedling emergence. This research was limited to the environmental factors that could potentially be altered through tillage and planting techniques. This literature review concerns only the soil physical factors studied in this research plus a brief review of the germination process. These topics will be discussed under the following headings:

1. Metabolism of germinating seeds
2. Temperature
3. Moisture
4. Soil structure
5. Depth of planting.

Metabolism of Germinating Seeds

Germination is a process which converts tissue into an actively growing organism with a recognizable root and shoot. The physiological processes of seed germination are (Gentile, 1971) as follows:

1) absorption of water;
2) beginning of cell enlargement and cell division;
3) increase in metabolic activities including digestion of stored food;

4) transport of food to growing regions;

5) increase in respiration and assimilation;

6) increase in cell division and enlargement;

7) differentiation of the cells into the various tissues and organs of the seedlings.

Dry viable seeds are characterized by low rate of metabolism. The first step in the process that leads to germination of corn and soybeans is imbibition of water by the seed. The seed responds to imbibition with a rapid increase in respiratory rate followed by a breakdown of reserve materials in the seed.

The complex chemical changes which occur during germination are generalized into three types by Mayer and Poljakoff-Mayber (1963): the breakdown of certain materials in the seed, the transport of materials from endosperm to the embryo or from the cotyledons to the growing parts, and lastly the synthesis of new materials from the breakdown products formed.

The breakdown of reserve materials in seed is initiated by hydration of proteins. Part of the proteins constitutes the various enzyme systems which act as catalysts for chemical reactions. Carbohydrates are normally broken down by amylases into sugars, including maltose and glucose. Fats and oils are broken down by the action of lipases. Proteins are broken down by proteases. Water is necessary for translocation of the various materials to be used for synthesis and energy sources.

The process of emergence is extremely different between corn and soybeans as described by Aldrich and Leng (1965) and Scott and Aldrich (1970). After the corn kernel has inbibed and chemical processes activated growth in the embryo, the radicle elongates and emerges from the seed coat. The plumule breaks through the seed coat one or two days after the radicle. The mesocotyl ordinarily elongates about half the distance to the surface. Lengthening of the coleoptile brings the leafy parts of the plant the rest of the way to the surface.

Soybean seedling establishment is initiated as the radicle penetrates the seed coat. The radicle develops into a root and forms a support for the reactive forces produced by the hypocotyl. The hypocotyl emerges from the seed, elongates, forms an arch and pushes upward. As the hypocotyl breaks the soil surface, it pulls the cotyledons and epicotyl upward.

Temperature

The exact mechanism by which temperature affects plant growth has not been delineated. It is a complex phenomenon composed of physical, chemical, and biological processes such as water absorption, enzyme reactions, and viscosity.

Lehenbauer (1914) studied the effect of temperature on corn growth. He grew maize seedlings in weak diffused light at constant temperature with the roots in a nutrient solution and the shoots in circulating air at 95 percent relative humidity. Prior to the initiation of a test, seedlings selected for uniformity were grown in a nutrient solution from 8 to 10 hours at 28C. Seedlings whose growth deviated widely from the average were not included in the tests. Tests were made for temperatures from 12C to 43C and exposure times (exposure time was defined as the length of time the seedlings had been exposed to the testing temperature) of up to 39 hours. Lehenbauer's main results and conclusions are as follows:

1. The optimum temperature for growth of shoots of maize seedlings in water culture for a 12-hour period was shown to be 32C.
2. The optimum temperature for growth was found to increase as length of exposure time was increased.
3. At temperatures over 31C there was a marked falling off in initial growth rate during prolonged periods of exposure.
4. At temperatures near minimum (12-14C) for growth of shoots of maize no decrease in growth rate was shown for prolonged exposure periods.
5. The growth rate doubled for a rise in temperature of 20 to 30C.

Lehenbauer's (1914) research showed that the rate of corn seedling growth increased linearly with temperature from approximately 10 to 30C. Blacklow (1972) planted corn in pots of wet, freely drained vermiculite, kept in darkened, constant temperature chambers ranging from 9.5 to 40C ($\pm$0.5C). The results of his research support Lehenbauer's result of seedling growth rate increasing linearly with temperature from 10 to 30C.

Willis, Larson and Kirkham (1957) conducted greenhouse studies on the influence of temperature and mulch on corn growth. They found that growth rate as affected by temperature followed the Van't Hoff law with a Q_{10}C being 2.0 to 2.8 for temperature ranges of 15.5-19C.

Van Wijk, Larson and Burrows (1959) studied the effect of mulch and unmulch soil on early corn growth in Iowa, South Carolina, Ohio, and Minnesota. Their data agreed in general with Lehenbauer showing increased growth rate for temperatures from 10 to 30C.

It is generally accepted that there exists an optimum temperature for corn growth. Lehenbauer (1914) found the optimum temperature to be 29-32C for the tests he conducted. Willis et al. (1957) found the optimum soil temperature at the 10 cm depth for corn growth in Central Iowa field conditions to be 23.9C. Allmaras, Burrows and Larson (1964) conducted experiments at nine locations in the eastern United States and found the optimum temperature for corn growth at the 10-cm soil depth to be 27.4C.

Soybeans apparently have a different growth response to temperature than corn. For some varieties there is a temperature induced inhibition of hypocotyl elongation at approximately 25C. Grabe and Metzer (1969) evaluated the emergence of 25 soybean varieties planted at three depths in sand at 15, 20, 25, and 30C. They divided the 25 varieties into three groups based on their ability to emerge at the 7.5 and 10 cm planting depth and 25C. Each group's ability to emerge was significantly different, at the 1% level of probability, than either of the other two groups. They concluded that varietal differences in emergence ability were evident and appeared to be genetically controlled. They also evaluated hypocotyl elongation in darkness for Hawkeye and Ford varieties planted 2.5 cm deep at temperatures of 15, 20, 25, and 30C. Hypocotyl elongation of Hawkeye was normal at all four temperatures. Hypocotyl elongation of Ford was severely inhibited at 25C, but at 30C growth showed an increase over that at 25C. Samimy (1970) studied hypocotyl elongation rates of Hawkeye, Mandarin, Shelby, and Clark soybean varieties at 20, 25, and 30C. He found that hypocotyl elongation rates for the first 72 hours were the same for all four varieties. After the first 72 hours growth, rates of Hawkeye and Mandarin exceeded the growth rates of Shelby and Clark at 25C.

Gilman (1972) determined the temperature response curve for hypocotyl elongation for Clark, Ford, Amsoy, Beeson, Hawkeye, and Wayne varieties. He grew the seeds in darkness in paper towels and had a temperature range of 20-32C $\pm$ 0.3C. Hypocotyl length of the short hypocotyl varieties (Clark, Ford, Amsoy, and Beeson) decreased linearly from 20 to 25C and increased linearly for temperatures above 25C. Hypocotyl length of Hawkeye and Wayne decreased slightly as temperatures were increased above 20C, but they did not show the inhibitory effect at 25C.

Thermal properties of the soil, surface cover, if any, and net energy input determine soil temperature. Tillage and cultural practices can alter soil thermal properties, and therefore it would seem logical to strive for soil thermal conditions that would optimize plant growth.

Kirkham and Powers (1971) derived the partial differential equation of heat flow based on Fourier's heat flow law. The following is their one-dimensional heat flow equation:

$$\partial T/\partial t = D(\partial^2 T/\partial z^2)$$

where D = the thermal diffusivity

T = temperature

t = time - hours

z = the axis of the heat flow - cm.

They defined thermal diffusivity as a measure of the change in temperature per unit time of a substance under a heat flow gradient. Diffusivity is given by the following equation:

$$D = K/\rho c$$

where K = thermal conductivity, defined as the rate at which a body conducts heat - cal $cm^{-1}sec^{-1}C^{-1}$

c = gravimetric heat capacity, defined as the calories of heat required to raise one gram of material one degree centigrade - cal $gm^{-1}C^{-1}$

ρ = density of the material - gm cm^{-3}.

Kirkham and Powers assumed all the heat transfer was by conduction, the thermal conductivity, K, and volumetric heat capacity, ρc, are independent of time and location. Kirkham and Powers (1971) and van Wijk (1966) present solutions to heat flow for the one dimensional case.

Fluker (1958) applied the following equation to predict annual soil temperature fluctuations from 0 to 3 m depth:

$$T = T_A + A_d \sin [(2\pi/364)(t-t_d)]$$

where T = average soil temperature at depth d in C

T_A = average annual temperature

A_d = the natural soil annual temperature in C at depth d below the ground surface

t_d = the time lag of soil temperature at depth d behind that at the ground surface

t = the time in days after December 31.

Burrows (1959) used a Fourier series type of solution and compared field results with theory. An experiment was conducted in which the treatments consisted of chopped cornstalk mulch applied at rates of 0, 22.7, 45.2, 90.8 and 181.6 q/Ha. Burrows concluded that soil temperature data alone is not sufficient to obtain an accurate estimate of soil thermal diffusivity, but that qualitative explanations of some of the soil temperature-mulch relationships can be made. Van Wijk et al. (1959) use heat conduction theory to estimate differences in soil temperature between mulch and unmulch soil. Their calculated values agreed well with observed temperatures.

Soil temperature can be greatly influenced by tillage and cultural practices. Mulch tillage is one method of influencing soil temperature. Van Wijk et al. (1959) listed three ways in which mulch influences soil temperature:

1. The mulch acts an an insulating layer on the soil surface, reducing the amount of heat that enters the soil.
2. A less fraction of incident radiant energy is converted into heat at the surface if the reflection coefficient of the mulch exceeds that of the unmulched soil.
3. Evaporation is somewhat reduced. This effect counteracts the previous two as regards soil temperature since a smaller fraction of the total heat generated

at the surface is used as latent heat of vaporization and sensible heat constitutes the larger fraction as compared with the unmulch soil.

Willis et al. (1957) found mulch plots with 5.7 q/Ha of straw were 0.9C colder than unmulch plots for the period June 8 - August 16. Silking dates on the mulched plots were approximately one week later with no significant difference in yield. They also noted a longer elapse of time between tasseling and silking for the mulch plots which indicated a possible physiological reaction of the plant to mulch. Burrows and Larson (1962) studied the effect of surface mulches of chopped cornstalks on corn growth and soil temperature. They found mulch reduced corn growth in north central states, and each 22.3 q of mulch applied over the range from 0 to 44.6 q/Ha reduced the average soil temperature during May and June at the 10 cm depth by about 0.4C.

Buchele (1954) demonstrated that by changing the surface topography and managing crop residue early season soil temperatures could be increased. He used a ridge farming scheme where crop residue was deposited between ridges and crops planted on the ridge. Shaw and Buchele (1957) compared temperatures of ridge-furrow configurations for various depths. They found ridge soil temperatures were higher than furrow soil temperatures for the period observed (April 29 - June 5). The maximum difference in diurnal soil temperature between the ridge and furrow usually occurred around the time of maximum temperature. Burrows (1963) showed that orientating the ridges in a north-south direction further increased the temperature in the ridges.

As with most environmental parameters, it is extremely difficult to consider the effects of one parameter alone, such as temperature on plant growth. An example is the inter-related effects of changes in soil moisture and soil temperature. Moisture movement in the liquid and in the vapor phases gives rise to transport of sensible and latent heat which influences the temperature distribution. Temperature gradients cause moisture movement so that temperature changes result in changes in moisture distribution. Other factors such as nutrient uptake and biological activity, which influence plant growth, are affected by temperature. Changes in cultural practices to alter temperatures for increase in plant growth will result in changes in other factors which may or may not promote increases in plant growth.

Moisture

The first process which occurs during germination is uptake of water or imbibition. Without moisture neither germination can be initiated nor plant growth sustained. Mayer and Poljakoff-Mayber (1963) indicated that the extent to which imbibition occurs is determined by the composition of the seed, the permeability of the seed coat, and the availability of water.

Stiles (1948) showed that three varieties of corn differed in percentage of initial 24-hour water intake and in percentage of final 96-hour water absorption. It was concluded that seeds exist with mesic (intermediate water), hydric (high water) or xeric (low water or desert) germination adaptation or tendencies. A similar investigation by Stiles (1949) with beans (soybeans, kidney beans, and butter beans) demonstrated that various bean seeds differ in the total amount of water absorbed and in rates of water absorption. Bean seeds also possessed degrees of adaptation to germination in mesic, hydric, and xeric conditions.

There apparently is a minimum seed moisture content that seeds must obtain before they will germinate. Hunter and Erickson (1952) found that minimum moisture content (wet basis) for corn was 30.5% and 50.0% for soybeans. They also established maximum soil moisture tensions above which germination will not occur. The maximum moisture tensions were 12.7 bars for corn and 6.8 bars for soybeans. Scott and Aldrich (1970) state a soybean seed must reach 50 percent moisture content and corn 30 percent moisture content before germination processes will start.

The storage and flow of moisture in the woil were related to the pore sizes and their distributions. The rate of flow of water in both saturated and unsaturated soils is usually considered as being proportional to the potential gradient. This is a statement of Darcy's law:

$$V_x = -K(\partial h/\partial x)$$

where V_x = the velocity of flow in the x direction - cm/sec
K = capillary conductivity for unsaturated flow - cm per second
$\partial h/\partial x$ = the hydraulic gradient in cm/cm

Darcy's law doesn't apply for all soils for unsaturated flow.

Kirkham and Powers (1971) present the differential equation of unsaturated moisture flow which is analogous to the differential equation for heat flow. Assuming one-dimensional flow, constant diffusivity and validity of Darcy's law, the equation is as follows:

$$\partial \theta/\partial t = D(\partial^2 \theta/\partial x^2)$$

where θ = the moisture content on volume basis - cm^3/cm^3
t = time - seconds
D = the diffusivity in cm^2/sec
X = an axis of cartesian coordinate system - cm.

Diffusivity, D, is seldom constant, and a more appropriate assumption is that D is a unique function of soil moisture which results in the following equation for one-dimensional flow:

$$\partial\theta/\partial t = \partial/\partial x[D(\theta)(\partial\theta/\partial x)].$$

Gardner (1960) presented graphs showing both K, capillary conductivity, and D, diffusivity as being dependent on the soil and soil moisture tension.

Stout (1959) studied the uptake of moisture by sugar beet seeds. He found that packing the soil in the seed zone caused sugar beet seeds to absorb water at a greater rate for a period of two to five hours; however, after that period seeds absorbed more water from uncompacted soil.

Phillips (1968) measured the water diffusivity of soybean, corn, and cotton seed when germinated in aerated, distilled water and in a silt loam at differing water contents. The diffusivity of soybean seed germinating in aerated, distilled water was approximately four times larger than for corn seed. In Zanesville silt loam at four moisture contents ranging from wilting percentage to field capacity, the diffusivities of both corn and soybean seed increased as soil moisture increased, but there were no apparent differences between corn and soybean seed diffusivities at each moisture content. Phillips found that diffusivity of soybean and corn seed for each moisture content increased with time. He concluded that this effect and the increase in diffusivity with increased moisture content were related to the percentage of seed becoming covered with a water film.

Although the composition of the seed and seed coat influence the imbibition process, the greatest potential for providing an optimum moisture condition concerns the availability of water to the seed. This includes seed contact and the ability of the environment surrounding the seed to store and transport water.

Dasberg and Mendel (1971) studied the effect of moisture stresses from 0.001 to 15 bars tension on grass and wheat seed germination in sand and sandy loam soil. They concluded that the rate of seed-water uptake governs germination, and the rate of uptake is determined by germination medium, its conductivity, and the area of contact between seed and medium. The optimum moisture tension, for germination was -0.005 bars in sand and -0.5 bars in sandy loam.

Sedgley (1963) showed that wetted area of contact influenced rate of germination. Collis-George and Hector (1966) studied the effects of wetted area of contact and matric potential from 9 to 243 cm tension on germination of *Medicago tribuloides* and *Lactuca sativa* seeds. They showed that as wetted area of contact decreased or matric potential increased rate of germination was depressed. Wetted area of contact was of consequence even at matric potentials near that of free water and was most important for germination of the last seeds in each population.

Soil moisture may be altered through tillage and cultural practices. Mulches may increase soil moisture available for plant use by reducing evaporation and increasing supply through increasing both infiltration and dwell time of water on the land. Mulch reduces evaporation by lowering the soil temperature and the vapor-pressure gradient between the soil water and the free atmosphere. In a three-year study by Moody, Jones and Lillard (1963) with corn grown on plots treated with 67 q of wheat straw per hectare, either placed on the surface or plowed down, surface mulched plots had more moisture in the 46 cm soil depth. The average seasonal differences showed mulched plots had more moisture than bare plots. The differences favoring mulched plots were: 1.2, 2.9, and 2.21 cm respectively for 1958, 1959, and 1960. Triplett, VanDoren and Schmidt (1968) showed corn stover left on the surface increased available soil moisture over corn stover plowed down.

Several researchers have measured the effect of various levels of residue on infiltration. Mannering, Meyer and Johnson (1966) found that surface mulch, which covered 95% of the soil surface, increased the percent of rainfall infiltration from 55% to 82% on minimum tilled plots. Triplett et al. (1968) found that surface residue increased both instantaneous infiltration and total infiltration.

The value of mulch to increase infiltration is questionable. Some research indicates no change in infiltration as a result of applied mulch. Till-planting is a ridge farming system that leaves crop residues on the soil surface until planting time. At planting time, residue and the top of the old ridges are placed between the rows and the crop planted on the remaining ridge. Wittmuss and Swanson (1964) compared infiltration rates of a till-planting system to a conventional tillage system. Two artificial storms were applied to plots. First a 60-minute 6.4 cm/hr storm followed by an 18-minute 10 cm/hr storm. There were essentially no differences in infiltration rates. Moldenhauer et al.(1971) found no significant difference in total runoff from artificial storms applied to plots with conventional, till-plant, and ridge tillage systems. This would indicate that the infiltration for the various systems studied probably was also not significantly different.

Soil moisture may also be influenced by altering the microtopograph. Buchele (1954) compared the soil moisture of a ridge system to a conventional system and found no significant difference. Shaw and Buchele (1957) compared soil moisture of the ridge to the furrow for the ridge farming system. They found the ridge, due to its elevation of approximately 25 cm, is drained quickly of its gravitational water after a rain, and its moisture content approaches that of field capacity.

Soil Structure

Soil structure is usually defined as the physical arrangement of primary and secondary soil particles. Soil structure in the broadest concept includes the nature and degree of particle bonding. Complete specification of soil structure, even as an instantaneous value, is difficult and the problem becomes even more difficult if variations with time are considered. Properties such as permeability, porosity, bulk density, strength, aggregate size, and aggregate size distribution have been used to characterize soil structure; and often these parameters have been incorrectly considered as synonymous with soil structure. Realizing soil structure has eluded quantitative measurement, this review will be concerned with properties used to characterize soil structure, their influence on seedling emergence, and how tillage or cultural practices influence these soil properties.

Soil structure has been recognized by several researchers as being important to seed germination and seedling emergence (Baver, 1932; Bowen, 1966; Bowen and Coble, 1967; Johnson and Buchele, 1961; Larson, 1964; Slipher, 1932 and Yoder, 1937). In the broadest sense, soil structure includes geometric arrangement of primary soil particles and bonding forces.

Moisture desorption has been the most widely used method of measuring noncapillary soil pore characteristics (Bradfield and Jamison, 1938; Childs, 1940; Leamer and Lutz, 1940 and Russell, 1949). The moisture desorption method as it has commonly been used consists of subjecting a saturated soil sample to a moisture tension through a porous medium and determining the volume of water withdrawn as a function of moisture tension. Pore size was calculated with the height of capillary rise equation by assuming that the moisture remaining in the soil at a given tension was a result of water surface tension. Further, the voids are assumed to be a circular in cross-section and then the height of capillary rise equation is given by

$$h = 2T/r\rho g$$

where h = height of rise - cm

T = water surface tension - dynes/cm

r = pore radius - cm

g = the acceleration of gravity - cm/sec^2

ρ = the density of water - gm/cm^3.

Another technique for measuring soil pore characteristics is the mercury intrusion method (Klock, Boersma, and DeBacker, 1969). This method is similar to moisture desorption except the displaced liquid is mercury, not water. These techniques have the disadvantages of being indirect measurements and not providing any information about pore orientation.

Soil structure can be changed through compaction. The degree of compaction is a function of soil type, soil moisture content, and applied force. The applied force may be from tillage tools, weather conditions, or wheels. Phillips and Kirkham (1962) evaluated the effect of soil compaction on corn growth. They conducted field tests with Colo clay soil at three degrees of compaction - normal compaction, moderate compaction, and severe compaction. Normal compaction was that compaction found under normal corn culture. Moderate compaction was produced by repeated passes of a tractor on the surface, and severe compaction was the moderate compaction plus compaction of the plow furrow with repeated tractor passes. They found that compaction reduced stands and yields adjusted for stand reduction. Because compaction influences many soil physical properties, Phillips and Kirkham measured several soil physical properties and determined their correlation with growth and yield. Bulk density and needle penetration were found to be the physical properties most highly correlated with reduction in growth and yield.

Johnson and Henry (1964) studied the effect of compaction pressure, soil granule size, and initial moisture content on emergence of corn and soil drying. They found surface compaction reduced soil drying rates especially at the large granule size, but emergence was reduced for increased compaction. Johnson and Henry (1967) germinated corn seeds in glass beads contained in pressure cells to study the effects of temperature and pressure on corn germination. Sprout growth decreased with increased cell pressure. There was a significant interaction of cell pressure and temperature. Sprout growth was depressed more as applied pressure increased for high temperatures (33C) as compared to the effect at low temperatures (16.5-22.2C).

Stout (1959) studied the effect of physical factors on sugar beet seedling emergence. Although sugar beet seedlings are in general more sensitive to harsh soil environments, Stout's conclusions may apply to corn and soybean seedling emergence. Stout showed that for each set of soil conditions there is a range of packing pressures which induces maximum seedling emergence. There was an interaction between soil moisture and soil compaction. Packing the soil improved seedling emergence when adequate moisture was available below the seed. If adequate moisture wasn't available, there was either no effect or a suppression of emergence.

Sheikh (1964) evaluated the effect of compaction pressure, soil grain size, moisture content, and temperature on emergence of corn and alfalfa. He concluded that emergence of corn and alfalfa seedlings decreases with soil surface compaction pressure and soil grain size and increases with initial soil moisture content and with soil temperature.

Several investigators have used soil resistance to penetrometers or probes as an indication of the mechanical resistance emerging seedlings have to overcome during the emergence process. Taylor, Parker and Roberson (1966) showed that corn, switchgrass, rye, onions, and wheat all had similar relationships between penetrometer resistance and percent seedling emergence. As the penetrometer resistance increased, emergence decreased. Morton and Buchele (1960) developed an instrument to measure the force and energy expended during the emergence of a mechanical seedling (probe). The mechanical seedling was forced upward through a surface soil formation in a manner similar to an emerging seedling. They concluded that force and energy (force x distance) required for emergence increased directly with compaction pressure, initial soil moisture content, amount of soil-surface drying, and inversely with soil moisture content at time of measurement.

Drew (1963) using a similar device to measure emergence force found that emergence force increased linearly with increasing compaction pressure and initial soil moisture. Sheikh (1964) showed that mechanical seedling force decreases with temperature and grain size but increases with initial moisture content and compaction pressure.

Soil aggregate size has been used to describe soil structure. Hoyle, Yamada and Hoyle (1972) established a relationship among tillage equipment, moisture content, aggregate size, and size distribution. By selecting the proper tillage tool and moisture content, optimum aggregate distributions can be obtained. Taylor and Johnson (1956) found that soil granules (by weight) smaller than 2 mm in diameter were significantly correlated with both early and late stands of corn. Johnson and Buchele (1961) evaluated the effect of soil granule size and compaction on emergence of corn. They found that as granule size increased and compactive effort decreased total emergence of corn was less complete.

Allmaras et al. (1965) measured the distribution of soil aggregate diameters in the row zone of row cropped corn. Large differences of aggregate measurements were observed among tillage treatments.

Depth of Planting

Depth of planting or seed depth has an indirect effect on plant emergence. Response of emerging seedlings to planting depth is usually related to other environmental factors such as soil temperature, soil moisture, or soil structure which are functions of depth. For instance, soil moisture may increase with depth, and planting shallow may result in poor emergence because of lack of moisture.

Soybeans are more sensitive to depth of planting than corn. Some soybean varieties have a temperature sensitive inhibition of stem elongation (Everson, 1970 and Samimy, 1970).

Everson (1970) found the maximum hypocotyl elongation at 25 degrees soil temperature for Ford soybeans was 7.5 cm. Therefore, if this variety was planted 10 cm deep with similar soil conditions, it would not emerge.

Morton and Buchele (1960) showed that emergence energy as measured with a mechanical seedling increases almost linearly with depth.

Sheikh (1972) found a curvilinear relationship between planting depth of soybeans (from 1.25-5 cm) and percent emergence. His data indicates there may be an interaction between soil compaction and planting depth on percent emergence.

EXPERIMENTAL METHODS AND PROCEDURE

Technique for Measuring Soil Structure

In the work reported in this thesis, a new technique was conceived and developed which permitted direct measurements of noncapillary soil pores and soil aggregates. The technique consists of obtaining a photograph which contrasts soil voids with soil aggregates and then scanning the photograph with a Flying-Spot Particle Analyzer (Brazee, Hedden and Keck, 1968) for information on soil pores and aggregates.

The soil sample to be analyzed was oven-dried and then impregnated with a fluorescent polyester resin. Extensive tests were not conducted to optimize the fixing agent or fluorescent material. A mixture of the following materials in the proportion indicated produced satisfactory results:

Material	Source	Proportion by volume
1. Polyester resin	Laminac #4110 American Cyanimid Co.	600
2. Fluorescent pigment	S-4654 (pulverized) Lawter Chemical, Inc.	40
3. Solvent	Styrene Monomer Eastman Kodak Co.	180
4. Catalyst	Lupersol DDM Lupersol Div. Wallace and Tiernan Co.	3

These quantities of materials were mixed together in the order listed. Soil samples were placed in a vacuum jar and held at a vacuum of approximately 73 cm Hg gauge for at least 3 minutes before the fluorescent polyester resin was introduced. Figure 1 shows the apparatus setup for impregnating three soil samples. The fluorescent polyester resin was slowly introduced to the soil samples while they were held under vacuum similar to a method described by Voorhees (1964) for nondestructive wetting of secondary soil aggregates with water.

After the samples were thoroughly wetted with the fluorescent polyester resin they were removed from the vacuum jar and allowed to cure at room temperature for at least three days. Following the curing process, the samples were cut with a diamond bladed saw. Figure 2 shows a sectioned sample. The freshly cut surfaces were cleaned and prepared for photographing.

A jig was constructed in a dark room for holding samples in a fixed position from the lights and camera. Two black lights (G.E. H100PL44-4 with ultraviolet filters) were positioned approximately 30 cm above the sample, as shown in Fig. 3.

A 35-mm camera, with appropriate lens extensions to provide a one to one ratio of subject to film image, was used. High contrast copy film and a K-2 filter provided a maximum

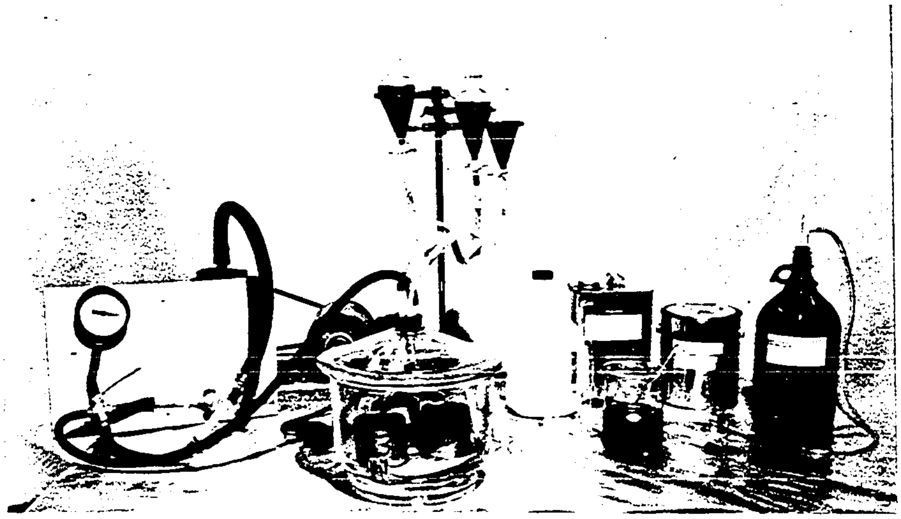


Fig. 1. Apparatus used to impregnate soil samples with polyester resin

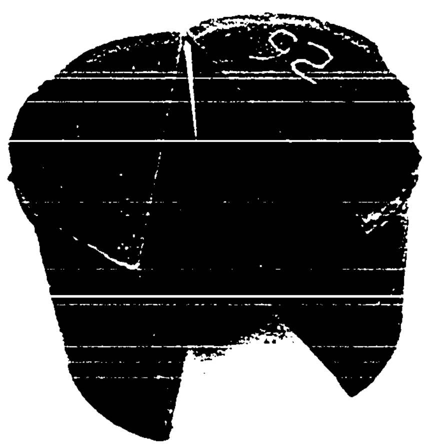


Fig. 2. Impregnated soil sample cut in half

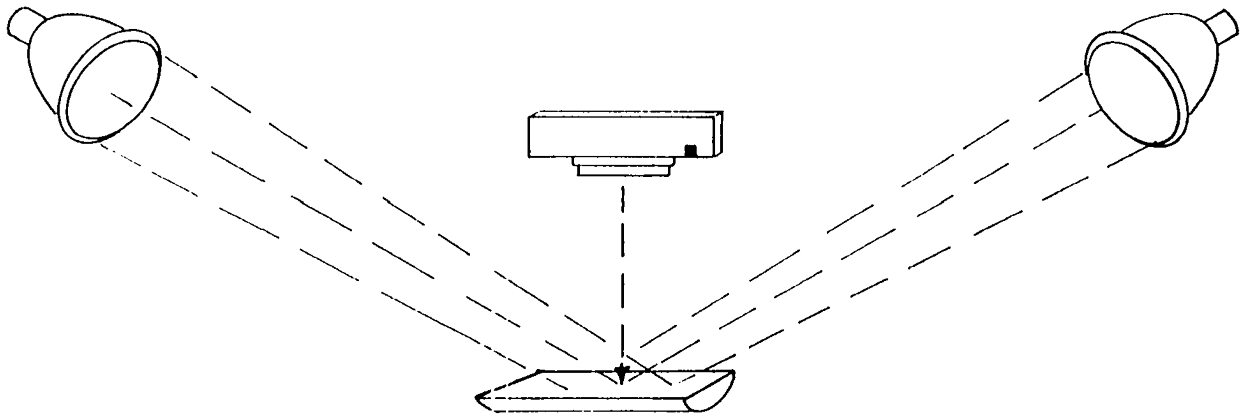


Fig. 3. Setup for photographing soil samples

contrast between voids (filled with fluorescent polyester resin) and aggregates. An exposure time of 12 seconds and aperature opening of f-5.6 were used. The negatives from this film were used to make contact reversals on Kodalith film to further increase the contrast between voids and aggregates.

The Kodalith reversals films were scanned with the Flying-Spot Particle Analyzer (FSPA) in the lineal analysis mode of operation. A complete description of the FSPA and its operation was written by Brazee et al. (1968). The FSPA is an instrument that scans an 18x18-mm area of a subject on 35-mm film with a small light beam that traverses the scan area approximately 900 times. In the lineal analysis mode of operation, information can be obtained on matrix (pore area for this case) and phase (aggregate area) intercept length classification and total matrix and phase areas. Information from the FSPA on intercept length is in the form of numbers of intercepts greater than a designated size. For this research the size categories for both phase and matrix intercepts were as follows:

1. 20 microns = 0.002 cm
2. 40 microns = 0.004 cm
3. 80 microns = 0.008 cm
4. 160 microns = 0.016 cm
5. 320 microns = 0.032 cm
6. 640 microns = 0.064 cm

7. 1280 microns = 0.128 cm

8. 2560 microns = 0.256 cm

9. 5120 microns = 0.512 cm

10. 10240 microns = 1.024 cm

11. 20480 microns = 2.048 cm

These categories were chosen to provide information in regard to noncapillary pores. The grain size of soil ranges from clay (0.0002 cm) to coarse sand (0.2 cm).

Each film frame was scanned in two directions. The two directions corresponded to the vertical and horizontal axis of the soil samples as they existed in the field and in the laboratory. These two directions will be referred to as an angle of zero degrees for horizontal and 90 degrees for vertical.

By converting the intercept lengths to a log scale, the distributions for number of intercepts vs. logarithm of intercepts, were more nearly symmetrical.

The mean, variance, coefficient of skewness, and coefficient of kurtosis were calculated for each distribution. The first four moments about the origin were calculated using the following formula (Selby and Weast, 1970):

$$m'_r = (1/n)\ \Sigma\ f_i\ X_i^{\ r}$$

where m'_r = the r^{th} moment about the origin

X_i i = 1,2,...,k = the class marks

$f_i \quad i = 1,2,\ldots,k$ = the class frequencies

n = the total number of observations.

The following relations exist between moments about the mean m_r and moments about the origin m'_r (Selby and Weast, 1970)

$$m_1 = m'_1 = \text{mean}$$
$$m_2 = m'_2 - (m'_1)^2 = \text{variance}$$
$$m_3 = m'_3 - 3m_1'm_2' + 2(m_1')^3$$
$$m_4 = m_4' - 4m_1'm_3' + 6(m'_1)^2m_2' - 3(m_1')^4$$

Sheppard's corrections for grouped data were applied and they were as follows (Selby and Weast, 1970)

$$m_{2c} = m_2 - (\delta^2/12)$$

$$m_{4c} = m_4 - (\delta^2m^2/2) + (7(\delta)^4/240)$$

where m_{2c} = the corrected moment for the 2nd moment about the mean

m_{4c} = corrected moment for the 4th moment about the mean

δ = the class interval.

The coefficient of skewness, α_3, and coefficient of kurtosis, α_4, are defined as follows:

$$\alpha_3 = m_3/(m_2)^{3/2}$$
$$\alpha_4 = m_4/m_2^{\,2}$$

Underwood (1970) derived the equation

$$V_V = A_A$$

where V_V = volume fraction • volume of feature per unit test volume

A_A = average area fraction • area of intercepted features per unit test area.

This equation states that the average area fraction A_A, determined on random sections through a volume represents an estimate of the volume fraction V_V of the phase under investigation. The only assumption is the need for randomly oriented sections. If the matrix area (pore area) measured by the FSPA is assumed to be an estimate of the average matrix area then, A_A, the average area fraction equals the matrix area divided by the total area scanned. Porosity is defined as the ratio of non-solids volume to total volume or equal to V_V. Therefore, A_A, as measured with the FSPA is an estimate of porosity.

Figures 4-6 show a soil sample fixed and prepared for photographing, its 35-mm film frame scanned by the FSPA, the zero angle matrix and phase distributions.

Field Experiment

In order to evaluate the effect of tillage systems, soil moisture, soil temperature, soil structure, and planting depth on corn seedling emergence under field conditions, a split-plot experimental design was used. Main plots (eight 76-cm rows 27 meters) which were ten different tillage cropping

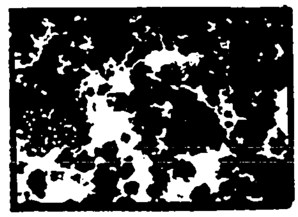


Fig. 5. Soil structure photograph of sample number 132

Fig. 4. Impregnated soil sample number 132

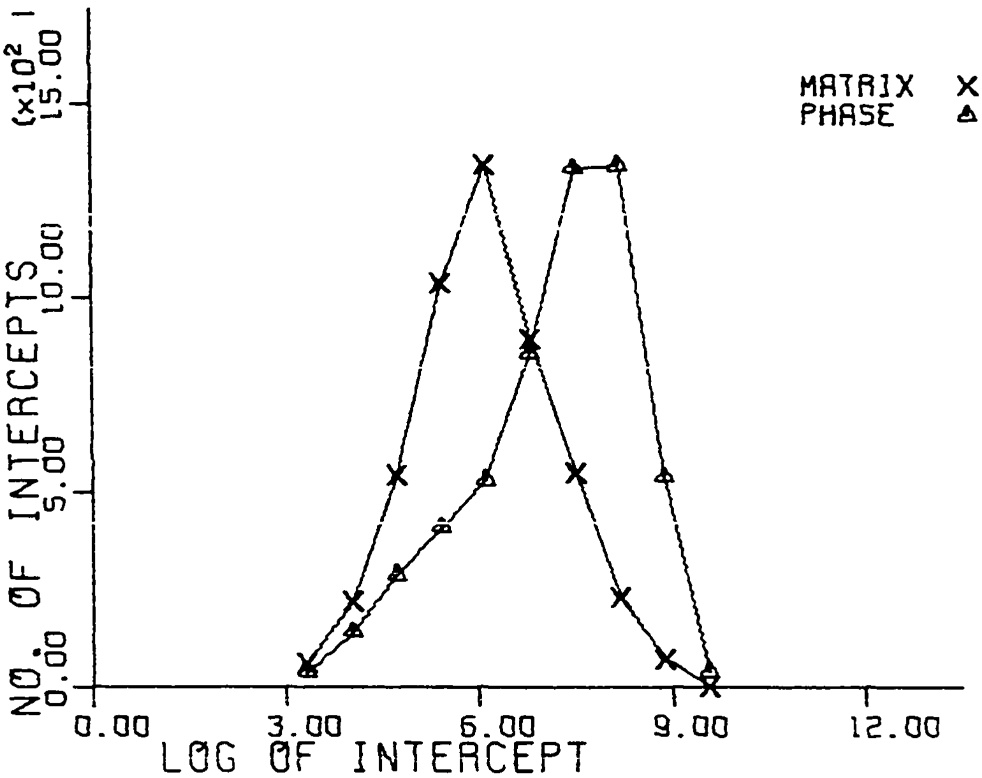


Fig. 6. Phase and matrix distribution from sample number 132

systems, were arranged in a randomized complete block design with four blocks. Subplots (four 76-cm rows 27 meters) which corresponded to use of different planter packing wheels were randomized within each main plot. The outside two rows of each subplot were considered border rows.

The experiment was conducted during 1970 on a portion of the Agronomy and Agricultural Engineering Research Center eight miles west of Ames, Iowa. The tillage cropping systems were initiated in 1967. The ten tillage cropping systems used in 1970 plus their history for 1967-69 are presented in Table 1.

Tillage treatments 1, 2, 3, 4, and 9 were designed to be tilled in conventional manner: fall plowed, disked, harrowed, etc. These treatments differed only in cropping rotation preceding 1970. Tillage treatments 5, 6, and 8 were a ridge farming scheme where crop residue was deposited between ridges and each year the new crop planted on the ridge. The only tillage in the spring prior to planting in this system was the double disk openers on the planter units. Treatment 7 was tilled with a power strip rotary tiller, and treatment number 10 was chisel plowed.

The subplots were two types of planter soil-packing wheels to provide a variation in soil conditions directly over the seed.

Table 1. Tillage and cropping history of the field experimental crops, 1967-1969 and the tillage treatments of 1970

1967	1968	1969	1970
1. Corn conventional	Oats and alfalfa	Corn conventional	Fall plowed
2. Oats and alfalfa	Corn conventional	Oats and alfalfa	Fall plowed
3. Corn conventional	Soybeans conventional	Soybeans conventional	Fall plowed
4. Soybeans conventional	Corn conventional	Corn conventional	Fall plowed
5. Corn ridged	Soybeans ridged	Corn ridged	Ridged
6. Soybeans ridged	Corn ridged	Soybeans ridged	Ridged
7. Corn strip tilled	Corn strip tilled	Corn strip tilled	Strip tilled
8. Corn ridged	Corn ridged	Corn ridged	Ridged
9. Corn spring plowed	Corn spring plowed	Corn fall plowed	Fall plowed
10. Corn spring plowed	Corn spring plowed	Corn spring plowed	Chisel plowed

Figure 7 shows rib packing wheels mounted on the planter units as the planter operates in one of the ridge tillage systems. Figure 8 shows concave packing wheels mounted on the planter and operating in a fall plowed treatment.

All plots received a broadcast treatment of 4.5 q/ha of 0-26-26 fertilizer on November 26, 1969, prior to fall tillage. On April 22, 1970, all plots received 2.3 q/ha acre of liquid nitrogen. Fall plowed treatments (treatments 1, 2, 3, 4, and 9) were disked and harrowed on May 9, 1970, and field cultivated and harrowed on June 1, 1970. The chisel plowing of treatment number 10 was completed on May 21, 1970.

Weed control consisted of a broadcast treatment of alachlor (Lasso) 2.2 kg/ha plus atrazine 1.1 kg/ha on May 11, 1970, and a broadcast application of 2.2 kg/ha of atrazine plus 3.8 liters of crop oil on June 18, 1970. In addition, paraquat was applied to plots 5, 6, 7, and 8 at the rate of 0.85 kg/ha on May 29, 1970. All plots were mechanically cultivated on June 24, 1970.

Insect control consisted of applying carbofuran (Furadan) in a band directly over each row at the rate of 1.1 kg/ha of active ingredient on June 24, 1970, just before cultivation. This treatment was to minimize corn rootworm and European corn borer damage.

June 3, 1970, DeKalb XL-66 hybrid seedcorn was planted with John Deere 71 unit planters set to theoretically drop

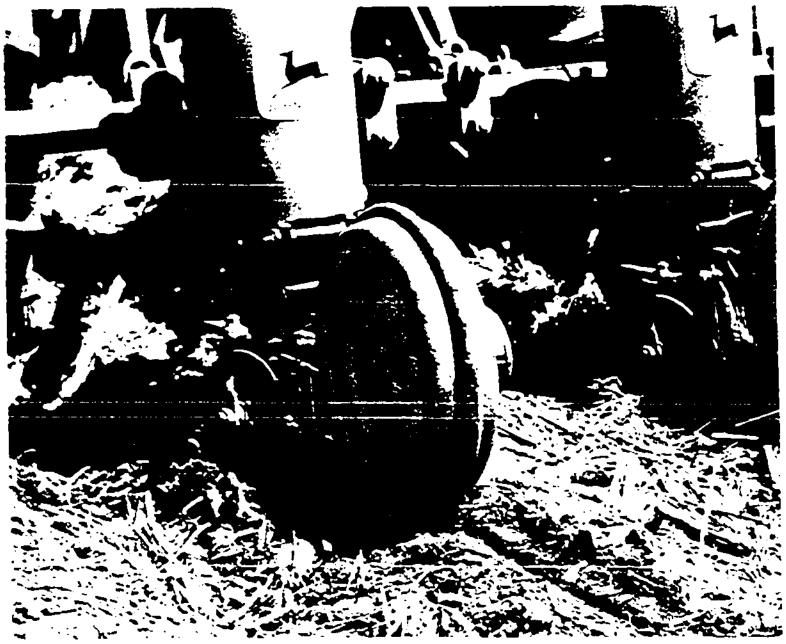


Fig. 7. Corn planter with rib packing wheel

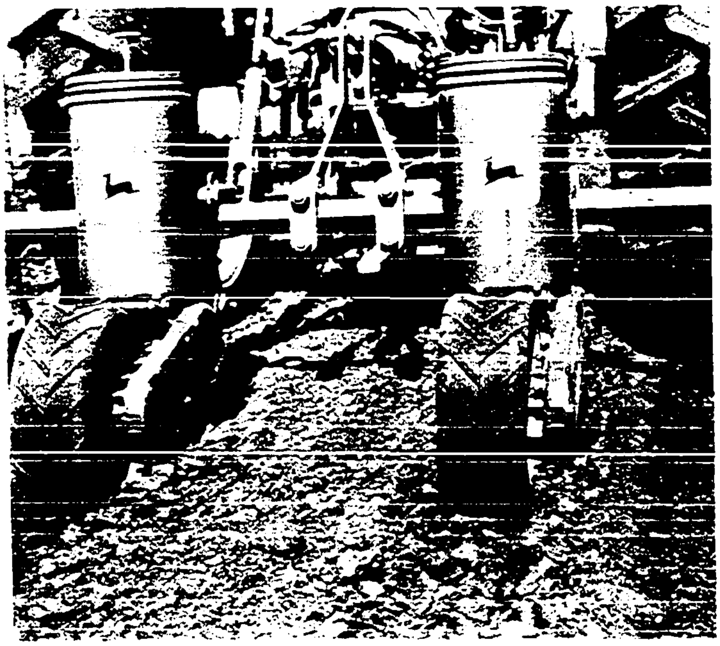


Fig. 8. Corn planter with concave packing wheel

82,000 seeds/ha or 170.8 seeds/row. Planting depth was set for approximately 5 cm in the fall plowed plots and not changed for any of the tillage treatments.

Data were collected on soil moisture, soil temperature, planting depth, penetrometer cone index, soil structure, weed infestation, seedling emergence and yield.

All potentially destructive measurements that could influence seedling emergence; soil moisture, soil temperature, planting depth, cone index, and soil structure were made in the north row of each two-row plot and seedling emergence counts were made in the south row. It should be noted that the specific planter unit (left or right) used to plant the north row was randomly selected; that is, the direction of planting for each plot was randomly selected. Yield data were collected as a composite from both rows.

Soil moisture

A 2.5 cm diameter cylindrical soil core sampler was used to obtain samples for gravimeteric moisture determination. Three core samples were taken within each row and mixed, making one composite sample. Each core was of 2.5 cm diameter, and consisted of soil from the surface to 7.6 cm deep. The samples were oven-dried and gravimetric moisture contents calculated. Moisture samples were taken on June 4, 6, 8, and 10.

The raw data as collected from the field can be seen in Table D-1 of Appendix D. The data were analyzed as a split-split plot. Main plots were tillage treatments, subplots were type of compaction wheel, and sub-subplots were moisture sampling date. An analysis of variance table can be seen in Table A-1 of Appendix A.

Temperature

Soil temperatures were taken by pushing a mercury thermometer 7.5 cm into the soil and reading 10 minutes later. Temperatures were measured daily at 1 p.m. from June 3-10 within each row. The data were analyzed as a split-split plot with tillage treatments as main plots, type of packing wheel as subplots, and date of measurement as sub-subplots. The analysis of variance is presented in Table A-2 of Appendix A, and the raw data are listed in Table D-2 of Appendix D.

Seed depth

Seed depth or planting depth was measured by excavating soil in a row until a seed was located and then determining the distance from the bottom of a flat surface placed on the soil surface to the center of the seed. This process was repeated three times in each plot, and the average for each set of three samples was used in the split plot analysis. Main plots were tillage treatments, and subplots were type of packing wheel. The raw data are presented in Table D-3 of Appendix D, and the analysis of variance table is shown in Table A-3 of Appendix A.

Cone index

A cone penetrometer was used as outlined by American Society of Agricultural Engineers Recommendation ASAE R313 (Amer. Soc. of Agric. Engrs. 1972) to get cone index readings. Readings were made at the surface, 2.5, 5, and 7.5 cm depth within each row. These readings were taken on June 9, 1970. The cone index readings taken in the field are listed in Table D-4 of Appendix D. These data were analyzed as a split-split plot. Main plots were tillage treatments, subplots were type of packing wheel, and sub-subplots were penetrometer depth. Table A-4 of Appendix A shows the analysis of variance.

Soil structure

Soil structure samples were taken by pressing steel soil sample cans 9.5 cm in diameter, 6.5 cm deep, and wall thickness 0.5 mm into the soil until the bottoms of the cans were flush with the soil surface. Soil was excavated from around the cans to aid in removing the cans containing the desired samples. One soil structure sample from within a row was taken from each plot. The samples were dried and fixed with a fluorescent polyester resin, photographed, scanned with the FSPA, and the data processed as described previously in the section "Technique for Measuring Soil Structure." Due to insufficient sample drying before the fixing process, only 40 samples were of high enough quality for photographing. This included two samples of every treatment. Because the samples were from four different blocks (replications) in the field, and not just two, the data were analyzed as if the tillage treatments and packing wheels treatments were completely randomized. A split-plot analysis was used with a factorial arrangement of tillage treatments and packing wheels treatments as main plots and scan angle as subplots. The analysis of variance can be seen in Tables A-6 through A-9 of Appendix A, and the FSPA raw data are shown in Table D-5 of Appendix D.

Weed infestation

Herbicide treatments were designed to minimize the need for early cultivations when seedling emergence data were collected.

Broadleaf and grass weed ratings were made on September 1, 1970. Both broadleaf and grass weeds were rated on a scale of 0-5 with 0 defined as a few weeds or weed-free and 5 a severe infestation. Each plot was rated for both types of weeds every 3 meters, and the average of the 10 ratings (plots were 32 meters long) were analyzed. A split-plot analysis with tillage treatments as main plots and packing wheels treatments as subplots was used. The analysis of variance can be seen in Tables A-9 and A-10 of Appendix A. The average broadleaf and grass ratings can be seen in Table D-6 of Appendix D.

Stand counts

Emergence counts were taken for each plot on June 8, the first day seedlings appeared, June 9, and June 10. Stand counts were made on June 23 prior to mechanical cultivation and on July 17. The emergence counts and stand counts were analyzed as a split-split plot with tillage treatments as main plots, packing wheels as subplots, and date of observation as sub-subplots. The analysis of variance is shown in Table A-11 of Appendix A, and the raw data are presented in Table D-8 of Appendix D.

On June 10, 1970, ten consecutive seeds within one row of each plot were investigated, and if seedlings had not emerged the reasons for not emerging were noted. Six different reasons were found which might have caused failure in emergence. They were insufficient moisture, rodent damage, mechanical impedance, nonviable seed, seedling killed by cutworm, and seedling killed by wireworm. These observations are listed in Table D-7 of Appendix D. An analysis of variance for each of these reasons is shown in Tables A-12 through A-17, Appendix A.

Yield

The corn from each two-row plot was harvested mechanically, weighed, and sampled for harvest moisture content. Yields were calculated on the basis of 15-1/2% moisture content. The yield data are shown in Table D-8 of Appendix D, and the analysis of the split plot experiment with yield as the dependent variable is presented in Table A-18 of Appendix A.

Soil Preparation

Soil for all laboratory experiments was excavated from the top six inches of an area on the Agronomy and Agricultural Engineering Research Center located eight miles west of Ames in August 1971. This soil is classified as Webster-Canisteo silty clay loam.

This soil was sieved with a rotary sieve developed by Luttrell (1963), and the portion passing the 2.5 cm screen but not passing the 1.25 cm screen was saved and the rest discarded. It was felt that aggregates of approximately the same size would provide a uniform material for laboratory studies. The uniform aggregates were reduced in size by pulverizing with a Model 2-E grinder made by W. W. Grinder

Corp., Wichita, Kansas. The pulverized material was separated into three classes by sieving, each having a different aggregate size distribution. These three classes, of approximately 500 kg each, representing fine, large, and a mixture of aggregates, served as a source of different soil structures for all laboratory experiments.

A dry sieve analysis as described by Day (1965) was replicated three times for each of the three soil structures used for laboratory experiments. Table 2 presents averages of the three sieve analyses for each structure. The sieve analysis gives an indication of the types of soil structures used in the laboratory experiments.

Table 2. Soil aggregate size distributions of soil used in laboratory experiments

Tyler sieve		Percent of soil by weight remaining on sieve		
No.	Opening - mm	Fine soil	Mixed soil	Large soil
4	4.699	0.0	7.8	11.4
8	2.362	0.1	19.0	43.2
14	1.168	2.2	27.8	35.8
28	0.589	70.6	21.0	5.2
48	0.295	16.1	16.2	2.0
100	0.147	7.1	5.6	1.2
200	0.074	2.8	1.9	0.7
PAN	---	1.1	0.7	0.5

One of the parameters examined in both the laboratory soil structure experiments and the controlled environment emergence studies was initial soil moisture. Three initial soil moisture contents were used in each study. They were 18 (moisture content at approximately 15 atm. tension), 23, and 28 (moisture content at approximately 1/3 atm. tension) percent soil moisture on dry basis. These soil moisture contents were obtained by adding appropriate amounts of water. Water was slowly added to each sample with an atomizing sprayer as the soil was stirred by hand. The moistened soil was placed in plastic bags, sealed, and allowed to equilibrate for at least 72 hours.

The soil structure tests and emergence tests were conducted on soil samples pressed into right circular open-end aluminum cylinders. For the emergence studies, the right circular sample cylinders were 7.5 cm long and 7.8 cm inside diameter. For the soil structure experiments, the cylinders were 7.5 cm long by 7.5 cm inside diameter. The quantity of soil required for a predetermined sample density was weighed to the nearest 0.1 gram. The soil was placed in a mold (Fig. 9) containing an aluminum sample cylinder and pressed simultaneously from both ends into the cylinder. The mold consisted of an outer retaining shell, an aluminum sample cylinder placed inside the retaining shell, two sleeves placed inside the retaining shell at each end of the sample

Fig. 9. Pouring soil into sample cylinder

Fig. 10. Equipment used to press soil samples

cylinder, and two compression pistons. Figure 10 shows the equipment used to press soil in the aluminum sample cylinders for emergence experiments.

Soil Structure Experiments

Two methods were used to quantify soil pore characteristics. They were moisture desorption and FSPA scanning, a method described earlier. The specific soil samples that were quantified by the above methods were identical to the soil structures used in the emergence studies. There were 36 samples consisting of two replications of three initial moisture contents (18, 23, and 25%), three initial soil sizes (fine, mixed, and large), and two compaction densities (1.0 and 1.2 gm/cm^3).

The moisture desorption technique was similar to that described by Vomocil (1965). The aluminum cylinders containing the compressed soil samples were placed in Tempe cells (Fig. 11) containing "one atm. high flow rate" porous plates. Tempe cells were obtained from Soilmoisture Equipment Co., Santa Barbara, California. The samples were saturated from the bottom and allowed to stand for 24 hours with zero tension.

Successive tensions of 20, 40, 60, 100, 150, and 200 cm of water were applied to each sample. The tensions were applied with regulated air pressure on top of the samples and measured with a 200 cm manometer. Each tension was

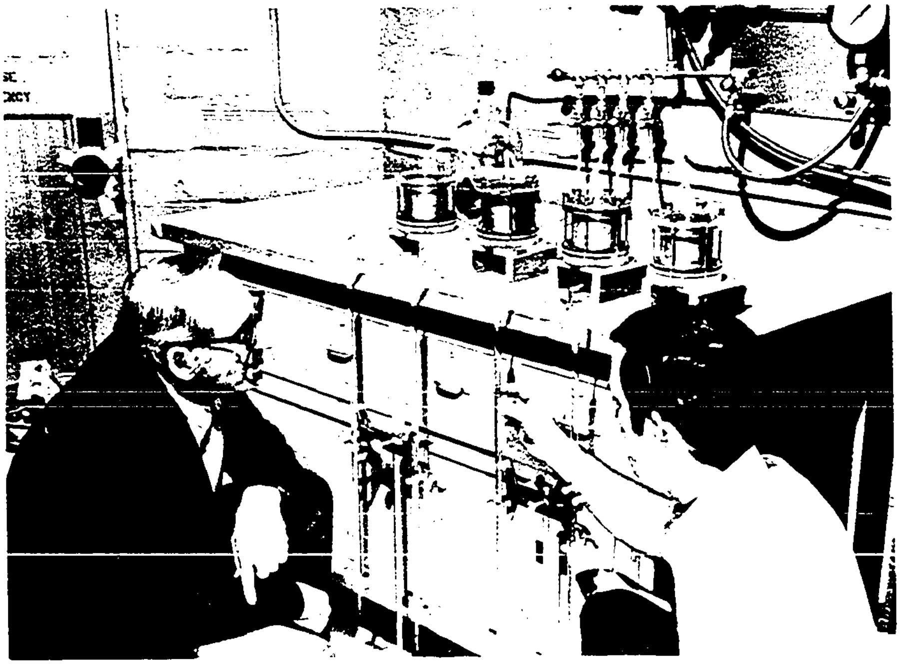


Fig. 11. Tempe cells used for moisture desorption tests

Fig. 12. Temperature controlled chamber

continuously applied until the flow of water from the sample stopped. This process took at least 24 hours for each tension. The volume of water removed from each sample for each moisture tension was recorded. After the completion of these tests, the soil samples were removed and gravimetric moisture measurements made.

The porosity, mean pore diameter, and pore diameter variance for each sample were calculated from the water removed vs. tension and gravimetric moisture measurements. The tensions were converted to equivalent pore diameters with the height of capillary rise equation ($h = 2T/r\rho g$). The pore diameters were transformed to a logarithmic scale. The mean and variance were calculated using the following formulas (Selby and Weast, 1970):

$$m_1' = (1/n)\ \Sigma\ f_i\ X_i$$

$$m_2' = (1/n)\ \Sigma\ f_i X_i^2$$

$$\text{mean} = m_1'$$

$$\text{variance} = m_2' - (m_1')^2$$

where X_i = the class marks, $i = 1,2,\ldots,k$ (pore diameters based on a log scale)

f_i = the volume of water extracted in the ith interval, $i = 1,2,\ldots,k$

n = the total volume extracted during the desorption process interval

Porosity was calculated from the total volume of water removed during the desorption process and the oven drying. Porosity equals the total volume of water removed (pore volume) divided by the bulk sample volume assumed to be the volume of the sampling can.

The analysis of variance for the mean and variance of the pore diameter (on a log scale) and porosity for soil structure are in Tables B-1, B-2 and B-3 of Appendix B.

The FSPA scanning technique (described in "Experimental Methods and Procedure") was used to find the mean and variance of the phase intercept lengths (based on a log scale), the mean and variance of the matrix intercept lengths (based on a log scale), and porosity of the 36 soil structure samples. The samples were scanned at zero and 90 degrees to obtain a measure of soil structure isotropy.

The results of the two techniques, FSPA scanning and moisture desorption for quantifying soil structure, were compared. They were compared by doing a multivariate analysis for correlation. As with most of the statistical computations used in this research, the multivariate analysis was one of the options provided in the Statistical Analysis System Service (1972) made available for use on the Iowa State University IBM model 360 computer.

Seedling Emergence Experiment

A factorial experiment was conducted to evaluate the effects of soil temperature, soil moisture, initial aggregate size, bulk density, planting depth, type of seed, and variety of seed on seedling emergence. The treatments were as follows:

Temperatures - 10, 18, and 26C

Moistures - 18, 23, and 28% (on oven dry weight basis)

Initial aggregate size - fine, mixed, and large

Bulk density - 1.0 g/cm^3 and 1.2 g/cm^3

Planting depths - 2.5 and 3.8 cm

Type of seeds - corn and soybeans

Varieties - corn soybeans A632XA619 and B57XB14A
Amsoy and Corsoy

Replications - 2

The factorial experiment was conducted in six parts because the controlled temperature chamber could only accommodate approximately 150 samples at a time. One replication of the indicated treatments would result in 432 experimental units. The six-part test consisted of the six combinations of type of seed (corn or soybeans) and the three temperatures. The random order in which these six tests were conducted was as follows:

Test 1 Soybeans at 18C

Test 2 Corn at 18C

Test 3 Corn at 10C

Test 4 Soybeans at 10C

Test 5 Soybeans at 26C

Test 6 Corn at 26C

Each test had 144 experimental units; three moistures, three initial aggregate sizes, two bulk densities, two planting depths, two varieties, and two replications.

Soil was prepared as described in the section "Soil Preparation for Laboratory Experiments." The planting depth was obtained by dividing the soil for each sample into two parts - one for the soil above the seed and one for below.

The bottom portion of soil was poured into the mold (Fig. 9), leveled, and then 10 seeds were randomly placed on top of the soil. The remaining portion of soil was poured on top of the seeds and pressed into the aluminum sample cylinder.

The aluminum sample cylinders were put in covered plastic containers that each held five samples. A cup containing water was also placed in the plastic box to provide a free water surface for minimizing moisture loss from the soil. The plastic boxes were placed in the controlled temperature chamber (Fig. 12). The soil temperature at the center of a sample in the controlled chamber varied ± 1C.

Burris, Edje and Wahab (1971) showed that soybean seed size influenced seedling growth. In order to reduce the experimental error due to variation in seed size, the soybean seeds were sieved and only the seeds that passed a 7.14-mm screen but not a 6.35-mm screen were used.

Both types of seed were treated with a fungicide prior to planting. The treatment was designed to minimize seedling injury due to fungi. Fungi were expected to cause severe seedling injury for the low temperature and high moisture soil conditions.

Every eight hours following planting, observations were made and recorded of the total number of seedlings emerged from each sample cylinder. These observations were continued for 28 days or until all seedlings had emerged, whichever came first.

Several indices have been proposed as measures of seedling vigor and emergence (Allan, Vogel and Peterson, 1962; Burris et al., 1969; Edje and Burris, 1971; Kotowski, 1926; and Maguire, 1962). Two methods were used in this research. They were fraction emerged and emergence rate. Emergence rate was a modification of the coefficient of velocity, K, as defined by Kotowski.

The average time, T_{av}, of emergence of the seedlings for a certain time period of n days is given by:

$$T_{av} = (A_1T_1 + A_2T_2 + \ldots + A_nT_n)/(A_1 + A_2 + \ldots + A_n)$$

where A_i = the number of seedlings emerging on the i^{th} day

T_i = the number of days elapsed since planting the seedlings.

Kotowski defined his coefficient of velocity K as the reciprocal of T_{av} multiplied by 100. Thus, his coefficient K is given by:

$$K = 100(A_1 + A_2 + \ldots + A_n)/(A_1T_1 + A_2T_2 + \ldots + A_nT_n)$$

The units of this equation are day^{-1}. The average time T_{av} to emerge is important, but the farmer is also interested in the total number of seedlings emerged. If the coefficient of velocity is multiplied by the total number of plants emerged, the resulting units are hundreds of plants per time which are units of rate.

Because previous indices did not adequately describe seedling emergence a new emergence rate index was developed and used for the laboratory emergence experiments using the following equation:

$$E_r = 100(A_1 + A_2 \ldots A_n)^2/(A_1T_1 + A_2T_2 \ldots + A_nT_n)$$

where E_r = emergence rate over n days in hundreds of plants per day

A_i = the number of seedlings emerged during the i^{th} time interval

T_i = the time after planting, in days.

Fraction emerged was calculated by dividing the total number of seedlings emerged in 28 days by 10 (the number of seeds planted). An arc sine transformation was made to the square root of the fraction emerged as suggested by Steel and

Torrie (1960). This transformation is recommended for data expressed as decimal fractions or percentages especially when the percentages cover a wide range of values. One of the assumptions in applying tests of significance in analysis of variance is that experimental errors be independently and normally distributed with a common variance. The transformation was applied so that the data would more nearly approach normality. The following orthogonal contrasts were made:

Temperature

1. Temperature linear
2. Temperature quadratic

Moisture

1. Moisture linear
2. Moisture quadratic

Initial soil aggregate size

1. Fine initial aggregates vs. large initial aggregates
2. Fine + large initial aggregates vs. mixed initial aggregates

These contrasts were also used to separate significant interactions into individual degrees of freedom. Tables C-5, C-6, C-7 and C-8 of Appendix C show the orthogonal contrasts for the significant effects. These orthogonal contrasts were used to select factors for developing prediction equations.

The two methods used to quantify soil pore characteristics, moisture desorption and FSPA scanning were each related to emergence rate, E_r (in units of hundreds of plants per day). Data from the laboratory emergence experiments were divided into six sets, (corn-10C, corn-18C, corn-26C, soybeans-10C, soybeans-18C and soybeans-26C), and used for relating the soil pore characteristics to seedling emergence. The data were divided into six sets because temperature interacted with soil moisture, initial aggregate size and bulk density (Tables C-1, C-2, C-3 and C-4 of Appendix C), and therefore the influence of moisture desorption and FSPA scanning parameters on seedling emergence would be dependent on the temperature at which the seedlings were grown.

The soil structure measurements of matrix intercept mean, matrix intercept variance, phase intercept mean, phase intercept variance, pore diameter mean, pore diameter variance, porosity measured with the FSPA and porosity measured by moisture desorption were related to seedling emergence rate for each of the six sets of data by regression analysis.

The following two equations were fitted by regression to the six data sets (corn-10C, corn-18C, corn-26C, soybeans-10C, soybeans-18C, and soybeans-26C):

$$E_r = \mu_o + \beta_1\mu_p + \beta_2\sigma_p + \beta_3\mu_m + \beta_4\sigma_m + \beta_5P_f$$

$$E_r = \mu_o + \beta_1\mu_D + \beta_2\sigma_D + \beta_3P_D$$

where E_r = emergence rate - hundreds of plants per day

μ_o = overall mean

μ_m = matrix intercept mean - microns

σ_m = matrix intercept variance - microns^2

μ_p = phase intercept mean - microns

σ_p = phase intercept variance - microns^2

P_f = porosity as measured by FSPA method - cm^3/cm^3

μ_D = pore diameter mean as measured by the moisture desorption method - microns

σ_D = pore diameter variance as measured by the moisture desorption method - microns

P_D = porosity as measured by the moisture desorption method - cm^3/cm^3

β_i = regression coefficients - units T^{-1} multiplied by the reciprocal of the factor associated with

Prediction Equations

Equations were developed for predicting emergence rate and the arc sine of the square root of the fraction emerged for both field and laboratory experiments. The factors and interactions that were significant at the 1% level for the laboratory test were included in the model (see analysis of variance Tables C-1 through C-8 for significant factors). To find the fraction of emerged seedlings predicted by the arc sine equation, take the sine of the left side of the equation considered as an angle in radians and square it.

$$E_{rc} = \mu_{rc0} + \beta_{rc1}(T) + \beta_{rc3}(M) + \beta_{rc4}(M^2) + \beta_{rc5}(D) + \beta_{rc6}(\rho) + \beta_{rc7}(T)M + \beta_{rc8}(T)M^2 + \beta_{rc9}(T^2)(M) + \beta_{rc10}(M)(\rho)$$

$$E_{fc} = \mu_{fc0} + \beta_{fc1}(T) + \beta_{fc2}(T^2) + \beta_{fc3}(M) + \beta_{fc5}(D) + \beta_{fc6}(\rho) + \beta_{fc7}(T)(M) + \beta_{fc11}(T)(D) + \beta_{fc12}(T^2)(D) + \beta_{fc13}(T)(\rho) + \beta_{fc14}(T^2)(\rho)$$

$$E_{rs} = \mu_{rs0} + \beta_{rs1}(T) + \beta_{rs5}(D) + \beta_{rs6}(\rho) + \beta_{rs11}(T)(D) + \beta_{rs13}(T)(\rho)$$

$$E_{fs} = \mu_{fs0} + \beta_{fs1}(T) + \beta_{fs2}(T^2) + \beta_{fs5}(D) + \beta_{fs6}(\rho) + \beta_{fs11}(T)(D) + \beta_{fs12}(T^2)(D)$$

where E_{rc} = emergence rate of corn - hundreds of plants per day

E_{fc} = arc sine of square root of fraction of corn emerged after 28 days - no units

E_{rs} = emergence rate of soybeans - hundreds of plants per day

E_{fs} = arc sine of square root of fraction of soybeans emerged after 28 days - no units

μ_{rc0}, μ_{rs0} = overall means - hundreds of plants per day

μ_{fc0}, μ_{fs0} = overall means - no units

β_{fci}, β_{fsi} = regression coefficients - units of reciprocal of factor associated with

β_{rci}, β_{rsi} = regression coefficients - units T^{-1} multiplied by the reciprocal of the factor associated with

T = temperature - C (for 10-26C)

M = moisture content = % on oven dry basis (for 18-28%)

D = planting depth - cm (for 2.5-3.75 cm)

ρ = bulk density - g/cm^3 (for 1.0-1.2 g/cm^3)

The following simplified equation was also fitted for the emergence rate of corn:

$$E_{rc} = \mu_{rc0} + \beta_{rc1}(T) + \beta_{rc3}(M) + \beta_{rc4}(M^2) + \beta_{rc5}(D) + \beta_{rc6}(\rho)$$

where E_{rc} = emergence rate of corn - hundreds of plants per day

β_{rci} = regression coefficients - units T^{-1} multiplied by the reciprocal of factor associated with

μ_{rc0} = overall mean

T = temperature - C (for 10-26C)

M = moisture - % (for 18-28% oven dry basis)

D = planting depth - cm (for 2.5-3.75 cm)

ρ = bulk density - g/cm^3(for 1.0-1.2 g/cm^3)

The field data were fitted by stepwise regression for emergence rate and arc sine of the square root of fraction emerged as dependent variables. The independent variables included in the stepwise regression were temperature, moisture, planting depth, density and these parameters squared.

DISCUSSION AND RESULTS

Field Experiment

Soil moisture

The analysis of variance for soil moisture is shown in Table A-1 of Appendix A. Tillage treatments had little or no effect on moisture content, as shown in Table 3. This result is contrary to the findings of Triplett et al. (1968). They found mulch increased the available soil moisture. The reasons for the apparent discrepancy are probably due to the location of sampling and the specific mulch systems used. Samples were taken near the surface within the rows. After planting, the amount of mulch directly over the row was approximately the same for all tillage systems. Mulch is blown off the row and accumulation in the farrow even in shallow ridges. Then too, the planter covers the mulch in the row so that all the conditions in the row tend to be the same. The middle might have had more difference in moisture content. The samples from the ridged plots were from the top of the ridges which Shaw and Buchele (1957) have shown to be the driest location in the ridge system. The chisel plowed plots were tilled in the spring prior to planting and the surface soil had a high proportion of large aggregates. This condition of large aggregates promotes rapid drying (Johnson and Buchele, 1961) and therefore the moisture conserving aspects of the mulch

Table 3. Effect of tillage treatment on soil moisture in the top 7.6 cm of soil

Tillage - 1970	Production system 1969	Soil moisture percent
Fall plowed	Corn - fall plowed	23.1
Fall plowed	Oats and alfalfa	21.0
Fall plowed	Soybeans - fall plowed	22.4
Fall plowed	Corn - fall plowed	23.0
Ridged system	Corn ridged	20.9
Ridged system	Soybeans ridged	20.4
Strip tilled	Corn strip tilled	20.0
Ridged system	Corn ridged	21.4
Fall plowed	Corn - fall plowed	20.1
Chisel plowed	Corn spring plowed	19.9

cover were probably negated by the tillage operation.

The increase in soil moisture of 1.0 percent caused by the rib packing wheel (Table 4) was significant at the 1% level. The effect the packing wheel had on soil moisture was dependent on the date of observation. The concave packing wheel resulted in a significantly lower soil moisture content for all dates except June 8. The effect of the packing wheel on soil moisture is probably a result of differences in temperature and differences in drying rates because of compaction. The rib packing wheel which concentrated its packing pressure directly over the

Table 4. Effect of type of packing wheel and date of sampling on soil moisture

Date of sampling	Soil moisture - Percent Type of packing wheel		Sampling date means
	Concave	Rib	
June 4	22.3	23.4	22.8
June 6	19.3	21.0	20.1
June 8	21.0	21.0	21.2
June 10	20.3	21.1	20.7
Packing wheel means	20.7	21.7	

LSD t_{05} for sampling date means = 0.5

LSD t_{05} for sampling date means for the same wheel = 0.6

LSD t_{05} for packing wheel means on a specific sampling date = 0.6

seed resulted in a slower drying rate. This is consistent with the results found by Johnson and Buchele (1961). They found that drying rate increased as compactive effort decreased.

Table 4 shows that most of the soil drying occurred prior to the second sampling (June 6) date. There was no addition of moisture in the form of rain during the sampling period.

Soil temperature

The effect of tillage treatment on soil temperature is shown in Table 5. The soil temperatures were not significantly

Table 5. Effect of tillage and packing wheel on mean soil temperature at 1 PM for June 3 through June 10

Tillage 1970	Production system 1969	Soil temperature - C: Type of packing wheel Concave	Rib	Tillage means
Fall plowed	Corn - fall plowed	25.9	23.5	24.7
Fall plowed	Oats and alfalfa	26.0	24.0	25.0
Fall plowed	Soybeans - fall plowed	25.9	24.0	25.0
Fall plowed	Corn - fall plowed	25.5	23.6	24.6
Ridged system	Corn ridged	25.9	24.4	25.1
Ridged system	Soybeans ridged	26.2	24.8	25.5
Strip tilled	Corn strip tilled	25.1	23.6	24.3
Ridged system	Corn ridged	25.7	24.9	25.3
Fall plowed	Corn - fall plowed	26.2	24.2	25.2
Chisel plowed	Corn - spring plowed	25.7	24.1	24.9
Packing wheel means		25.8	24.1	

LSD t_{05} for packing wheel means = 0.1

LSD t_{05} for packing wheel means for the same tillage system = 0.5

LSD t_{05} for tillage means for a specific wheel = 0.8

different for the various tillage systems (Table A-2 of Appendix A). This result was due to surface conditions directly over the row being similar. There was little mulch over the seed in any of the plots and therefore the reflecting and/or insulating influence of mulch on soil temperature probably did not exist where temperatures were taken.

Soil temperature is highly dependent on soil moisture. The soil moisture tests showed no significant differences among tillage treatments and therefore the soil temperatures would tend to be similar.

The rib packing wheel caused the average temperature to be 1.7 degrees lower than the concave packing wheel. The dense condition of the soil created by the rib wheel resulted in less moisture loss and a lower temperature. The soil temperature of rows compacted with the rib packing wheel was lower than the concave packing wheels for all tillage systems. The magnitude of the effect varied with tillage system. The rib packing wheel depressed temperatures from 1.9 to 2.4 degrees for fall plowed treatments and from 0.8 to 1.6 degrees for the ridged treatments and chisel plowed treatment. This indicates tillage has an effect on the change in temperature due to compaction by a packing wheel. Table 6 shows the effect of sampling date and packing wheels on soil temperature. On the first sampling date the average temperatures of the conditions created by the two wheels were not significantly different. This may have been caused by the fact that moisture influenced temperature and at the first sampling date moisture conditions between packing wheel treatments may not have stabilized from a rain on June 2, 1970.

Table 6. Effect of wheel and date on soil temperature

Date of sampling	Soil temperature - C: Type of packing wheel: Concave	Rib	Sampling date means
June 3	21.4	21.1	21.2
June 4	20.7	19.6	20.2
June 5	27.7	25.0	26.4
June 6	28.1	25.1	26.6
June 7	27.9	25.5	26.7
June 8	27.9	25.7	26.7
June 9	26.9	25.6	26.2
June 10	25.9	25.2	25.6
Packing wheel means	25.8	24.1	

LSD t_{05} for sampling date means = 0.3

LSD t_{05} for sampling date means for same packing wheel = 0.3

LSD t_{05} for packing wheel means on a specific sampling date = 0.3

Table 7 shows the effect of sampling date and tillage system on soil temperature. The ridged treatments and the chisel plowed treatments had higher temperatures than the fall plowed plots on the first sampling date. All treatments tended to have similar temperatures on the following sampling

Table 7. Effect of tillage and sampling date on soil temperature

	Soil temperature - C							
Tillage - 1970	June 3	June 4	June 5	June 6	June 7	June 8	June 9	June 10
Fall plowed	20.3	19.7	26.4	25.9	26.9	26.7	26.0	25.3
Fall plowed	21.1	20.2	26.1	26.2	27.0	27.5	26.5	25.5
Fall plowed	20.5	20.2	26.4	26.7	27.0	27.0	26.4	25.5
Fall plowed	20.2	20.0	25.9	26.1	26.7	26.4	26.1	25.1
Ridged system	21.9	20.6	26.6	26.7	26.9	26.1	26.1	26.2
Ridged system	22.7	20.3	26.6	27.0	27.0	27.8	26.6	25.8
Strip tilled	19.6	19.6	26.0	26.4	26.0	26.0	25.8	25.2
Ridged system	23.1	20.5	26.7	27.0	26.3	26.4	26.5	25.9
Fall plowed	20.6	20.5	26.9	27.0	27.1	27.1	26.6	25.9
Chisel plowed	22.4	20.1	25.9	26.9	26.2	26.7	25.8	25.4

LSD t_{05} for sampling date means within a tillage system = 0.7

LSD t_{05} for tillage systems means within a sampling date = 1.0

dates. The ridged treatments and the chisel plowed treatment may have drained faster from the rain on June 2, 1970 and therefore resulted in higher temperatures on June 3. The first two sampling dates had temperatures approximately 6 degrees lower than the last six dates. The second day was overcast and tended to produce low temperatures with little variation among treatments.

Planting depth

The analysis of variance for planting depth can be seen in Table A-3 of Appendix A. Table 8 shows the effect of tillage treatment on planting depth. The planter did not penetrate into the soil as deeply for the ridge systems as it did for the fall plowed treatments. The planting depth for the ridge treatment that had soybeans in 1969 was not significantly different from the fall plowed treatments. This was probably due to less trash in the row at planting time for the ridged treatment that had soybeans in 1969 than the ridge treatments that had corn in 1969, or maybe soil strength as indicated by cone index readings. In the ridged system, new crops are planted on top of the ridges in the same location as the previous crops. Shredding stalks tends to concentrate most of the residue in the furrows between ridges, but at planting time corn stubs remain in the row and must be planted through. Planting through corn stubs causes the planter to bounce and results in shallower less uniform planting depth. It also

Table 8. Effect of tillage treatment on planting depth

Tillage - 1970	Production system 1969	Planting depth - cm
Fall plowed	Corn - fall plowed	5.25 c[+]
Fall plowed	Oats and alfalfa	5.33 c
Fall plowed	Soybeans - fall plowed	5.22 c
Fall plowed	Corn - fall plowed	5.59 c
Ridged system	Corn ridged	4.19 b
Ridged system	Soybeans ridged	4.94 bc
Strip tilled	Corn strip tilled	4.20 b
Ridged system	Corn ridged	2.91 a
Fall plowed	Corn - fall plowed	5.11 bc
Chisel plowed	Corn - spring plowed	4.81 bc

[+]Means with the same letter are not significantly different at the 5% level with the Duncan's multiple range test.

takes more force to cut through corn stubs than through soil, therefore the planter operates for the same weight on the planter, shallower in the old ridges.

The average planting depth for the concave packing wheel was 5.2 cm and the average planting depth for the rib packing wheel was 4.3 cm. This was a result of the rib wheel compacting the soil over the row more than the concave packing wheel.

Cone index

The analysis of variance for penetrometer cone index is shown in Table A-4 of Appendix A. Table 9 presents the tillage treatment means and indicates which treatments were significantly different as tested with Duncan's multiple range test. The ridged system that had soybeans in 1968 and corn in 1969 and the strip tilled treatments had significantly higher average cone indexes for the top 7.6 cm of soil than soybean and corn rotations plowed in the fall. The strip tilled treatment must have compacted the soil below the tilled zone (6 to 7 cm).

Table 10 shows the effect of tillage treatments and depth on cone index. At the surface or zero depth differences between tillage treatments were not large enough for significance. At 2.5 cm the effect of crop rotation within the ridged system on cone index was dramatic. Soybeans grown the previous year caused the soil to have an 18% lower resistance to penetration following the planting operation as compared to ridges with corn the previous year. This effect was consistent at 5 and 7.6 cm.

The effect of packing wheel on cone index was dependent on the depth (Table 11). The rib packing wheel increased the cone index near the surface. At 7.6 cm the cone index was approximately the same for both packing wheels. For the range of moisture contents in this experiment, soil resistance

Table 9. Effect of tillage treatment on mean penetrometer cone index for top 7.6 cm of soil

Tillage - 1970	Production system 1969	Cone index Newtons/cm^2
Fall plowed	Corn - fall plowed	48.4 a[+]
Fall plowed	Oats and alfalfa	55.0 ab
Fall plowed	Soybeans - fall plowed	48.7 a
Fall plowed	Corn - fall plowed	50.1 a
Ridged system	Corn ridged	68.0 b
Ridged system	Soybeans ridged	53.8 ab
Strip tilled	Corn strip tilled	66.7 b
Ridged system	Corn ridged	63.7 ab
Fall plowed	Corn - fall plowed	60.6 ab
Chisel plowed	Corn - spring plowed	51.8 ab

[+]Means with the same letter are not significantly different at the 5% level with the Duncan's multiple range test.

to penetration increases as soil moisture decreases. Table 4 shows that the concave packing wheel had a significantly lower moisture content and therefore if the cone index was adjusted for moisture content the difference between the cone indexes of the packing wheels would be even greater. This shows that the compaction effect was even greater than it would appear to be because there was a difference in moisture content.

Table 10. Effect of tillage and depth on penetrometer cone index

Tillage - 1970	Cone index - Newtons/cm^2			
	Depth - cm			
	0	2.54	5.08	7.62
Fall plowed	14.7	44.4	63.8	70.7
Fall plowed	17.2	46.1	75.9	80.6
Fall plowed	15.1	41.4	66.8	71.6
Fall plowed	13.4	43.5	68.1	75.4
Ridged system	19.4	56.9	91.0	104.8
Ridged system	11.6	35.8	74.6	93.1
Strip tilled	16.4	44.0	89.2	117.3
Ridged system	11.6	47.0	88.8	107.3
Fall plowed	18.5	48.7	79.3	95.7
Chisel plowed	13.8	40.1	69.8	83.6
Depth means	15.2	44.8	76.7	90.0

LSD t_{05} for depth means = 4.0

LSD t_{05} for depth means within a tillage system = 12.7

LSD t_{05} for tillage system means within a depth = 8.9

Table 11. Effect of packing wheel and depth on penetrometer cone index

Type of wheel	Cone index - Newtons/cm^2				
	Depth - cm				
	0	2.5	5.08	7.62	Mean
Concave wheel	9.7	33.9	68.6	86.9	49.8
Rib wheel	20.6	55.7	84.8	93.1	63.6

LSD t_{05} for depth means for specific wheel = 5.7

LSD t_{05} for wheel means within a depth = 8.6

Soil structure

Table 12 summarizes the results of the effects of tillage and packing wheels on soil density. The tillage treatments and the packing wheels did not significantly affect soil density (Table A-5 of Appendix A). This was probably a result of the technique in obtaining an "undisturbed" soil sample. Differences may have existed, but they were smaller than could be detected with the technique used. The minimum and maximum of all the samples taken was 0.91 and 1.28 g/cm^3.

Soil structure was quantified for two replicates of the field experiment by the FSPA scanning technique. Five parameters were measured with the scanning technique. These parameters were phase intercept mean, which was a measure of the mean aggregate size, phase intercept variance, matrix

Table 12. Effect of tillage treatment and packing wheel on soil density

Tillage - 1970	Soil density - g/cm^3 Type of packing wheel Concave	Rib
Fall plowed	1.11	1.15
Fall plowed	1.20	1.16
Fall plowed	1.14	1.12
Fall plowed	1.13	1.18
Ridged system	1.08	1.09
Ridged system	1.09	1.11
Strip tilled	1.10	1.13
Ridged system	1.11	1.03
Fall plowed	1.18	1.17
Chisel plowed	1.16	1.12
Mean	1.13	1.13

intercept mean which was a measure of the mean noncapillary pore size, matrix intercept variance and porosity.

The results of the 40 samples that were analyzed with the FSPA scanning technique are summarized in Tables 13, 14 and 15. The analysis of variance is listed in Tables A-6, A-7 and A-8 of Appendix A. The analysis of variance indicates that the angle of scanning was the only treatment for which means were found to be significantly different. The result of angle of

Table 13. Effect of tillage treatment on phase intercept mean, phase intercept variance and porosity

Tillage - 1970	Phase intercept+ Mean	Variance	Porosity cm^3/cm^3
Fall plowed	6.04	1.49	0.36
Fall plowed	5.97	1.37	0.43
Fall plowed	6.07	2.26	0.29
Fall plowed	5.51	6.79	0.14
Ridged system	6.19	1.70	0.33
Ridged system	5.97	1.32	0.43
Strip tilled	6.10	1.36	0.42
Ridged system	6.35	1.82	0.38
Fall plowed	6.27	1.83	0.29
Chisel plowed	6.20	1.81	0.35

+The means and variances are based on the natural logarithms of the intercepts in units of microns.

Table 14. Effect of packing wheel on phase intercept mean, phase intercept variance and porosity

Type of wheel	Phase intercept+ Mean	Variance	Porosity cm^3/cm^3
Concave	5.95	2.18	0.34
Rib	6.18	2.17	0.35

+The means and variances are based on the natural logarithms of the intercepts in units of microns.

Table 15. Effect of angle scanned on phase intercept mean, phase intercept variance and porosity

Angle scanned	Phase intercept[+]		Porosity
	Mean	Variance	cm^3/cm^3
0°	6.08	2.28	0.339
90°	6.06	2.07	0.347*

[+]The means and variances are based on the natural logarithms of the intercepts in units of microns.

*Indicates statistically significant at the 5% level.

scan being significant is highly questionable because it may be a systematic instrument error of the FSPA. The results indicated porosity was 0.339 for the zero degree scan angle and 0.347 for the 90 degree scan angle (Table 15), and this difference was significant at the 5% level. Physically, the porosity should be independent of the angle scanned. Porosity is calculated as the ratio of matrix area to total area scanned and changing the angle of scan should not affect either the total area scanned or the matrix area.

A problem did arise in measuring the matrix intercept lengths with the FSPA so these data were not presented. The problem associated with the matrix intercept length measurements was in addition to the suspected systematic error related to porosity measurements.

Weed infestation

The weed infestation was low and probably no yield reduction would result from the levels in this experiment. There were significant differences in levels of grass weed infestation (Table A-9 of Appendix A) but no significant differences in broadleaf weed infestation. Table 16 shows the effect of tillage on weed infestation. The three ridged treatments and the chisel plowed treatment had the highest grass infestation. The two ridge treatments that had corn in 1969 had a significantly higher grass infestation than the fall plowed treatments and the strip plowed treatment. This type of pattern was probably a result of time of herbicide application and tillage treatment.

The preemergence application of alachlor plus atrazine was made on May 11 well after some of the grass weeds had emerged. These herbicides are often ineffective on emerged grasses. The fall plowed treatments received a secondary tillage before planting and after herbicide application which would have killed most of the emerged grasses. The ridged treatments and the chisel plowed treatment received an application of a contact weed killer prior to planting. The contact weed killer must have been less effective at killing the emerged grasses in the ridged and chisel plowed treatments than the secondary tillage in the fall plowed treatments.

Table 16. Effect of tillage treatment on weed infestation

Tillage - 1970	Weed ratings - 0-5[+] Grass	Broadleaf
Fall plowed	0.0 a[++]	0.0
Fall plowed	0.0 a	0.0
Fall plowed	0.0 a	0.0
Fall plowed	0.0 a	0.0
Ridged system	0.9 b	0.1
Ridged system	0.4 ab	0.1
Strip tilled	0.2 a	0.2
Ridged system	1.0 b	0.2
Fall plowed	0.0 a	0.0
Chisel plowed	0.5 ab	0.1

[+]0 - weed free; 5 - heavy infestation.

[++]Means with the same letter are not significantly different at the 5% level with the Duncan's multiple range test.

Stand

The analysis of variance for stand counts can be seen in Table A-11 of Appendix A. The effects of tillage and packing wheel on stand counts are shown in Table 17. The ridged treatments that had corn in 1969 had stand counts lower than fall plowed treatments and chisel plowed treatments. This was probably due to shallow planting for these treatments (see

Table 17. Effect of tillage treatment and type of packing wheel on stand of corn

Tillage - 1970	Stand counts--Plants/m^2 Type of packing wheel Concave	Rib	Means
Fall plowed	5.77	5.31	5.54
Fall plowed	5.51	5.49	5.50
Fall plowed	5.63	5.48	5.55
Fall plowed	5.69	5.44	5.57
Ridged system	4.55	3.31	3.92
Ridged system	4.87	4.86	4.86
Strip tilled	4.41	4.39	4.40
Ridged system	3.52	4.09	3.80
Fall plowed	5.69	5.29	5.50
Chisel plowed	4.99	4.71	4.85
Packing wheel means	5.06	4.83	

LSD t_{05} for tillage treatment means = 0.7

LSD t_{05} for wheel means within a tillage treatment = 0.2

LSD t_{05} for tillage treatment means for a specific type of wheel = 1.8

planting depth in Table 8). The corn had sufficient moisture to germinate but not enough to emerge. The strip tilled treatment stand was lower than the fall plowed treatments. This stand depression probably was due to increased cone index in the strip tilled plots.

The rib packing wheel resulted in lower stands in all plots except one ridged system. It is not apparent to the author why the effect of packing wheel on stand for the two ridged systems that had corn in 1969 was not consistent. For one ridged treatment the stands were higher with the concave packing wheel, but for the other the stands were highest with the rib packing wheel.

Table 18 shows the effect of tillage and date of observation on stand. Stand increased with time for the period of June 8-June 23. All plots were cultivated on June 24 and this accounts for the lower stand on July 17. The tillage system effect on stand was dependent on the date the stand was counted. The first day plants started to emerge (June 8) there were no significant differences among the stands for the various tillage systems. The harsh environments caused by soil moisture, soil temperature and cone index depressed the rate of emergence after the first day.

The ridged system treatments, which were planted shallower than the fall plowed treatments and consequently the seed was in the soil with less available moisture, had significantly

Table 18. Effect of tillage treatment and date of observation on stand count

Tillage - 1970	Stand counts--Plants/m^2				
	June 8	June 9	June 10	June 23	July 17
Fall plowed	0.77	6.51	7.02	6.76	6.64
Fall plowed	1.17	6.06	6.87	6.73	6.66
Fall plowed	0.95	6.15	7.07	6.88	6.70
Fall plowed	0.60	6.33	7.06	6.96	6.88
Ridged system	0.32	3.61	4.71	5.66	5.33
Ridged system	0.93	5.48	5.91	5.99	6.00
Strip tilled	0.38	4.70	6.00	5.86	5.04
Ridged system	0.42	3.55	4.72	5.33	5.00
Fall plowed	0.80	6.09	7.05	6.88	6.63
Chisel plowed	0.81	5.10	5.93	6.32	6.08
Date means	0.71	5.36	6.23	6.33	6.10

LSD t_{05} for date means = 0.18

LSD t_{05} for date means within a tillage treatment = 0.58

LSD t_{05} for tillage treatment means for a specific date = .86

less total plants emerged on the second day than the fall plowed treatments. This effect that appeared on the second day of emergence remained present the rest of the growing season. Buchele (1954) found that new ridges formed each year resulted in a more rapid rate of emergence and a more uniform stand than flat plots.

Table 19 shows the effect of packing wheel and date of observation on stand count. For the first observation the rib packing wheel treatment had more plants emerged than the concave packing wheel treatment. The second day and thereafter more plants emerged from the concave packing wheel treatment. There was a combination of effects that caused this interaction of date and packing wheel. The rib packing wheel resulted in higher soil moisture, lower temperature, shallower planting depth and more compact soil than the concave wheel. The higher moisture is a favorable condition but shallower planting depth (if moisture is critical and increases with depth) compaction and lower temperature are detrimental to emergence. The difference in soil moisture contents between the rib packing wheel and concave packing wheel treatments decreased with time (Table 4). After the first day of emergence the advantages the rib packing wheel treatment had because of increased available moisture and shallower planting depth were negated by the disadvantage due to increased resistance to penetration, lower temperature and shallower planting depth.

Table 19. Effect of packing wheel and date of observation on stand count

Date	Stand counts--Plants/m^2 Type of packing wheel Concave	Rib
June 8	0.44	0.98
June 9	5.63	5.09
June 10	6.47	5.99
June 23	6.54	6.14
July 17	6.23	5.97
Wheel means	5.06	4.83

LSD t_{05} for date means for specific wheel = 0.37

LSD t_{05} for wheel means for specific date = 0.15

Because many of the seeds did not emerge, soil was excavated and one of six reasons assigned for lack of emergence. Tables 20 and 21 summarize the results of these observations. The analysis of variances for these effects are listed in Appendix A, Tables A-12, A-13, A-14, A-15, A-16 and A-17. Tillage treatments did not significantly affect any of the reasons for lack of emergence. It should be noted that only ten seeds were investigated for each row. Because of the variability of emergence within treatments and the small sample

Table 20. Effect of tillage treatment on reasons for seedlings not emerging

Tillage - 1970	The mean number of seedlings not emerged per ten seeds planted					
	Insufficient moisture	Rodent damage	Mechanical impedance	Nonviable seed	Killed by	
					Cut worm	Wire worm
Fall plowed	0.0	0.1	0.0	0.0	0.1	0.1
Fall plowed	0.0	0.0	0.0	0.0	0.3	0.3
Fall plowed	0.0	0.1	0.1	0.0	0.0	0.1
Fall plowed	0.0	0.0	0.0	0.0	0.1	0.1
Ridged system	1.8	0.0	0.0	0.0	0.4	0.4
Ridged system	0.8	0.0	0.1	0.0	0.5	0.5
Strip tilled	0.8	0.5	0.1	0.1	0.6	0.1
Ridged system	1.3	0.0	0.0	0.1	0.5	0.3
Fall plowed	0.0	0.1	0.1	0.1	0.1	0.4
Chisel plowed	0.1	0.0	0.1	0.0	0.5	0.0

Table 21. Effect of type of packing wheel on reasons for seedlings not emerging

Type of packing wheel	The mean number of seedlings not emerged per ten seeds planted					
	Insufficient moisture	Rodent damage	Mechanical impedance	Nonviable seed	Killed by	
					Cut-worm	Wire-worm
Concave	0.13	0.0	0.1	0.1	0.2	0.2
Rib	0.80	0.2	0.1	0.0	0.4	0.3

size (10 seeds), only large differences in treatment effects would be expected to be significantly different. Although the tillage treatment effects were not significant the trend of the means (Table 20) was consistent with the final stands as shown in Table 18. The ridged systems, strip tilled and chisel plowed treatments had the highest mean number of seeds not emerging because of insufficient moisture. The lack of moisture was due to shallower planting in these treatments (see depth of planting, Table 8).

Tillage systems which leave residue on the surface such as ridged systems often are condemned for being conducive to insect damage. Tillage systems did not significantly affect cutworm or wireworm damage (Table 20).

The type of press wheel did significantly influence the number of seedlings that did not emerge because of insufficient moisture (Table 21). This was not because of differences in the average moisture content of the treatments but because of planting depth (rib wheel planted 4.3 cm deep and concave wheel planted 5.2 cm deep). Soil moisture content decreased from seed depth to the soil surface and therefore planting shallower resulted in less available soil moisture.

Yield

Yields in general were low because a full season variety corn was planted late in the season and did not reach maturity before the first killing frost. Table 22 shows the effect of

Table 22. Effect of tillage treatments and type of packing wheel on yield

Tillage - 1970	Yield in q/ha at 15.5% moisture content		
	Type of packing wheel		Tillage means
	Concave	Rib	
Fall plowed	56.2	47.3	51.7
Fall plowed	60.8	53.4	57.1
Fall plowed	54.0	49.0	51.5
Fall plowed	56.1	54.2	55.1
Ridged system	59.3	61.2	60.2
Ridged system	59.9	62.2	61.0
Strip tilled	56.4	60.4	58.4
Ridged system	48.9	59.5	54.2
Fall plowed	54.8	53.9	54.4
Chisel plowed	52.0	53.6	52.8
Packing wheel means	55.8	55.4	

LSD t_{05} for packing wheel means for a given tillage = 10.5

LSD t_{05} for tillage means for a given type of packing wheel = 8.8

tillage treatments and type of packing wheel on grain yield. Neither tillage treatments nor type of packing wheel produced significantly different yields. There was a significant interaction of type of packing wheel and tillage system. The rib packing wheel had the highest yields for ridged systems but the concave wheel had the highest yields for the fall plowed treatments. The highest yield for all treatments was a ridged system that had soybeans the previous year with a rib packing wheel. The lowest yield was from a fall plowed treatment planted with a rib packing wheel.

Soil Structure Experiment

Moisture desorption

The effects of initial soil aggregate size, soil moisture and soil density on soil pore characteristics (measured by moisture desorption) were evaluated in the laboratory. The analysis of variance for each of the soil pore characteristics, mean pore diameter, pore diameter variance and porisity are shown in Tables B-1, B-2, and B-3 of Appendix B.

Table 23 shows the effects of soil moisture and soil density on mean pore diameter, pore diameter variance and porosity as measured by moisture desorption.

The porosity was not affected by soil moisture content. This effect was expected because the void volume (space not occupied by soil) is dependent on the amount of soil particles per unit volume and not the moisture within the voids. Porosity was significantly affected by soil density as expected. Porosity determined from desorption data was subject to initial saturation of the soil sample. A check on the degree of saturation was made by calculating porosity based on soil particle density. The following equation relates porosity to soil particles:

$$\text{Porosity} = 1 - (\rho_B/\rho_P)$$

where ρ_B = bulk density - g/cm^3

ρ_P = soil particle density - g/cm^3.

If ρ_P is assumed to equal 2.65 g/cm^3 and the bulk densities of 1.0 and 1.2 g/cm^3 substituted into the equation, the resulting porosities are 0.62 and 0.55. If saturation was complete in the desorption method, then porosity would equal 0.62 for bulk density of 1.0 g/cm^3 and 0.55 for bulk density of 1.2 g/cm^3. The results in Table 23 show that the samples must have been nearly saturated.

The pore diameter increased significantly between 18 and 23% moisture but increased very little between 23 and 28% (Table 23). Variance of pore diameter and porosity were not significantly affected by moisture content (Table 23).

The pore diameter decreased as soil density increased however the variance of pore diameter increased as soil density increased (Table 23) indicating greater variability in pore diameter with dense soil. Porosity decreased as soil density increased.

Table 23. Effect of soil moisture and soil density on soil pore characteristics

Soil moisture percent	Soil density g/cm^3	Mean pore diameter+	Variance of pore diameter+	Porosity cm^3/cm^3
18	1.0	5.54	1.46	0.58
18	1.2	4.49	1.10	0.52
23	1.0	6.06	0.94	0.63
23	1.2	5.72	1.43	0.54
28	1.0	6.18	0.80	0.62
28	1.2	5.87	1.35	0.53
Mean	1.0	5.93	1.06	0.61
Mean	1.2	5.52	1.29	0.53
18	Mean	5.26	1.28	0.55
23	Mean	5.89	1.18	0.58
28	Mean	6.02	1.07	0.57

LSD t_{05} for differences in moisture levels = 0.20

LSD t_{05} for differences in density at same moisture = 0.14

+The numbers presented in this table for mean and variance are based on the natural logarithms of the pore diameters measured in microns.

There was a significant interaction of the soil moisture and soil density. The decrease in mean pore diameter was greater for 18% moisture than for 23 and 28% moisture as density increased from 1.0 to 1.2 g/cm^3.

The variance of pore diameter increased as density increased for 23 and 28% moisture but decreased as density increased for 18% indicating the increased compaction caused the pores to become more uniform at 18% but less uniform for 23 and 28% moisture.

Table 24 shows the effects of soil moisture and initial aggregate size on soil pore characteristics. The initial aggregate size significantly affected mean pore diameter. As the initial aggregate size increased, the mean pore diameter increased. Neither the pore variance nor porosity were significantly affected by initial aggregate size. The effect of aggregate size on mean pore diameter was dependent on the moisture content. At 28% moisture there were no significant changes in mean pore size as the initial aggregate size was increased but at 18% the variation with aggregate size was large. This was probably a result of the initial aggregates losing their identity at 28% moisture during the process of mixing water into the sample.

Table 25 shows that the effect of soil density on mean pore diameter was dependent on the initial aggregate size. As the soil density was increased by compaction pressure, the

Table 24. Effect of soil moisture and initial aggregate size on soil pore characteristics

Soil moisture percent	Soil size	Mean pore diameter+	Variance of pore diameter+	Porosity cm^3/cm^3
18	Fine	4.74	1.08	0.54
18	Mixed	5.19	1.38	0.58
18	Large	5.86	1.38	0.54
23	Fine	5.76	1.28	0.59
23	Mixed	5.91	1.15	0.58
23	Large	6.01	1.11	0.58
28	Fine	5.99	1.14	0.55
28	Mixed	6.00	1.09	0.59
28	Large	6.08	0.99	0.58
Mean	Fine	5.49	1.16	0.56
Mean	Mixed	5.70	1.21	0.58
Mean	Large	5.98	1.16	0.57

LSD t_{05} for differences in size = 0.20

LSD t_{05} for differences in size for same moisture level = 0.35

+The numbers presented in this table for mean and variance are based on the natural logarithms of the pore diameter measured in microns.

Table 25. Effect of initial aggregate size and soil density on mean pore size

Soil density g/cm^3	Mean pore diameter (based on logarithm of pore diameter in microns)		
	Initial soil aggregate size		
	Fine	Mixed	Large
1.0	5.74	5.94	6.10
1.2	5.25	5.47	5.86

LSD t_{05} for differences in density at same size = 0.14

LSD t_{05} for differences in size for same density = 0.32

mean pore size decreased. This decrease in mean pore diameter was more pronounced for the small and mixed aggregate sizes.

FSPA scanning

The effects of initial soil aggregate size, soil moisture, and soil density on soil structure characteristics measured with the FSPA scanning technique (phase intercept mean, μ_p, phase intercept variance, σ_p, matrix intercept mean, μ_m, matrix intercept variance, σ_m, and porosity, P_f) were studied in the laboratory. The analysis of variance for each of the soil parameters is listed in Tables B-4, B-5, B-6, B-7 and B-8 of Appendix B. Table 26 summarizes the independent variables, initial soil aggregate size, soil moisture, soil

Table 26. Soil factors and their interactions significantly affecting soil structure characteristics

Soil factors	Soil structure characteristics				
	Phase intercept		Matrix intercept		Porosity
	Mean (μ_p)	Variance (σ_p)	Mean (μ_m)	Variance (σ_m)	(p_f)
Initial aggregate size			**	*	
Soil moisture	**		**	**	*
Soil density	**		**	**	**
Angle of scanning	*	**	**	**	**
Initial size by density		*	*		**
Moisture by density	**	*	*		*
Size by moisture by density	*				**

*Indicates factors were statistically significant at the 5% level.

**Indicates factors were statistically significant at the 1% level.

density and angle of scan and their interactions that significantly affected μ_p, σ_p, μ_m, σ_m and P_f.

Figures 13-20 show one replication of every combination of soil conditions measured. The photographs are prints of films scanned with the FSPA. The white in the photographs represents void areas and black represents soil aggregates. The soil structure characteristics, μ_p, σ_p, μ_m, σ_m and P_f of each photograph shown in Fig. 13-20 as measured with the FSPA scanning technique appear directly under the photograph. These figures show the variation in soil structures studied in this research.

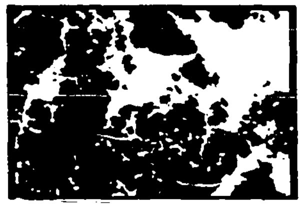
There was a physical relationship among the variables aggregate size, pore size and porosity (as measured with the FSPA which is not necessarily the same as calculated from bulk volume, particle weight and particle density). It was physically impossible to change only one of the variables; if one was changed, then at least one of the others also changed. To interpret the results, this concept along with the fact that the FSPA scanning technique concerns large pores (non-capillary) and aggregates but not small pores and small particles such as intra-aggregate pores should be remembered.

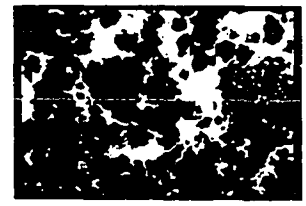
Initial aggregate size did not affect the mean or variance of the phase intercepts (Table 27), but the matrix intercept means and variance were significantly effected by initial aggregate size. This seems like a physical impossibility; the aggregate size not changing but the pore size significantly changing for the same average bulk density (1.1 g/cm^3 which is an average of 1.0 and 1.2 g/cm^3). This phenomenon could be possible if the density changed and would be analogous to

Density

1.0 g/cm^3 | 1.2 g/cm^3

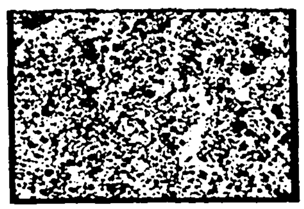
Moisture 28%





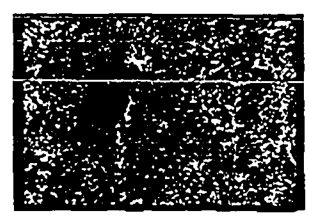
	1.0 g/cm^3	1.2 g/cm^3
Phase Mean	μ_p = 7.14	μ_p = 7.07
Phase Var.	σ_p = 1.76	σ_p = 1.60
Matrix Mean	μ_m = 6.21	μ_m = 6.15
Matrix Var.	σ_m = 1.43	σ_m = 1.17
	Porosity = 0.26	Porosity = 0.26

Moisture 23%



	1.0 g/cm^3	1.2 g/cm^3
Phase Mean	μ_p = 5.54	μ_p = 6.01
Phase Var.	σ_p = 1.37	σ_p = 1.49
Matrix Mean	μ_m = 5.67	μ_m = 5.37
Matrix Var.	σ_m = 0.86	σ_m = 0.70
	Porosity = 0.24	Porosity = 0.16

Moisture 18%



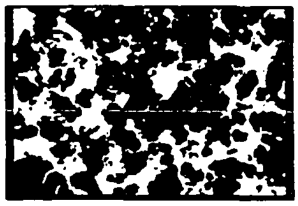
	1.0 g/cm^3	1.2 g/cm^3
Phase Mean	μ_p = 5.53	μ_p = 6.27
Phase Var.	σ_p = 0.81	σ_p = 1.16
Matrix Mean	μ_m = 5.76	μ_m = 4.97
Matrix Var.	σ_m = 0.83	σ_m = 0.55
	Porosity = 0.52	Porosity = 0.13

Fig. 13. Effect of bulk density and moisture on phase mean, phase variance, matrix mean, matrix variance and porosity for fine initial aggregate size

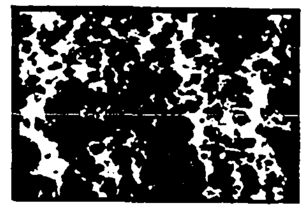
Density

1.0 g/cm^3 | 1.2 g/cm^3

Moisture 28%

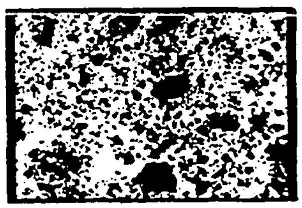


μ_p = 6.75
σ_p = 1.31
μ_m = 6.50
σ_m = 1.37
Porosity = 0.43

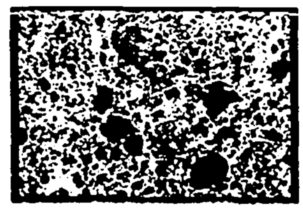


μ_p = 6.69
σ_p = 1.37
μ_m = 6.22
σ_m = 1.24
Porosity = 0.36

Moisture 23%

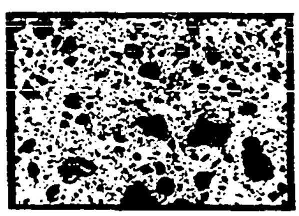


μ_p = 6.05
σ_p = 0.98
μ_m = 6.07
σ_m = 0.97
Porosity = 0.44

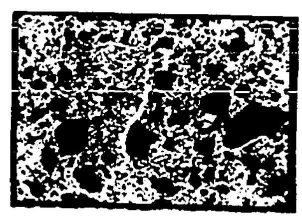


μ_p = 6.16
σ_p = 0.94
μ_m = 5.78
σ_m = 0.83
Porosity = 0.35

Moisture 18%



μ_p = 5.33
σ_p = 1.75
μ_m = 5.59
σ_m = 0.88
Porosity = 0.16



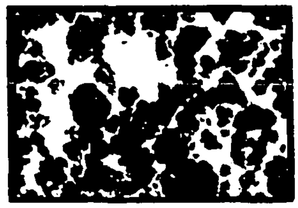
μ_p = 5.92
σ_p = 1.13
μ_m = 5.23
σ_m = 0.73
Porosity = 0.24

Fig. 14. Effect of bulk density and moisture on phase mean, phase variance, matrix mean, matrix variance and porosity for mixed initial aggregate size

Density

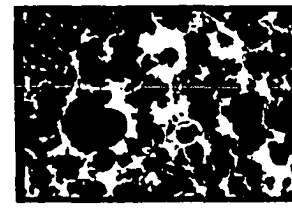
Moisture 28%

1.0 g/cm^3



$\mu_p = 6.72$
$\sigma_p = 1.39$
$\mu_m = 6.44$
$\sigma_m = 1.56$
Porosity = 0.45

1.2 g/cm^3



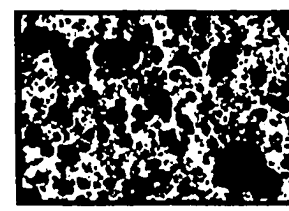
$\mu_p = 6.63$
$\sigma_p = 1.38$
$\mu_m = 6.31$
$\sigma_m = 1.35$
Porosity = 0.42

Moisture 23%

1.0 g/cm^3

$\mu_p = 5.72$
$\sigma_p = 2.06$
$\mu_m = 6.17$
$\sigma_m = 0.99$
Porosity = 0.26

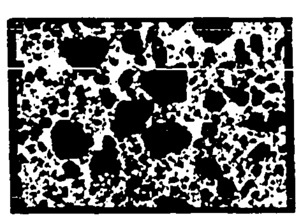
1.2 g/cm^3



$\mu_p = 6.48$
$\sigma_p = 1.47$
$\mu_m = 6.04$
$\sigma_m = 0.97$
Porosity = 0.28

Moisture 18%

1.0 g/cm^3



$\mu_p = 5.99$
$\sigma_p = 2.03$
$\mu_m = 5.95$
$\sigma_m = 1.03$
Porosity = 0.26

1.2 g/cm^3

$\mu_p = 6.00$
$\sigma_p = 1.37$
$\mu_m = 5.84$
$\sigma_m = 0.91$
Porosity = 0.32

Fig. 15. Effect of bulk density and moisture on phase mean, phase variance, matrix mean, matrix variance and porosity for large initial aggregate size

Density

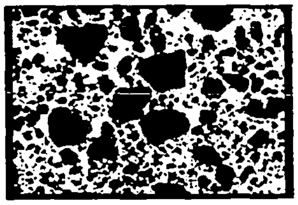
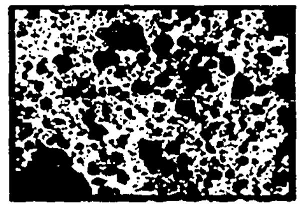
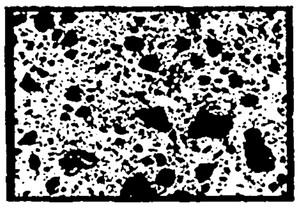
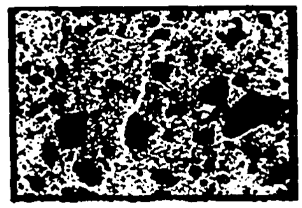
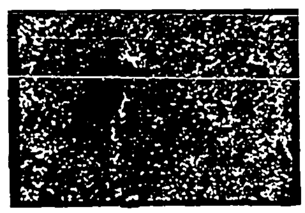
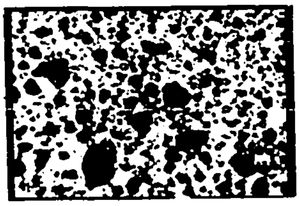
	1.0 g/cm³	1.2 g/cm³
Initial Aggregate Size Large		
	μ_p = 5.99 σ_p = 2.03 μ_m = 5.95 σ_m = 1.03 Porosity = 0.26	μ_p = 6.00 σ_p = 1.37 μ_m = 5.84 σ_m = 0.91 Porosity = 0.32
Initial Aggregate Size Mixed		
	μ_p = 5.33 σ_p = 1.75 μ_m = 5.59 σ_m = 0.88 Porosity = 0.16	μ_p = 5.92 σ_p = 1.13 μ_m = 5.23 σ_m = 0.73 Porosity = 0.24
Initial Aggregate Size Fine		
	μ_p = 5.53 σ_p = 0.81 μ_m = 5.76 σ_m = 0.83 Porosity = 0.52	μ_p = 6.27 σ_p = 1.16 μ_m = 4.97 σ_m = 0.55 Porosity = 0.13

Fig. 16. Effect of bulk density and initial aggregate size on phase mean, phase variance, matrix mean, matrix variance and porosity for 18% moisture

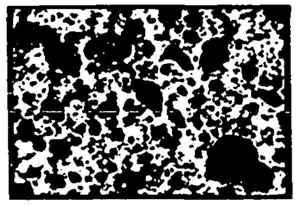
Density

1.0 g/cm^3 | **1.2 g/cm^3**

Initial Aggregate Size Large

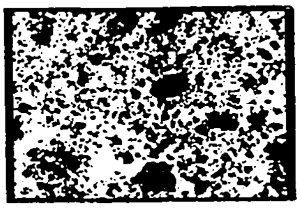


$\mu_p = 5.72$
$\sigma_p = 2.06$
$\mu_m = 6.17$
$\sigma_m = 0.99$
Porosity = 0.26

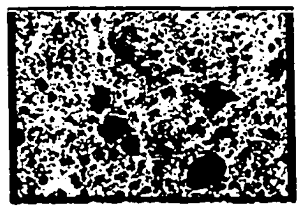


$\mu_p = 6.48$
$\sigma_p = 1.47$
$\mu_m = 6.04$
$\sigma_m = 0.97$
Porosity = 0.28

Initial Aggregate Size Mixed

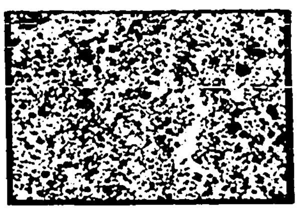


$\mu_p = 6.05$
$\sigma_p = 0.98$
$\mu_m = 6.07$
$\sigma_m = 0.97$
Porosity = 0.44

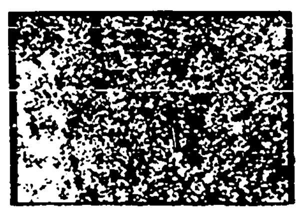


$\mu_p = 6.16$
$\sigma_p = 0.94$
$\mu_m = 5.78$
$\sigma_m = 0.83$
Porosity = 0.35

Initial Aggregate Size Fine



$\mu_p = 5.54$
$\sigma_p = 1.37$
$\mu_m = 5.67$
$\sigma_m = 0.86$
Porosity = 0.24



$\mu_p = 6.01$
$\sigma_p = 1.49$
$\mu_m = 5.37$
$\sigma_m = 0.70$
Porosity = 0.16

Fig. 17. Effect of bulk density and initial aggregate size on phase mean, phase variance, matrix mean, matrix variance and porosity for 23% moisture

Density

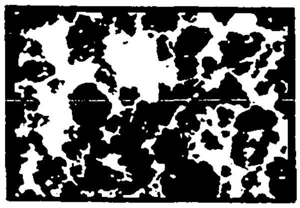
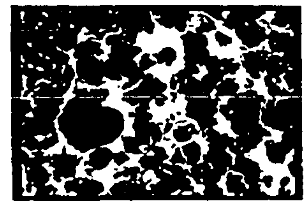
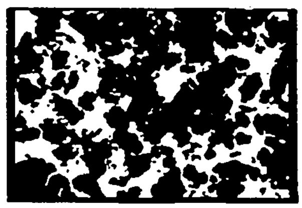
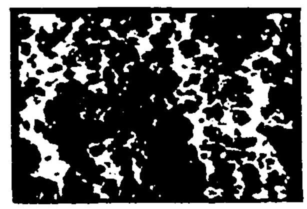
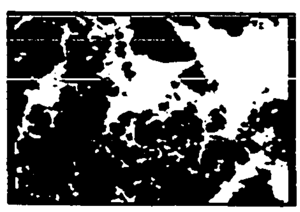
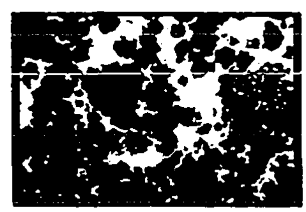
	1.0 g/cm^3	1.2 g/cm^3
Initial Aggregate Size Large		
	μ_p = 6.72 σ_p = 1.39 μ_m = 6.44 σ_m = 1.56 Porosity = 0.45	μ_p = 6.63 σ_p = 1.38 μ_m = 6.31 σ_m = 1.35 Porosity = 0.42
Initial Aggregate Size Mixed		
	μ_p = 6.75 σ_p = 1.31 μ_m = 6.50 σ_m = 1.37 Porosity = 0.43	μ_p = 6.69 σ_p = 1.37 μ_m = 6.22 σ_m = 1.24 Porosity = 0.36
Initial Aggregate Size Fine		
	μ_p = 7.14 σ_p = 1.76 μ_m = 6.21 σ_m = 1.43 Porosity = 0.26	μ_p = 7.07 σ_p = 1.60 μ_m = 6.15 σ_m = 1.17 Porosity = 0.26

Fig. 18. Effect of bulk density and initial aggregate size on phase mean, phase variance, matrix mean, matrix variance and porosity for 28% moisture

Moisture

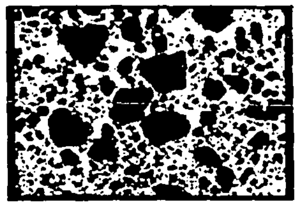
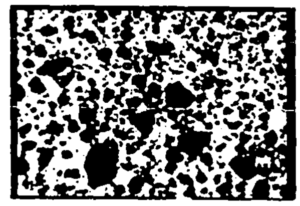
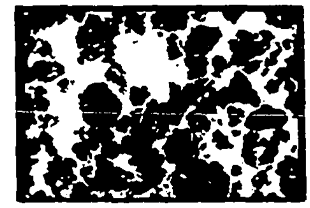
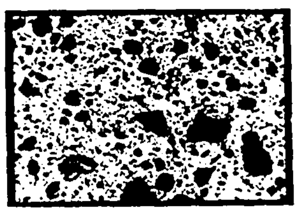
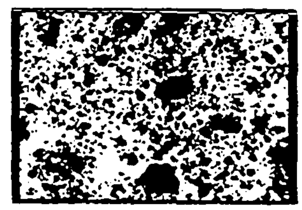
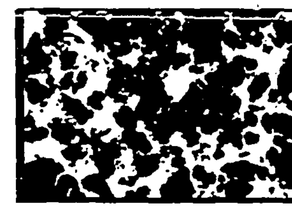
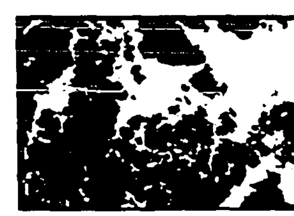
Initial Aggregate Size	18%	23%	28%
Large			
	μ_p = 5.99	μ_p = 5.72	μ_p = 6.72
	σ_p = 2.03	σ_p = 2.06	σ_p = 1.39
	μ_m = 5.95	μ_m = 6.17	μ_m = 6.44
	σ_m = 1.03	σ_m = 0.99	σ_m = 1.56
	Porosity = 0.26	Porosity = 0.26	Porosity = 0.45
Mixed			
	μ_p = 5.33	μ_p = 6.05	μ_p = 6.75
	σ_p = 1.75	σ_p = 0.98	σ_p = 1.31
	μ_m = 5.59	μ_m = 6.07	μ_m = 6.50
	σ_m = 0.88	σ_m = 0.97	σ_m = 1.37
	Porosity = 0.16	Porosity = 0.44	Porosity = 0.43
Fine			
	μ_p = 5.53	μ_p = 5.54	μ_p = 7.14
	σ_p = 0.81	σ_p = 1.37	σ_p = 1.76
	μ_m = 5.76	μ_m = 5.67	μ_m = 6.21
	σ_m = 0.83	σ_m = 0.86	σ_m = 1.43
	Porosity = 0.52	Porosity = 0.24	Porosity = 0.26

Fig. 19. Effect of initial aggregate size and moisture on phase mean, phase variance, matrix mean, matrix variance and porosity for 1.0 g/cm^3 soil density

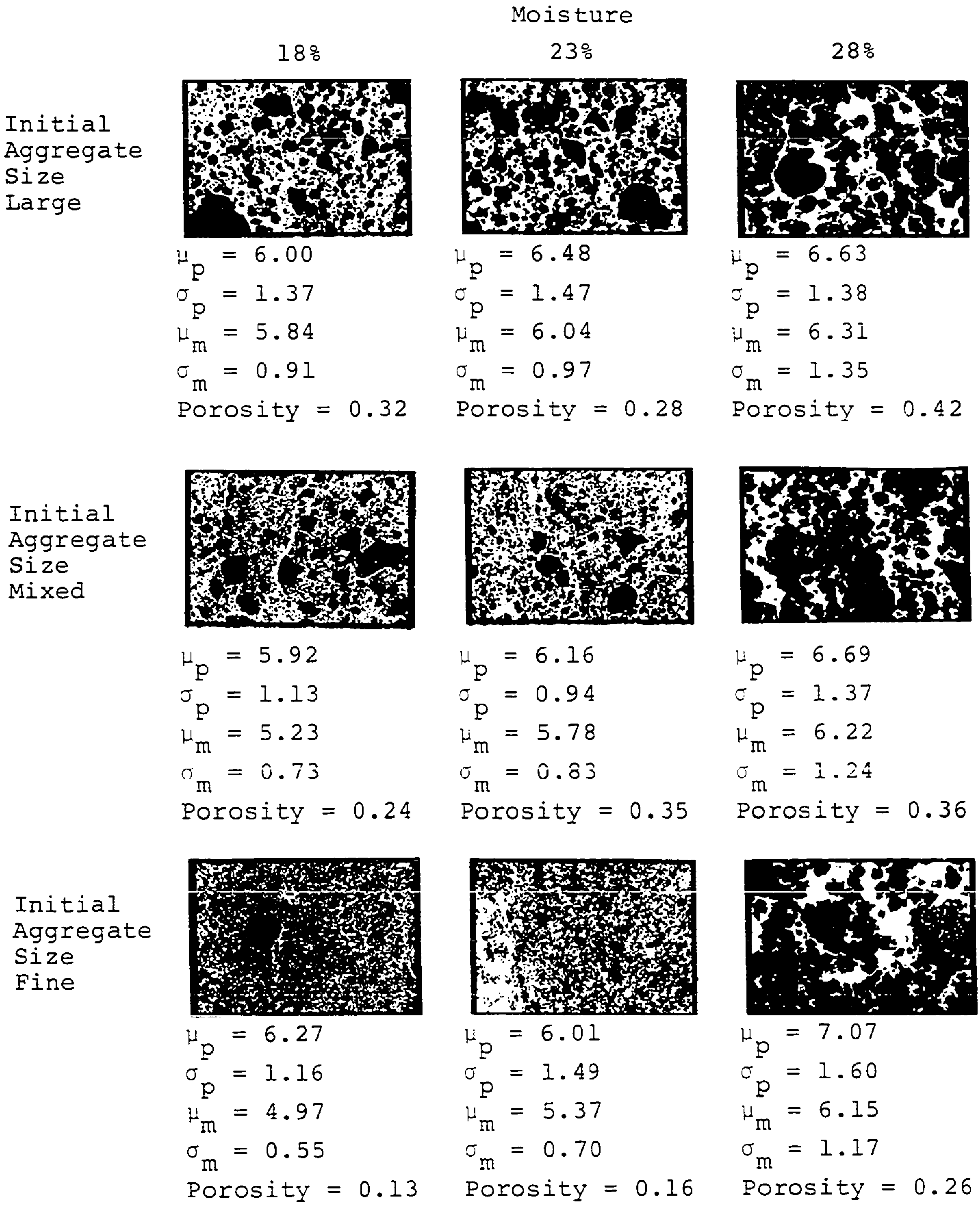


Fig. 20. Effect of initial aggregate size and moisture on phase mean, phase variance, matrix mean, matrix variance and porosity for 1.2 g/cm^3 soil density

filling a container with sand and vibrating it. The sand particles would not change their size or shape but the vibration would arrange the particles in such a manner that less volume would be occupied by the sand. The bulk density would increase, pore size decrease and particle size remain constant. Table 27 shows that porosity increased with an increase in mean matrix intercept length but not significantly.

The intercept variances for both phase and matrix increased as initial aggregate size increased, but only the matrix variance increase was statistically significant. This indicates the pores become more uniform as they decreased in size.

Soil moisture per se does not affect soil structure characteristics except for cases of swelling or shrinking due to changes in moisture. The effects due to moisture in this research were not due to shrinking or swelling but rather to the change in aggregate size during addition of moisture. The change in aggregate size with addition of moisture is evident in Figs. 13-20. The initial aggregate size changed as aggregates both fractured into smaller aggregates and combined with other aggregates to form larger ones.

Table 28 shows the effects of moisture on soil structure characteristics. Phase intercept mean and matrix intercept mean increased significantly as moisture increased from 23 to 28%. The soil became sticky at 28% moisture and larger

Table 27. Effect of initial aggregate size on soil structure characteristics measured with FSPA scanning technique

Initial aggregate size	Phase intercept+		Matrix intercept+		Porosity
	Mean	Variance	Mean	Variance	cm^3/cm^3
Fine	6.24	1.28	5.68	0.94	0.29
Mixed	6.11	1.36	5.86	0.98	0.30
Large	6.26	1.57	6.14	1.10	0.33
			_**	_ *	
LSD t_{05} for mean initial aggregate size			0.11	0.11	

+The numbers presented in this table for intercept means and variances are based on the natural logarithms of the intercepts measured in microns.

*Indicates means are statistically significant at the 5% level.

**Indicates means are statistically significant at the 1% level.

aggregates were formed with large spaces between them. Figures 13, 14 and 15 show this effect for each initial aggregate size. It should be noted (Table 26) that there was an interaction with density and moisture. This means that the effect of moisture on phase and matrix intercept means was dependent on the level of density.

Table 28. Effect of soil moisture on soil structure characteristics measured with the FSPA scanning technique

Moisture content % dry wt. basis	Phase intercept[+]		Matrix intercept[+]		Porosity cm^3/cm^3
	Mean	Variance	Mean	Variance	
18	5.85	1.33	5.57	0.80	0.27
23	6.00	1.46	5.83	0.87	0.28
28	6.77	1.42	6.29	1.35	0.37
	_**		_**	_**	_*
LSD t_{05}	0.19		0.11	0.11	

[+]The numbers presented in this table for intercept means and variances are based on the natural logarithms of the intercepts measured in microns.

*Indicates interactions were statistically significant at the 5% level.

**Indicates interactions were statistically significant at the 1% level.

The variance of the matrix intercepts increased significantly as the moisture content increased, but the variance of the phase intercepts did not significantly change as moisture increased (Table 28). As the phase intercepts (aggregates) increased in mean length there was little or no change in uniformity, but as the matrix intercepts (pores) increased in mean length the uniformity decreased. Porosity increased with moisture.

The compacting process used to create two densities (1.0 and 1.2 g/cm^3) affected the phase intercept mean, matrix intercept mean, matrix intercept variance and porosity (Table 29). Phase intercept mean increased, matrix intercept mean decreased and porosity decreased as soil density increased. Physically, soil aggregates were combined into larger aggregates, mean pore size decreased and total soil volume decreased as the density of the samples were increased. The variance of the phase intercepts did not change as density increased but the variance of the matrix intercepts decreased.

Table 29. Effect of soil density on soil structure characteristics measured with the FSPA scanning technique

Soil density	Phase intercept+		Matrix intercept+		Porosity
g/cm^3	Mean	Variance	Mean	Variance	cm^3/cm^3
1.0	6.08	1.44	6.04	1.10	0.35
1.2	6.33	1.37	5.75	0.92	0.27
	-**		-**	-**	-**

+The numbers presented in this table for intercept means and variances are based on the natural logarithms of the intercepts measured in microns.

**Indicates means are statistically significant at the 1% level.

Each film was scanned in two directions (0 and 90 degrees) to obtain an indication of isotropy. Table 30 shows the effect of angle of scan on soil pore characteristics or physically the effect of a compaction process on orientation

Table 30. Effect of angle of scanning on soil structure characteristics measured with the FSPA scanning technique

Angle of scan degrees	Phase intercept+		Matrix intercept+		Porosity cm^3/cm^3
	Mean	Variance	Mean	Variance	
0	6.24	1.33	5.91	0.97	0.32
90	6.17	1.48	5.87	1.05	0.30
	_*	_**	_**	_**	_**

+The numbers presented in this table for means and variances are based on the natural logarithms of the intercepts measured in microns.

*Indicates means are statistically significant at the 5% level.

**Indicates means are statistically significant at the 1% level.

of pores and aggregates. The 90 degree scan angle represented intercepts measured parallel to the direction of compaction force and 0 degrees was perpendicular to the direction of compaction force.

A disturbing phenomenon appears in the results from scanning in two directions. Porosity was significantly different for direction of scanning. This would indicate a systematic instrument error with the FSPA. There is a possibility that the intercept lengths may also have been affected by this apparent systematic error. The intercept lengths were assumed to be correctly measured regardless of angle of scan.

Table 30 shows that in the direction of the compaction force (ninety degree scan angle), the mean phase intercept and mean matrix intercepts were decreased and the intercept variances were increased as compared to the direction perpendicular to the compaction force. Figure 21 shows a physical interpretation of the compacting process. By compacting, the particles became larger and oriented, the pores became smaller and oriented, and the porosity decreased.

Table 31 shows the effects of moisture and density on soil structure characteristics. The interaction of moisture and density was significant for phase intercept variance, matrix intercept mean and porosity. The phase intercept mean increased as density increased for 18 and 23% moisture content but phase intercept mean did not increase significantly for 28% moisture. Matrix intercept mean decreased as density increased for 18 and 23% moisture but the effect was not significant for 28% moisture.

Porosity decreased as density increased for each moisture content but was not significant at 28%. This would indicate that at the 18 and 23% moisture content the additional compaction from 1.0 and 1.2 g/cm^3 took place primarily between aggregates and contact between aggregates became sufficient to appear as solid particles. At 28% the additional compaction

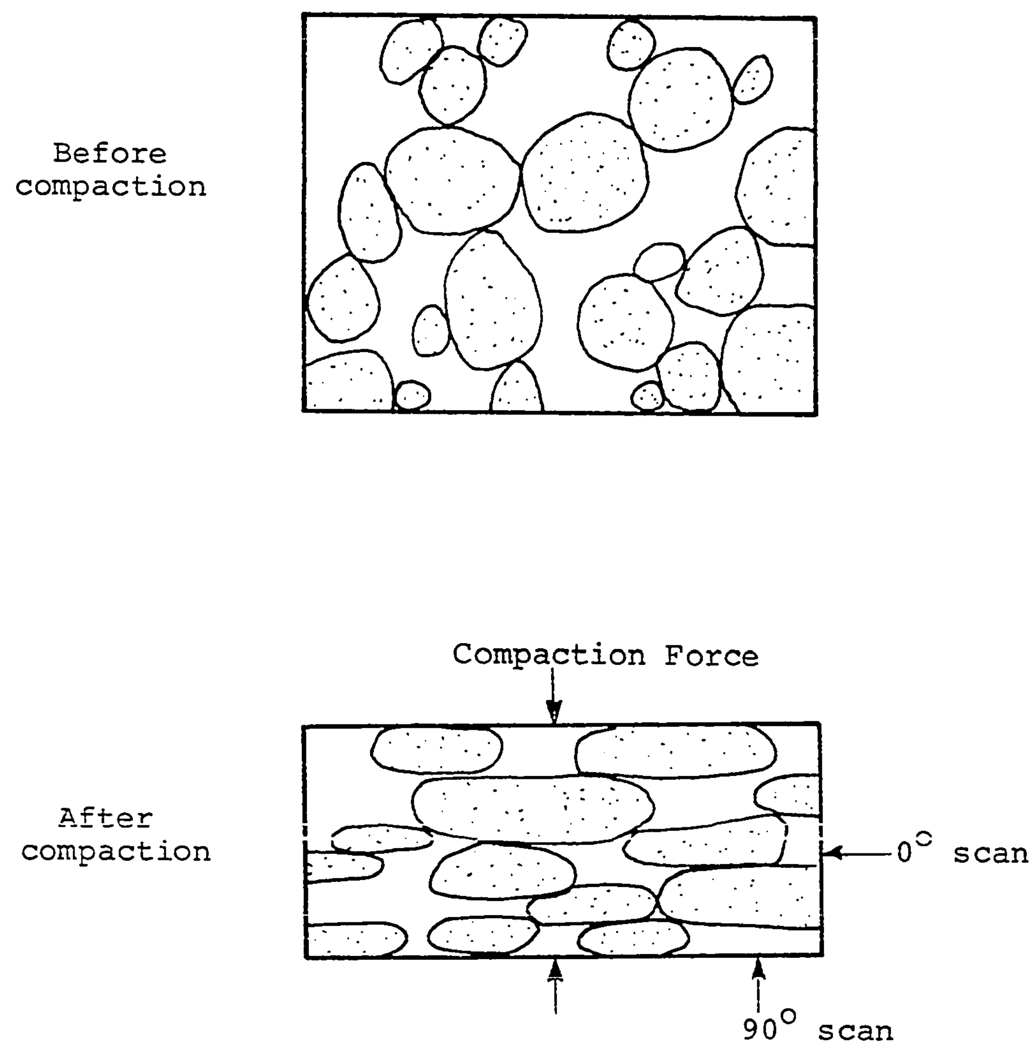


Fig. 21. Idealized effect of compaction on soil structure

Table 31. Effect of initial aggregate size and soil moisture on soil structure characteristics

Moisture percent	Soil density g/cm^3	Soil pore characteristics: Phase intercept+ Mean	Phase intercept+ Variance	Matrix intercept+ Mean	Matrix intercept+ Variance	Porosity cm^3/cm^3
18	1.0	5.64	1.34	5.77	0.87	0.35
18	1.2	6.07	1.33	5.36	0.73	0.21
23	1.0	5.81	1.55	6.00	0.94	0.31
23	1.2	6.19	1.37	5.66	0.81	0.24
28	1.0	6.80	1.44	6.24	1.48	0.39
28	1.2	6.74	1.40	6.24	1.23	0.36
LSD t_{05} for difference in density at same moisture		-** 0.18		-* 0.14		-* 0.05

+The numbers presented in this table for means and variances are based on the natural logarithms of the intercepts measured in microns.

*Indicates interactions were statistically significant at the 5% level.

**Indicates interactions were statistically significant at the 1% level.

from 1.0 to 1.2 g/cm^3 was primarily within aggregates and particles that appeared solid at 1.0 g/cm^3 increased their density during the compaction process because matrix intercept mean, phase intercept mean and porosity did not change significantly at 28% moisture.

Matrix intercept mean as well as porosity decreased as density increased for each size class (Table 32) but this change was significant only for the fine class. The results indicate the compaction process for the fine size consisted of the matrix mean length decreasing in length and aggregates combining with others to make larger aggregates. The larger initial aggregate sizes apparently compacted the existing aggregates as well as combining aggregates because porosity did not significantly change.

Figures 19 and 20 show the effect of the three way interaction of initial aggregate size, soil moisture and compaction on porosity and mean phase intercept. These interactions resulted in a drastic change for the fine size at 18% as it was compacted from 1.0 to 1.2 g/cm^3. The change was from 0.13 to 0.52 for porosity and from 6.27 to 5.53 for phase intercept mean. These were the highest and lowest porosities measured. This effect was consistent for replication 2 as well as replication 1 shown in Figs. 19 and 20. An apparent reason for this was that many of the voids for fine 18% and 1.0 g/cm^3 were near the threshold of detection by the FSPA (near 20 microns). The compaction process reduced the void space sufficiently so that many of aggregates appeared to combine and therefore resulted in a larger phase intercept mean, smaller matrix intercept mean and a decrease in porosity.

Table 32. Effect of initial aggregate size and soil density on soil structure characteristics

Initial aggregate size	Soil density g/cm^3	Soil pore characteristics				Porosity
		Phase intercept$^+$		Matrix intercept$^+$		
		Mean	Variance	Mean	Variance	cm^3/cm^3
Fine	1.0	6.07	1.20	5.90	1.06	0.38
Fine	1.2	6.41	1.36	5.46	0.82	0.20
Mixed	1.0	6.05	1.40	5.98	0.32	0.32
Mixed	1.2	6.18	1.33	5.74	0.29	0.29
Large	1.0	6.12	1.73	6.22	0.35	0.35
Large	1.2	6.41	1.41	6.06	0.32	0.32
LSD t_{05} for difference in density at same aggregate size			-* 0.24	-* 0.14		-** 0.05

$^+$The numbers presented in this table for means and variances are based on the natural logarithms of the intercepts measured in microns.

*Indicates interactions were statistically significant at the 5% level.

**Indicates interactions were statistically significant at the 1% level.

A comparison of the two techniques to quantifying soil structure was made by linear correlation. Table 33 shows the correlations and the probabilities for the hypothesis $\rho = 0$. Because the magnitude of correlation coefficients may be biased by the range of the conditions selected, a multivariate analysis was conducted adjusting for treatment levels and replications. Table 34 shows the correlation coefficients

Table 33. Correlation coefficients and probabilities for soil structure

	FSPA scanning					Moisture desorption		
	Matrix intercept		Phase intercept			Soil pore diameter		
	Mean	Variance	Mean	Variance	Porosity	Mean	Variance	Porosity
	μ_m	σ_m	μ_p	σ_p	P_f	μ_d	σ_d	P_d
μ_m	1.0000							
Probability	0.0000							
σ_m	0.8714	1.0000						
Probability	0.0001	0.0000						
μ_p	0.5069	0.6840	1.0000					
Probability	0.0019	0.0001	0.0000					
σ_p	0.2240	0.1858	0.0445	1.0000				
Probability	0.1863	0.2775	0.7924	0.0000				
P_f	0.6652	0.5646	0.1598	-.4464	1.0000			
Probability	0.0001	0.0006	0.6456	0.0064	0.0000			
μ_d	0.8321	0.6818	0.3001	0.3627	0.3978	1.0000		
Probability	0.0001	0.0001	0.0720	0.0280	0.0155	0.0000		
σ_d	-.1592	-.2694	-.2235	-.2071	-.0145	-.1696	1.0000	
Probability	0.6440	0.1084	0.1872	0.2236	0.9305	0.3241	0.0000	
P_d	0.2945	0.2419	-.1560	0.1846	0.1979	0.4721	-.4951	1.0000
Probability	0.0778	0.1519	0.6333	0.2809	0.2460	0.0039	0.0025	0.0000

Table 34. Partial correlation coefficients adjusted for soil moisture, soil density, initial aggregate size and replication and probabilities

	FSPA scanning					Moisture desorption		
	Matrix intercept		Phase intercept			Soil pore diameter		
	Mean	Variance	Mean	Variance	Porosity	Mean	Variance	Porosity
	μ_m	σ_m	μ_p	σ_p	P_f	μ_d	σ_d	P_d
μ_m	1.0000							
Probability	0.0000							
σ_m	0.2518	1.0000						
Probability	0.5119	0.0000						
μ_p	-.0180	-.2875	1.0000					
Probability	0.9598	0.5751	0.0000					
σ_p	0.0839	0.3986	-.1117	1.0000				
Probability	0.8119	0.2532	0.7555	0.0000				
P_f	0.4202	-.1316	0.0887	-.7029	1.0000			
Probability	0.2253	0.7165	0.8019	0.0226	0.0000			
μ_d	0.2918	0.2731	-.0304	0.2976	0.1330	1.0000		
Probability	0.5826	0.5500	0.9313	0.5927	0.7138	0.0000		
σ_d	-.1185	-.0760	-.5667	-.0403	-.2860	-.5867	1.0000	
Probability	0.7421	0.8284	0.0854	0.9082	0.5725	0.0725	0.0000	
P_d	0.2438	-.1814	0.4461	0.2788	0.1052	0.7876	-.7436	1.0000
Probability	0.5027	0.6201	0.1945	0.5600	0.7685	0.0070	0.0134	0.0000

obtained by a multivariate analysis which adjusted the data for soil moisture, soil density and initial soil aggregate size and replication. Of particular interest are the correlations between mean matrix intercept, μ_m, and mean pore diameter, μ_d, matrix variance, σ_m, and pore diameter variance, and porosity by scanning, P_p, and porosity by moisture desorption. The matrix intercept mean length and pore diameter should be correlated as well as their variances and the two measures of porosity.

Table 33 shows that μ_d and μ_m are highly correlated but σ_d and σ_m and P_d and P_f are not correlated. There is reason to question whether the values of P_f because the P_d's as measured with the desorption technique were within a few percent of the theoretical porosity based on bulk density and particle density. The reason the FSPA scanning did not give a measure for P_f that correlated highly with P_d may have been because measurements of samples with small pores and small particles were questionable. No attempt was made to correlate P_f and P_d for only samples with large pores and large particles. Figure 13 shows a wide variation in porosity for the two samples at 18%. In fact these were the maximum and minimum porosities of all samples. The only difference in these two samples was the bulk density. It is highly unlikely that the voids approximately 10 by 20 microns (threshold detection of FSPA) and larger compressed sufficiently to change

P_f from 0.52 to 0.13 by compacting the soil from 1.0 to 1.2 g/cm^3.

The partial correlations adjusted for soil moisture, soil density and initial aggregate size shown in Table 34 provide an opportunity to look at correlations within a sampling method. The results show that only porosity measured by moisture desorption correlated highly with mean pore diameter and pore diameter variance.

Seedling Emergence Experiment

Soybeans - emergence rate

The analysis of variance for soybean rate of emergence is shown in Tablc C-1 of Appendix C. Orthogonal contrasts were made to partition the sums of squares into individual degrees of freedom. Table C-5 shows the orthogonal contrasts for temperature and the significant interaction of temperature by density, temperature by depth and moisture by variety.

Although there is no legitimate error to test the effects of temperature, it is apparent from the sum of squares that temperature affected soybean rate of emergence and the effect was primarily linear. Figure 22 shows a plot of the mean effect of temperature on emergence rate of soybeans. The plots show the effect is linear. The ordinate for plots in Figs. 22-25 and Figs. 29-35 is in plants per day which is equal to emergence rate divided by 100.

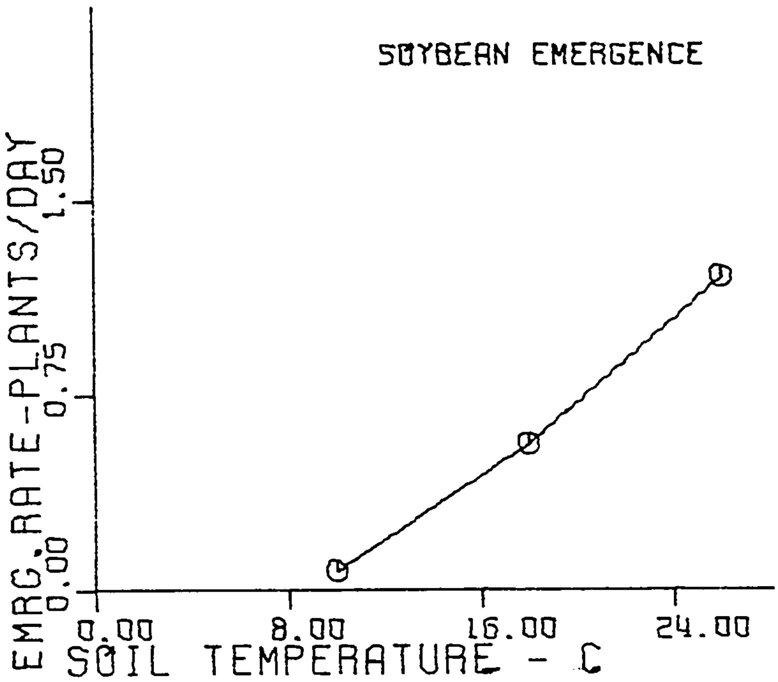


Fig. 22. Effect of soil temperature on soybean emergence rate

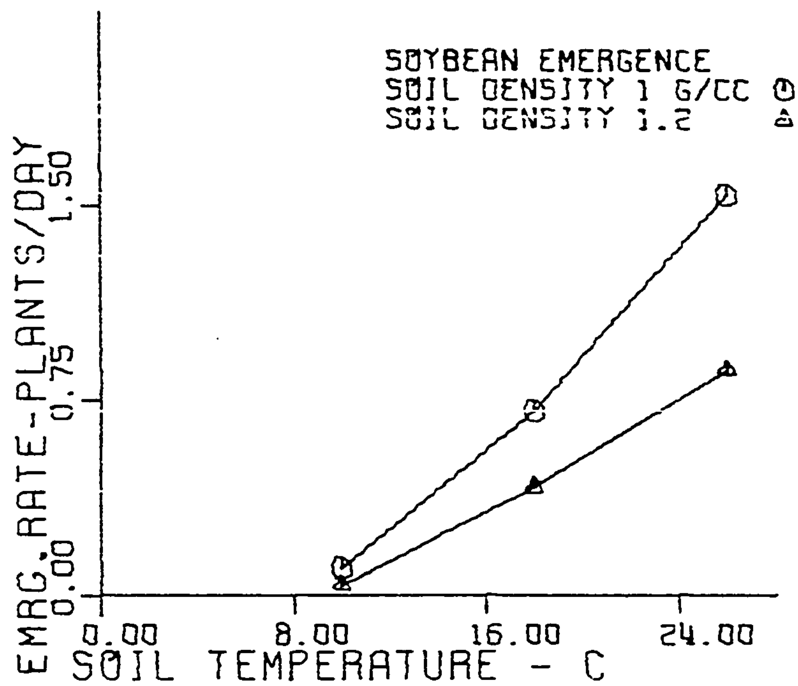


Fig. 23. Effect of soil temperature and soil density on soybean emergence rate

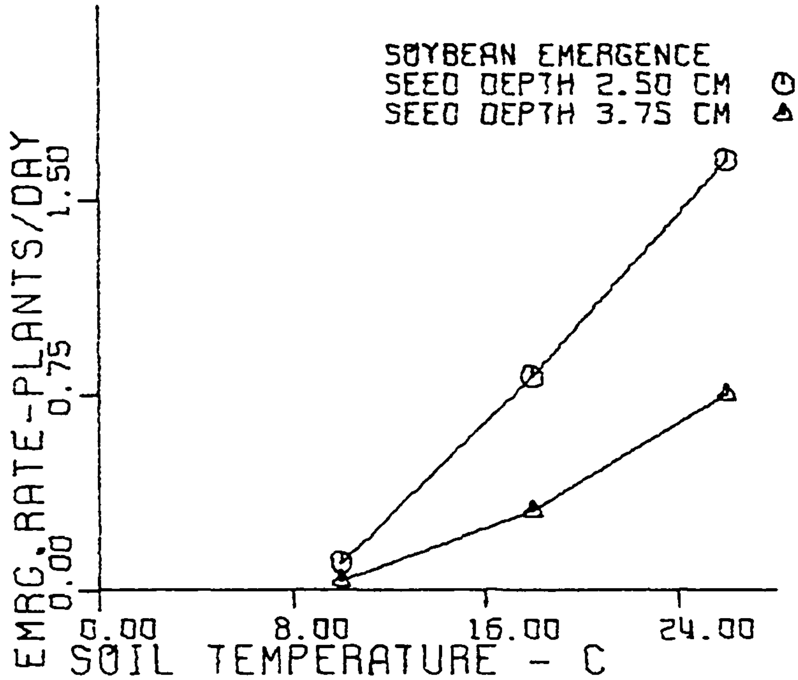


Fig. 24. Effect of soil temperature and seed depth on soybean emergence rate

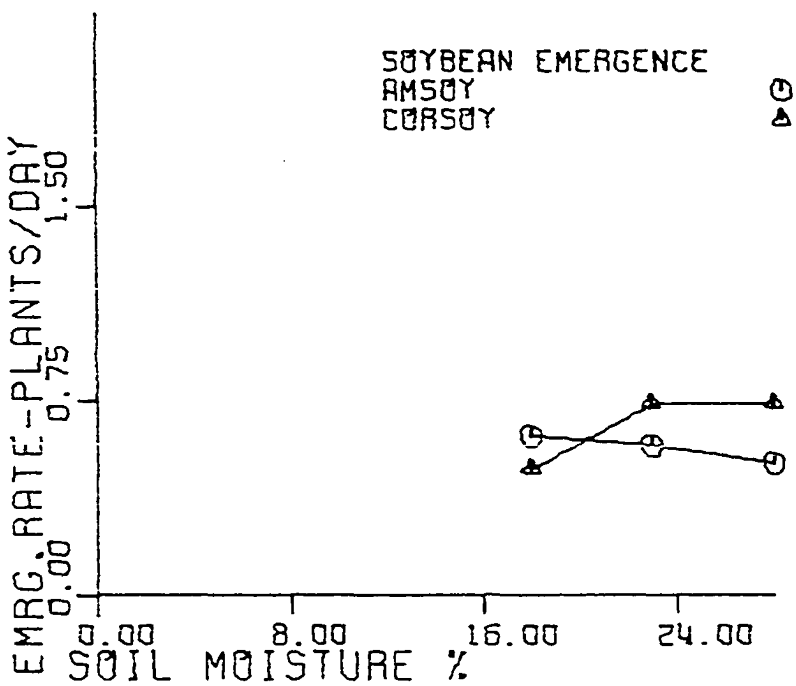


Fig. 25. Effect of soil moisture and variety on soybean emergence rate

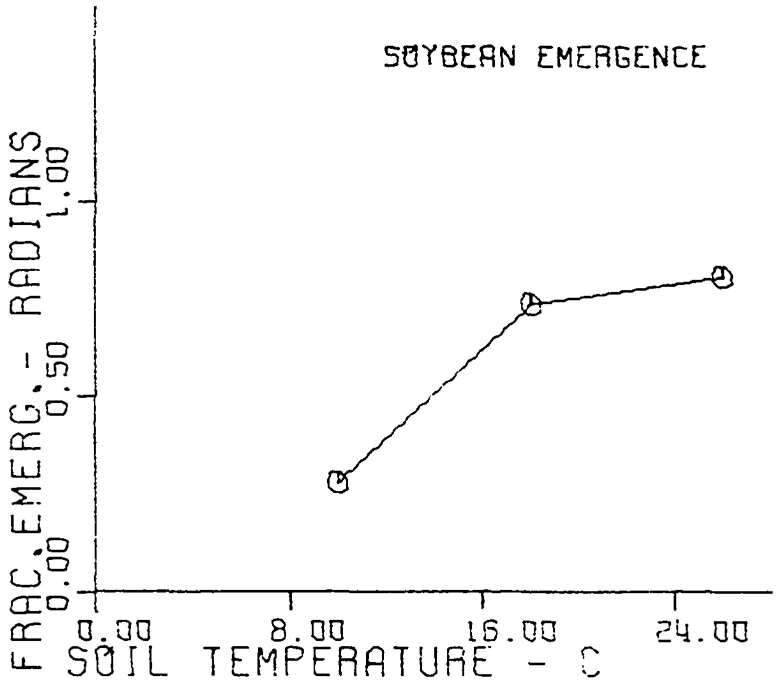


Fig. 26. Effect of soil temperature on arc sine of square root of fraction of soybeans emerged

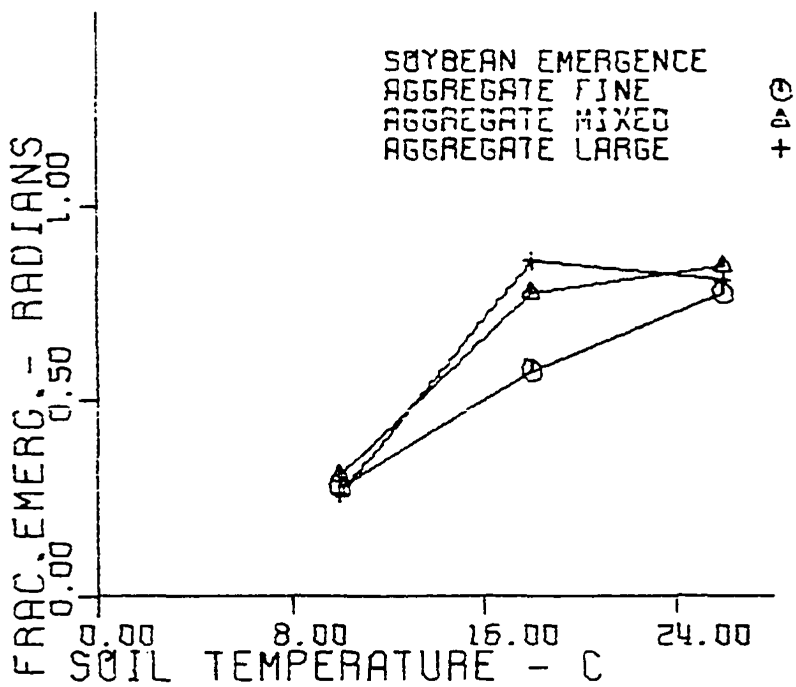


Fig. 27. Effect of soil temperature and initial aggregate size on arc sine of square root of fraction of soybeans emerged

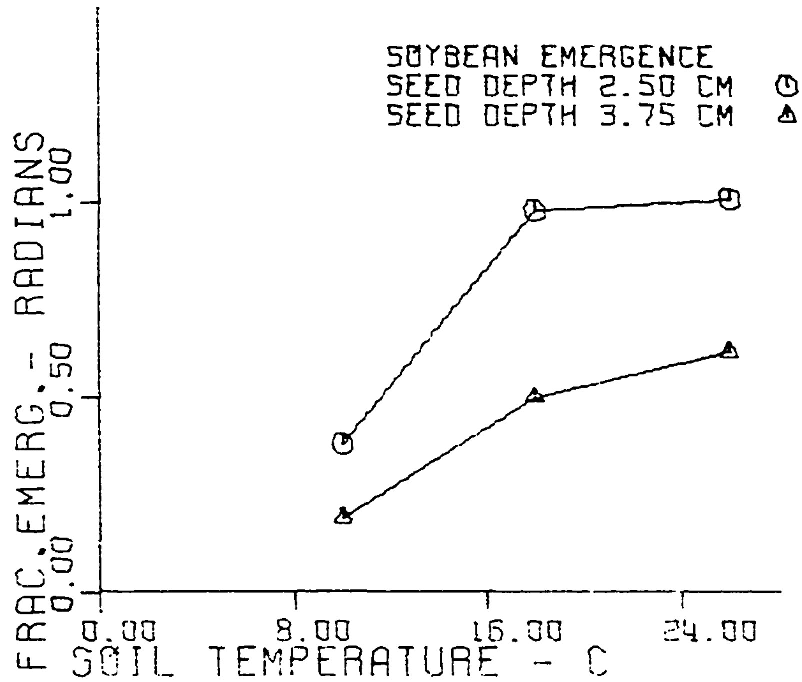


Fig. 28. Effect of soil temperature and seed depth on arc sine of square root of fraction of soybeans emerged

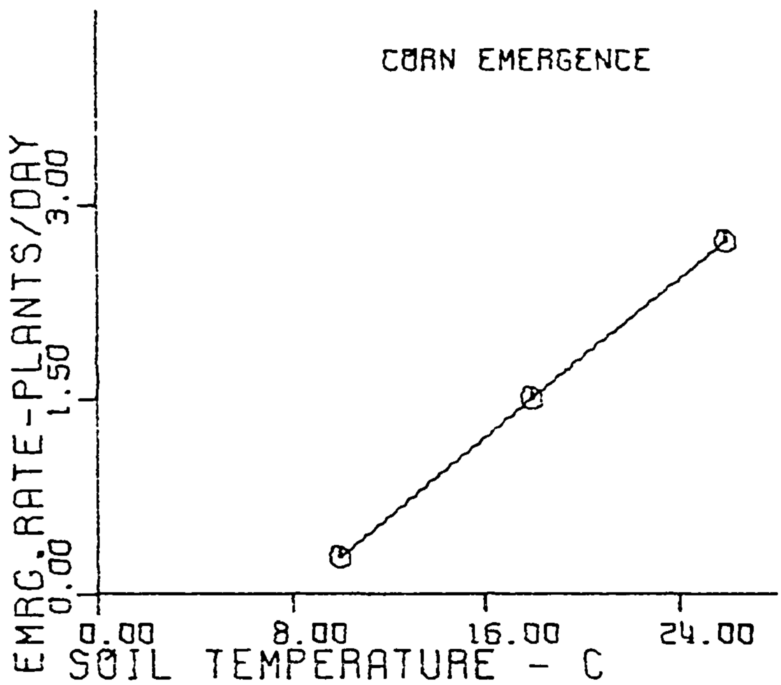


Fig. 29. Effect of soil temperature on corn emergence rate

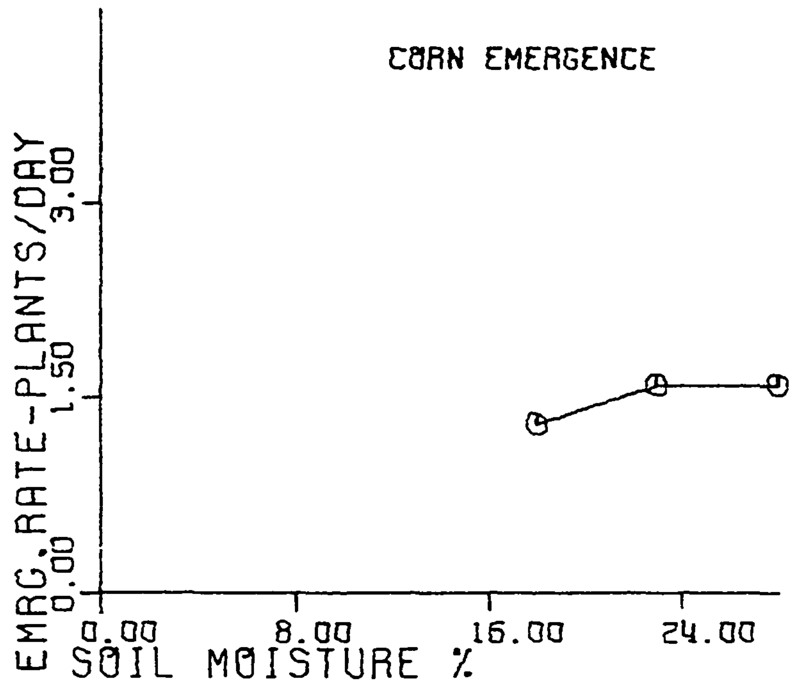


Fig. 30. Effect of soil moisture on corn emergence rate

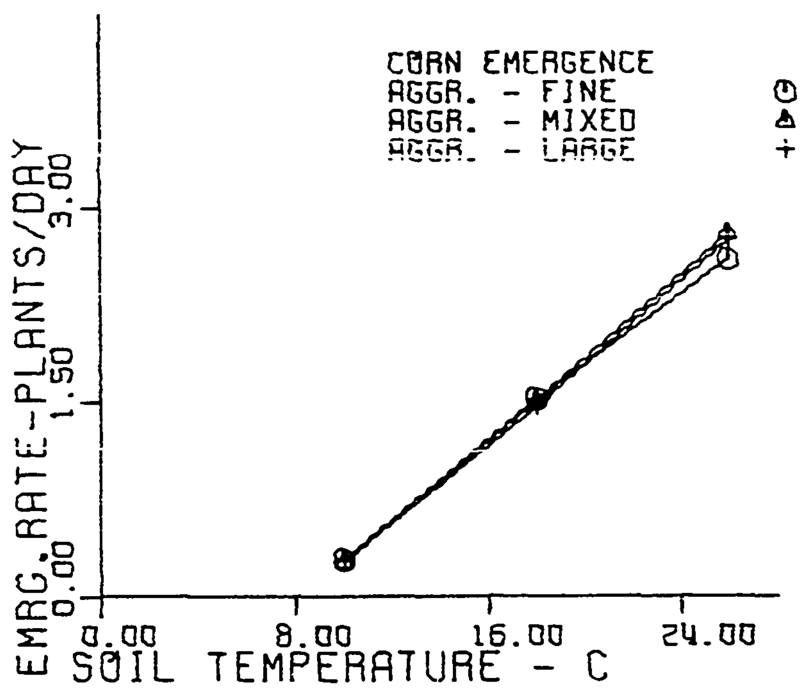


Fig. 31. Effect of soil temperature and initial aggregate size on corn emergence rate

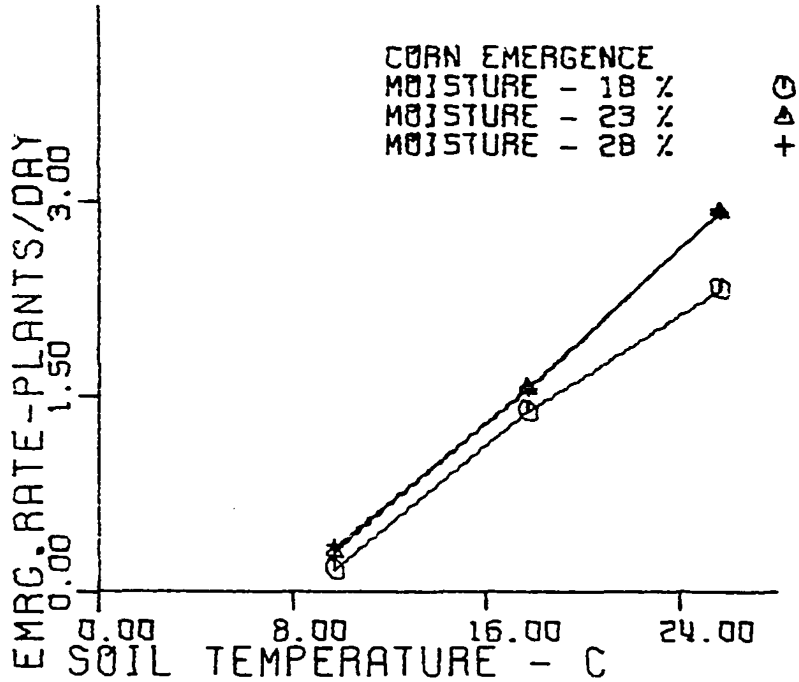


Fig. 32. Effect of soil temperature and soil moisture on corn emergence rate

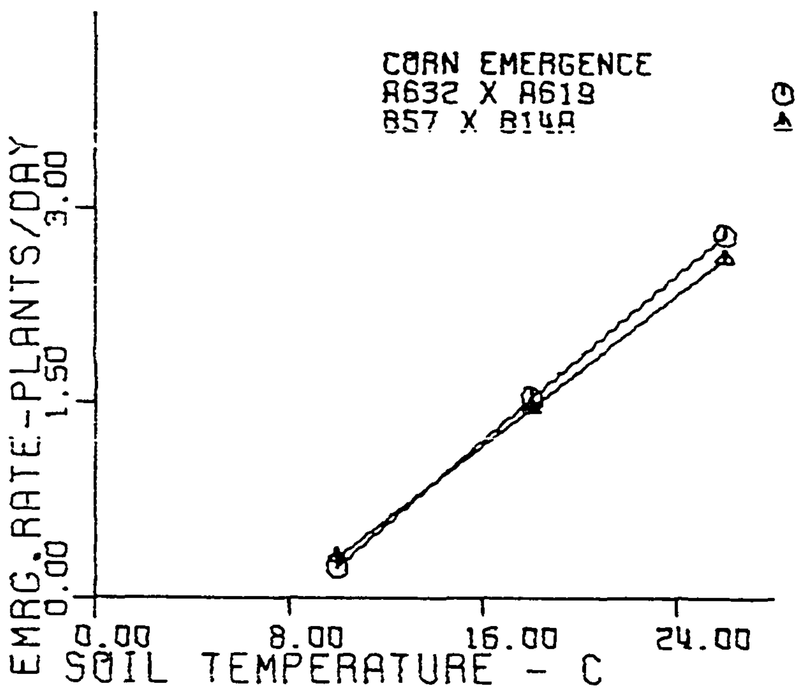


Fig. 33. Effect of soil temperature and variety on corn emergence rate

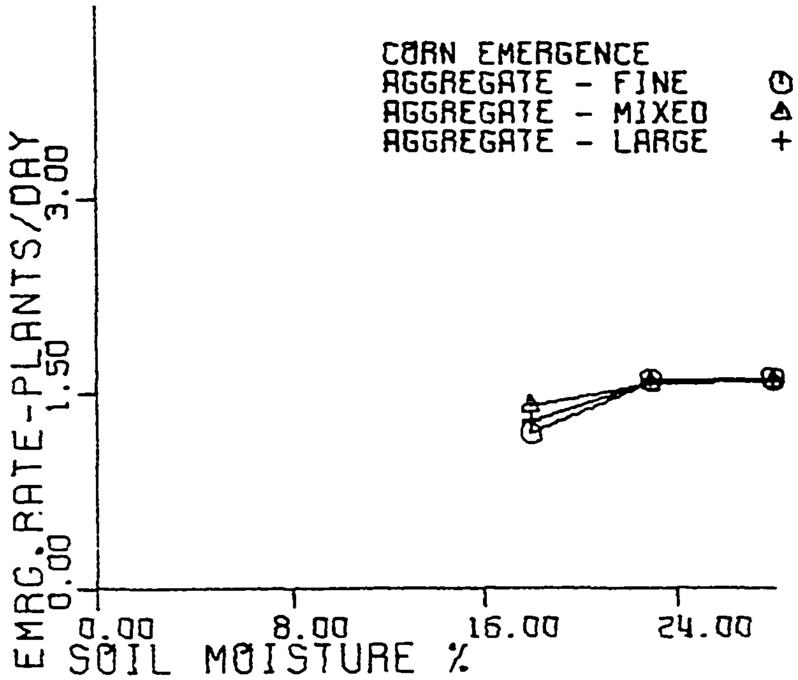


Fig. 34. Effect of soil moisture and initial aggregate size on corn emergence rate

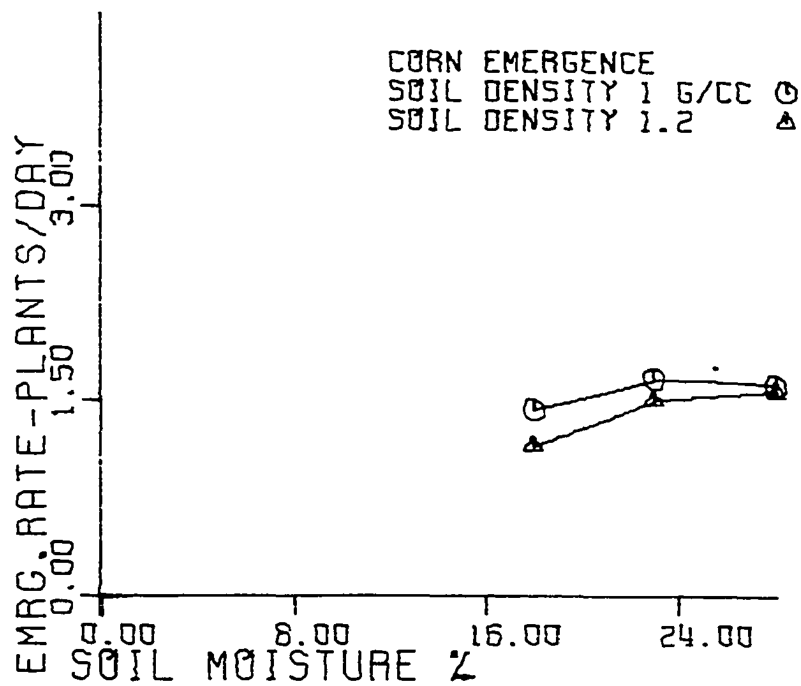


Fig. 35. Effect of soil moisture and soil density on corn emergence rate

There was a significant interaction of temperature and density on emergence rate of soybeans. From Table C-5 the orthogonal contrasts indicate the interaction was between temperature linear and soil density. Figure 23 shows that an increase in soil density from 1.0 to 1.2 g/cm^3 had little influence on soybean emergence rate at 10C but the rate of emergence was reduced by increasing soil density from 1.0 to 1.2 g/cm^3 at 26C.

There was also a significant interaction of soil temperature and depth of planting. The orthogonal contrasts of Table C-5 indicates the interaction of temperature linear by depth was significant. Figure 24 shows that planting depth had little effect on the rate of emergence at 10C but increasing the planting depth from 2.5 to 3.75 cm reduced the rate of emergence at 18 and 26C.

The two varieties, Amsoy and Corsoy responded differently to changes in moisture. The orthogonal contrasts (Table C-5) indicate this interaction was moisture linear by variety. Figure 25 shows that emergence rate of Amsoy decreased as moisture increased from 18 to 28% but the emergence rate of Corsoy increased as moisture increased from 18 to 28%. It is apparent from Fig. 25 that if the two varieties are averaged, moisture had little effect on rate of emergence. The effect of moisture on the emergence rate of the two varieties may not have been a moisture effect at all. The levels of moisture influenced soil structure characteristics, mean pore diameter, pore diameter variance, phase intercept mean, matrix intercept mean and matrix intercept variance. It is possible that the response of varieties is really a reaction to soil structure and not soil moisture.

Depth of planting significantly affected emergence rate. Emergence rate averaged over all other factors decreased from 86.4 plants/day for planting depth of 2.5 cm to 36.5 plants/day for planting depth of 3.75 cm. With only two planting depths, there was not sufficient information to determine if the effect of planting depth on emergence rate was linear or quadratic.

Sheikh (1972) showed that a curvilinear relationship existed between planting depth and percent of soybeans emerged.

Soil density affected emergence rate. The emergence rate of soybeans decreased from 79 plants/day to 44 plants/day as density increased from 1.0 to 1.2 g/cm^3. This indicates that compacting soil at planting time with a packing wheel may be detrimental to seedling emergence.

Soybeans - fraction emerged transformation

The fraction of soybeans emerged data were transformed to arc sine of the square root of the fraction emerged and expressed in radians. In this section the dependent variable, arc sine of the square root of the fraction emerged will be referred to as E_{fs} and expressed in radians. To obtain fraction emerged from E_{fs}, find the sine of the angle E_{fs} (expressed in radians) and square it.

The analysis of variance for E_{fs} is listed in Table C-2 of Appendix C. Orthogonal contrasts were made as they were for emergence rate and are shown in Table C-6 of Appendix C.

Figure 26 shows that temperature effect cannot be described by linear effects alone. E_{fs} increased as temperature increased but the magnitude of increase was much larger from 10 to 18C than from 18 to 26C.

The size of initial aggregates affected E_{fs}. The E_{fs} for fine initial aggregates was 0.55, E_{fs} for mixed aggregates was 0.64 and E_{fs} for large aggregates was 0.60. This may be a reflection of soil strength, seed soil contact and transfer of moisture through the soil. Measurements were not made of soil strength, seed soil contact or moisture transfer in the soil so the delineation of the exact effect of soil size on E_{fs} was not possible. It is important to recognize that aggregate size and size distribution affected soybean emergence.

The effect of temperature on E_{fs} was dependent on the aggregate size. Figure 27 shows a plot of E_{fs} vs temperature for the three aggregate sizes used. This result indicates that the optimum size distribution of aggregates to obtain a maximum number of soybean seedlings is dependent on the temperature of the seed environment. The size distribution that is appropriate of one temperature is not necessarily the appropriate distribution for another soil temperature.

The influence of temperature on E_{fs} was also dependent on depth of planting. Figure 28 shows that the 2.5 cm depth had a larger E_{fs} and therefore a larger percent of soybeans emerged at every temperature than for the planting depth 3.75 cm. The practical application of this interaction is that for predicting soybean emergence including a term for temperature and a term for planting depth is not sufficient. There must also be a term for the interaction.

Both compaction of soil from 1.0 to 1.2 g/cm^3 and increasing planting depth from 2.5 to 2.75 decreased E_{fs} but there was an interaction of planting and soil density on E_{fs}. Increasing planting depth from 2.5 to 3.75 cm at a soil density of 1.0 g/cm^3 decreased E_{fs} from 0.88 to 0.63, but increasing planting depth from 2.5 to 3.75 cm at a soil density of 1.2 g/cm^3 decreased E_{fs} from 0.71 to 0.23.

A harsh environment of either planting deep or compacting the soil reduced the total number of seedlings emerged but the combination of both planting deep and compacting the soil was much worse than the simple effects of planting deep and compacting soil

The soybean seedling appears to generate the emergence force to emerge from a shallow planted compacted soil by but not the energy to maintain that force for the longer time required to emerge from deeper depth.

Corn - emergence rate

The analysis of variance for emergence rate of corn is shown in Table C-3 of Appendix C. The orthogonal contrasts are listed in Table C-7 of Appendix C.

The effect of temperature was almost a perfect linear effect. Figure 29 shows the temperature effect. This linear effect is consistent with Lehenbauer's (1914) findings. The effect of temperature was dependent on soil aggregate size, soil moisture and corn variety.

Soil moisture had a quadratic effect on emergence rate. Figure 30 shows the effect of soil moisture. The effect of soil moisture on emergence rate was dependent on soil temperature, initial aggregate size and soil density. It is important to note that the effects due to changes in moisture may really have been due to changes in soil structure.

Figure 31 shows the interaction of temperature and initial aggregate size on emergence rate. At 10C, the initial aggregate size did not make much difference but at 26C there was a significant difference. The small aggregates reduced the emergence rate at 26C.

Figure 32 shows the moisture and temperature interaction. For 23 and 28% soil moisture content, the response to temperature was the same. When soil moisture level was 18% the increase of emergence rate with temperature was reduced, especially for increases in temperature near 26C. This was probably a result of seedlings using water at a higher rate due to increased growth rate at 26C. At 18% moisture and at 26C moisture limited seedling growth.

The two varieties responded differently to changes in temperature. Figure 33 shows that B57XB14A had a higher emergence rate at 10C than A632XA619 but A632XA619 had a higher emergence at 18 and 26C. This indicates that there are some genetic factors controlling the response of corn to environmental conditions. Mock and Eberhart (1972) found that cold-tolerance can be developed by selection within adapted maize populations.

The size of initial aggregates influenced the effect of soil moisture on emergence rate. Again it should be recognized that soil structure and soil moisture were confounded and apparent responses to moisture may really be responses to soil structure. Figure 34 shows that the initial aggregate size did not change the emergence rate for 23 and 28% moisture but at 18% moisture the mixed aggregates produced the best emergence rate.

Figure 35 shows the interaction of moisture and compaction on emergence rate. An increase in soil density from 1.0 to 1.2 g/cm^3 reduces the rate of emergence for all levels of moisture but compaction was most critical at 18% moisture.

Corn - fraction emerged transformation

The analysis of variance for the square root of the fraction of corn emerged, E_{fs}, is shown in Table C-4 of Appendix C. Orthogonal contrasts for significant factors are listed in Table C-8 of Appendix C. From the mean squares of the orthogonal contrasts for temperature, it is apparent that linear and quadratic terms are needed to describe the influence of temperature on E_{fs}. The effects of temperature on E_{fs} are dependent on soil moisture, soil density, planting depth and variety.

Figure 36 shows the effect of temperature on E_{fs}. Figure 36 indicates there is an optimum temperature for corn seedling emergence. The optimum temperature is dependent on soil density, soil moisture, planting depth and variety.

Figure 37 shows the effect of moisture on E_{fs}. The influence of moisture was confounded with soil structure. The influence of moisture shown in Fig. 37 may actually have been due to changes in soil structure.

The interaction of soil temperature and soil moisture was significant at the 1% level. Figure 38 shows the interaction of moisture and temperature. The percent of plants emerged was approximately the same for all soil moistures at 18 and 26C but at 10C the low moisture depressed plant emergence. This type of effect seemed to occur often regardless of the type of seed or the method of measuring plant response. One environmental factor depressed plant response and even stop

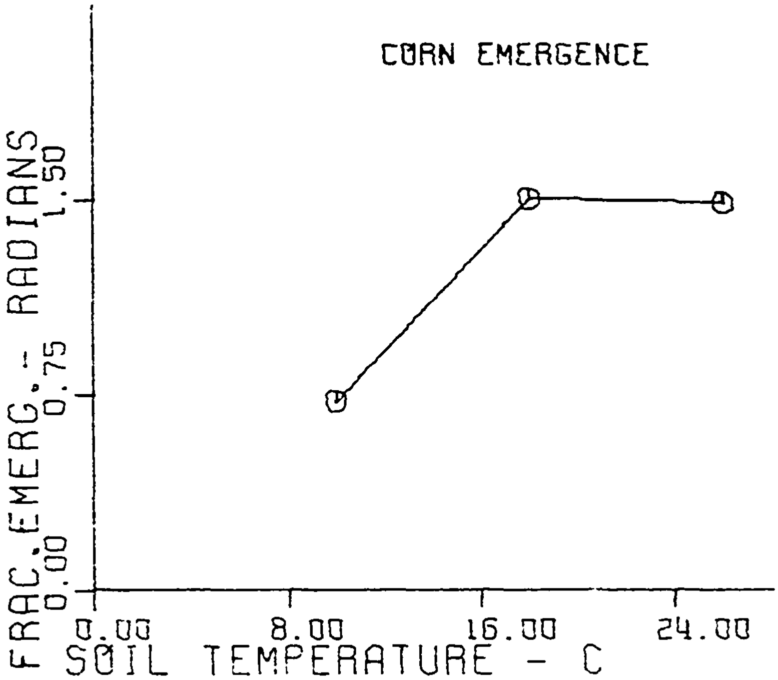


Fig. 36. Effect of soil temperature on arc sine of square root of fraction of corn emerged

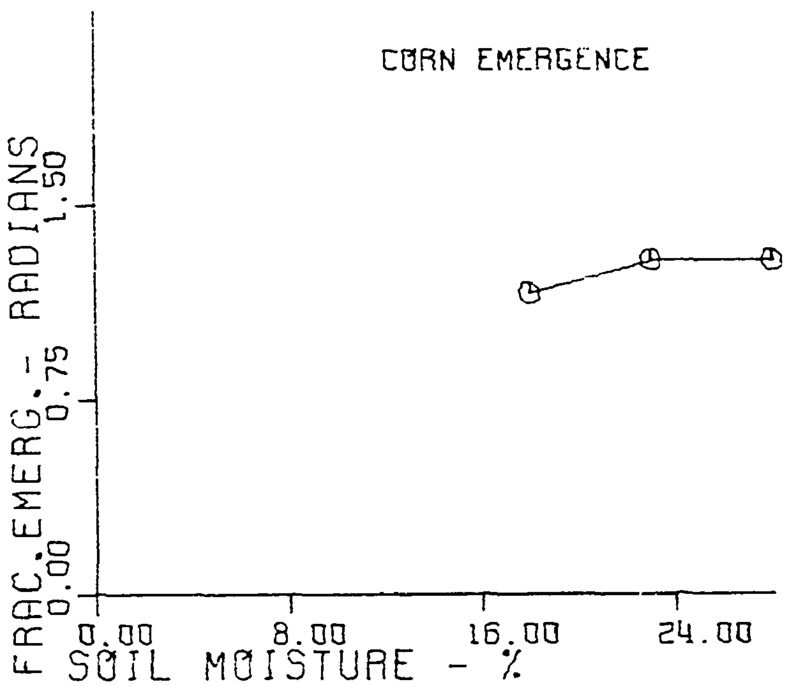


Fig. 37. Effect of soil moisture on arc sine of square root of fraction of corn emerged

plant growth but the presence of two or more harsh conditions such as low moisture and low temperature usually resulted in a greater growth depression than would be expected. This points out the importance of including several environmental factors in the same test. Tests conducted with all variables held constant but one have limited application because interactions did affect corn emergence in these studies.

Figure 39 shows the interaction of soil temperature and soil density on E_{fs}. Increasing soil density from 1.0 to 1.2 g/cm^3 did not affect the percent of plants emerged at 18 and 26C but at 10C the increase in density from 1.0 to 1.2 g/cm^3 depressed plant emergence. This is another example of two harsh environmental conditions resulting in an extreme depression in plant response.

Figure 40 shows the effect of soil temperature and planting depth on E_{fs}. This result was similar to the effect of soil temperature and density. At the high temperatures, increasing planting depth from 2.5 to 3.75 cm did not decrease E_{fs} significantly but at 10C the increase in planting depth resulted in a significant reduction of plants emerged.

Varieties responded differently to changes in temperature. Figure 41 shows the response of the two varieties to changes in temperature. A632XA619 had better emergence at 18 and 26C than B57XB14A but B57XB14A had a higher emergence than A632XA619 at 10C.

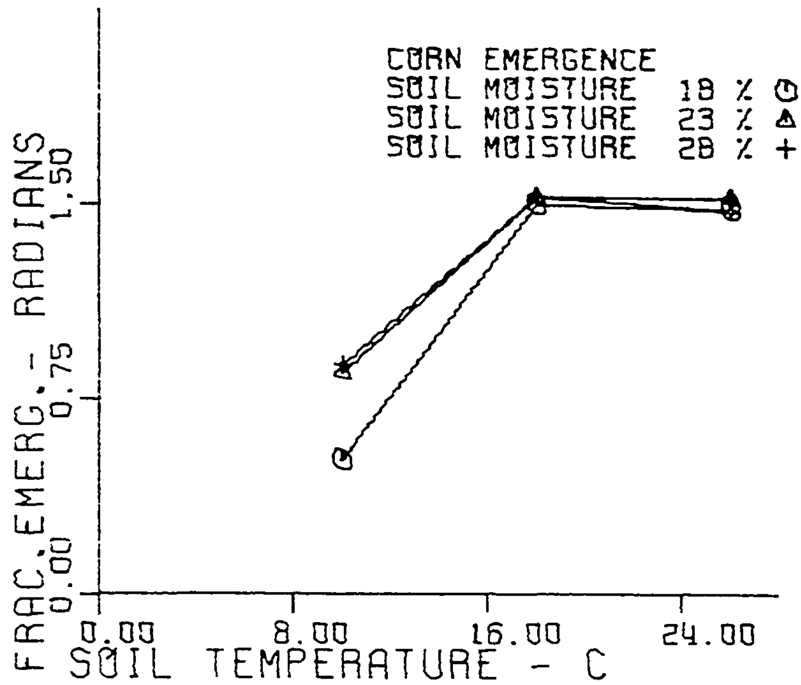


Fig. 38. Effect of soil temperature and soil moisture on arc sine of square root of fraction of corn emerged

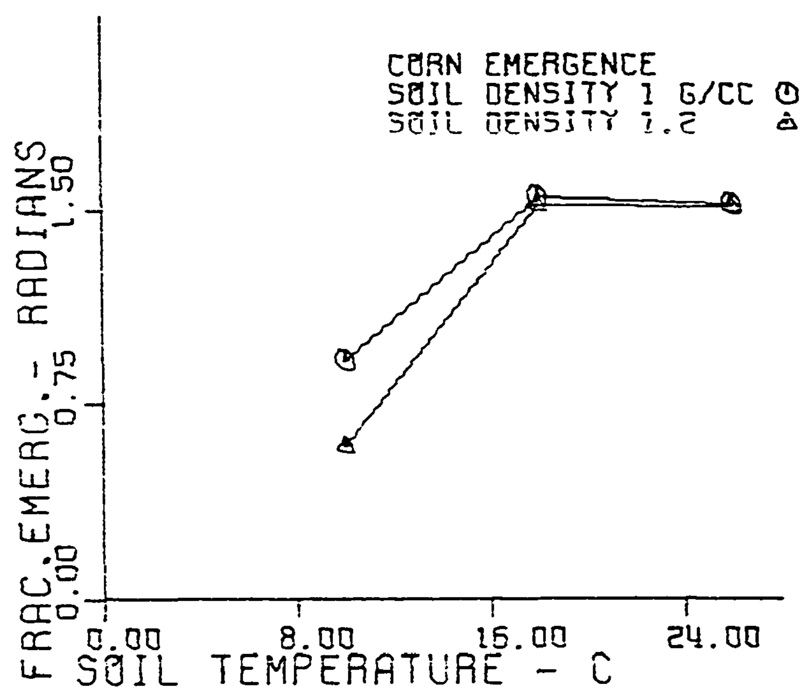


Fig. 39. Effect of soil temperature and soil density on arc sine of square root of fraction of corn emerged

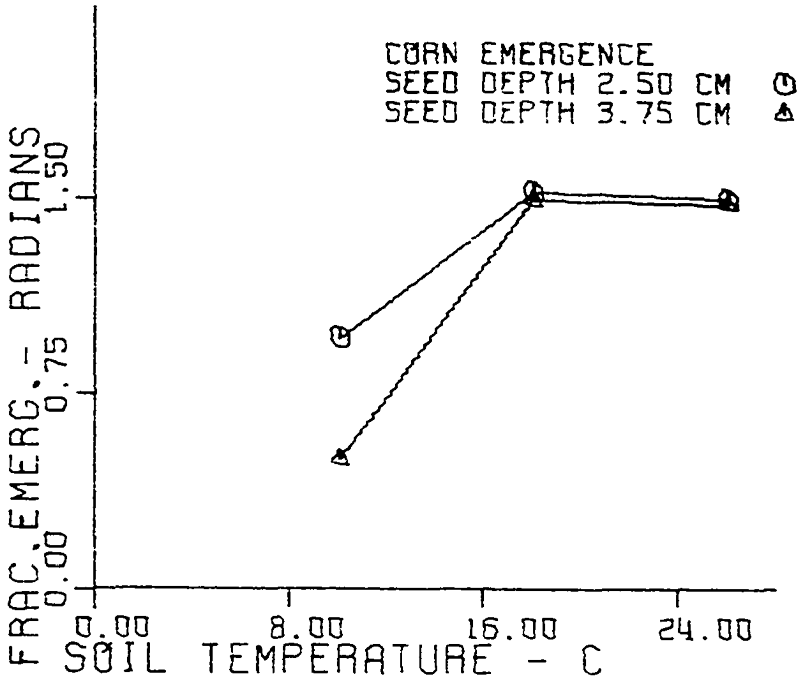


Fig. 40. Effect of soil temperature and seed depth on arc sine of square root of fraction of corn emerged

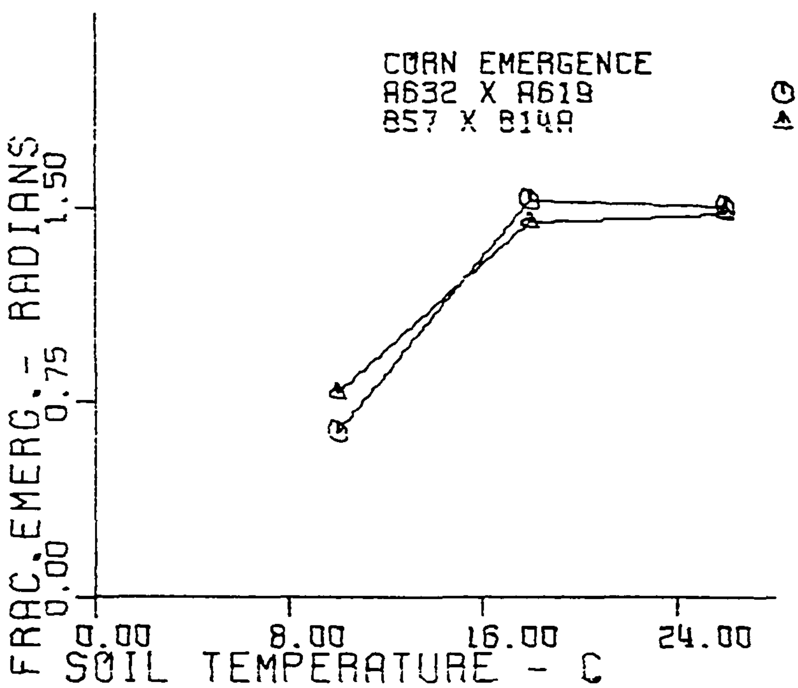


Fig. 41. Effect of soil temperature and variety on arc sine of square root of fraction of corn emerged

Both soil density and planting depth averaged over all other factors significantly affected E_{fs}. Increasing soil density from 1.0 to 1.2 g/cm^3 reduced the percent of seedlings emerged. Increasing planting depth from 2.5 cm to 3.75 cm reduced the percent of seedlings emerged.

Prediction Equations

Prediction of corn emergence for field conditions

From the Statistical Analysis Systems (Service, 1972) the stepwise regression procedure was used to regress emergence rate and arc sine of square root of fraction emerged on soil temperature, soil moisture, planting depth, soil density, penetrometer cone index, the squares of these factors and all the second order interactions. The stepwise regression procedure enters one variable at a time provided it is significant at the 0.50% level. After entering a variable, a check is made to assure that those variables currently in the model are significant at the 0.10% level. Any variable not meeting this requirement is deleted from the model.

The regression equation for emergence rate of the field data was

$$E_{rc} = 95.24 + 6.66(D)(\rho^2)$$

where D = planting depth - cm

ρ = soil density - g/cm^3.

The coefficient of determination, r^2, was equal to 0.17. The regression coefficient 6.66 was significant at the 1% level for the hypothesis $\beta = 0$.

The regression equation for the arc sine of the square root of the fraction emerged was

$$E_{fc} = 0.40 + 0.034(D)(\rho^2) + 0.00002(T^2)(M) + 0.15(\rho^2)$$

where D = planting depth - cm

ρ = soil density - g/cm^3

T = soil temperature - C

M = soil moisture - % (oven dry basis).

The coefficient of determination, r^2, was equal to 0.53. The coefficients for $(D)(\rho)$ and $(T^2)(M)$ were significant at the 1% level and the coefficient for ρ^2 was significant at the 5% level for the hypothesis $\beta = 0$.

These equations show the extreme differences in field and laboratory emergence conditions. The field conditions were dynamic and the laboratory were static. Soil drying conditions existed in the field during emergence and moisture increased with depth. The soil temperatures and soil moistures were held relatively constant during laboratory tests. In the laboratory emergence tests, increasing soil density and planting depth decreased seedling emergence rate and fraction of seedlings emerged. The regression for E_{rc} and E_{fc} for field conditions indicate that both E_{rc} and E_{fc} increased as soil density and planting depth increase. These conditions are probably a reflection on soil moisture.

Prediction of seedling emergence based on soil structure parameters

The coefficients for the regression of emergence rate, E_r, and arc sine of the square root of fraction emerged, E_f, on soil structure parameters are shown in Tables 35 and 36. The six data sets from the laboratory emergence tests were averaged over replications, varieties and planting depths. There were 18 degrees of freedom for each data set (3 levels of moisture, 2 levels of soil density and 3 initial aggregate sizes). During the addition of moisture to the soil to obtain moisture levels of 18, 23 and 28% the soil became sticky and different soil structures resulted. Therefore, moisture effects and soil structure effects were confounded. The analysis of variance for the emergence tests, Tables C-1, C-2, C-3 and C-4 of Appendix C, shows that moisture did not significantly influence E_r and E_f for the soybean tests. Moisture did significantly affect corn E_r and E_f. The regression equations for E_f and E_r for soybeans reflect effects due to soil structure but the equations for E_f and E_r for corn contain effects of both moisture and soil structure.

Tables 35 and 36 show that the parameters of soil structure measured by moisture desorption and FSPA scanning technique significantly influenced seedling emergence. This

Table 35. Regression coefficients and coefficients of determination, r^2, for regression of emergence rate and arc sine of the square root of fraction emerged for corn and soybeans on soil structure parameters

Dependent variable	r^2	Overall mean μ	Regression coefficients: Phase intercept Mean μ_p β_1	Phase intercept Variance σ_p β_2	Matrix intercept Mean μ_m β_3	Matrix intercept Variance σ_m β_4	Porosity P_f β_5
$E_{fc}10$[+]	0.45	2.91			-0.51	0.97	
$E_{fc}18$		No coefficients significant at 10% level					
$E_{fc}26$	0.28	0.97			0.09*		
$E_{rc}10$	0.39	-16.1	-13.3*		21.5		
$E_{rc}18$	0.53	148.3	-19.0		20.4		
$E_{rc}26$	0.59	96.1	-43.7		75.9		
$E_{fs}10$	0.60	2.03	-0.38			0.61	
$E_{fs}18$	0.37	0.28				0.45	
$E_{fs}26$		No coefficients significant at 10% level					
$E_{rs}10$	0.52	56.7	-10.6			16.3	
$E_{rs}18$	0.63	251.1				-44.4	-133.0*
$E_{rs}26$	0.23	333.0			-65.5*	111.7*	

[+]The subscripts 10, 18 and 26 represent the temperatures of the data sets. The subscripts c and s represent corn and soybean data sets. The subscripts f and r represent tranformed fraction emerged and emergance rate.

*Indicates coefficients significant at 5% level for hypothesis $\beta = 0$. All other coefficients are significant at 1% level.

Table 36. Regression coefficients and coefficients of determination, r^2, for regression emergence rate E_r and arc sine of the square root of fraction emerged E_f for corn and soybeans on soil pore characteristics

		Regression coefficients			
		Overall mean	Pore diameter		Porosity
			Mean	Variance	
Dependent			μ_D	σ_D	P_D
variable	r^2	μ_0	β_1	β_2	β_3
E_{fc} 10[+]	0.43	-1.55			4.00
E_{fc} 18	0.23	1.27			0.43*
E_{fc} 26	0.37	1.00	0.085		
E_{rc} 10	0.41	-6.91			170.0
E_{rc} 18	0.51	11.7		18.2*	206.5*
E_{rc} 26	0.41	6.8	46.4		
E_{fs} 10	0.67	-1.39			2.95
E_{fs} 18	0.70	-1.70	0.18*		2.47
E_{fs} 26	0.39	-0.76			2.76
E_{rs} 10	0.65	-41.0			84.5
E_{rs} 18	0.61	-139.9			344.5
E_{rs} 26	0.42	130.8		-60.4	

[+]The subscripts 10, 18 and 26 represent the temperatures of the data sets. The subscripts c and s represent corn and soybean data sets. The subscripts f and r represent transformed fraction emerged and emergence rate.

*Indicates coefficients significant at 5% level for hypothesis $\beta = 0$. All other coefficients are significant at the 1% level.

is a significant finding in the case for soybeans where the effect is due to soil structure. This indicates tillage can influence soybean seedling emergence by altering soil structure.

A comparison of the coefficients of determination shows that the moisture desorption parameters in most cases had larger values than the FSPA scanning technique. This indicates that the desorption parameters account for a larger portion of the variation in seedling emergence than the FSPA scanning parameters.

For the FSPA scanning technique, the sign of the coefficient associated with mean phase intercept was always negative when that factor was significant. This indicates that an increase in mean phase intercept decreases seedling emergence rate or percent of emergence. The mean matrix intercept coefficient was negative for some cases and positive for other cases. The phase intercept variance was not significant for any of the data sets. Porosity as measured by the FSPA method was significant only for soybean emergence rate at 18C.

The porosity as measured by the moisture desorption technique was significant and had a positive coefficient for 10 and 18C. The positive coefficient associated with porosity indicates that increasing the density of soil significantly reduces E_r and E_f for both soybeans and corn. The desorption technique is not necessary to obtain a measure of porosity. Porosity can be calculated from bulk density and particle density.

It is interesting to note that the coefficients of determination are generally the highest for the low temperatures. This means soil structure becomes more important to seedling emergence as the temperature decreases (the environment became harsher).

Prediction of seedling emergence from soil physical factors

Table 37 lists the regression coefficients for the soil physical factors and their interactions that were found to be significant at the 1% level (Tables C-1 through C-8 of Appendix C). Table 37 shows that interactions are significant to the process of seedling emergence. Of these interactions for predicting E_{rc}, E_{rs}, E_{fc} and E_{fs} all but one of them contain a temperature factor. The interactions must be considered to interpret the results in Table 37. An example of their importance is the equation for E_{rs}. If only the coefficients for depth of planting, D, and soil density, ρ, are considered, it would appear that increasing ρ and increasing D would increase E_{rs}. If all the coefficients are considered in which D and ρ appear, then the total effect of D and ρ on E_{rs} results in decreasing E_{rs} as D and ρ increase.

Based on the sums of squares (Table C-3 of Appendix C) soil temperature, soil moisture, planting depth and soil density were included in a simplified regression equation for predicting E_{rc}. The coefficient of determination was almost as high for the simplified equation as the equation containing

Table 37. Regression coefficients for regression of emergence rate and arc sine of square root of fraction emerged of corn and soybeans on soil physical factors

Factor	Coefficient	Regression coefficients: Emergence rate: Corn E_{rc}^{+}	Emergence rate: Corn E_{rc}	Emergence rate: Soybeans E_{rs}	Fraction emerged: Corn E_{fc}	Fraction emerged: Soybeans E_{fs}
	μ_{ij} 0	-367.4	599.0	-363.3	7.288	-1.01
T^{++}	β_{ij} 1	15.26	-22.3**	41.0	-0572	0.44
T^2	β_{ij} 2		-	-	0.014	-0.01
M	β_{ij} 3	30.18	-46.9	-	0.056	-
M^2	β_{ij} 4	-0.59	0.89	-	-	-
D	β_{ij} 5	-13.19	-13.1	34.7	-1.27	0.56
ρ	β_{ij} 6	-80.43	-346.3	169.7	-5.38	-1.43
(T)(M)	β_{ij} 7		4.23	-	-0.0024	-
$(T)(M^2)$	β_{ij} 8		-0.11	-	-	-
$(T^2)(M)$	β_{ij} 9		-0.03	-	-	-
$(M)(\rho)$	β_{ij} 10		11.53	-	-	-
(T)(D)	β_{ij} 11		-	-4.11	0.11	-0.094
$(T^2)(D)$	β_{ij} 12		-	-	-0.0026	0.0024
$(T)(\rho)$	β_{ij} 13		-	-18.99	0.483	-
$(T^2)(\rho)$	β_{ij} 14		-	-	-0.011	-
Coefficient of determination		0.95	0.96	0.73	0.70	0.54

+Simplified equation for corn.

++The letter symbols are as follows: T=temperature - C, M=moisture %, D=planting depth - cm and ρ=soil density -g/cm^3.

**The coefficients in this table are significant at the 1% level for hypothesis $\beta = 0$.

the interaction factors (Table 37).

The coefficient of determination, r^2, is a measure of the amount of variation accounted for by regression. The coefficients of determination for regression equations of emergence rate were 0.96 and 0.73 as compared to 0.70 and 0.54 for the regression equations of arc sine of square root of fraction emerged. This indicates the new method of describing seedling emergence as emergence rate is more sensitive to the effects of soil physical factors on seedling emergence than fraction of seedlings emerged for the conditions studied.

SUMMARY

Field Experiment

A field experiment was conducted to observe problems associated with seedling emergence and to evaluate the effects of soil physical factors on corn emergence. Ten different tillage systems and two types of planter packing wheels were used to provide a variation in soil physical factors. Soil temperature, soil moisture, planting depth, penetrometer cone index, soil density, soil pore and aggregate size characteristics, porosity, weed infestation, stand counts and grain yield were measured. Reasons for lack of emergence were noted for each treatment. Tillage and type of packing wheel were found to influence stand. Of the soil physical factors measured, only soil temperature, soil moisture, soil density and planting depth affected seedling emergence.

Soil Structure Measurements

A technique was developed to quantify soil pore size, soil aggregates size and their orientation. The technique consisted of fixing soil with a fluorescent polyester resin, sectioning the soil, obtaining a photograph with black light that contrasted soil pores and aggregates and scanning the film with a Flying-Spot Particle Analyzer (FSPA). The FSPA provided information regarding the distribution of pore and aggregate sizes. From these distributions the mean and variance of aggregate size (phase intercept mean and variance), the mean and variance of pore size (matrix intercept mean and variance) and porosity were calculated.

These soil structure parameters were related to corn and soybean seedling emergence and compared to soil structure characteristics measured by moisture desorption.

Soybean and corn seedling emergence was found to be influenced by soil structure. The two methods of measuring soil structure accounted for approximately the same amount of variation in seedling emergence due to soil structure effects.

Emergence Experiment

An experiment was conducted to evaluate the effects of soil physical factors on corn and soybean seedling emergence and to provide data for development of equations for predicting emergence.

The experimental treatments consisted of three levels of soil temperature (10, 18 and 26C), three levels of soil moisture 18 (approximately 15 atm. tension) 23 and 28% (approximately 1/3 atm. tension), three initial aggregate sizes, two soil densities, two types of seed (corn and soybeans), two varieties (corn - A632XA619 and B57XB14A, soybeans - Amsoy and Corsoy) and two replications.

Observations were made every eight hours noting the total number of plants emerged for each experimental unit. From these data, emergence rate, a new method was developed in this research to describe seedling emergence, and fraction of seedlings emerged were calculated. The new method was found to describe seedling emergence better than fraction emerged. Corn emergence was found to increase with soil temperature and soil moisture and to decrease as planting depth and soil density increased. Soybean emergence increased as the temperature increased and decreased as planting depth and soil density increased.

CONCLUSIONS

Field Experiment

1. Tillage systems had little or no influence on soil aggregate size, soil aggregate variance, or porosity as measured with the Flying-Spot Particle Analyzer scanning technique.
2. Tillage systems which ranged from "clean tilled" to no primary or secondary tillage, had little or no influence on the number of corn seedlings killed at emergence by wire worms (*Melanotus cribulosus*) or black cut worms (*Agrotis ypsilon*).
3. The rib packing wheel treatment resulted in higher moisture in the top 7.5 cm of soil in the row for the first 3 days following planting, a lower soil temperature at 7.5 cm depth in the row (except for the first 24 hours following planting) during emergence, a higher cone index in the row for the top 5 cm of soil, a shallower planting depth, a higher stand on the first day of emergence and lower stand thereafter as compared to a concave packing wheel.
4. The field conditions studied, the arc sine of the square root of the fraction of corn emerged better described seedling emergence than emergence rate.

Soil Structure Experiment

1. The technique developed for measuring soil structure characteristics by scanning films that contrasted non-capillary pores and soil aggregates with a Flying Spot Particle Analyzer provided a method for making direct measurements of noncapillary pore and aggregate size characteristics and orientation.
2. For the conditions studied, the process of forming soil samples by compressing soil in right circular cylinders resulted in oriented noncapillary pores and aggregates. The void and aggregate were longer and more uniform perpendicular to the direction of compression force than parallel to the direction of compression force.
3. Increasing soil density from 1.0 to 1.2 g/cm^3 increased the aggregate size, decreased pore size and increased the uniformity of the pore size.

Emergence Experiments

1. Emergence rate described the process of corn and soybean seedling emergence under controlled soil physical factors better than arc sine of the square root of the fraction emerged.

2. Corn and soybean seedling emergence rates were significantly influenced by soil structure characteristics measured by the Flying-Spot Particle Analyzer scanning technique and the moisture desorption technique.
3. The soil structure characteristics measured with the Flying-Spot Particle Analyzer scanning technique accounted for approximately the same amount of variation in seedling emergence as the parameters measured by moisture desorption.

Prediction Equations

1. Under controlled laboratory conditions, emergence rate of corn and arc sine of square root of fraction emerged were found to be a function of soil temperature, soil moisture, planting depth and soil density. Emergence rate and arc sine of square root of fraction emerged increased with soil temperature and soil moisture and decreased as planting depth and soil density increased.
2. The emergence rate of soybeans and arc sine of the square root of fraction emerged were found to be functions of soil temperature, planting depth and soil density. Emergence rate increased with temperature, and decreased as soil density and planting depth increased. Arc sine of the square root of the fraction emerged, decreased as planting depth and soil density increased. Arc sine of the square root of the fraction emerged increased to a maximum at about 20C then decreased as temperature was varied from

10 to 26C.

3. Under the field conditions, the emergence rate of corn was found to increase with planting depth and soil density. The arc sine of the square root of the fraction emerged increased with planting depth, soil density, soil temperature and soil moisture.

REFERENCES

Aldrich, S. R., and E. R. Leng. 1965. Modern corn production. The Farm Quarterly, Cincinnati, Ohio.

Allan, R. E., O. A. Vogel, and C. J. Peterson. 1962. Seedling emergence rate of fall-sown wheat and its association with plant height and coleoptile length. Agron. J. 54:347-350.

Allmaras, R. R., R. E. Burnell, W. B. Voorhees, and W. E. Larson. 1965. Aggregate size distribution in the row zone of tillage experiments. Soil Sci. Soc. Amer. Proc. 29:645-650.

Allmaras, R. R., W. C. Burrows, and W. E. Larson. 1964. Early growth of corn as affected by soil temperature. Soil Sci. Soc. Amer. Proc. 28:271-275.

Amer. Soc. Agric. Engrs. 1972. A.S.A.E. recommendation: ASAE R313, pp. 319-320. In Agric. Engrs. Yearbook. Amer. Soc. Agric. Engrs., St. Joseph, Mich.

Baver, L. D. 1932. The physical properties of soil of interest to agricultural engineers. Amer. Soc. Agric. Engrs., Trans. 26:68-71.

Blacklow, W. M. 1972. Influence of temperature on germination and elongation of the radicle and shoot of corn (*Zea mays* L.). Crop Sci. 12:647-650.

Bowen, H. D. 1966. Measurement of edaphic factors for determining planter specifications. Amer. Soc. Agric. Engrs., Trans. 9:725-735.

Bowen, H. D., and C. G. Coble. 1967. Environmental requirements for germination and emergence, pp. 10-14. *In* Tillage for Greater Crop Production. Amer. Soc. Agric. Engrs., St. Joseph, Mich.

Bradfield, R., and V. C. Jamison. 1938. Soil structure--attempts at its quantitative characterization. Soil Sci. Soc. Amer. Proc. 3:70-76.

Brazee, R. D., O. K. Hedden, and P. T. Keck. 1968. The U.S. Department of Agriculture flying-spot particle analyzer. Unpublished mimeograph copy. U.S. Dept. Agric., Wooster, Ohio.

Buchele, W. F. 1954. Ridge farming and plant root environment. Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Burris, J. S., O. T. Edje, and A. H. Wahab. 1969. Evaluation of various indices of seed and seedling vigor in soybeans (Glycine max (L.) Merr.) Assoc. Official Seed Analysts, Proc. 59:73-81.

Burris, J. S., A. H. Wahab, and O. T. Edje. 1971. Effects of seed size on seedling performance in soybeans. Crop Sci. 11:492-496.

Burrows, W. C. 1959. Mulch influence on soil temperature and corn growth. Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Burrows, W. C. 1963. Characterization of soil temperature distribution from various tillage-induced microreliefs. Soil Sci. Soc. Amer. Proc. 27:350-353.

Burrows, W. C., and W. E. Larson. 1962. Effect of amount of mulch on soil temperature and early growth of corn. Agron. J. 54:19-23.

Childs, E. C. 1940. The use of soil moisture characteristics in soil studies. Soil Sci. 50:239-252.

Collis-George, N., and J. B. Hector. 1966. Germination of seeds as influenced by matric potential and by area of contact between seed and soil water. Australian J. Soil Res. 4:145-164.

Dasberg, S., and K. Mendel. 1971. The effect of soil water and aeration on seed germination. J. Exp. Botany 22: 992-998.

Day, P. R. 1965. Particle-fractionation and particle-size analysis, pp. 545-567. In Methods of Soil Analysis. Amer. Soc. Agron., Madison, Wis.

Drew, L. O. 1963. The effect of soil parameters on the mechanics of emerging seedlings. Unpublished Ph.D. thesis. Library, Michigan State Univ., East Lansing.

Edje, O. T., and J. S. Burris. 1971. Effects of soybean seed vigor on field performance. Agron. J. 63:536-538.

Everson, L. E. 1970. Depth of planting soybean seed. Iowa Farm Sci. 24(9):9-11.

Fluker, B. J. 1958. Soil temperatures. Soil Sci. 86:35-46.

Gardner, W. R. 1960. Dynamic aspects of water availability to plants. Soil Sci. 89:63-73.

Gentile, Arthur C. 1971. Plant growth. The Natural History Press, Garden City, New York.

Gilman, D. F. 1972. Effects of temperature on hypocotyl elongation in soybeans (Glycine max. (L.) Merrill). Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Grabe, D. F., and R. B. Metzer. 1969. Temperature-induced inhibition of soybean hypocotyl elongation and seedling emergence. Crop Sci. 9:331-333.

Hoyle, B. J., H. Yamada, and T. D. Hoyle. 1972. Aggresizing to eliminate objectionable soil clods. California Agric. 26(11):3-5.

Hunter, J. R., and A. E. Erickson. 1952. Relation of seed germination to soil moisture tension. Agron. J. 44:107-109.

Johnson, W. H., and W. F. Buchele. 1961. Influence of soil granule size and compaction on rate of soil drying and emergence of corn. Amer. Soc. Agric. Engrs., Trans. 4: 170-174.

Johnson, W. H., and J. E. Henry. 1964. Influence of simulated row compaction on seedling emergence and soil drying rates. Amer. Soc. Agric. Engrs., Trans. 7:252-255.

Johnson, W. H., and J. E. Henry. 1967. Response of germinating corn to temperature and pressure. Amer. Soc. Agric. Engrs., Trans 10:539-542.

Kirkham, D., and W. L. Powers. 1971. Advanced soil physics. John Wiley and Sons, Inc., New York.

Klock, G. O., L. Boersma, and L. W. DeBacker. 1969. Pore size distributions as measured by the mercury intrusion method and their use in predicting permeability. Soil Sci. Soc. Amer. Proc. 33:12-15.

Kotowski, F. 1926. Temperature relations to germination of vegetable seed. Amer. Soc. Hort. Sci. 23:176-184.

Larson, W. E. 1964. Soil parameters for evaluating tillage needs and operations. Soil Sci. Soc. Amer. Proc. 28: 118-122.

Leamer, R. W., and J. F. Lutz. 1940. Determination of pore size distribution in soils. Soil Sci. 49:347-360.

Leamer, R. W., and B. Shaw. 1941. A simple apparatus for measuring noncapillary porosity on an extensive scale. Agron. J. 33:1003-1008.

Lehenbauer, P. A. 1914. Growth of mazie seedlings in relation to soil temperature. Physiol. Res. 1:247-288.

Luttrell, D. H. 1963. The effect of tillage operations on bulk density and other physical properties of soil. Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Maguire, J. D. 1962. Speed of germination aid in selection and evaluation of seedling emergence and vigor. Crop Sci. 2:176-177.

Mannering, J. V., L. D. Meyer, and C. B. Johnson. 1966. Infiltration and erosion as affected by minimum tillage for corn (Zea mays L.) Soil Sci. Soc. Amer. Proc. 30: 101-105.

Mayer, A. M., and A. Poljakoff-Mayber. 1963. The germination of seeds. The Macmillan Co., New York.

Mock, J. J. and S. A. Eberhart. 1972. Cold tolerance in adapted maize populations. Crop Sci. 12:466-469.

Moldenhauer, W. C., W. G. Lovely, N. P. Swanson, and H. D. Currence. 1971. Effect of row grades and tillage systems on soil and water losses. J. Soil Water Conserv. 26(5):193-195.

Moody, J. E., J. N. Jones, Jr., and J. H. Lillard. 1963. Influence of straw mulch on soil moisture, soil temperature and the growth of corn. Soil Sci. Soc. Amer. Proc. 27:700-703.

Morton, C. T., and W. F. Buchele. 1960. Emergence energy of plant seedlings. Agric. Engineering 41:428-31, 453-455.

Phillips, R. E. 1968. Water diffusivity of germinating soybeans, corn, and cotton seed. Agron. J. 60:568-571.

Phillips, R. E., and D. Kirkham. 1962. Soil compaction in the field and corn growth. Agron. J. 54:29-34.

Russell, M. B. 1949. Methods of measuring soil structure and aeration. Soil Sci. 68:25-35.

Samimy, C. 1970. Physiological basis for the temperature dependent short growth of hypocotyls in some varieties of soybeans. Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Scott, W. O., and S. R. Aldrich. 1970. Modern soybean production. The Farm Quarterly, Cincinnati, Ohio.

Sedgley, R. H. 1963. The importance of liquid-seed contact during the germination of Medicago tribuloides Desr. Australian J. Agric. Res. 14:646-653.

Selby, S. M. and R. C. Weast. 1970. Handbook of tables for mathematics. Chemical Rubber Co., Cleveland, Ohio.

Service, Jolayne. 1972. A user's guide to the statistical analysis system. Student Supply Stores, North Carolina State Univ., Raleigh.

Shaw, R. H., and W. F. Buchele. 1957. The effect of the shape of the soil surface profile on soil temperature and moisture. Iowa State Univ. J. of Sci. 32:95-104.

Sheikh, G. S. 1964. Soil mechanics and emergence force of plants. Unpublished M.S. thesis. Library, Iowa State Univ., Ames.

Sheikh, G. S. 1972. The mechanics of cutting equipment and emergence of seedlings. Unpublished Ph.D. thesis. Library, Iowa State Univ., Ames.

Slipher, J. A. 1932. The mechanical manipulation of soil as it affects structure. Amer. Soc. of Agric. Engrs., Trans. 26:58-60.

Steel, R. G. D., and Torrie, J. H. 1960. Principles and procedures of statistics. McGraw-Hill Book Co., Inc., New York.

Stiles, I. E. 1948. Relation of water to the germination of corn and cotton seeds. Plant Phys. 23:201-222.

Stiles, I. E. 1949. Relation of water to the germination of bean seeds. Plant Phys. 24:540-545.

Stout, B. A. 1959. The effect of physical factors on sugar beet seedling emergence. Unpublished Ph.D. thesis. Library, Michigan State Univ., East Lansing.

Taylor, G. S., and W. H. Johnson. 1956. Tillage studies with corn on an Ohio lakebed clay soil. Soil Sci. Soc. Amer. Proc. 20:274-278.

Taylor, H. M., J. J. Parker, Jr., and G. M. Roberson. 1966. Soil strength and seedling emergence relations. Agron. J. 58:393-395.

Triplett, G. B., Jr., D. M. VanDoren, Jr., and B. L. Schmidt. 1968. Effect of corn (Zea mays L.) stover mulch on no-tillage corn yield and water infiltration. Agron. J. 64:236-239.

Underwood, E. E. 1970. Quantitative stereology. Addison-Wesley, Reading, Mass.

Van Wijk, W. R. 1966. Physics of plant environment. North-Holland Publishing Co., Amsterdam.

Van Wijk, W. R., W. E. Larwon, and W. C. Burrows. 1959. Soil temperature and early growth of corn from mulched and unmulched soil. Soil Sci. Soc. Amer. Proc. 23:428-434.

Vomocil, J. A. 1965. Porosity, pp. 299-314. In Methods of Soil Analysis. Amer. Soc. of Agron., Madison, Wis.

Voorhees, W. B. 1964. A vacuum chamber for nondestructive wetting of secondary soil aggregates. Soil Sci. Soc. Amer. Proc. 28:291-292.

Willis, W. O., W. E. Larson, and D. Kirkham. 1957. Corn growth as affected by soil temperature and mulch. Agron. J. 49:323-328.

Wittmuss, H. D., and N. P. Swanson. 1964. Till-planted corn reduces soil losses. Agric. Engineering 45:256-257.

Yoder, R. E. 1937. The significance of soil structure in relation to the tilth problem. Soil Sci. Soc. Amer. Proc. 2:21-33.

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APPENDIX A: ANALYSIS OF VARIANCE OF FIELD EXPERIMENT DATA

Table A-1. Analysis of variance of soil moisture

Source	Sum of squares	D.F.	Mean square	F value
Replication	770.3942	3	256.7980	
Tillage	437.3994	9	48.5999	1.48
Error A	887.3837	27	32.8660	
Press wheel	76.9701	1	76.9701	28.64**
Tillage by wheel	14.0903	9	1.5655	0.58
Error B	80.6339	30	2.6877	
Date	329.5544	3	109.8514	51.16**
Tillage by date	74.1932	27	2.7478	1.28
Wheel by date	18.5298	3	6.1766	2.88*
Tillage by wheel by date	33.9780	27	1.2584	0.59
Error C	386.5273	180	2.1473	
Total	3109.6550	319		

*Significant at 5% level.

**Significant at 1% level.

Table A-2. Analysis of variance of soil temperature[+]

Source	Sum of squares	D.F.	Mean square	F value
Replication	314.8886	3	104.9628	
Tillage	237.6076	9	26.4008	2.04
Error A	349.5593	27	12.9466	
Press wheel	1509.8500	1	1509.8500	435.47**
Tillage by wheel	83.7202	9	9.3022	2.68*
Error B	104.0156	30	3.4671	
Date	12886.3800	7	1840.9120	494.42**
Tillage by date	375.6523	63	5.9627	1.60*
Wheel by date	453.7810	7	64.8258	17.41**
Tillage by wheel by date	255.0391	63	4.0482	1.09
Error C	1563.8200	420	3.7233	
Total	18134.3300	639		

[+]The data used in this analysis were in units of degrees fahrenheit.

*Significant at 5% level.

**Significant at 1% level.

Table A-3. Analysis of variance of planting depth

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.4284	3	0.1428	
Tillage	43.7373	9	4.8597	6.10**
Error A	21.4946	27	0.7960	
Wheel	18.7796	1	18.7796	32.96**
Tillage by wheel	2.7124	9	0.3013	0.53
Residual	17.0917	30	0.5697	
Total	104.2441	79	1.3195	

**Indicates statistically significant at 1% level.

Table A-4. Analysis of variance for cone index

Source	Sum of squares	D.F.	Mean square	F value
Replication	8794.776	3	2931.5921	
Tillage	16105.451	9	1789.4946	2.28*
Error A	21194.638	27	784.9866	
Wheel	15176.684	1	15176.6844	15.47**
Tillage by wheel	2143.471	9	238.1634	0.24
Error B	29433.374	30	981.1125	
Depth	270185.168	3	90061.7228	544.17**
Tillage by depth	12790.986	27	473.7402	2.86**
Wheel by depth	2725.604	3	908.5347	5.49**
Tillage by wheel by depth	2982.364	27	110.4579	0.67
Residual	29790.563	180	165.5031	
Total	411323.081	319	1289.4140	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table A-5. Analysis of variance for soil density

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.04435	3	0.01478	
Tillage	0.10307	9	0.01145	2.06
Error A	0.14995	27	0.00555	
Wheel	0.00036	1	0.00036	0.12
Tillage by wheel	0.03247	9	0.00360	1.21
Residual	0.08951	30	0.00298	
Total	0.41973	79	0.00531	

Table A-6. Analysis of variance for phase intercept mean

Source	Sum of squares	D.F.	Mean square	F value
Tillage	3.8800	9	0.4311	0.53
Error A	8.1276	10	0.8127	
Wheel	1.0695	1	1.0695	4.26
Tillage by wheel	1.1223	9	0.1247	0.50
Error B	2.5113	10	0.2511	
Angle	0.0099	1	0.0099	0.68
Tillage by angle	0.0207	9	0.0134	0.92
Wheel by angle	0.0004	1	0.0004	0.03
Tillage by wheel by angle	0.0655	9	0.0072	0.50
Residual	0.2933	20	0.0146	
Total	17.2010	79	0.2177	

Table A-7. Analysis of variance for phase intercept variance

Source	Sum of squares	D.F.	Mean square	F value
Tillage	195.5578	9	21.7286	0.92
Error A	236.2597	10	23.6259	
Wheel	0.0032	1	0.0032	0.00
Tillage by wheel	15.1231	9	1.6803	0.94
Error B	17.7897	10	1.7789	
Angle	0.9095	1	0.9095	7.15*
Tillage by angle	1.2191	9	0.1354	1.06
Wheel by angle	0.0013	1	0.0013	0.01
Tillage by wheel by angle	1.4398	9	0.1599	1.26
Residual	2.5454	20	0.1272	
Total	470.8490	79	5.9601	

*Indicates statistically significant at the 5% level.

Table A-8. Analysis of variance porosity

Source	Sum of squares	D.F.	Mean square	F value
Tillage	0.54592	9	0.060658	0.60
Error A	1.00812	10	0.100812	
Wheel	0.01300	1	0.013005	0.27
Tillage by wheel	0.06082	9	0.006757	0.14
Error B	0.47322	10	0.047322	
Angle	0.00128	1	0.001280	6.32*
Tillage by angle	0.00264	9	0.000293	1.45
Wheel by angle	0.00004	1	0.000045	0.22
Tillage by wheel by angle	0.00118	9	0.000131	0.65
Residual	0.00405	20	0.000202	
Total	2.11030	79	0.026712	

*Indicates statistically significant at the 5% level.

Table A-9. Analysis of variance for grass weed ratings

Source	Sum of squares	D.F.	Mean square	F value
Replication	2.4359	3	0.8119	
Tillage	10.5223	9	1.1691	2.59*
Error A	12.1996	27	0.4518	
Wheel	0.1102	1	0.1102	0.55
Tillage by wheel	1.4400	9	0.1600	0.80
Error	6.0332	30	0.2011	
Total	32.7413	79		

*Indicates statistically significant at the 5% level.

Table A-10. Analysis of variance for broadleaf weed ratings

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.1233	3	0.0411	
Tillage	0.5066	9	0.0562	2.01
Error A	0.7548	27	0.0279	
Wheel	0.0105	1	0.0105	0.45
Tillage by wheel	0.2128	9	0.0236	1.01
Error	0.7036	30	0.0234	
Total	2.3118	79		

Table A-11. Analysis of variance for stand

Source	Sum of squares	D.F.	Mean square	F value
Replication	5.61812	3	1.872706	
Tillage	174.54479	9	19.393866	8.74**
Error A	59.89320	27	2.218267	
Wheel	5.12188	1	5.121884	6.05*
Tillage by wheel	18.77684	9	2.086315	2.47*
Error B	25.38174	30	0.846058	
Date	1839.84956	4	459.962389	1308.40**
Tillage by date	43.93561	36	1.220434	3.47**
Wheel by date	15.56222	4	3.890556	11.07**
Tillage by wheel by date	15.98422	36	0.444006	1.26
Residual	84.37078	240	0.351545	
Total	2289.03896	399	5.736940	

*Indicates statistically significant at the 5% level.

**Indicates statistically significant at the 1% level.

Table A-12. Analysis of variance for insufficient moisture

Source	Sum of squares	D.F.	Mean square	F value
Replication	2.8374	3	0.9458	
Tillage	30.2624	9	3.3624	1.84
Error A	49.2873	27	1.8254	
Wheel	9.1124	1	9.1124	5.40*
Tillage by wheel	19.7624	9	2.1958	1.30
Error B	50.6246	30	1.6874	
Total	161.8868	79	1.6874	

*Indicates statistically significant at the 5% level.

Table A-13. Analysis of variance for rodent damage

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.3374	3	0.1124	
Tillage	1.7624	9	0.1958	0.77
Error A	6.7874	27	0.2513	
Wheel	0.6124	1	0.6124	2.57
Tillage by wheel	1.7624	9	0.1958	0.82
Error B	7.1249	30	0.2374	
Total	18.3874	79		

Table A-14. Analysis of variance for soil compaction

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.1374	3	0.0458	
Tillage	0.3124	9	0.0347	0.54
Error A	1.7374	27	0.0643	
Wheel	0.0124	1	0.0124	0.20
Tillage by wheel	0.6124	9	0.0680	1.08
Error B	1.8750	30	0.0625	
Total	4.6875	79		

Table A-15. Analysis of variance for nonviable seed

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.3374	3	0.1124	
Tillage	0.2624	9	0.0291	1.00
Error A	0.7874	27	0.0291	
Wheel	0.0124	1	0.0124	0.33
Tillage by wheel	0.3624	9	0.0402	1.07
Error B	1.1249	30	0.0374	
Total	2.8874	79		

Table A-16. Analysis of variance for cut worm kill

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.4374	3	0.1458	
Tillage	3.3124	9	0.3680	1.67
Error A	5.9374	27	0.2199	
Wheel	0.6124	1	0.6124	2.67
Tillage by wheel	2.0124	9	0.2236	0.97
Error B	6.8750	30	0.2291	
Total	19.1875	79		

Table A-17. Analysis of variance for wire worm kill

Source	Sum of squares	D.F.	Mean square	F value
Replication	0.0500	3	0.0166	
Tillage	1.6999	9	0.1888	0.82
Error A	6.1999	27	0.2296	
Wheel	0.0500	1	0.0500	0.31
Tillage by wheel	1.1999	9	0.1333	0.84
Error B	4.7500	30	0.1583	
Total	13.9499	79		

Table A-18. Analysis of variance for yield

Source	Sum of squares	D.F.	Mean square	F value
Replication	701.4786	3	233.8262	
Tillage	834.0012	9	92.6668	1.75
Error A	1428.6752	27	52.9138	
Wheel	2.5671	1	2.5671	0.11
Tillage by wheel	606.1083	9	67.3453	2.99*
Residual	674.9141	30	22.4971	
Total	4247.7448	79	53.7689	

*Indicates statistically significant at the 5% level.

APPENDIX B: ANALYSIS OF VARIANCE OF SOIL STRUCTURE EXPERIMENTS

Table B-1. Analysis of variance of mean pore diameter

Source	Sum of squares	D.F.	Mean square	F value
Size	1.4262	2	0.7131	17.03**
Moisture	3.9464	2	1.9732	47.13**
Size by moisture	1.2270	4	0.3067	7.33**
Error A	0.3767	9	0.0419	
Density	1.4600	1	1.4600	121.59**
Size by density	0.1153	2	0.0576	4.80*
Moisture by density	0.1035	2	0.0517	4.31*
Size by moisture by density	0.0948	4	0.0237	1.97
Residual	0.1081	9	0.0120	
Total	8.8582	35	0.2530	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table B-2. Analysis of variance of pore diameter variance

Source	Sum of squares	D.F.	Mean square	F value
Size	0.0172	2	0.00860	0.10
Moisture	0.2543	2	0.12715	1.54
Size by moisture	0.3242	4	0.08106	0.98
Error A	0.7451	9	0.08279	
Density	0.4601	1	0.46013	11.41**
Size by density	0.1799	2	0.08996	2.23
Moisture by density	1.5238	2	0.76193	18.90**
Size by moisture by density	0.4811	4	0.12029	2.98
Residual	0.3628	9	0.04031	
Total	4.3488	35	0.12425	

**Indicates statistically significant at 1% level.

Table B-3. Analysis of variance of porosity measured by moisture desorption

Source	Sum of squares	D.F.	Mean square	F value
Size	0.00333	2	0.001666	0.40
Moisture	0.00547	2	0.002738	0.66
Size by moisture	0.00309	4	0.000772	0.19
Error A	0.03717	9	0.004130	
Density	0.05638	1	0.056382	15.59**
Size by density	0.00150	2	0.000750	0.21
Moisture by density	0.00245	2	0.001228	0.34
Size by moisture by density	0.00197	4	0.000494	0.14
Residual	0.03256	9	0.003618	
Total	0.14394	35	0.004112	

**Indicates statistically significant at 1% level.

Table B-4. Analysis of variance of phase intercept mean

Source	Sum of squares	D.F.	Mean square	F value
Size	0.3088	2	0.15441	2.07
Moisture	11.6259	2	5.81295	70.69**
Size by moisture	0.5279	4	0.13198	1.77
Error A	0.6726	9	0.0747	
Density	1.1225	1	1.12250	29.08**
Size by density	0.1482	2	0.07413	1.92
Moisture by density	0.8947	2	0.44737	11.59**
Size by moisture by density	0.8258	4	0.20647	5.35*
Error B	0.3474	9	0.03860	
Angle	0.0690	1	0.06906	6.63*
Size by angle	0.0112	2	0.00560	0.54
Moisture by angle	0.0257	2	0.01287	1.23
Size by moisture by angle	0.0169	4	0.00423	.41
Density by angle	0.0048	1	0.00483	.46
Size by density by angle	0.0517	2	0.02585	2.48
Moisture by density by angle	0.0192	2	0.00962	0.92
Size by moisture by density by angle	0.0512	4	0.01281	1.23
Residual	0.1876	18	0.0104	
Total	16.9117	71	0.23819	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table B-5. Analysis of variance of phase intercept variance

Source	Sum of squares	D.F.	Mean square	F value
Size	1.08500	2	0.542504	1.69
Moisture	0.21705	2	0.108529	0.34
Size by moisture	1.83718	4	0.459295	1.43
Error A	2.89246	9	0.321385	
Density	0.10656	1	0.106568	1.52
Size by density	0.71851	2	0.359259	5.11*
Moisture by density	0.10070	2	0.050351	0.72
Size by moisture by density	1.09547	4	0.273868	3.90*
Error B	0.63276	9	0.070306	
Angle	0.36836	1	0.368368	40.70**
Size by angle	0.03343	2	0.016718	1.85
Moisture by angle	0.07401	2	0.037009	4.09*
Size by moisture by angle	0.04353	4	0.010884	1.20
Density by angle	0.00116	1	0.001168	0.13
Size by density by angle	0.03570	2	0.017851	1.97
Moisture by density by angle	0.02238	2	0.011193	1.24
Size by moisture by density by angle	0.04310	4	0.010776	1.19
Residual	0.16293	18	0.008596	
Total	9.47038	71	0.133385	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table B-6. Analysis of variance of mean matrix intercept

Source	Sum of squares	D.F.	Mean square	F value
Size	2.5642	2	1.28211	55.95**
Moisture	6.3731	2	3.18657	139.06**
Size by moisture	0.5038	4	0.12597	5.50*
Error A	0.2062	9	0.02292	
Density	1.4535	1	1.45351	60.02**
Size by density	0.2452	2	0.12262	5.06*
Moisture by density	0.3234	2	0.16171	6.68*
Size by moisture by density	0.2103	4	0.05258	2.17
Error B	0.2179	9	0.02421	
Angle	0.0325	1	0.03251	19.08**
Size by angle	0.0050	2	0.00252	1.48
Moisture by angle	0.0026	2	0.00131	0.77
Size by moisture by angle	0.0028	4	0.00072	0.42
Density by angle	0.0001	1	0.00016	0.09
Size by density by angle	0.0092	2	0.00461	2.71
Moisture by density by angle	0.0055	2	0.00275	1.62
Size by moisture by density by angle	0.0171	4	0.00429	2.52
Residual	0.0307	18	0.00170	
Total	12.2038	71	0.17188	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table B-7. Analysis of variance of matrix intercept variance

Source	Sum of squares	D.F.	Mean square	F value
Size	0.31821	2	0.1591	6.47*
Moisture	4.33861	2	2.1693	88.17**
Size by moisture	0.24075	4	0.0601	2.45
Error A	0.22143	9	0.02460	
Density	0.56180	1	0.5618	49.10**
Size by density	0.04980	2	0.0249	2.18
Moisture by density	0.04923	2	0.0246	2.15
Size by moisture by density	0.05268	4	0.0131	1.15
Error B	0.10297	9	0.0114	
Angle	0.10733	1	0.1073	53.23**
Size by angle	0.02183	2	0.0109	5.41*
Moisture by angle	0.00107	2	0.0005	0.27
Size by moisture by angle	0.01922	4	0.0048	2.38
Density by angle	0.00125	1	0.0012	0.62
Size by density by angle	0.00645	2	0.0032	1.60
Moisture by density by angle	0.00423	2	0.0021	1.05
Size by moisture by density by angle	0.00588	4	0.0014	0.73
Residual	0.04235	19	0.0022	
Total	6.1391	71	0.0864	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

Table B-8. Analysis of variance of porosity measured by FSPA scanning

Source	Sum of squares	D.F.	Mean square	F value
Size	0.024752	2	0.01237	0.77
Moisture	0.148969	2	0.07448	4.63*
Size by moisture	0.067897	4	0.01697	1.06
Error A	0.144688	9	0.01795	
Density	0.120868	1	0.12086	37.53**
Size by density	0.092769	2	0.04638	14.40**
Moisture by density	0.034469	2	0.01723	5.35*
Size by moisture by density	0.171180	4	0.04279	13.29**
Error B	0.028987	9	0.00322	
Angle	0.004512	1	0.00451	14.31**
Size by angle	0.001108	2	0.00055	1.76
Moisture by angle	0.000225	2	0.00011	0.36
Size by moisture by angle	0.000391	4	0.00009	0.31
Density by angle	0.000501	1	0.00050	1.59
Size by density by angle	0.000369	2	0.00018	0.59
Moisture by density by angle	0.001002	2	0.00050	1.59
Size by moisture by density by angle	0.002863	4	0.00071	2.27
Residual	0.005675	18	0.000315	
Total	0.851231	71	0.01198	

*Indicates statistically significant at 5% level.

**Indicates statistically significant at 1% level.

APPENDIX C: ANALYSIS OF SEEDLING EMERGENCE EXPERIMENT

Table C-1. Analysis of variance for emergence rate of soybeans grown in the laboratory

Source	Sum of squares	D.F.	Mean square	F value
Temperature	934610.34	2	467305.169	
Size	6966.33	2	3483.166	3.65
Moisture	8743.50	2	4371.750	4.58
Temperature by size	7788.64	4	1947.159	2.04
Temperature by moisture	10989.75	4	2747.438	2.88
Moisture by size	3025.38	4	756.345	0.79
Temperature by moisture by size	9965.06	8	1245.633	1.31
Error A	25757.20	27	953.971	
Density	127948.78	1	127948.776	87.00**
Temperature by density	67879.63	2	33939.815	23.08**
Size by density	43.88	2	21.939	0.01
Moisture by density	14427.27	2	7213.634	4.90
Temperature by size by density	3756.93	4	939.232	0.64
Temperature by moisture by density	17233.86	4	4308.464	2.93
Moisture by size by density	6329.28	4	1582.321	1.08
Temperature by moisture by size by density	24351.59	8	3043.948	2.07
Depth	268639.87	1	268639.870	182.88**

**Indicates statistically significant at the 1% level.

Table C-1 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by depth	125925.05	2	62962.525	42.81**
Size by depth	2231.95	2	1115.973	0.76
Moisture by depth	521.25	2	260.626	0.18
Temperature by size by depth	1808.56	4	452.141	0.31
Temperature by moisture by depth	6939.96	4	1734.991	1.18
Moisture by size by depth	3708.86	4	927.214	0.63
Temperature by moisture by size by depth	13498.25	8	1687.281	1.15
Density by depth	4414.06	1	4414.057	3.00
Temperature by density by depth	3584.63	2	1792.316	1.22
Size by density by depth	2041.83	2	1020.916	0.69
Moisture by density by depth	2735.97	2	1367.985	0.93
Temperature by size by density by depth	2454.35	4	613.589	0.42
Temperature by moisture by density by depth	2540.13	4	635.032	0.43
Moisture by size by density by depth	8829.58	4	2207.395	1.50
Temperature by moisture by size by density by depth	16098.46	8	2012.308	1.36
Variety	8907.01	1	8907.008	6.06
Temperature by variety	2194.37	2	1097.184	0.75

Table C-1 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Size by variety	226.75	2	113.377	0.08
Moisture by variety	26007.59	2	13003.796	8.84**
Temperature by size by variety	1022.31	4	255.576	0.17
Temperature by moisture by variety	19790.35	4	4947.587	3.36
Moisture by size by variety	1636.96	4	409.239	0.28
Temperature by moisture by size by variety	2252.06	8	281.507	0.19
Density by variety	106.35	1	106.354	0.07
Temperature by density by variety	8429.59	2	4214.795	2.87
Size by density by variety	2914.91	2	1457.456	0.99
Moisture by density by variety	3073.11	2	1536.553	1.04
Temperature by size by density by variety	4195.72	4	1048.931	0.71
Temperature by moisture by density by variety	3114.47	4	778.617	0.53
Moisture by size by density by variety	6316.82	4	1579.204	1.07
Temperature by moisture by size by density by variety	9839.42	8	1229.928	0.84
Depth by variety	3.14	1	3.138	0.00
Temperature by depth by variety	45.77	2	22.883	0.02

Table C-1 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Size by depth by variety	1406.44	2	703.222	0.48
Moisture by depth by variety	2348.74	2	1174.369	0.80
Temperature by size by depth by variety	1057.20	4	364.300	0.18
Temperature by moisture by depth by variety	543.19	4	135.797	0.09
Moisture by size by depth by variety	8230.56	4	2057.641	1.40
Temperature by moisture by size by depth by variety	12312.63	8	1539.079	1.05
Density by depth by variety	1120.24	1	1120.243	0.76
Temperature by density by depth by variety	4183.26	2	2091.631	1.42
Size by density by depth by variety	3861.25	2	1930.625	1.31
Moisture by density by depth by variety	142.09	2	71.047	0.05
Temperature by size by density by depth by variety	8505.72	4	2126.431	1.45
Temperature by moisture by density by depth by variety	1128.59	4	282.146	0.19
Moisture by size by density by depth by variety	7661.38	4	1915.344	1.30

Table C-1 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by moisture by size by density by variety	16940.36	8	2117.545	1.44
Residual	277969.02	189	1470.736	
Corrected total	2183277.55	431	5065.609	

Table C-2. Analysis of variance for arc sine square root of fraction emerged of soybeans grown in the laboratory

Source	Sum of squares	D.F.	Mean square	F value
Temperature	23.6926	2	11.8463	
Size	0.8800	2	0.4400	6.98**
Moisture	0.1486	2	0.0743	1.18
Temperature by size	1.1659	4	0.2914	4.63**
Temperature by moisture	0.5037	4	0.1259	2.00
Moisture by size	0.2718	4	0.0679	1.08
Temperature by moisture by size	0.6030	8	0.0753	1.20
Error A	1.7015	27	0.0630	
Density	8.8377	1	8.8377	109.66**
Temperature by density	0.1086	2	0.0543	0.67
Size by density	0.2203	2	0.1101	1.37
Moisture by density	0.0896	2	0.0448	0.56
Temperature by size by density	0.4899	4	0.1224	1.52
Temperature by moisture by density	1.0630	4	0.2657	3.30
Moisture by size by density	0.1069	4	0.0267	0.33
Temperature by moisture by size by density	1.2657	8	0.1582	1.96
Depth	14.0066	1	14.0066	173.80**

**Indicates statistically significant at the 1% level.

Table C-2 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by depth	1.5986	2	0.7993	9.92**
Size by depth	0.1464	2	0.0732	0.91
Moisture by depth	0.1650	2	0.0825	1.02
Temperature by size by depth	0.2052	4	0.0513	0.64
Temperature by moisture by depth	0.4690	4	0.1172	1.46
Moisture by size by depth	0.2304	4	0.0576	0.72
Temperature by moisture by size by depth	0.6359	8	0.0794	0.99
Density by depth	1.4261	1	1.4261	17.70**
Temperature by density by depth	0.9757	2	0.4878	6.05
Size by density by depth	0.0679	2	0.0339	0.42
Moisture by density by depth	0.0562	2	0.0281	0.35
Temperature by size by density by depth	0.1608	4	0.0402	0.50
Temperature by moisture by density by depth	0.4346	4	0.1086	1.35
Moisture by size by density by depth	0.3723	4	0.0930	1.16
Temperature by moisture by size by density by depth	1.1906	8	0.1488	1.85
Variety	1.2580	1	1.2580	15.61**

Table C-2 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by variety	0.0625	2	0.0312	0.39
Size by variety	0.0675	2	0.0337	0.42
Moisture by variety	1.6339	2	0.8169	10.14
Temperature by size by variety	0.1795	4	0.0448	0.56
Temperature by moisture by variety	0.3771	4	0.0942	1.17
Moisture by size by variety	0.1574	4	0.0393	0.49
Temperature by moisture by size by variety	0.2515	8	0.0314	0.39
Density by variety	0.0152	1	0.0152	0.19
Temperature by density by variety	0.6124	2	0.3062	3.80
Size by density by variety	0.0274	2	0.0137	0.17
Moisture by density by variety	0.1892	2	0.0946	1.17
Temperature by size by density by variety	0.1514	4	0.0378	0.47
Temperature by moisture by density by variety	0.0183	4	0.0045	0.06
Moisture by size by density by variety	0.2896	4	0.0724	0.90
Temperature by moisture by size by density by variety	0.6863	8	0.0857	1.06
Depth by variety	0.0000	1	0.0000	0.00

Table C-2 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by depth by variety	0.0664	2	0.0332	0.41
Size by depth by variety	0.2811	2	0.1405	1.74
Moisture by depth by variety	0.2051	2	0.1025	1.27
Temperature by size by depth by variety	0.0122	4	0.0030	0.04
Temperature by moisture by depth by variety	0.4868	4	0.1217	1.51
Moisture by size by depth by variety	0.3363	4	0.0840	1.04
Temperature by moisture by size by depth by variety	0.4933	8	0.0616	0.77
Density by depth by variety	0.0116	1	0.0116	0.14
Temperature by density by depth by variety	0.2125	2	0.1062	1.32
Size by density by depth by variety	0.2552	2	0.1276	1.58
Moisture by density by depth by variety	0.1096	2	0.0548	0.68
Temperature by size by density by depth by variety	0.4251	4	0.1062	1.32
Temperature by moisture by density by depth by variety	0.0971	4	0.0242	0.30

Table C-2 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Moisture by size by density by depth by variety	0.2612	4	0.0653	0.81
Temperature by moisture by size by density by depth by variety	0.6353	8	0.0794	0.99
Residual	15.2316	189	0.0805	
Corrected total	88.3913	431	0.2050	

Table C-3. Analysis of variance for emergence rate of corn grown in the laboratory

Source	Sum of squares	D.F.	Mean square	F value
Temperature	4307189.24	2	2153594.62	
Size	2094.01	2	1047.01	2.87
Moisture	91149.19	2	45574.60	124.80**
Temperature by size	9016.2C	4	2254.05	6.17**
Temperature by moisture	39082.24	4	9770.56	36.76**
Moisture by size	8670.30	4	2167.58	5.94**
Temperature by moisture by size	5012.59	8	626.57	1.72
Error A	9859.71	27	365.17	
Density	28368.20	1	28368.20	77.04**
Temperature by density	2139.36	2	1069.68	2.90
Size by density	145.63	2	72.81	0.20
Moisture by density	9580.73	2	4790.37	13.01**
Temperature by size by density	3907.32	4	976.83	2.65
Temperature by moisture by density	4368.69	4	1092.17	2.97
Moisture by size by density	2984.51	4	746.13	2.03
Temperature by moisture by size by density	6426.78	8	803.35	2.18
Depth	30064.01	1	30064.01	81.64**

**Indicates statistically significant at the 1% level.

Table C-3 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by depth	1245.05	2	622.53	1.69
Size by depth	677.41	2	388.70	0.92
Moisture by depth	2500.64	2	1250.32	3.40
Temperature by size by depth	989.11	4	247.28	0.67
Temperature by moisture by depth	2635.68	4	658.92	1.79
Moisture by size by depth	1019.65	4	254.91	0.69
Temperature by moisture by size by depth	3420.85	8	427.61	1.16
Density by depth	1589.24	1	1589.24	4.32
Temperature by density by depth	112.19	2	56.10	0.15
Size by density by depth	1692.58	2	846.29	2.30
Moisture by density by depth	424.39	2	212.19	0.58
Temperature by size by density by depth	548.23	4	137.06	0.37
Temperature by moisture by density by depth	1101.86	4	275.47	0.75
Moisture by size by density by depth	755.06	4	188.76	0.51
Temperature by moisture by size by density by depth	2055.87	8	256.98	0.70
Variety	2366.54	1	2366.54	6.43
Temperature by variety	10966.49	2	5483.25	14.89**

Table C-3 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Size by variety	476.07	2	238.04	0.65
Moisture by variety	221.76	2	110.88	0.30
Temperature by size by variety	591.99	4	148.00	0.40
Temperature by moisture by variety	971.30	4	242.82	0.66
Moisture by size by variety	3372.37	4	843.09	2.29
Temperature by moisture by size by variety	2632.98	8	329.12	0.89
Density by variety	558.94	1	558.94	1.52
Temperature by density by variety	825.70	2	412.85	1.12
Size by density by variety	1750.18	2	875.09	2.38
Moisture by density by variety	64.59	2	32.29	0.09
Temperature by size by density by variety	2321.89	4	580.47	1.58
Temperature by moisture by density by variety	1198.33	4	299.58	0.81
Moisture by size by density by variety	778.78	4	194.69	0.53
Temperature by moisture by size by density by variety	570.67	8	71.33	0.19
Depth by variety	50.05	1	50.05	0.14
Temperature by depth by variety	202.09	2	101.05	0.27

Table C-3 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Size by depth by variety	1659.92	2	829.96	2.25
Moisture by depth by variety	803.32	2	401.66	1.09
Temperature by size by depth by variety	629.68	4	157.42	0.43
Temperature by moisture by depth by variety	1685.17	4	421.29	1.14
Moisture by size by depth by variety	1129.35	4	282.34	0.77
Temperature by moisture by size by depth by variety	1630.49	8	203.81	0.55
Density by depth by variety	179.29	1	179.29	0.49
Temperature by density by depth by variety	1145.77	2	572.88	1.56
Size by density by depth by variety	196.26	2	98.13	0.27
Moisture by density by depth by variety	1590.38	2	795.19	2.16
Temperature by size by density by depth by variety	805.27	4	201.32	0.55
Temperature by moisture by density by depth by variety	913.81	4	228.45	0.62
Moisture by size by density by depth by variety	510.64	4	127.66	0.35

Table C-3 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by moisture by size by density by depth by variety	3983.31	8	497.91	1.35
Residual	69595.37	189	368.23	
Corrected total	4697205.29	431	10898.39	

Table C-4. Analysis of variance for arc sine square root of fraction emerged of corn grown in the laboratory

Source	Sum of squares	D.F.	Mean square	F value
Temperature	56.4847	2	28.2423	
Size	0.0576	2	0.0288	0.43
Moisture	1.6899	2	0.8449	12.59**
Temperature by size	0.3610	4	0.0902	1.35
Temperature by moisture	2.4731	4	0.6182	9.21**
Moisture by size	0.8566	4	0.2141	3.19
Temperature by moisture by size	0.8059	8	0.1007	1.50
Error A	1.8119	27	0.0671	
Density	1.5308	1	1.5308	31.31**
Temperature by density	2.2714	2	1.1357	23.23**
Size by density	0.1986	2	0.0993	2.03
Moisture by density	0.3068	2	0.1534	3.14
Temperature by size by density	0.5544	4	0.1386	2.83
Temperature by moisture by density	0.5126	4	0.1281	2.62
Moisture by size by density	0.1226	4	0.0306	0.63
Temperature by moisture by size by density	0.1025	8	0.0128	0.26
Depth	3.3010	1	3.3010	67.51**
Temperature by depth	4.6254	2	2.3127	47.29**

**Indicates statistically significant at the 1% level.

Table C-4 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Size by depth	0.3266	2	0.1633	3.34
Moisture by depth	0.0270	2	0.0135	0.28
Temperature by size by depth	0.3980	4	0.0995	2.04
Temperature by moisture by depth	0.1649	4	0.0412	0.84
Moisture by size by depth	0.0191	4	0.0047	0.10
Temperature by moisture by size by depth	0.2689	8	0.0336	0.69
Density by depth	0.0393	1	0.0393	0.81
Temperature by density by depth	0.0243	2	0.0121	4.98**
Moisture by density by depth	0.0156	2	0.0078	0.16
Temperature by size by density by depth	0.3715	4	0.0928	1.90
Temperature by moisture by density by depth	0.1276	4	0.0319	0.65
Moisture by size by density by depth	0.0919	4	0.0229	0.47
Temperature by moisture by size by depth	0.1504	8	0.0188	0.38
Variety	0.0015	1	0.0015	0.03
Temperature by variety	1.2583	2	0.6291	12.87**
Size by variety	0.0974	2	0.0487	1.00
Moisture by variety	0.1207	2	0.0603	1.23
Temperature by size by variety	0.3680	4	0.0920	1.88

Table C-4 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by moisture by variety	0.5269	4	0.1317	2.69
Moisture by size by variety	0.1979	4	0.0494	1.01
Temperature by moisture by size by variety	0.4506	8	0.0563	1.15
Density by variety	0.4117	1	0.4117	8.42**
Temperature by density by variety	0.2232	2	0.1116	2.28
Size by density by variety	0.0520	2	0.0260	0.53
Moisture by density by variety	0.0037	2	0.0018	0.04
Temperature by size by density by variety	0.1094	4	0.0273	0.56
Temperature by moisture by density by variety	0.0192	4	0.0048	0.10
Moisture by size by density by variety	0.0870	4	0.0217	0.44
Temperature by moisture by size by variety	0.2478	8	0.0309	0.63
Depth by variety	0.0220	1	0.0220	0.45
Temperature by depth by variety	0.2611	2	0.1305	2.67
Size by depth by variety	0.1022	2	0.0511	1.05
Moisture by depth by variety	0.0669	2	0.0334	0.68
Temperature by size by depth by variety	0.0539	4	0.0134	0.28

Table C-4 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by moisture by depth by variety	0.1469	4	0.0367	0.75
Moisture by size by depth by variety	0.0775	4	0.0193	0.40
Temperature by moisture by size by depth by variety	0.1159	8	0.0144	0.30
Density by depth by variety	0.3323	1	0.3323	6.80**
Temperature by density by depth by variety	0.6713	2	0.3356	6.87**
Size by density by depth by variety	0.0972	2	0.0486	0.99
Moisture by density by depth by variety	0.1046	2	0.0523	7.07
Temperature by size by density by depth by variety	0.2642	4	0.0660	1.35
Temperature by moisture by density by depth by variety	0.1646	4	0.0411	0.84
Moisture by size by density by depth by variety	0.1226	4	0.0306	0.63
Temperature by moisture by size by density by depth by variety	0.3879	8	0.0484	0.99
Residual	9.2420	189	0.0488	
Corrected total	96.9906	431	0.2250	

Table C-5. Orthogonal contrasts for emergence rate of laboratory soybean experiments

Source	Sum of squares	D.F.	Mean square	F value
Temperature	934610	2	467305	
Temperature linear	929222	1	929222	
Temperature quadratic	5388	1	5388	
Temperature by density	67880	2	33940	23.08**
Temperature linear vs density	66452	1	66452	45.18**
Temperature quadratic vs density	1428	1	1428	0.97
Temperature by depth	125925	2	62963	42.81**
Temperature linear vs depth	125657	1	125657	85.44**
Temperature quadratic vs depth	268	1	268	0.18
Moisture by variety	26007	2	13003	8.84**
Moisture linear vs variety	22843	1	22843	15.53**
Moisture quadratic vs variety	3165	1	3165	2.15

**Indicates statistically significant at the 1% level.

Table C-6. Orthogonal contrasts for arc sine of square root of fraction emerged of laboratory soybean experiments

Source	Sum of squares	D.F.	Mean square	F value
Temperature	23.6927	2	11.8463	
Temperature linear	20.1952	1	20.1952	
Temperature quadratic	3.4975	1	3.4975	
Size	0.8800	2	0.4400	6.98**
Soil contrast 1	0.6248	1	0.6248	9.91**
Soil contrast 2	0.2552	1	0.2552	4.05
Temperature by size	1.1659	4	0.2915	4.63**
Temperature linear vs soil contrast 1	0.0211	1	0.0211	0.33
Temperature quadratic vs soil contrast 1	0.0029	1	0.0029	0.05
Temperature linear vs soil contrast 2	1.1378	1	1.1378	18.05**
Temperature quadratic vs soil contrast 2	0.0042	1	0.0042	0.07
Temperature by depth	1.5986	2	0.7993	9.92**
Temperature linear vs depth	.7224	1	.7224	8.96**
Temperature quadratic vs depth	.8762	1	.8762	10.87**

**Indicates statistically significant at the 1% level.

Table C-7. Orthogonal contrast for emergence rate of laboratory corn experiments

Source	Sum of squares	D.F.	Mean square	F value
Temperature	4307189.24	2	2153594.62	No test
Temperature linear	4307143.98	1	4307143.98	
Temperature quadratic	45.26	1	45.26	
Moisture	91149.19	2	45574.60	124.80**
Moisture linear	70153.02	1	70153.02	192.11**
Moisture quadratic	20996.18	1	20996.18	57.50**
Temperature by size	9016.20	4	2254.05	6.17**
Temperature linear vs soil contrast 1	2901.83	1	2901.83	7.95**
Temperature quadratic vs soil contrast 1	2715.75	1	2715.75	7.44
Temperature linear vs soil contrast 2	3062.17	1	3062.17	8.39**
Temperature quadratic vs soil contrast 2	336.44	1	336.44	0.92
Temperature by moisture	39082.24	4	9770.56	26.76**
Temperature linear vs moisture linear	21432.83	1	21432.83	58.21**
Temperature quadratic vs moisture linear	6468.34	1	6468.34	17.57**
Temperature linear vs moisture quadratic	9684.54	1	9648.54	26.30**
Temperature quadratic vs moisture quadratic	1496.53	1	1496.53	4.06
Moisture by size	8670.30	4	2167.58	5.94**
Moisture linear vs soil contrast 1	1564.83	1	1564.83	4.28
Moisture quadratic vs soil contrast 1	204.67	1	204.67	0.56
Moisture linear vs soil contrast 2	4935.65	1	4935.65	13.52**
Moisture quadratic vs soil contrast 2	1965.16	1	1965.16	5.38

**Indicates statistically significant at the 1% level.

Table C-7 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Moisture by density	9580.73	2	4790.37	13.01**
Moisture linear vs density	9577.91	1	9577.91	26.00**
Moisture quadratic vs density	02.82	1	2.82	0.00
Temperature by variety	10966.49	2	5483.25	14.89**
Temperature linear vs variety	10636.99	1	10636.99	28.89**
Temperature quadratic vs variety	329.51	1	329.51	0.89

Table C-8. Orthogonal contrasts for arc sine of square root of fraction emerged of laboratory corn experiments

Source	Sum of squares	D.F.	Mean square	F value
Temperature	56.4847	2	28.2423	
Temperature linear	41.1773	1	41.1773	
Temperature quadratic	15.3075	1	15.3075	
Moisture	1.6900	2	0.8450	12.59**
Moisture linear	1.2198	1	1.2198	18.18**
Moisture quadratic	0.4701	1	0.4701	7.00
Temperature by moisture	2.4732	4	0.6183	9.21**
Temperature linear vs moisture linear	1.7548	1	1.7548	26.15**
Temperature quadratic vs moisture linear	0.3845	1	0.3845	5.73
Temperature linear vs moisture quadratic	0.1803	1	0.1803	2.69
Temperature quadratic vs moisture quadratic	0.1536	1	0.1536	2.29
Temperature by density	2.2715	2	1.1357	23.22**
Temperature linear vs density	1.8263	1	1.8263	37.35**
Temperature quadratic vs density	.4452	1	.4452	9.10**
Temperature by depth	4.6254	2	2.3127	47.29**
Temperature linear vs depth	3.5430	1	3.5430	72.45**
Temperature quadratic vs depth	1.0824	1	1.0824	22.14**
Size by compaction by depth	0.4873	2	0.2437	4.98**
Soil contrast 1 vs density by depth	0.0147	1	0.0147	0.30
Soil contrast 2 vs density by depth	0.4726	1	0.4726	9.66**
Temperature by variety	1.2583	2	0.6292	12.87**
Temperature linear vs variety	.8618	1	.8618	17.62**
Temperature quadratic vs variety	.3965	1	.3965	8.11**

**Indicates statistically significant at the 1% level.

Table C-8 (Continued)

Source	Sum of squares	D.F.	Mean square	F value
Temperature by density by depth by variety	0.6714	2	0.3357	6.87**
Temperature linear vs density by depth by variety	0.4899	1	0.4899	10.02**
Temperature quadratic vs density by depth by variety	0.1815	1	0.1815	3.71

APPENDIX D: FIELD EXPERIMENT DATA

The digits listed in the column headed "Plot Ident." refer to plot identification. The digits correspond to the following treatments:

Left most digit = Replication number

Second from left = Tillage treatment

1 = Fall plowed

2 = Fall plowed

3 = Fall plowed

4 = Fall plowed

5 = Ridged

6 = Ridged

7 = Strip tilled

8 = Ridged

9 = Fall plowed

0 = Chisel plowed

Third from left = packing wheel treatment

1 = Concave wheel

2 = Rib wheel

Fourth from left (Table D-5) = angle of scan

0 = Zero degrees

9 = Ninety degrees

TABLE D-1. SOIL MOISTURE CONTENT ON INDICATED DAY IN PERCENT - OVEN DRY BASIS

PLOT IDENT.	DATE OF OBSERVATION 6/4/70	6/6/70	6/8/70	6/10/70
111	24.02	20.84	22.03	22.38
112	24.98	22.56	23.87	21.21
121	24.61	24.11	26.21	25.77
122	26.42	25.35	25.00	25.82
131	23.23	20.78	23.58	20.55
132	25.16	23.10	25.29	21.92
141	22.78	19.86	22.99	21.28
142	24.18	20.96	23.39	20.46
151	23.35	20.18	21.49	21.10
152	23.48	23.62	22.97	21.78
161	23.60	21.83	21.45	20.55
162	25.41	24.55	22.72	22.05
171	22.84	21.49	20.79	18.35
172	24.92	23.73	23.49	21.69
181	27.00	22.71	26.23	23.53
182	28.48	24.97	25.84	26.88
191	22.08	19.88	21.16	21.05
192	25.65	24.42	24.59	22.56
101	25.06	21.18	21.97	23.98
102	24.75	20.60	20.75	23.66
211	21.16	21.33	20.97	20.41
212	24.68	23.01	22.56	20.26
221	21.72	18.44	20.53	18.99
222	25.00	21.15	22.71	21.50
231	26.28	19.34	22.07	24.60
232	25.08	21.85	21.82	24.22
241	26.96	24.18	22.86	25.64
242	25.28	23.80	23.90	23.63
251	24.48	22.60	22.04	19.42
252	26.11	24.09	22.60	20.78
261	23.47	18.92	20.68	19.23
262	21.11	20.47	19.69	20.38
271	19.80	17.94	19.13	18.39
272	20.46	18.89	19.59	18.98
281	23.37	22.60	23.85	22.42
282	25.93	22.56	22.44	24.14
291	24.41	21.74	22.53	20.92
292	24.96	22.95	23.04	21.64
201	21.86	18.80	22.43	21.40
202	23.30	19.82	21.73	21.85

TABLE D-1. CONTINUED

PLOT IDENT.	DATE OF OBSERVATION 6/4/70	6/6/70	6/8/70	6/10/70
311	26.67	20.65	23.61	23.43
312	28.94	23.71	25.51	26.93
321	22.62	16.29	19.05	20.21
322	24.73	16.87	18.86	22.71
331	22.29	17.41	19.26	20.60
332	23.63	21.60	20.60	21.49
341	25.03	21.45	22.11	20.94
342	25.59	24.26	25.07	24.33
351	21.91	19.96	24.02	19.40
352	23.45	21.58	22.19	19.74
361	16.36	19.63	26.28	19.54
362	20.67	19.40	20.33	19.72
371	24.92	20.11	23.39	23.35
372	24.07	23.21	22.94	23.27
381	20.76	18.57	18.19	17.67
382	18.17	17.71	17.63	16.30
391	18.15	14.32	16.49	16.22
392	20.32	14.75	18.30	17.48
301	18.65	15.94	16.48	16.42
302	18.33	16.18	16.32	15.83
411	21.84	18.13	25.48	23.51
412	26.07	22.60	21.83	23.90
421	20.23	16.17	15.51	18.91
422	18.93	16.44	15.37	17.25
431	23.07	21.22	22.86	20.89
432	22.81	22.86	24.31	21.99
441	21.62	21.28	23.92	20.63
442	22.24	21.78	24.24	19.75
451	18.22	16.39	17.50	15.03
452	17.58	17.96	17.57	16.66
461	20.63	14.93	16.35	18.38
462	21.08	15.39	16.75	19.97
471	16.81	12.72	13.69	12.75
472	18.84	15.99	15.11	16.92
481	18.23	18.53	18.83	15.13
482	19.03	20.63	20.29	17.61
491	20.30	14.82	15.58	21.40
492	19.94	16.57	16.62	17.83
401	19.99	15.16	17.04	18.16
402	27.77	16.17	16.79	17.56

TABLE D-2. SOIL TEMPERATURE ON INDICATED DAY IN DEGREES C

PLOT IDENT.	DATE OF OBSERVATION 6/3/70	6/4/70	6/5/70	6/6/70	6/7/70	6/8/70	6/9/70	6/10/70
111	21.11	20.00	27.78	27.78	28.33	27.78	26.67	25.00
112	20.00	19.44	23.89	25.56	25.00	25.00	24.44	24.44
121	20.00	21.11	25.56	27.22	26.67	27.22	26.67	25.56
122	20.56	19.44	24.44	22.78	23.89	25.00	24.44	24.44
131	18.33	21.11	27.22	27.22	27.78	27.78	26.11	26.11
132	20.00	19.44	23.89	24.44	25.00	25.00	25.00	23.89
141	21.11	20.56	27.78	27.78	27.22	24.44	27.22	25.56
142	20.00	19.44	22.22	26.11	25.56	26.11	25.56	23.89
151	21.67	20.56	25.00	27.22	27.78	28.33	26.67	26.11
152	22.78	20.56	25.56	25.56	25.00	26.11	25.00	26.11
161	22.22	20.00	26.67	26.67	28.89	26.67	26.11	26.11
162	21.67	20.00	23.89	22.78	22.78	26.67	23.33	23.89
171	19.44	20.00	27.22	27.78	27.78	25.56	26.11	25.00
172	18.33	18.89	25.00	25.00	24.44	25.56	25.00	24.44
181	21.67	20.00	26.67	26.11	27.78	27.78	26.11	26.11
182	22.22	21.11	25.56	27.22	23.89	24.44	25.56	25.00
191	18.33	21.11	27.78	26.67	26.67	26.67	26.11	26.11
192	20.00	18.89	22.78	25.00	23.89	24.44	24.44	24.44
101	21.11	20.00	28.89	27.78	27.22	26.11	25.00	26.11
102	21.67	18.33	22.78	24.44	25.00	24.44	23.89	23.89

TABLE D-2. CONTINUED

PLOT IDENT.	DATE OF OBSERVATION 6/3/70	6/4/70	6/5/70	6/6/70	6/7/70	6/8/70	6/9/70	6/10/70
211	22.22	20.56	29.44	27.22	28.89	28.33	26.11	25.56
212	20.56	18.89	23.89	23.89	25.56	25.00	25.00	25.56
221	22.22	20.56	27.22	25.56	28.33	27.78	26.11	25.56
222	21.67	18.33	24.44	21.11	25.00	28.33	26.11	24.44
231	22.22	20.00	27.78	27.22	28.33	27.78	26.11	25.00
232	21.67	18.89	23.33	25.00	25.56	26.11	26.11	24.44
241	20.00	20.00	26.11	27.78	27.78	26.67	27.22	25.00
242	20.56	19.44	23.89	23.89	24.44	25.56	25.00	25.00
251	25.00	21.11	25.00	28.33	28.33	28.33	26.11	25.56
252	21.67	20.56	30.00	27.78	26.11	22.78	24.44	25.56
261	24.44	21.11	28.89	29.44	26.67	29.44	28.33	25.56
262	25.00	20.56	26.67	26.67	22.22	26.67	26.67	25.56
271	20.00	20.00	27.22	26.67	28.33	27.22	26.67	25.00
272	20.56	18.89	24.44	25.56	25.00	25.00	25.00	25.56
281	23.89	19.44	28.33	29.44	25.56	26.67	26.11	25.00
282	21.67	20.56	26.67	25.56	25.56	25.56	26.11	25.00
291	21.11	20.00	28.33	29.44	27.78	28.89	27.22	25.56
292	21.11	19.44	25.00	25.56	26.11	26.11	25.56	25.00
201	22.78	20.00	25.56	26.67	27.78	27.22	25.56	25.00
202	20.00	18.89	22.22	23.89	25.56	26.11	24.44	24.44

TABLE D-2. CONTINUED

PLOT IDENT.	DATE OF OBSERVATION 6/3/70	6/4/70	6/5/70	6/6/70	6/7/70	6/8/70	6/9/70	6/10/70
311	20.56	20.00	28.33	28.89	27.22	28.33	27.22	25.00
312	18.33	18.33	24.44	25.00	25.56	25.56	25.56	25.00
321	20.56	20.00	27.78	30.00	30.00	29.44	28.89	26.11
322	20.56	18.89	25.56	26.67	26.67	26.11	25.00	25.00
331	20.56	20.56	27.78	29.44	28.33	28.89	28.33	26.67
332	20.00	20.00	27.78	25.56	26.67	26.11	26.11	25.56
341	20.56	20.56	29.44	28.33	27.78	27.78	26.67	25.56
342	20.00	18.89	24.44	25.56	26.67	25.00	25.56	23.89
351	18.89	20.00	27.78	28.33	26.67	27.22	26.67	25.56
352	19.44	19.44	23.89	25.00	25.56	24.44	25.56	27.78
361	21.11	19.44	27.78	27.22	27.78	27.22	26.67	26.11
362	21.11	20.00	27.22	24.44	27.78	26.67	26.11	25.56
371	18.33	20.00	25.56	28.33	25.56	26.11	25.56	24.44
372	19.44	18.33	24.44	23.89	25.00	24.44	25.56	23.89
381	25.00	21.67	25.56	26.67	25.00	28.33	27.78	27.22
382	25.00	19.44	28.33	27.22	28.33	23.89	27.22	26.11
391	21.67	22.78	30.00	28.89	29.44	28.33	28.33	26.67
392	21.67	20.00	26.11	28.33	27.22	26.11	26.67	25.00
301	23.33	21.67	27.78	30.00	21.67	28.89	27.22	26.11
302	24.44	20.00	25.56	26.67	26.67	26.67	26.67	25.00

TABLE D-2. CONTINUED

PLOT IDENT.	DATE OF OBSERVATION 6/3/70	6/4/70	6/5/70	6/6/70	6/7/70	6/8/70	6/9/70	6/10/70
411	20.00	21.11	28.33	27.78	28.89	28.33	27.78	26.67
412	19.44	19.44	24.44	21.11	25.56	25.56	25.00	25.00
421	21.67	22.78	28.89	29.44	29.44	29.44	27.78	26.67
422	21.67	20.56	24.44	26.67	26.11	26.11	26.67	26.11
431	20.00	21.11	28.33	28.89	29.44	28.89	27.22	27.22
432	20.56	20.00	25.00	25.56	25.00	25.56	25.56	25.00
441	20.00	20.56	28.89	26.67	28.89	28.89	26.11	26.67
442	19.44	20.00	23.89	22.22	25.56	26.11	25.56	25.00
451	22.78	22.22	29.44	29.44	29.44	27.78	27.22	26.67
452	22.78	20.56	26.11	22.22	25.56	23.33	26.67	26.11
461	23.89	21.11	25.00	31.11	30.56	30.56	28.33	25.56
462	21.67	20.56	26.67	27.22	28.89	28.33	27.22	27.78
471	19.44	21.11	28.89	27.78	28.89	27.78	26.67	26.67
472	21.11	19.44	25.00	25.56	22.78	26.11	25.56	26.67
481	23.33	21.67	28.89	27.78	27.78	27.22	26.67	26.11
482	22.22	19.44	23.89	26.11	26.11	26.67	26.11	26.67
491	20.56	21.11	30.00	27.22	30.00	28.89	27.78	27.78
492	20.00	20.00	25.00	25.00	25.56	27.22	26.67	26.67
401	22.78	21.11	28.89	29.44	29.44	28.33	26.67	26.67
402	22.78	20.56	25.00	26.11	26.11	26.11	26.67	25.56

TABLE D-3. PLANTING DEPTH AND SOIL DENSITY

PLOT IDENT.	DEPTH OBSERVATIONS IN CM OBSER. 1	OBSER. 2	OBSER. 3	SOIL DENSITY G/CC
111	6.98	6.98	6.98	1.10
112	4.76	3.81	4.13	1.15
121	5.40	5.71	6.03	1.16
122	5.08	5.71	5.08	1.06
131	5.08	5.08	5.08	1.18
132	5.71	5.71	6.03	1.08
141	6.35	6.35	6.35	1.16
142	5.08	5.40	5.40	1.13
151	5.71	6.03	4.44	1.16
152	3.49	3.17	3.17	1.13
161	6.35	6.35	6.35	1.08
162	2.54	2.54	2.54	0.96
171	3.17	4.13	4.44	1.02
172	3.17	2.86	3.17	1.06
181	2.54	2.54	2.54	1.03
182	1.27	1.59	1.27	0.99
191	5.71	6.35	5.71	1.15
192	5.40	5.71	5.71	1.16
101	5.40	5.52	5.71	1.08
102	4.76	4.76	5.08	1.06
211	6.35	6.35	6.35	1.13
212	5.40	5.71	6.98	1.16
221	5.71	5.71	5.08	1.18
222	4.76	4.44	4.13	1.15
231	6.03	6.03	6.98	1.10
232	4.44	4.13	4.13	1.16
241	6.35	6.35	6.35	1.13
242	5.08	5.08	4.76	1.20
251	3.17	4.13	3.17	0.98
252	3.81	3.81	3.81	1.10
261	5.08	5.08	4.44	1.08
262	3.81	4.44	3.81	1.18
271	5.08	5.08	5.08	1.12
272	4.44	4.13	4.13	1.16
281	3.49	3.81	4.13	1.11
282	2.54	2.22	2.22	0.98
291	6.35	5.71	5.71	1.17
292	3.81	4.44	4.44	1.10
201	5.08	5.71	5.40	1.14
202	4.44	4.13	4.44	0.91

TABLE D-3. CONTINUED

PLOT IDENT.	DEPTH OBSERVATIONS IN CM OBSER. 1	OBSER. 2	OBSER. 3	SOIL DENSITY G/CC
311	5.08	5.08	5.40	1.04
312	4.44	4.44	4.13	1.12
321	5.40	5.71	6.03	1.18
322	4.44	4.76	4.44	1.17
331	5.71	5.40	5.71	1.16
332	5.08	5.08	5.08	1.14
341	6.35	6.35	6.35	1.10
342	4.44	4.44	4.44	1.18
351	5.08	5.08	5.08	0.99
352	3.17	2.54	2.54	1.08
361	5.08	5.08	5.08	1.08
362	5.08	5.08	5.08	1.08
371	4.44	4.44	5.08	1.08
372	3.81	3.81	4.44	1.07
381	1.27	1.27	1.27	1.22
382	3.17	3.17	3.81	1.11
391	5.08	5.40	6.03	1.17
392	5.08	5.08	5.08	1.23
301	5.08	5.71	5.71	1.19
302	4.44	4.44	4.44	1.28
411	5.08	5.08	5.08	1.15
412	3.81	3.81	3.81	1.16
421	6.35	6.35	6.35	1.28
422	5.08	5.08	5.08	1.27
431	5.08	5.08	5.71	1.10
432	4.44	4.13	4.44	1.10
441	5.71	6.03	6.03	1.13
442	5.08	5.08	5.08	1.21
451	4.44	4.44	5.08	1.17
452	5.08	5.08	5.08	1.03
461	6.98	6.35	6.98	1.08
462	5.08	5.08	4.52	1.19
471	5.08	5.71	4.44	1.18
472	3.81	3.17	3.81	1.20
481	5.08	5.08	4.44	1.07
482	4.44	3.81	4.44	1.02
491	4.44	4.44	3.81	1.20
492	4.44	4.44	4.44	1.19
401	4.76	4.76	5.08	1.21
402	3.49	3.81	3.49	1.21

TABLE D-4. CONE INDEX FOR INDICATED DEPTH

PLOT IDENT.	CONE INDEX - NEWTONS/SQ CM DEPTH 0-CM	DEPTH 2.5-CM	DEPTH 5.0-CM	DEPTH 7.5-CM
111	6.90	20.69	55.18	82.77
112	13.80	55.18	79.32	89.67
121	6.90	34.49	68.98	79.32
122	20.69	48.28	65.53	58.63
131	10.35	31.04	75.87	89.67
132	24.14	62.08	82.77	82.77
141	6.90	27.59	55.18	68.98
142	20.69	41.39	75.87	89.67
151	3.45	34.49	72.42	86.22
152	6.90	31.04	72.42	89.67
161	6.90	20.69	55.18	93.12
162	13.80	37.94	89.67	96.57
171	10.35	34.49	65.53	96.57
172	27.59	62.08	89.67	103.46
181	13.80	37.94	82.77	100.01
182	13.80	34.49	58.63	65.53
191	10.35	27.59	41.39	62.08
192	24.14	41.39	48.28	58.63
101	13.80	34.49	89.67	110.36
102	10.35	27.59	41.39	55.18
211	6.90	24.14	41.39	65.53
212	17.24	27.59	24.14	24.14
221	13.80	31.04	51.73	75.87
222	20.69	55.18	79.32	82.77
231	13.80	27.59	41.39	55.18
232	17.24	41.39	65.53	82.77
241	10.35	27.59	41.39	51.73
242	31.04	82.77	65.53	65.53
251	17.24	48.28	89.67	103.46
252	34.49	68.98	96.57	110.36
261	6.90	24.14	51.73	68.98
262	17.24	48.28	93.12	100.01
271	6.90	34.49	75.87	89.67
272	27.59	62.08	86.22	103.46
281	3.45	24.14	68.98	103.46
282	27.59	82.77	117.26	120.71
291	10.35	37.94	82.77	100.01
292	20.69	62.08	96.57	96.57
201	13.80	37.94	72.42	79.32
202	20.69	62.08	103.46	124.16

TABLE D-4. CONTINUED

PLOT IDENT.	CONE INDEX - NEWTONS/SQ CM DEPTH 0-CM	DEPTH 2.5-CM	DEPTH 5.0-CM	DEPTH 7.5-CM
311	6.90	51.73	93.12	96.57
312	17.24	44.83	55.18	55.18
321	10.35	41.39	68.98	75.87
322	20.69	51.73	79.32	65.53
331	13.80	48.28	68.98	55.18
332	13.80	44.83	75.87	65.53
341	6.90	27.59	48.28	72.42
342	13.80	55.18	82.77	79.32
351	20.69	65.53	93.12	103.46
352	34.49	103.46	151.75	127.60
361	6.90	27.59	65.53	79.32
362	13.80	48.28	82.77	103.46
371	6.90	34.49	89.67	106.91
372	13.80	20.69	79.32	110.36
381	6.90	27.59	68.98	93.12
382	6.90	58.63	110.36	134.50
391	6.90	27.59	55.18	79.32
392	24.14	68.98	96.57	120.71
301	6.90	27.59	48.28	48.28
302	17.24	48.28	62.08	68.98
411	6.90	27.59	37.94	41.39
412	41.39	103.46	124.16	110.36
421	17.24	41.39	89.67	117.26
422	27.59	65.53	103.46	89.67
431	10.35	34.49	75.87	93.12
432	17.24	41.39	48.28	48.28
441	6.90	55.18	110.36	106.91
442	10.35	31.04	65.53	68.98
451	6.90	34.49	68.98	110.36
452	31.04	68.98	82.77	106.91
461	6.90	20.69	62.08	100.01
462	20.69	58.63	96.57	103.46
471	10.35	34.49	89.67	134.50
472	27.59	68.98	137.95	193.13
481	6.90	41.39	103.46	141.40
482	13.80	68.98	100.01	100.01
491	20.69	41.39	96.57	124.16
492	31.04	82.77	117.26	124.16
401	10.35	24.14	31.04	34.49
402	17.24	58.63	110.36	148.30

TABLE D-5. SOIL STRUCTURE MEASUREMENTS MADE WITH FSPA ON PHASE INTERCEPTS

PLOT	AREA-SQ MICRONS		NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS										
IDENT.	TOTAL	MATRIX	20	40	80	160	320	640	1280	2560	5120	10240	20480
1110	1660914	447911	10136	9996	9577	8708	6809	4699	2757	1278	492	0	0
1119	1660896	451274	10316	10199	9671	8531	6817	4609	2510	1294	340	53	0
1120	1660907	238298	7240	7158	6884	6344	5349	4017	2670	1618	891	58	0
1129	1660905	231984	7526	7440	7205	6579	5479	4237	2934	1797	981	30	0
1210	1660908	737859	17002	16507	15151	12226	8324	4343	1575	284	20	0	0
1219	1660907	684183	16087	15662	14252	11461	7824	4284	1797	497	103	1	0
1220	1660890	275055	10907	10708	10203	9210	7561	5597	3413	1507	402	18	0
1229	1660889	236634	10610	10434	9912	8932	7488	5509	3465	1685	522	0	0
1310	1660896	491586	14264	13986	13206	11539	8943	5784	2911	767	54	0	0
1319	1660917	496961	13954	13645	12702	10924	8361	5383	2803	915	108	1	0
1320	1660909	144543	5308	5227	5058	4764	4152	3438	2555	1555	972	460	0
1329	1661050	112351	5007	4980	4845	4497	4029	3427	2770	2032	1124	205	0
1410	1661031	472443	13547	13267	12499	10859	8133	5357	2737	958	176	0	0
1419	1661020	481639	13260	13050	12223	10494	7864	4775	2697	987	195	27	0
1420	1661091	432758	12394	12207	11649	10327	8061	5321	2720	993	263	58	0
1429	1661040	413450	12216	11997	11433	10152	8106	5477	3098	1196	238	0	0
1510	1661030	708710	7835	7623	7107	6079	4741	3260	2061	1071	347	49	0
1519	1661021	756352	8756	8516	7958	6870	5277	3353	1777	938	387	0	0
1520	1661031	657091	12019	11714	10947	9191	6893	4395	2337	885	94	0	0
1529	1661041	710591	13098	12776	11774	9794	7033	4245	2083	653	132	0	0

TABLE D-5. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
1610	1661020	337699	10824	10627	10219	9256	7654	5576	3073	1230	450	20	0
1619	1661030	377874	12538	12347	11786	10510	8456	5686	3163	1332	149	0	0
1620	1661030	766373	7521	7401	7016	6297	5229	3830	2224	1102	115	0	0
1629	1661010	809278	8240	8119	7716	6838	5384	3771	2055	732	178	0	0
1710	1661031	576652	11468	11295	10798	9463	7348	4924	2738	967	134	0	0
1719	1661030	640877	10642	10480	9958	8712	6782	4508	2424	864	98	14	0
1720	1661020	699342	7780	7656	7291	6379	5207	3833	2506	1058	273	1	0
1729	1661041	677164	9408	9255	8811	7892	6619	4812	2683	858	101	0	0
1810	1661010	220316	5004	4967	4777	4362	3933	3398	2693	1912	1042	227	0
1819	1661021	232697	7173	7112	6980	6597	5912	5110	3888	2110	584	0	0
1820	1661021	384504	8205	8101	7725	6985	5928	4511	2971	1679	558	23	0
1829	1661030	393354	9730	9581	9193	8292	6914	5205	3194	1636	278	0	0
1910	1661030	234297	9368	9292	8968	8263	6924	5176	3303	1696	568	53	0
1919	1661040	247075	10012	9892	9489	8585	7135	5379	3438	1583	590	7	0
1920	1661031	580167	8159	8021	7647	6713	5251	3470	2214	1295	505	72	0
1929	1661021	587779	9106	8952	8430	7340	5729	4204	2617	1380	217	0	0
1010	1661050	544575	7879	7748	7323	6538	5229	3888	2560	1301	449	85	0
1019	1661069	563372	9530	9290	8701	7512	5981	4230	2728	1290	292	29	0
1020	1661043	631707	10108	9919	9338	8169	6517	4418	2460	918	263	0	0
1029	1661060	609809	10256	10019	9324	8212	6498	4366	2343	967	184	46	0

TABLE D-5. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2110	1661049	821181	18578	17841	15654	11999	7478	3592	1159	242	32	0	0
2119	1661040	785595	18059	17324	15376	11865	7722	3967	1391	259	19	0	0
2120	1660969	858928	15394	14968	13513	10806	7145	3648	1484	226	6	0	0
2129	1660989	893494	15515	15013	13546	10554	7012	3396	1233	220	2	0	0
2210	1661196	779102	12730	12410	11355	9385	6719	3790	1865	606	88	0	0
2219	1661229	763107	12759	12451	11373	9271	6701	4001	1881	565	58	29	0
2220	1660990	1093086	8210	8041	7484	5980	4377	2577	1370	341	48	0	0
2229	1660977	1098337	9066	8824	8096	6711	4786	2886	1193	209	4	0	0
2310	1660969	674005	11950	11550	10368	8201	5560	3250	1763	914	347	72	0
2319	1660987	650478	12625	12187	10951	8565	6014	3792	2291	1051	166	0	0
2320	1660983	629492	13203	12827	11810	9801	7080	4594	2344	935	54	0	0
2329	1660974	674965	14533	14102	12891	10633	7726	4717	2029	520	70	0	0
2410	1660979	12692	1881	1867	1836	1773	1714	1625	1524	1362	1128	804	0
2419	1660976	12895	1932	1924	1888	1803	1675	1570	1461	1306	1041	837	0
2420	1661225	22208	3046	3022	2936	2834	2664	2410	2040	1644	1132	608	0
2429	1661230	26046	3110	3049	2935	2674	2505	2251	1859	1561	1127	695	0
2510	1660973	367350	9233	9061	8468	7403	5884	4317	2967	1653	564	16	0
2519	1660985	391454	9980	9687	9020	7750	6215	4575	2956	1566	445	38	0
2520	1660987	390851	10821	10633	10122	9018	7478	5704	3488	1255	244	14	0
2529	1660979	360783	12762	12537	11749	10499	8830	6629	3699	1129	70	0	0

TABLE D-5. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2610	1660969	967354	13839	13356	11756	8866	5469	3001	1108	316	22	0	0
2619	1660979	1009507	14388	13800	12038	8941	5513	2838	957	152	0	0	0
2710	1661019	667483	13888	13523	12635	10733	7833	4838	2194	544	55	0	0
2719	1661003	702781	14977	14532	13296	10854	7657	4480	2170	425	16	0	0
2720	1660998	808715	12901	12553	11627	9903	7265	4385	1742	374	3	0	0
2729	1660999	841967	12181	11873	10957	9149	6825	4037	1804	396	5	0	0
2810	1661013	1072457	9466	9161	8435	7084	5003	2941	1191	269	5	0	0
2819	1660979	1139257	9776	9522	8734	7200	5166	2690	816	84	0	0	0
2820	1660980	759080	8552	8339	7763	6774	5429	3998	2316	923	160	4	0
2829	1660999	776762	9547	9338	8705	7635	6060	4310	2223	762	68	0	0
2910	1660998	895494	16570	15942	14284	11314	7238	3571	1106	102	0	0	0
2919	1660987	933115	15750	15054	13466	10416	6707	3207	1065	137	2	0	0
2920	1660979	193045	6259	6175	5951	5521	4989	4169	3077	1923	812	199	0
2929	1660993	261706	7362	7262	6955	6359	5682	4532	3393	1867	734	42	0
2010	1661216	608800	11144	10788	9894	8405	6309	4160	2403	1043	301	23	0
2019	1661198	615798	11020	10734	9917	8376	6604	4619	2776	989	126	0	0
2020	1660994	503847	8361	8168	7609	6745	5547	4179	2766	1363	418	34	0
2029	1660989	558542	9233	9066	8588	7545	6075	4428	2469	1057	326	80	0
2620	1660983	740776	17367	16824	15204	12156	8316	4322	1549	336	23	0	0
2629	1660973	725001	18027	17340	15724	12496	8591	4468	1557	264	0	0	0

TABLE D-6. WEED RATINGS

PLOT IDENT.	BROADLEAF RATING 0-5	GRASS RATING 0-5
111	0.00	0.00
112	0.00	0.00
121	0.00	0.00
122	0.00	0.00
131	0.00	0.00
132	0.00	0.00
141	0.00	0.00
142	0.00	0.00
151	0.11	0.00
152	0.06	0.00
161	0.00	0.00
162	0.06	0.00
171	0.78	0.78
172	0.06	0.00
181	0.61	0.06
182	0.56	0.00
191	0.00	0.00
192	0.06	0.00
101	0.06	0.22
102	0.00	0.06
211	0.11	0.17
212	0.00	0.00
221	0.00	0.00
222	0.00	0.00
231	0.00	0.00
232	0.06	0.00
241	0.00	0.00
242	0.00	0.00
251	1.17	0.33
252	0.50	0.17
261	0.78	0.61
262	0.00	0.00
271	0.00	0.00
272	0.06	0.00
281	0.89	0.00
282	1.17	0.72
291	0.00	0.00
292	0.00	0.17
201	2.56	0.56
202	1.50	0.17

TABLE D-6. CONTINUED

PLOT IDENT.	BROADLEAF RATING 0-5	GRASS RATING 0-5
311	0.11	0.00
312	0.11	0.06
321	0.00	0.00
322	0.00	0.00
331	0.00	0.00
332	0.00	0.00
341	0.06	0.00
342	0.17	0.00
351	1.06	0.00
352	3.56	0.06
361	0.78	0.11
362	1.28	0.33
371	0.50	0.44
372	0.00	0.39
381	2.44	0.00
382	0.11	0.00
391	0.00	0.00
392	0.00	0.00
301	0.06	0.00
302	0.00	0.00
411	0.00	0.00
412	0.00	0.00
421	0.00	0.00
422	0.00	0.00
431	0.00	0.00
432	0.00	0.00
441	0.00	0.00
442	0.00	0.00
451	0.11	0.00
452	0.22	0.00
461	0.00	0.00
462	0.00	0.00
471	0.00	0.11
472	0.00	0.17
481	1.44	0.22
482	1.06	0.39
491	0.00	0.00
492	0.00	0.00
401	0.00	0.00
402	0.06	0.00

TABLE D-7. REASONS FOR NOT EMERGING

PLOT IDENT.	LACK OF MOISTURE	RODENT DAMAGE	COMPACT SOIL	DEAD SEED	CUT WORM	WIRE WORM
111	0	0	0	0	0	0
112	0	1	0	0	0	0
121	0	0	0	0	0	0
122	0	0	0	0	0	0
131	0	0	0	0	0	0
132	0	0	0	0	0	0
141	0	0	0	0	0	0
142	0	0	0	0	0	0
151	1	0	0	0	0	1
152	0	0	0	0	0	0
161	0	0	0	0	0	1
162	0	0	0	0	1	1
171	0	0	0	0	0	0
172	0	0	0	1	1	0
181	1	0	0	1	1	0
182	4	0	0	0	0	1
191	0	0	0	1	0	0
192	0	0	0	0	0	0
101	0	0	0	0	1	0
102	1	0	0	0	0	0
211	0	0	0	0	0	0
212	0	0	0	0	0	1
221	0	0	0	0	1	0
222	0	0	0	0	0	0
231	0	0	0	0	0	0
232	0	1	1	0	0	0
241	0	0	0	0	0	0
242	0	0	0	0	1	0
251	0	0	0	0	1	0
252	9	0	0	0	0	0
261	0	0	0	0	0	1
262	0	0	0	0	1	1
271	0	0	1	0	0	0
272	0	0	0	0	1	0
281	0	0	0	0	0	0
282	1	0	0	0	0	0
291	0	0	0	0	0	0
292	0	0	0	0	0	1
201	0	0	0	0	1	0
202	0	0	0	0	2	0

TABLE D-7. CONTINUED

PLOT IDENT.	LACK OF MOISTURE	RODENT DAMAGE	COMPACT SOIL	DEAD SEED	CUT WORM	WIRE WORM
311	0	0	0	0	0	0
312	0	0	0	0	1	0
321	0	0	0	0	0	1
322	0	0	0	0	1	1
331	0	0	0	0	0	0
332	0	0	0	0	0	0
341	0	0	0	0	0	1
342	0	0	0	0	0	0
351	0	0	0	0	0	1
352	3	0	0	0	1	0
361	0	0	1	0	0	0
362	0	0	0	0	1	0
371	0	0	0	0	1	0
372	0	0	0	0	1	0
381	1	0	0	0	0	0
382	1	0	0	0	1	0
391	0	0	0	0	0	1
392	0	1	0	0	0	0
301	0	0	1	0	0	0
302	0	0	0	0	0	0
411	0	0	0	0	0	0
412	0	0	0	0	0	0
421	0	0	0	0	0	0
422	0	0	0	0	0	0
431	0	0	0	0	0	0
432	0	0	0	0	0	1
441	0	0	0	0	0	0
442	0	0	0	0	0	0
451	0	0	0	0	1	0
452	2	0	0	0	0	1
461	1	0	0	0	0	0
462	5	0	0	0	1	0
471	0	0	0	0	1	1
472	6	4	0	0	0	0
481	1	0	0	0	1	0
482	0	0	0	0	1	1
491	0	0	0	0	0	0
492	0	0	1	0	1	1
401	0	0	0	0	0	0
402	0	0	0	0	0	0

TABLE D-8. STAND COUNTS ON INDICATED DAY AND YIELD

PLOT IDENT.	PLANTS/SQ METER 6/8/70	6/9/70	6/10/70	6/23/70	7/17/70	YIELD Q/HA
111	0.43	6.60	7.56	7.56	7.41	62.97
112	1.77	6.89	7.27	6.60	6.89	57.48
121	0.29	4.26	5.88	6.31	6.36	66.95
122	0.96	4.54	6.55	5.79	5.98	60.61
131	0.43	5.07	7.22	6.70	6.70	67.92
132	1.20	4.88	6.41	6.36	5.79	59.55
141	0.33	7.27	6.98	7.13	7.13	50.96
142	1.00	5.21	7.13	7.13	7.13	54.66
151	0.29	4.16	5.93	6.46	6.22	65.24
152	1.58	5.50	6.12	5.74	5.74	64.27
161	1.00	6.74	7.03	6.26	6.26	62.66
162	2.77	5.50	5.69	5.31	5.50	65.50
171	0.00	3.49	5.88	6.22	2.30	46.98
172	0.48	3.01	6.31	5.07	4.59	60.59
181	0.00	2.01	3.35	4.50	4.30	60.44
182	1.48	4.30	4.93	5.40	5.02	65.30
191	0.19	4.97	7.27	7.13	7.17	60.61
192	0.53	3.78	6.70	6.26	6.17	60.58
101	0.24	3.16	5.21	6.22	6.03	59.41
102	0.38	2.96	4.59	5.60	5.69	53.05
211	1.24	7.08	7.27	7.08	6.79	54.63
212	1.00	5.60	6.65	6.84	6.26	45.41
221	0.14	6.46	7.22	6.65	6.98	56.70
222	0.33	6.26	7.17	6.98	6.60	48.37
231	0.43	6.70	7.22	7.13	6.36	58.46
232	0.19	5.88	7.08	6.98	6.98	41.82
241	0.10	6.36	7.22	7.22	7.17	63.29
242	1.67	6.26	6.98	7.03	6.98	57.71
251	0.10	5.40	6.50	6.31	4.97	52.00
252	0.14	0.48	1.24	4.78	4.30	55.85
261	0.14	5.45	6.55	6.26	6.70	47.35
262	0.72	6.79	6.36	6.46	6.79	55.23
271	0.24	5.64	6.84	6.60	6.50	56.86
272	0.72	5.40	6.41	6.26	5.60	63.17
281	0.10	3.87	5.93	6.50	6.07	52.40
282	0.53	3.54	4.54	5.88	5.69	52.83
291	0.96	7.13	7.32	7.17	6.89	52.88
292	1.00	6.50	7.08	7.03	6.93	52.26
201	0.91	5.50	6.03	6.03	6.07	50.02
202	0.38	5.31	6.36	5.83	5.07	58.38

TABLE D-8. CONTINUED

PLOT IDENT.	PLANTS/SQ METER 6/8/70	6/9/70	6/10/70	6/23/70	7/17/70	YIELD Q/HA
311	0.14	6.50	7.22	6.74	6.84	59.09
312	0.38	5.79	6.36	5.31	5.50	47.52
321	1.29	6.70	7.17	7.22	7.22	59.03
322	1.48	6.70	6.93	6.93	6.89	49.43
331	0.96	7.17	7.36	7.27	7.32	42.80
332	3.16	6.46	7.03	6.84	6.89	55.58
341	0.29	7.03	7.17	7.03	6.98	62.20
342	0.33	5.40	6.98	6.79	6.79	54.58
351	0.10	4.50	5.02	5.83	5.98	64.57
352	0.00	0.91	2.25	5.02	5.40	64.44
361	0.19	4.88	6.03	5.74	5.69	64.41
362	1.58	5.93	6.17	5.36	5.40	66.06
371	0.10	4.02	5.21	5.64	5.21	55.34
372	0.38	5.74	6.41	5.93	6.12	57.73
381	0.24	4.30	4.93	5.50	4.59	37.84
382	0.72	4.30	4.78	5.55	5.40	59.29
391	0.77	7.17	7.13	7.22	7.13	47.15
392	1.58	6.41	6.89	6.74	6.70	50.77
301	0.33	5.36	6.03	6.93	6.65	48.00
302	2.20	5.40	5.69	6.50	6.60	52.93
411	0.19	7.03	7.51	7.17	6.93	47.03
412	0.96	6.55	6.26	6.74	6.46	37.98
421	2.58	6.74	6.74	7.08	6.84	59.53
422	2.25	6.79	7.22	6.89	6.41	54.09
431	0.43	6.84	7.17	7.03	6.98	45.68
432	0.81	6.17	7.03	6.74	6.60	38.26
441	0.29	6.84	7.32	7.13	6.79	46.93
442	0.77	6.22	6.70	6.22	6.03	48.69
451	0.24	5.69	6.36	5.74	5.07	54.13
452	0.10	2.25	4.21	5.40	4.93	59.12
461	0.19	4.88	5.36	6.36	5.64	63.91
462	0.81	3.68	4.11	6.12	6.03	60.78
471	0.43	6.60	6.55	5.64	5.02	65.32
472	0.72	3.68	4.40	5.50	4.93	59.17
481	0.00	1.58	3.97	4.45	4.16	43.96
482	0.29	4.50	5.31	4.83	4.73	59.48
491	0.24	6.70	7.27	7.22	6.65	57.72
492	1.15	6.07	6.74	6.22	5.36	50.91
401	1.20	7.08	6.93	6.93	6.84	49.44
402	0.86	5.98	6.60	6.50	5.64	49.10

APPENDIX E: SOIL STRUCTURE EXPERIMENT DATA

The digits listed in the column headed "Plot Ident." refer to the plot identification. The digits correspond to the following treatments:

Left most digit = Replication number

Second from left = Initial soil moisture

1 = 18%

2 = 23%

3 = 28%

Third from left = Initial aggregate size and soil bulk density

1 = Fine initial aggregate - 1.0 g/cm^3

2 = Fine initial aggregate - 1.2 g/cm^3

3 = Mixed initial aggregate - 1.0 g/cm^3

4 = Mixed initial aggregate - 1.2 g/cm^3

5 = Large initial aggregate - 1.0 g/cm^3

6 = Large initial aggregate - 1.2 g/cm^3

Fourth from left (Tables E-1 and E-2) = Angle of scan

0 = Zero degrees

9 = Ninety degrees

TABLE E-1. SOIL STRUCTURE CHARACTERISTICS - PHASE INTERCEPT DATA

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
1110	1660875	869357	20076	19722	18014	13821	7995	2897	479	35	0	0	0
1119	1660901	865064	19106	18655	16908	12972	7822	3239	698	29	0	0	0
1120	1660753	224619	16484	16211	15694	14437	11761	7742	3384	656	15	0	0
1129	1660764	190310	15662	15243	14666	13228	10633	7207	3634	978	70	2	0
1130	1660739	267884	22602	19785	15764	12610	8852	5122	2038	733	136	0	0
1139	1660743	250242	23687	21070	16323	12879	8849	5229	2273	671	102	0	0
1140	1660613	396538	18140	17878	16835	14291	10166	5692	2309	674	17	0	0
1149	1660587	400681	17908	17627	16588	13676	9600	5594	2466	713	41	0	0
1150	1660754	435946	10918	10180	9445	8093	6253	4303	2347	1215	395	18	0
1159	1660740	421594	11041	10217	9327	7951	5934	4041	2446	1448	253	0	0
1160	1660538	585296	13260	13091	12397	10640	8048	4959	2119	658	168	0	0
1169	1660656	469126	13958	13294	12298	10345	7699	5058	2502	749	83	0	0
1210	1660759	406070	21902	19930	17630	15550	11415	5070	1098	36	0	0	0
1219	1660750	392213	22111	19738	17010	14633	10661	5410	1345	130	3	0	0
1220	1660749	295707	16369	15730	14998	13751	11084	7056	3071	633	23	0	0
1229	1660770	225337	17822	16209	14561	13239	10540	6666	2985	669	41	0	0
1230	1660750	745888	12904	12683	12183	11001	8281	4488	1392	295	18	0	0
1239	1660760	703694	12887	12556	12007	10809	8153	4661	1675	321	21	0	0

TABLE E-1. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
1240	1660599	562157	14085	13974	13537	12426	9744	5592	2042	420	10	0	0
1249	1660595	582089	13570	13457	12979	11654	8718	5097	2220	644	36	0	0
1250	1660740	511416	11349	10473	9755	9057	7646	5251	2403	723	20	0	0
1259	1660750	335241	16531	13151	10098	8693	7287	5054	2382	814	108	0	0
1260	1660736	444829	9742	9415	9078	8516	7337	5522	2913	1093	83	0	0
1269	1660769	468574	9072	8849	8507	7846	6565	4967	2902	1270	203	12	0
1310	1660905	469635	4992	4964	4841	4612	4184	3583	2640	1710	709	120	0
1319	1660905	395449	4739	4688	4532	4310	3980	3460	2568	1597	653	168	0
1320	1660970	399977	5535	5498	5356	5066	4654	4120	3261	1924	579	38	0
1329	1660959	469018	5794	5725	5579	5275	4790	3983	2881	1601	592	12	0
1330	1660986	723535	6766	6685	6469	6058	5500	4432	2780	1061	93	0	0
1339	1660983	692648	6654	6597	6443	6013	5295	4225	2958	1117	132	5	0
1340	1661000	613076	7522	7448	7236	6746	6051	4742	2953	1147	170	0	0
1349	1661008	582195	7542	7449	7203	6652	5848	4633	2787	1168	349	17	0
1350	1660975	750904	6501	6416	6254	5875	5288	4208	2622	1005	61	0	0
1359	1660957	727013	6276	6182	5944	5507	4902	3925	2572	1132	224	0	0
1360	1660970	680881	7574	7489	7234	6701	5875	4716	3027	1209	0	0	0
1369	1660979	707519	7268	7190	6928	6325	5563	4283	2714	942	232	0	0

TABLE E-1. CONTINUED

PLCT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2110	1660880	862240	22770	22126	19650	14013	7345	2377	544	53	0	0	0
2119	1660885	875609	21977	21343	18789	13515	7313	2697	508	5	0	0	0
2120	1660759	123059	14117	13627	13023	12167	10411	7500	4286	1170	78	2	0
2129	1660763	119059	14339	13781	12855	11645	9666	6862	3902	1386	210	9	0
2130	1660763	439268	17254	16686	15747	13617	9771	5616	1940	394	56	0	0
2139	1660763	420084	19053	18198	16867	14153	9763	5010	1807	431	28	0	0
2140	1660683	433981	19360	18656	17198	13913	9064	4950	1917	510	66	0	0
2149	1660644	417494	15909	15602	14661	12075	8300	4860	2056	692	133	57	0
2150	1660743	649504	13316	12681	11759	9753	7231	4807	1919	296	0	0	0
2159	1660739	592573	14053	12845	11670	9707	7196	4597	2093	265	4	0	0
2160	1660764	421372	13364	12884	12146	10681	8320	5572	2887	910	9	0	0
2169	1660774	414336	12534	12014	11259	9656	7306	5120	2956	1098	137	14	0
2210	1660760	634126	16799	16451	15721	14002	10063	4843	1355	53	0	0	0
2219	1660749	626296	15983	15638	14921	13155	9455	4983	1593	193	2	0	0
2220	1660760	374950	17311	17139	16602	15120	12043	6847	2295	343	19	0	0
2229	1660749	378443	16466	16195	15597	14077	11053	6520	2658	465	23	0	0
2230	1660770	393836	15109	13571	12241	11170	8953	5280	2051	665	115	0	0
2239	1660760	356793	15840	14222	11870	10445	8230	5242	2365	791	174	0	0

TABLE E-1. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2240	1660763	236812	15598	13872	12370	11016	9187	6021	2882	902	198	0	0
2249	1660769	222041	15335	13828	11725	10290	8398	5616	2789	1156	315	13	0
2250	1660759	602177	10841	9714	8399	7498	6472	4620	2149	571	153	0	0
2259	1660749	540177	11254	9815	8471	7589	6518	4838	2241	588	208	0	0
2260	1660749	478489	10139	10010	9652	8898	7566	5754	2951	1002	108	0	0
2269	1660764	451906	9319	9204	8851	8160	6868	5005	3043	1317	262	6	0
2310	1660885	633374	5527	5450	5267	4927	4505	3777	2775	1568	271	7	0
2319	1660891	580558	6037	5983	5790	5417	4901	4233	3089	1534	280	13	0
2320	1661007	584849	7838	7729	7461	6868	5956	4672	3078	1324	200	0	0
2329	1660979	561975	8185	8075	7779	7200	6275	4755	2896	1184	253	14	0
2330	1660983	692003	7521	7421	7161	6625	5881	4839	2968	904	55	0	0
2339	1660990	721588	7329	7245	6954	6395	5531	4246	2788	849	187	0	0
2340	1661003	641588	8096	8015	7829	7369	6501	5091	3081	995	41	0	0
2349	1661019	591217	7660	7574	7286	6786	6026	4736	2886	1082	212	35	0
2350	1660968	721078	7377	7295	7058	6611	5736	4622	2832	862	76	0	0
2359	1660968	646747	7558	7492	7253	6758	5951	4836	2853	1026	195	0	0
2360	1660967	658889	6763	6698	6510	6087	5402	4337	2460	1138	298	3	0
2369	1660968	620177	6711	6680	6466	6091	5371	4290	2779	1199	287	3	0

TABLE E-2. SOIL STRUCTURE CHARACTERISTICS - MATRIX INTERCEPT DATA

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
1110	1660875	869357	19790	19523	18459	15389	10064	4460	1132	105	1	0	0
1119	1660901	865064	18722	18521	17424	14235	9206	4212	1149	218	32	4	0
1120	1660753	224619	14965	14408	11822	6918	2147	264	7	0	0	0	0
1129	1660764	190310	14062	13385	10611	6058	2035	288	3	0	0	0	0
1130	1660739	267884	14331	14023	12782	10301	6449	2782	559	58	0	0	0
1139	1660743	250242	13961	13682	12187	9748	6249	2539	478	35	3	0	0
1140	1660613	396538	17154	16706	14224	9978	4734	1337	104	4	0	0	0
1149	1660587	400681	16691	16170	13681	9325	4479	1281	283	20	0	0	0
1150	1660754	435946	9095	8965	8410	7272	5494	3056	941	142	0	0	0
1159	1660740	421594	9029	8894	8329	7173	5230	3122	1059	226	0	0	0
1160	1660538	585296	12524	12447	11705	10087	7091	3649	907	66	0	0	0
1169	1660656	469126	12176	11991	11007	9168	6357	3244	940	100	8	0	0
1210	1660759	406070	16993	16637	15305	12673	8084	3389	643	11	0	0	0
1219	1660750	392213	16079	15797	14467	11698	7617	3482	790	35	0	0	0
1220	1660749	295707	14003	13728	12330	9294	4808	1215	103	0	0	0	0
1229	1660770	225337	13991	13565	11911	8758	4618	1373	179	8	0	0	0
1230	1660750	745888	12091	11996	11501	10181	7600	4411	1540	367	40	0	0
1239	1660760	703694	11697	11582	11111	9695	7245	4241	1664	322	27	0	0

TABLE E-2. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
1240	1660599	562157	13393	13271	12544	10624	6900	3158	736	46	0	0	0
1249	1660595	582089	12922	12746	11927	9895	6514	3197	894	111	0	0	0
1250	1660740	511416	9346	9299	8898	8138	6500	4031	1562	163	0	0	0
1259	1660750	335241	9008	8894	8463	7556	5789	3775	1570	245	0	0	0
1260	1660736	444829	8786	8666	8283	7319	5782	3191	937	63	0	0	0
1269	1660769	468574	8133	8056	7591	6604	5000	3054	1182	142	5	0	0
1310	1660905	469635	4546	4491	4298	3823	2873	1847	1008	572	143	0	0
1319	1660905	395449	3957	3919	3755	3237	2322	1392	891	468	86	0	0
1320	1660970	399977	4959	4901	4682	4135	3093	1746	850	300	68	0	0
1329	1660959	469018	5324	5271	5042	4541	3397	2103	1124	398	2	0	0
1330	1660986	723535	6212	6154	5980	5507	4468	3311	2217	776	29	0	0
1339	1660983	692648	5904	5855	5642	5132	4130	2832	2118	833	75	0	0
1340	1661000	613076	6754	6712	6449	5791	4597	3139	1781	424	23	0	0
1349	1661008	582195	6752	6658	6350	5462	4106	2668	1345	476	85	1	0
1350	1660975	750904	6049	5971	5752	5266	4254	3124	1919	813	243	0	0
1359	1660957	727013	5634	5584	5315	4748	3705	2626	1792	817	288	0	0
1360	1660970	680881	7042	6962	6678	6046	4761	3091	1874	567	104	0	0
1369	1660979	707519	6767	6694	6426	5666	4431	3110	1888	804	45	0	0

TABLE E-2. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2110	1660880	862240	22124	21823	20324	16489	10370	4255	857	43	0	0	0
2119	1660885	875609	21278	21019	19332	15623	9671	4128	1102	181	6	0	0
2120	1660759	123059	12541	11983	9273	5054	1393	149	7	0	0	0	0
2129	1660763	119059	11968	11461	8785	4949	1535	214	29	0	0	0	0
2130	1660763	439268	15064	14948	13873	11312	6764	2548	390	14	0	0	0
2139	1660763	420084	16549	16293	14868	11780	6970	2574	373	11	0	0	0
2140	1660683	433981	17232	16880	15286	11813	6728	2439	406	7	0	0	0
2149	1660644	417494	14797	14582	12945	9868	5724	2115	353	30	0	0	0
2150	1660743	649504	11618	11509	10975	9766	7552	4363	1588	305	4	0	0
2159	1660739	592573	11666	11524	10967	9733	7438	4545	1636	299	0	0	0
2160	1660764	421372	11802	11667	10970	9335	6139	2703	630	27	0	0	0
2169	1660774	414336	10889	10712	9839	8112	5430	2682	725	92	3	0	0
2210	1660760	634126	15621	15477	14683	12348	8314	3946	799	40	0	0	0
2219	1660749	626296	14788	14641	13714	11413	7644	3664	1053	133	3	0	0
2220	1660760	374950	16206	15721	13636	9592	4739	1285	81	0	0	0	0
2229	1660749	378443	15197	15104	12828	9207	5007	1498	188	29	0	0	0
2230	1660770	393836	11622	11547	11011	9506	6689	3441	780	116	4	0	0
2239	1660760	356793	10926	10736	10108	8549	6163	3149	918	149	0	0	0

TABLE E-2. CONTINUED

PLOT IDENT.	AREA-SQ MICRONS TOTAL	MATRIX	NUMBER OF INTERCEPTS LARGER THAN INDICATED SIZE - MICRONS 20	40	80	160	320	640	1280	2560	5120	10240	20480
2240	1660763	236812	11373	11181	10312	8237	5161	2032	256	1	0	0	0
2249	1660769	222041	10280	10084	9149	7266	2535	889	114	0	0	0	0
2250	1660759	602177	8080	8049	7772	7146	5957	4043	2033	585	61	0	0
2259	1660749	540177	7613	7569	7217	6568	5531	3913	1887	592	62	0	0
2260	1660749	478489	9256	9143	8699	7602	5553	3068	949	70	0	0	0
2269	1660764	451906	8358	8225	7653	6428	4902	2878	881	105	1	0	0
2310	1660885	633374	5068	5016	4798	4199	3404	2474	1612	820	182	0	0
2319	1660891	580558	5196	5153	4903	4193	3061	2044	1453	728	213	0	0
2320	1661007	584849	7412	7317	6933	5991	4381	2861	1460	473	41	0	0
2329	1660979	561975	7417	7298	6882	5919	4354	2837	1413	345	26	0	0
2330	1660983	692003	6987	6895	6467	5616	4462	3207	1734	788	55	0	0
2339	1660990	721588	6852	6709	6267	5358	4204	3091	2075	855	95	6	0
2340	1661003	641588	7712	7621	7285	6665	5336	3340	1714	426	10	0	0
2349	1661019	591217	7097	7010	6690	5919	4510	3005	1506	413	6	0	0
2350	1660968	721078	7112	7076	6792	6241	5025	3530	1652	651	120	0	0
2359	1660968	646747	6861	6788	6435	5758	4516	3067	1568	527	143	0	0
2360	1660967	658889	6307	6293	6065	5576	4618	3207	1887	571	36	0	0
2369	1660968	620177	5879	5840	5644	5189	4233	3011	1762	633	15	4	0

TABLE E-3. SOIL STRUCTURE MEASURED BY MOISTURE DESORPTION

PLOT IDENT.	POROSITY PERCENT BY WT.	MOISTURE CONTENT IN PERCENT - VOLUME BASIS MOISTURE TENSION IN CM OF WATER 0	20	40	60	100	150	200
111	63.07	65.65	47.68	32.43	28.09	24.99	23.48	22.52
112	55.42	56.61	53.13	38.64	33.01	29.54	27.77	26.67
113	62.54	61.42	39.94	33.25	30.46	27.74	25.19	24.23
114	56.20	57.94	52.72	34.75	31.51	29.01	27.74	26.64
115	63.55	60.75	28.87	27.30	26.09	25.33	24.32	21.65
116	55.29	50.29	34.35	32.99	31.36	29.86	28.93	27.88
121	63.87	62.12	30.52	27.01	25.97	24.81	24.00	23.13
122	64.53	66.35	35.19	29.68	27.86	26.12	25.28	24.93
123	64.25	60.75	30.32	26.90	25.68	24.64	24.06	23.42
124	55.84	55.22	37.54	33.19	31.86	30.81	30.23	29.59
125	62.81	61.54	29.62	27.77	26.70	25.91	25.45	24.75
126	55.78	55.83	36.41	33.74	32.70	31.42	30.67	30.23
131	63.06	62.29	32.38	30.93	29.80	29.07	28.61	27.91
132	56.23	43.80	36.90	35.97	35.48	34.75	34.00	33.71
133	64.09	63.30	31.42	30.17	29.42	28.38	27.42	26.49
134	55.46	54.14	38.49	36.75	35.80	34.90	33.97	33.22
135	62.89	61.16	33.22	31.48	30.67	29.80	29.01	28.03
136	55.78	54.03	37.51	36.35	35.62	34.64	33.59	32.67

TABLE E-3. CONTINUED

PLOT IDENT.	POROSITY PERCENT BY WT.	MOISTURE CONTENT IN PERCENT - VOLUME BASIS MOISTURE TENSION IN CM OF WATER 0	20	40	60	100	150	200
211	63.07	48.06	38.03	31.36	27.16	25.19	23.30	22.52
212	56.00	45.28	44.35	37.39	33.16	30.14	28.52	27.77
213	63.59	59.74	35.68	32.38	28.90	25.83	24.03	23.16
214	55.44	52.03	43.33	33.71	31.01	28.52	27.30	26.49
215	63.55	53.42	28.35	25.68	24.72	23.33	22.29	21.65
216	55.26	53.10	34.84	30.72	30.09	28.99	27.65	27.16
221	63.71	65.83	37.13	31.33	28.55	26.93	25.83	25.30
222	64.53	40.67	32.72	30.00	27.94	27.07	25.74	24.93
223	62.70	62.84	31.48	29.39	28.49	27.19	26.49	25.80
224	55.68	54.46	37.80	34.14	33.28	31.94	30.96	30.00
225	62.85	65.36	30.64	29.25	28.49	27.62	26.96	26.29
226	55.78	48.99	35.10	34.35	33.13	32.52	31.62	30.23
231	62.68	60.81	30.67	29.97	28.81	28.14	27.71	26.90
232	55.79	54.03	36.93	35.59	34.96	33.74	33.13	32.43
233	62.66	61.42	30.64	29.77	29.10	28.58	27.83	27.57
234	55.61	56.09	39.57	37.77	35.36	34.49	33.83	33.13
235	61.90	60.78	28.90	27.94	27.42	26.87	25.80	25.62
236	55.42	55.91	37.16	35.86	35.22	34.84	34.17	33.94

APPENDIX F: EMERGENCE EXPERIMENTAL DATA

The digits listed in the column headed "Plot Ident." refer to the plot identification. The digits correspond to the following treatments:

Left most digit = Replication number

Second from left = Seed type

1 = Corn

2 = Soybeans

Third from left = Soil temperature

1 = 10C

2 = 18C

3 = 26C

Fourth from left = Soil moisture

1 = 18%

2 = 23%

3 = 28%

Fifth from left = Seed depth

1 = 2.5 cm

2 = 3.75 cm

Sixth from left = Variety

1 = Amsoy for soybeans and A632XA619 for corn

2 = Corsoy for soybeans and B57XB14A for corn

Seventh from left = Initial soil aggregate size and soil density

1 = Fine initial aggregate - 1.0 g/cm^3

2 = Fine initial aggregate - 1.2 g/cm^3

3 = Mixed initial aggregate - 1.0 g/cm^3

4 = Mixed initial aggregate - 1.2 g/cm^3

5 = Large initial aggregate - 1.0 g/cm^3

6 = Large initial aggregate - 1.2 g/cm^3

TABLE F-1. SOYBEAN EMERGENCE EXPERIMENT TEMPERATURE - 10C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12111111	18	2.5	AMSOY	FINE	1.0	5.74	1
22111111	18	2.5	AMSOY	FINE	1.0	9.66	2
12111121	18	2.5	AMSOY	FINE	1.2	0.00	0
22111121	18	2.5	AMSOY	FINE	1.2	0.00	0
12111131	18	2.5	AMSOY	MIXED	1.0	19.60	4
22111131	18	2.5	AMSOY	MIXED	1.0	48.87	9
12111141	18	2.5	AMSOY	MIXED	1.2	0.00	0
22111141	18	2.5	AMSOY	MIXED	1.2	0.00	0
12111151	18	2.5	AMSOY	LARGE	1.0	31.57	7
22111151	18	2.5	AMSOY	LARGE	1.0	0.00	0
12111161	18	2.5	AMSOY	LARGE	1.2	0.00	0
22111161	18	2.5	AMSOY	LARGE	1.2	0.00	0
12111211	18	2.5	CORSOY	FINE	1.0	35.28	7
22111211	18	2.5	CORSOY	FINE	1.0	0.00	0
12111221	18	2.5	CORSOY	FINE	1.2	7.88	2
22111221	18	2.5	CORSOY	FINE	1.2	0.00	0
12111231	18	2.5	CORSOY	MIXED	1.0	9.66	2
22111231	18	2.5	CORSOY	MIXED	1.0	0.00	0
12111241	18	2.5	CORSOY	MIXED	1.2	0.00	0
22111241	18	2.5	CORSOY	MIXED	1.2	0.00	0
12111251	18	2.5	CORSOY	LARGE	1.0	17.04	4
22111251	18	2.5	CORSOY	LARGE	1.0	17.43	3
12111261	18	2.5	CORSOY	LARGE	1.2	0.00	0
22111261	18	2.5	CORSOY	LARGE	1.2	0.00	0

TABLE F-1. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12112111	18	3.8	AMSOY	FINE	1.0	0.00	0
22112111	18	3.8	AMSOY	FINE	1.0	0.00	0
12112121	18	3.8	AMSOY	FINE	1.2	0.00	0
22112121	18	3.8	AMSOY	FINE	1.2	0.00	0
12112131	18	3.8	AMSOY	MIXED	1.0	4.94	1
22112131	18	3.8	AMSOY	MIXED	1.0	0.00	0
12112141	18	3.8	AMSOY	MIXED	1.2	0.00	0
22112141	18	3.8	AMSOY	MIXED	1.2	0.00	0
12112151	18	3.8	AMSOY	LARGE	1.0	3.71	1
22112151	18	3.8	AMSOY	LARGE	1.0	3.88	1
12112161	18	3.8	AMSOY	LARGE	1.2	0.00	0
22112161	18	3.8	AMSOY	LARGE	1.2	0.00	0
12112211	18	3.8	CORSOY	FINE	1.0	3.72	1
22112211	18	3.8	CORSOY	FINE	1.0	3.72	1
12112221	18	3.8	CORSOY	FINE	1.2	0.00	0
22112221	18	3.8	CORSOY	FINE	1.2	0.00	0
12112231	18	3.8	CORSOY	MIXED	1.0	17.04	4
22112231	18	3.8	CORSOY	MIXED	1.0	12.45	3
12112241	18	3.8	CORSOY	MIXED	1.2	0.00	0
22112241	18	3.8	CORSOY	MIXED	1.2	0.00	0
12112251	18	3.8	CORSOY	LARGE	1.0	0.00	0
22112251	18	3.8	CORSOY	LARGE	1.0	3.96	1
12112261	18	3.8	CORSOY	LARGE	1.2	0.00	0
22112261	18	3.8	CORSOY	LARGE	1.2	0.00	0

TABLE F-1. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12121111	23	2.5	AMSOY	FINE	1.0	4.17	1
22121111	23	2.5	AMSOY	FINE	1.0	15.39	3
12121121	23	2.5	AMSOY	FINE	1.2	0.00	0
22121121	23	2.5	AMSOY	FINE	1.2	23.20	4
12121131	23	2.5	AMSOY	MIXED	1.0	3.72	1
22121131	23	2.5	AMSOY	MIXED	1.0	25.04	4
12121141	23	2.5	AMSOY	MIXED	1.2	10.78	2
22121141	23	2.5	AMSOY	MIXED	1.2	0.00	0
12121151	23	2.5	AMSOY	LARGE	1.0	0.00	0
22121151	23	2.5	AMSOY	LARGE	1.0	12.34	2
12121161	23	2.5	AMSOY	LARGE	1.2	22.52	4
22121161	23	2.5	AMSOY	LARGE	1.2	0.00	0
12121211	23	2.5	CORSOY	FINE	1.0	8.72	2
22121211	23	2.5	CORSOY	FINE	1.0	21.44	4
12121221	23	2.5	CORSOY	FINE	1.2	13.68	3
22121221	23	2.5	CORSOY	FINE	1.2	18.60	4
12121231	23	2.5	CORSOY	MIXED	1.0	16.29	3
22121231	23	2.5	CORSOY	MIXED	1.0	46.20	7
12121241	23	2.5	CORSOY	MIXED	1.2	7.88	2
22121241	23	2.5	CORSOY	MIXED	1.2	9.94	2
12121251	23	2.5	CORSOY	LARGE	1.0	20.32	4
22121251	23	2.5	CORSOY	LARGE	1.0	24.60	5
12121261	23	2.5	CORSOY	LARGE	1.2	9.18	2
22121261	23	2.5	CORSOY	LARGE	1.2	0.00	0

TABLE F-1. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12122111	23	3.8	AMSOY	FINE	1.0	0.00	0
22122111	23	3.8	AMSOY	FINE	1.0	0.00	0
12122121	23	3.8	AMSOY	FINE	1.2	0.00	0
22122121	23	3.8	AMSOY	FINE	1.2	0.00	0
12122131	23	3.8	AMSOY	MIXED	1.0	7.66	2
22122131	23	3.8	AMSOY	MIXED	1.0	5.58	1
12122141	23	3.8	AMSOY	MIXED	1.2	0.00	0
22122141	23	3.8	AMSOY	MIXED	1.2	0.00	0
12122151	23	3.8	AMSOY	LARGE	1.0	9.14	2
22122151	23	3.8	AMSOY	LARGE	1.0	3.86	1
12122161	23	3.8	AMSOY	LARGE	1.2	0.00	0
22122161	23	3.8	AMSOY	LARGE	1.2	0.00	0
12122211	23	3.8	CORSOY	FINE	1.0	0.00	0
22122211	23	3.8	CORSOY	FINE	1.0	27.48	6
12122221	23	3.8	CORSOY	FINE	1.2	0.00	0
22122221	23	3.8	CORSOY	FINE	1.2	0.00	0
12122231	23	3.8	CORSOY	MIXED	1.0	29.10	6
22122231	23	3.8	CORSOY	MIXED	1.0	4.39	1
12122241	23	3.8	CORSOY	MIXED	1.2	0.00	0
22122241	23	3.8	CORSOY	MIXED	1.2	0.00	0
12122251	23	3.8	CORSOY	LARGE	1.0	0.00	0
22122251	23	3.8	CORSOY	LARGE	1.0	13.29	3
12122261	23	3.8	CORSOY	LARGE	1.2	0.00	0
22122261	23	3.8	CORSOY	LARGE	1.2	0.00	0

TABLE F-1. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12131111	28	2.5	AMSOY	FINE	1.0	4.04	1
22131111	28	2.5	AMSOY	FINE	1.0	5.71	1
12131121	28	2.5	AMSOY	FINE	1.2	0.00	0
22131121	28	2.5	AMSOY	FINE	1.2	0.00	0
12131131	28	2.5	AMSOY	MIXED	1.0	0.00	0
22131131	28	2.5	AMSOY	MIXED	1.0	34.65	7
12131141	28	2.5	AMSOY	MIXED	1.2	4.71	1
22131141	28	2.5	AMSOY	MIXED	1.2	0.00	0
12131151	28	2.5	AMSOY	LARGE	1.0	0.00	0
22131151	28	2.5	AMSOY	LARGE	1.0	0.00	0
12131161	28	2.5	AMSOY	LARGE	1.2	3.89	1
22131161	28	2.5	AMSOY	LARGE	1.2	18.08	4
12131211	28	2.5	CORSOY	FINE	1.0	15.48	3
22131211	28	2.5	CORSOY	FINE	1.0	16.23	3
12131221	28	2.5	CORSOY	FINE	1.2	20.52	4
22131221	28	2.5	CORSOY	FINE	1.2	3.72	1
12131231	28	2.5	CORSOY	MIXED	1.0	14.01	3
22131231	28	2.5	CORSOY	MIXED	1.0	29.22	6
12131241	28	2.5	CORSOY	MIXED	1.2	4.17	1
22131241	28	2.5	CORSOY	MIXED	1.2	3.72	1
12131251	28	2.5	CORSOY	LARGE	1.0	16.71	3
22131251	28	2.5	CORSOY	LARGE	1.0	4.01	1
12131261	28	2.5	CORSOY	LARGE	1.2	11.97	3
22131261	28	2.5	CORSOY	LARGE	1.2	38.82	6

TABLE F-1. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12132111	28	3.8	AMSOY	FINE	1.0	0.00	0
22132111	28	3.8	AMSOY	FINE	1.0	4.02	1
12132121	28	3.8	AMSOY	FINE	1.2	17.56	4
22132121	28	3.8	AMSOY	FINE	1.2	0.00	0
12132131	28	3.8	AMSOY	MIXED	1.0	0.00	0
22132131	28	3.8	AMSOY	MIXED	1.0	4.65	1
12132141	28	3.8	AMSOY	MIXED	1.2	0.00	0
22132141	28	3.8	AMSOY	MIXED	1.2	5.53	1
12132151	28	3.8	AMSOY	LARGE	1.0	0.00	0
22132151	28	3.8	AMSOY	LARGE	1.0	4.18	1
12132161	28	3.8	AMSOY	LARGE	1.2	0.00	0
22132161	28	3.8	AMSOY	LARGE	1.2	0.00	0
12132211	28	3.8	CORSOY	FINE	1.0	12.54	3
22132211	28	3.8	CORSOY	FINE	1.0	8.38	2
12132221	28	3.8	CORSOY	FINE	1.2	5.15	1
22132221	28	3.8	CORSOY	FINE	1.2	8.10	2
12132231	28	3.8	CORSOY	MIXED	1.0	9.96	2
22132231	28	3.8	CORSOY	MIXED	1.0	9.50	2
12132241	28	3.8	CORSOY	MIXED	1.2	0.00	0
22132241	28	3.8	CORSOY	MIXED	1.2	0.00	0
12132251	28	3.8	CORSOY	LARGE	1.0	8.76	2
22132251	28	3.8	CORSOY	LARGE	1.0	3.88	1
12132261	28	3.8	CORSOY	LARGE	1.2	0.00	0
22132261	28	3.8	CORSOY	LARGE	1.2	7.42	2

TABLE F-2. SOYBEAN EMERGENCE EXPERIMENT TEMPERATURE - 18C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12211111	18	2.5	AMSOY	FINE	1.0	67.50	6
22211111	18	2.5	AMSOY	FINE	1.0	42.18	3
12211121	18	2.5	AMSOY	FINE	1.2	4.84	1
22211121	18	2.5	AMSOY	FINE	1.2	140.80	10
12211131	18	2.5	AMSOY	MIXED	1.0	105.66	9
22211131	18	2.5	AMSOY	MIXED	1.0	109.50	10
12211141	18	2.5	AMSOY	MIXED	1.2	78.72	8
22211141	18	2.5	AMSOY	MIXED	1.2	110.53	7
12211151	18	2.5	AMSOY	LARGE	1.0	96.74	7
22211151	18	2.5	AMSOY	LARGE	1.0	117.99	9
12211161	18	2.5	AMSOY	LARGE	1.2	121.50	10
22211161	18	2.5	AMSOY	LARGE	1.2	105.52	8
12211211	18	2.5	CORSOY	FINE	1.0	78.95	5
22211211	18	2.5	CORSOY	FINE	1.0	85.02	6
12211221	18	2.5	CORSOY	FINE	1.2	111.50	10
22211221	18	2.5	CORSOY	FINE	1.2	27.28	2
12211231	18	2.5	CORSOY	MIXED	1.0	85.02	6
22211231	18	2.5	CORSOY	MIXED	1.0	66.24	6
12211241	18	2.5	CORSOY	MIXED	1.2	51.42	6
22211241	18	2.5	CORSOY	MIXED	1.2	72.48	6
12211251	18	2.5	CORSOY	LARGE	1.0	94.90	10
22211251	18	2.5	CORSOY	LARGE	1.0	72.80	7
12211261	18	2.5	CORSOY	LARGE	1.2	84.06	9
22211261	18	2.5	CORSOY	LARGE	1.2	121.00	10

TABLE F-2. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12212111	18	3.8	AMSOY	FINE	1.0	8.11	1
22212111	18	3.8	AMSOY	FINE	1.0	0.00	0
12212121	18	3.8	AMSOY	FINE	1.2	0.00	0
22212121	18	3.8	AMSOY	FINE	1.2	0.00	0
12212131	18	3.8	AMSOY	MIXED	1.0	61.12	8
22212131	18	3.8	AMSOY	MIXED	1.0	26.52	4
12212141	18	3.8	AMSOY	MIXED	1.2	0.00	0
22212141	18	3.8	AMSOY	MIXED	1.2	34.08	6
12212151	18	3.8	AMSOY	LARGE	1.0	56.35	7
22212151	18	3.8	AMSOY	LARGE	1.0	41.04	4
12212161	18	3.8	AMSOY	LARGE	1.2	0.00	0
22212161	18	3.8	AMSOY	LARGE	1.2	28.08	4
12212211	18	3.8	CORSOY	FINE	1.0	0.00	0
22212211	18	3.8	CORSOY	FINE	1.0	36.36	4
12212221	18	3.8	CORSOY	FINE	1.2	0.00	0
22212221	18	3.8	CORSOY	FINE	1.2	0.00	0
12212231	18	3.8	CORSOY	MIXED	1.0	39.45	5
22212231	18	3.8	CORSOY	MIXED	1.0	50.68	7
12212241	18	3.8	CORSOY	MIXED	1.2	5.66	1
22212241	18	3.8	CORSOY	MIXED	1.2	11.66	2
12212251	18	3.8	CORSOY	LARGE	1.0	91.44	8
22212251	18	3.8	CORSOY	LARGE	1.0	62.02	7
12212261	18	3.8	CORSOY	LARGE	1.2	0.00	0
22212261	18	3.8	CORSOY	LARGE	1.2	0.00	0

TABLE F-2. CONTINUED

PLOT IDENT.	MOISTURE %--DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12221111	23	2.5	AMSOY	FINE	1.0	137.12	8
22221111	23	2.5	AMSOY	FINE	1.0	83.02	7
12221121	23	2.5	AMSOY	FINE	1.2	57.70	5
22221121	23	2.5	AMSOY	FINE	1.2	58.60	5
12221131	23	2.5	AMSOY	MIXED	1.0	28.58	2
22221131	23	2.5	AMSOY	MIXED	1.0	75.00	6
12221141	23	2.5	AMSOY	MIXED	1.2	57.25	5
22221141	23	2.5	AMSOY	MIXED	1.2	124.64	8
12221151	23	2.5	AMSOY	LARGE	1.0	114.87	7
22221151	23	2.5	AMSOY	LARGE	1.0	109.69	7
12221161	23	2.5	AMSOY	LARGE	1.2	83.84	8
22221161	23	2.5	AMSOY	LARGE	1.2	104.32	8
12221211	23	2.5	CORSOY	FINE	1.0	104.88	6
22221211	23	2.5	CORSOY	FINE	1.0	119.28	8
12221221	23	2.5	CORSOY	FINE	1.2	32.00	4
22221221	23	2.5	CORSOY	FINE	1.2	117.76	8
12221231	23	2.5	CORSOY	MIXED	1.0	121.52	8
22221231	23	2.5	CORSOY	MIXED	1.0	82.08	8
12221241	23	2.5	CORSOY	MIXED	1.2	106.92	6
22221241	23	2.5	CORSOY	MIXED	1.2	46.98	6
12221251	23	2.5	CORSOY	LARGE	1.0	126.10	10
22221251	23	2.5	CORSOY	LARGE	1.0	93.66	7
12221261	23	2.5	CORSOY	LARGE	1.2	107.55	9
22221261	23	2.5	CORSOY	LARGE	1.2	83.70	6

TABLE F-2. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12222111	23	3.8	AMSOY	FINE	1.0	38.04	3
22222111	23	3.8	AMSOY	FINE	1.0	13.64	1
12222121	23	3.8	AMSOY	FINE	1.2	0.00	0
22222121	23	3.8	AMSOY	FINE	1.2	0.00	0
12222131	23	3.8	AMSOY	MIXED	1.0	12.64	2
22222131	23	3.8	AMSOY	MIXED	1.0	77.70	6
12222141	23	3.8	AMSOY	MIXED	1.2	0.00	0
22222141	23	3.8	AMSOY	MIXED	1.2	0.00	0
12222151	23	3.8	AMSOY	LARGE	1.0	74.25	5
22222151	23	3.8	AMSOY	LARGE	1.0	79.87	7
12222161	23	3.8	AMSOY	LARGE	1.2	0.00	0
22222161	23	3.8	AMSOY	LARGE	1.2	77.76	8
12222211	23	3.8	CORSOY	FINE	1.0	41.20	5
22222211	23	3.8	CORSOY	FINE	1.0	52.80	5
12222221	23	3.8	CORSOY	FINE	1.2	0.00	0
22222221	23	3.8	CORSOY	FINE	1.2	0.00	0
12222231	23	3.8	CORSOY	MIXED	1.0	81.20	7
22222231	23	3.8	CORSOY	MIXED	1.0	121.00	10
12222241	23	3.8	CORSOY	MIXED	1.2	0.00	0
22222241	23	3.8	CORSOY	MIXED	1.2	0.00	0
12222251	23	3.8	CORSOY	LARGE	1.0	34.62	3
22222251	23	3.8	CORSOY	LARGE	1.0	105.52	8
12222261	23	3.8	CORSOY	LARGE	1.2	93.66	7
22222261	23	3.8	CORSOY	LARGE	1.2	0.00	0

TABLE F-2. CONTINUED

PLOT IDENT.	MOISTURE %--DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12231111	28	2.5	AMSOY	FINE	1.0	41.04	4
22231111	28	2.5	AMSOY	FINE	1.0	94.74	6
12231121	28	2.5	AMSOY	FINE	1.2	50.00	5
22231121	28	2.5	AMSOY	FINE	1.2	15.79	1
12231131	28	2.5	AMSOY	MIXED	1.0	85.25	5
22231131	28	2.5	AMSOY	MIXED	1.0	75.00	5
12231141	28	2.5	AMSOY	MIXED	1.2	46.16	4
22231141	28	2.5	AMSOY	MIXED	1.2	78.66	9
12231151	28	2.5	AMSOY	LARGE	1.0	71.52	6
22231151	28	2.5	AMSOY	LARGE	1.0	54.56	4
12231161	28	2.5	AMSOY	LARGE	1.2	17.40	2
22231161	28	2.5	AMSOY	LARGE	1.2	51.66	6
12231211	28	2.5	CORSOY	FINE	1.0	119.70	9
22231211	28	2.5	CORSOY	FINE	1.0	96.11	7
12231221	28	2.5	CORSOY	FINE	1.2	86.48	8
22231221	28	2.5	CORSOY	FINE	1.2	54.35	5
12231231	28	2.5	CORSOY	MIXED	1.0	90.99	9
22231231	28	2.5	CORSOY	MIXED	1.0	145.53	9
12231241	28	2.5	CORSOY	MIXED	1.2	65.88	6
22231241	28	2.5	CORSOY	MIXED	1.2	28.08	4
12231251	28	2.5	CORSOY	LARGE	1.0	132.03	9
22231251	28	2.5	CORSOY	LARGE	1.0	73.15	7
12231261	28	2.5	CORSOY	LARGE	1.2	64.10	5
22231261	28	2.5	CORSOY	LARGE	1.2	73.84	8

TABLE F-2. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12232111	28	3.8	AMSOY	FINE	1.0	18.76	2
22232111	28	3.8	AMSOY	FINE	1.0	6.67	1
12232121	28	3.8	AMSOY	FINE	1.2	17.64	2
22232121	28	3.8	AMSOY	FINE	1.2	0.00	0
12232131	28	3.8	AMSOY	MIXED	1.0	70.70	7
22232131	28	3.8	AMSOY	MIXED	1.0	52.16	4
12232141	28	3.8	AMSOY	MIXED	1.2	12.50	2
22232141	28	3.8	AMSOY	MIXED	1.2	10.44	2
12232151	28	3.8	AMSOY	LARGE	1.0	65.46	6
22232151	28	3.8	AMSOY	LARGE	1.0	46.98	6
12232161	28	3.8	AMSOY	LARGE	1.2	6.00	1
22232161	28	3.8	AMSOY	LARGE	1.2	0.00	0
12232211	28	3.8	CORSOY	FINE	1.0	10.71	1
22232211	28	3.8	CORSOY	FINE	1.0	72.00	6
12232221	28	3.8	CORSOY	FINE	1.2	6.98	1
22232221	28	3.8	CORSOY	FINE	1.2	12.90	2
12232231	28	3.8	CORSOY	MIXED	1.0	80.00	8
22232231	28	3.8	CORSOY	MIXED	1.0	83.70	6
12232241	28	3.8	CORSOY	MIXED	1.2	13.18	2
22232241	28	3.8	CORSOY	MIXED	1.2	0.00	0
12232251	28	3.8	CORSOY	LARGE	1.0	83.44	8
22232251	28	3.8	CORSOY	LARGE	1.0	25.47	3
12232261	28	3.8	CORSOY	LARGE	1.2	6.67	1
22232261	28	3.8	CORSOY	LARGE	1.2	30.96	4

TABLE F-3. SOYBEAN EMERGENCE EXPERIMENT TEMPERATURE - 26C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12311111	18	2.5	AMSOY	FINE	1.0	143.73	9
22311111	18	2.5	AMSOY	FINE	1.0	227.52	9
12311121	18	2.5	AMSOY	FINE	1.2	192.85	7
22311121	18	2.5	AMSOY	FINE	1.2	171.78	7
12311131	18	2.5	AMSOY	MIXED	1.0	195.03	9
22311131	18	2.5	AMSOY	MIXED	1.0	163.73	7
12311141	18	2.5	AMSOY	MIXED	1.2	134.26	7
22311141	18	2.5	AMSOY	MIXED	1.2	151.12	8
12311151	18	2.5	AMSOY	LARGE	1.0	125.40	6
22311151	18	2.5	AMSOY	LARGE	1.0	186.84	9
12311161	18	2.5	AMSOY	LARGE	1.2	132.66	6
22311161	18	2.5	AMSOY	LARGE	1.2	133.91	7
12311211	18	2.5	CORSOY	FINE	1.0	190.47	7
22311211	18	2.5	CORSOY	FINE	1.0	156.59	7
12311221	18	2.5	CORSOY	FINE	1.2	98.76	6
22311221	18	2.5	CORSOY	FINE	1.2	182.96	8
12311231	18	2.5	CORSOY	MIXED	1.0	126.48	6
22311231	18	2.5	CORSOY	MIXED	1.0	84.88	4
12311241	18	2.5	CORSOY	MIXED	1.2	71.40	4
22311241	18	2.5	CORSOY	MIXED	1.2	159.12	8
12311251	18	2.5	CORSOY	LARGE	1.0	131.74	7
22311251	18	2.5	CORSOY	LARGE	1.0	58.30	5
12311261	18	2.5	CORSOY	LARGE	1.2	96.08	8
22311261	18	2.5	CORSOY	LARGE	1.2	139.37	7

TABLE F-3. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12312111	18	3.8	AMSOY	FINE	1.0	136.50	7
22312111	18	3.8	AMSOY	FINE	1.0	109.32	6
12312121	18	3.8	AMSOY	FINE	1.2	94.24	8
22312121	18	3.8	AMSOY	FINE	1.2	0.00	0
12312131	18	3.8	AMSOY	MIXED	1.0	146.02	7
22312131	18	3.8	AMSOY	MIXED	1.0	149.68	8
12312141	18	3.8	AMSOY	MIXED	1.2	26.34	3
22312141	18	3.8	AMSOY	MIXED	1.2	0.00	0
12312151	18	3.8	AMSOY	LARGE	1.0	120.26	7
22312151	18	3.8	AMSOY	LARGE	1.0	115.44	8
12312161	18	3.8	AMSOY	LARGE	1.2	40.88	4
22312161	18	3.8	AMSOY	LARGE	1.2	58.35	5
12312211	18	3.8	CORSOY	FINE	1.0	113.26	7
22312211	18	3.8	CORSOY	FINE	1.0	25.50	2
12312221	18	3.8	CORSOY	FINE	1.2	0.00	0
22312221	18	3.8	CORSOY	FINE	1.2	0.00	0
12312231	18	3.8	CORSOY	MIXED	1.0	47.37	3
22312231	18	3.8	CORSOY	MIXED	1.0	145.67	7
12312241	18	3.8	CORSOY	MIXED	1.2	0.00	0
22312241	18	3.8	CORSOY	MIXED	1.2	56.95	5
12312251	18	3.8	CORSOY	LARGE	1.0	0.00	0
22312251	18	3.8	CORSOY	LARGE	1.0	11.23	1
12312261	18	3.8	CORSOY	LARGE	1.2	211.95	9
22312261	18	3.8	CORSOY	LARGE	1.2	52.08	4

TABLE F-3. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12321111	23	2.5	AMSOY	FINE	1.0	100.66	7
22321111	23	2.5	AMSOY	FINE	1.0	204.75	9
12321121	23	2.5	AMSOY	FINE	1.2	84.42	6
22321121	23	2.5	AMSOY	FINE	1.2	92.82	3
12321131	23	2.5	AMSOY	MIXED	1.0	197.28	9
22321131	23	2.5	AMSOY	MIXED	1.0	104.16	8
12321141	23	2.5	AMSOY	MIXED	1.2	190.71	9
22321141	23	2.5	AMSOY	MIXED	1.2	193.20	7
12321151	23	2.5	AMSOY	LARGE	1.0	199.60	8
22321151	23	2.5	AMSOY	LARGE	1.0	281.16	9
12321161	23	2.5	AMSOY	LARGE	1.2	213.30	9
22321161	23	2.5	AMSOY	LARGE	1.2	41.82	3
12321211	23	2.5	CORSOY	FINE	1.0	247.86	9
22321211	23	2.5	CORSOY	FINE	1.0	197.28	8
12321221	23	2.5	CORSOY	FINE	1.2	192.24	6
22321221	23	2.5	CORSOY	FINE	1.2	75.95	5
12321231	23	2.5	CORSOY	MIXED	1.0	244.30	10
22321231	23	2.5	CORSOY	MIXED	1.0	278.73	9
12321241	23	2.5	CORSOY	MIXED	1.2	225.00	9
22321241	23	2.5	CORSOY	MIXED	1.2	176.96	7
12321251	23	2.5	CORSOY	LARGE	1.0	260.40	10
22321251	23	2.5	CORSOY	LARGE	1.0	150.20	5
12321261	23	2.5	CORSOY	LARGE	1.2	128.00	4
22321261	23	2.5	CORSOY	LARGE	1.2	97.02	6

TABLE F-3. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12322111	23	3.8	AMSOY	FINE	1.0	134.22	6
22322111	23	3.8	AMSOY	FINE	1.0	72.20	4
12322121	23	3.8	AMSOY	FINE	1.2	0.00	0
22322121	23	3.8	AMSOY	FINE	1.2	31.02	3
12322131	23	3.8	AMSOY	MIXED	1.0	0.00	0
22322131	23	3.8	AMSOY	MIXED	1.0	254.70	9
12322141	23	3.8	AMSOY	MIXED	1.2	0.00	0
22322141	23	3.8	AMSOY	MIXED	1.2	15.54	2
12322151	23	3.8	AMSOY	LARGE	1.0	19.63	1
22322151	23	3.8	AMSOY	LARGE	1.0	178.00	8
12322161	23	3.8	AMSOY	LARGE	1.2	0.00	0
22322161	23	3.8	AMSOY	LARGE	1.2	0.00	0
12322211	23	3.8	CORSOY	FINE	1.0	131.64	6
22322211	23	3.8	CORSOY	FINE	1.0	27.81	3
12322221	23	3.8	CORSOY	FINE	1.2	36.76	4
22322221	23	3.8	CORSOY	FINE	1.2	132.08	8
12322231	23	3.8	CORSOY	MIXED	1.0	72.52	4
22322231	23	3.8	CORSOY	MIXED	1.0	169.47	9
12322241	23	3.8	CORSOY	MIXED	1.2	51.03	3
22322241	23	3.8	CORSOY	MIXED	1.2	28.11	3
12322251	23	3.8	CORSOY	LARGE	1.0	218.20	10
22322251	23	3.8	CORSOY	LARGE	1.0	200.00	8
12322261	23	3.8	CORSOY	LARGE	1.2	48.80	5
22322261	23	3.8	CORSOY	LARGE	1.2	32.40	3

TABLE F-3. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12331111	28	2.5	AMSOY	FINE	1.0	137.90	5
22331111	28	2.5	AMSOY	FINE	1.0	291.15	9
12331121	28	2.5	AMSOY	FINE	1.2	48.92	2
22331121	28	2.5	AMSOY	FINE	1.2	178.48	8
12331131	28	2.5	AMSOY	MIXED	1.0	137.88	6
22331131	28	2.5	AMSOY	MIXED	1.0	242.48	8
12331141	28	2.5	AMSOY	MIXED	1.2	181.92	6
22331141	28	2.5	AMSOY	MIXED	1.2	69.36	4
12331151	28	2.5	AMSOY	LARGE	1.0	279.36	9
22331151	28	2.5	AMSOY	LARGE	1.0	172.27	7
12331161	28	2.5	AMSOY	LARGE	1.2	125.45	5
22331161	28	2.5	AMSOY	LARGE	1.2	0.00	0
12331211	28	2.5	CORSOY	FINE	1.0	214.64	8
22331211	28	2.5	CORSOY	FINE	1.0	294.12	9
12331221	28	2.5	CORSOY	FINE	1.2	192.08	8
22331221	28	2.5	CORSOY	FINE	1.2	69.20	4
12331231	28	2.5	CORSOY	MIXED	1.0	266.85	9
22331231	28	2.5	CORSOY	MIXED	1.0	251.10	9
12331241	28	2.5	CORSOY	MIXED	1.2	69.52	4
22331241	28	2.5	CORSOY	MIXED	1.2	203.12	8
12331251	28	2.5	CORSOY	LARGE	1.0	243.36	9
22331251	28	2.5	CORSOY	LARGE	1.0	225.00	9
12331261	28	2.5	CORSOY	LARGE	1.2	213.12	8
22331261	28	2.5	CORSOY	LARGE	1.2	213.60	8

TABLE F-3. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
12332111	28	3.8	AMSOY	FINE	1.0	101.60	5
22332111	28	3.8	AMSOY	FINE	1.0	79.29	3
12332121	28	3.8	AMSOY	FINE	1.2	0.00	0
22332121	28	3.8	AMSOY	FINE	1.2	0.00	0
12332131	28	3.8	AMSOY	MIXED	1.0	144.13	7
22332131	28	3.8	AMSOY	MIXED	1.0	119.60	5
12332141	28	3.8	AMSOY	MIXED	1.2	0.00	0
22332141	28	3.8	AMSOY	MIXED	1.2	16.18	1
12332151	28	3.8	AMSOY	LARGE	1.0	168.42	7
22332151	28	3.8	AMSOY	LARGE	1.0	87.32	4
12332161	28	3.8	AMSOY	LARGE	1.2	14.52	1
22332161	28	3.8	AMSOY	LARGE	1.2	0.00	0
12332211	28	3.8	CORSOY	FINE	1.0	172.26	9
22332211	28	3.8	CORSOY	FINE	1.0	147.78	6
12332221	28	3.8	CORSOY	FINE	1.2	0.00	0
22332221	28	3.8	CORSOY	FINE	1.2	18.50	1
12332231	28	3.8	CORSOY	MIXED	1.0	175.92	8
22332231	28	3.8	CORSOY	MIXED	1.0	20.56	1
12332241	28	3.8	CORSOY	MIXED	1.2	214.80	8
22332241	28	3.8	CORSOY	MIXED	1.2	147.92	8
12332251	28	3.8	CORSOY	LARGE	1.0	186.48	8
22332251	28	3.8	CORSOY	LARGE	1.0	104.44	4
12332261	28	3.8	CORSOY	LARGE	1.2	0.00	0
22332261	28	3.8	CORSOY	LARGE	1.2	0.00	0

TABLE F-4. CORN EMERGENCE EXPERIMENT TEMPERATURE - 10C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11111112	18	2.5	A632XA619	FINE	1.0	0.00	0
21111112	18	2.5	A632XA619	FINE	1.0	24.90	5
11111122	18	2.5	A632XA619	FINE	1.2	0.00	0
21111122	18	2.5	A632XA619	FINE	1.2	25.05	5
11111132	18	2.5	A632XA619	MIXED	1.0	50.90	10
21111132	18	2.5	A632XA619	MIXED	1.0	19.72	4
11111142	18	2.5	A632XA619	MIXED	1.2	14.43	3
21111142	18	2.5	A632XA619	MIXED	1.2	36.30	6
11111152	18	2.5	A632XA619	LARGE	1.0	9.86	2
21111152	18	2.5	A632XA619	LARGE	1.0	51.84	9
11111162	18	2.5	A632XA619	LARGE	1.2	0.00	0
21111162	18	2.5	A632XA619	LARGE	1.2	0.00	0
11111212	18	2.5	B57XB14A	FINE	1.0	39.13	7
21111212	18	2.5	B57XB14A	FINE	1.0	20.88	4
11111222	18	2.5	B57XB14A	FINE	1.2	0.00	0
21111222	18	2.5	B57XB14A	FINE	1.2	20.92	4
11111232	18	2.5	B57XB14A	MIXED	1.0	45.28	8
21111232	18	2.5	B57XB14A	MIXED	1.0	52.64	8
11111242	18	2.5	B57XB14A	MIXED	1.2	24.76	4
21111242	18	2.5	B57XB14A	MIXED	1.2	5.19	1
11111252	18	2.5	B57XB14A	LARGE	1.0	52.90	10
21111252	18	2.5	B57XB14A	LARGE	1.0	52.48	8
11111262	18	2.5	B57XB14A	LARGE	1.2	19.64	4
21111262	18	2.5	B57XB14A	LARGE	1.2	33.42	6

TABLE F-4. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11112112	18	3.8	A632XA619	FINE	1.0	0.00	0
21112112	18	3.8	A632XA619	FINE	1.0	0.00	0
11112122	18	3.8	A632XA619	FINE	1.2	0.00	0
21112122	18	3.8	A632XA619	FINE	1.2	0.00	0
11112132	18	3.8	A632XA619	MIXED	1.0	0.00	0
21112132	18	3.8	A632XA619	MIXED	1.0	52.20	9
11112142	18	3.8	A632XA619	MIXED	1.2	0.00	0
21112142	18	3.8	A632XA619	MIXED	1.2	0.00	0
11112152	18	3.8	A632XA619	LARGE	1.0	0.00	0
21112152	18	3.8	A632XA619	LARGE	1.0	0.00	0
11112162	18	3.8	A632XA619	LARGE	1.2	0.00	0
21112162	18	3.8	A632XA619	LARGE	1.2	0.00	0
11112212	18	3.8	B57XB14A	FINE	1.0	9.94	2
21112212	18	3.8	B57XB14A	FINE	1.0	25.60	5
11112222	18	3.8	B57XB14A	FINE	1.2	0.00	0
21112222	18	3.8	B57XB14A	FINE	1.2	32.22	6
11112232	18	3.8	B57XB14A	MIXED	1.0	4.98	1
21112232	18	3.8	B57XB14A	MIXED	1.0	52.02	9
11112242	18	3.8	B57XB14A	MIXED	1.2	0.00	0
21112242	18	3.8	B57XB14A	MIXED	1.2	0.00	0
11112252	18	3.8	B57XB14A	LARGE	1.0	30.60	6
21112252	18	3.8	B57XB14A	LARGE	1.0	35.70	6
11112262	18	3.8	B57XB14A	LARGE	1.2	0.00	0
21112262	18	3.8	B57XB14A	LARGE	1.2	4.89	1

TABLE F-4. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11121112	23	2.5	A632XA619	FINE	1.0	62.50	10
21121112	23	2.5	A632XA619	FINE	1.0	53.40	10
11121122	23	2.5	A632XA619	FINE	1.2	10.04	2
21121122	23	2.5	A632XA619	FINE	1.2	21.20	4
11121132	23	2.5	A632XA619	MIXED	1.0	36.82	7
21121132	23	2.5	A632XA619	MIXED	1.0	78.80	10
11121142	23	2.5	A632XA619	MIXED	1.2	26.65	5
21121142	23	2.5	A632XA619	MIXED	1.2	51.39	9
11121152	23	2.5	A632XA619	LARGE	1.0	54.20	10
21121152	23	2.5	A632XA619	LARGE	1.0	62.70	10
11121162	23	2.5	A632XA619	LARGE	1.2	37.94	7
21121162	23	2.5	A632XA619	LARGE	1.2	43.04	8
11121212	23	2.5	B57XB14A	FINE	1.0	55.20	8
21121212	23	2.5	B57XB14A	FINE	1.0	53.12	8
11121222	23	2.5	B57XB14A	FINE	1.2	21.80	4
21121222	23	2.5	B57XB14A	FINE	1.2	43.82	7
11121232	23	2.5	B57XB14A	MIXED	1.0	46.00	8
21121232	23	2.5	B57XB14A	MIXED	1.0	45.92	8
11121242	23	2.5	B57XB14A	MIXED	1.2	24.95	5
21121242	23	2.5	B57XB14A	MIXED	1.2	14.64	3
11121252	23	2.5	B57XB14A	LARGE	1.0	67.14	9
21121252	23	2.5	B57XB14A	LARGE	1.0	56.60	10
11121262	23	2.5	B57XB14A	LARGE	1.2	16.59	3
21121262	23	2.5	B57XB14A	LARGE	1.2	46.53	9

TABLE F-4. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11122112	23	3.8	A632XA619	FINE	1.0	0.00	0
21122112	23	3.8	A632XA619	FINE	1.0	15.03	3
11122122	23	3.8	A632XA619	FINE	1.2	0.00	0
21122122	23	3.8	A632XA619	FINE	1.2	46.71	9
11122132	23	3.8	A632XA619	MIXED	1.0	4.82	1
21122132	23	3.8	A632XA619	MIXED	1.0	44.24	8
11122142	23	3.8	A632XA619	MIXED	1.2	19.64	4
21122142	23	3.8	A632XA619	MIXED	1.2	0.00	0
11122152	23	3.8	A632XA619	LARGE	1.0	24.55	5
21122152	23	3.8	A632XA619	LARGE	1.0	0.00	0
11122162	23	3.8	A632XA619	LARGE	1.2	9.62	2
21122162	23	3.8	A632XA619	LARGE	1.2	26.45	5
11122212	23	3.8	B57XB14A	FINE	1.0	25.52	4
21122212	23	3.8	B57XB14A	FINE	1.0	49.86	9
11122222	23	3.8	B57XB14A	FINE	1.2	25.90	5
21122222	23	3.8	B57XB14A	FINE	1.2	9.62	2
11122232	23	3.8	B57XB14A	MIXED	1.0	50.49	9
21122232	23	3.8	B57XB14A	MIXED	1.0	29.58	6
11122242	23	3.8	B57XB14A	MIXED	1.2	0.00	0
21122242	23	3.8	B57XB14A	MIXED	1.2	0.00	0
11122252	23	3.8	B57XB14A	LARGE	1.0	38.50	7
21122252	23	3.8	B57XB14A	LARGE	1.0	43.12	8
11122262	23	3.8	B57XB14A	LARGE	1.2	9.80	2
21122262	23	3.8	B57XB14A	LARGE	1.2	0.00	0

TABLE F-4. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11131112	28	2.5	A632XA619	FINE	1.0	40.14	6
21131112	28	2.5	A632XA619	FINE	1.0	37.52	7
11131122	28	2.5	A632XA619	FINE	1.2	31.26	6
21131122	28	2.5	A632XA619	FINE	1.2	75.80	10
11131132	28	2.5	A632XA619	MIXED	1.0	41.02	7
21131132	28	2.5	A632XA619	MIXED	1.0	49.14	9
11131142	28	2.5	A632XA619	MIXED	1.2	30.66	6
21131142	28	2.5	A632XA619	MIXED	1.2	19.96	4
11131152	28	2.5	A632XA619	LARGE	1.0	59.40	10
21131152	28	2.5	A632XA619	LARGE	1.0	41.92	8
11131162	28	2.5	A632XA619	LARGE	1.2	20.60	4
21131162	28	2.5	A632XA619	LARGE	1.2	33.72	6
11131212	28	2.5	B57XB14A	FINE	1.0	55.30	10
21131212	28	2.5	B57XB14A	FINE	1.0	48.80	8
11131222	28	2.5	B57XB14A	FINE	1.2	49.95	9
21131222	28	2.5	B57XB14A	FINE	1.2	51.84	8
11131232	28	2.5	B57XB14A	MIXED	1.0	72.63	9
21131232	28	2.5	B57XB14A	MIXED	1.0	23.16	4
11131242	28	2.5	B57XB14A	MIXED	1.2	50.40	9
21131242	28	2.5	B57XB14A	MIXED	1.2	61.04	8
11131252	28	2.5	B57XB14A	LARGE	1.0	73.10	10
21131252	28	2.5	B57XB14A	LARGE	1.0	45.50	7
11131262	28	2.5	B57XB14A	LARGE	1.2	52.74	9
21131262	28	2.5	B57XB14A	LARGE	1.2	60.88	8

TABLE F-4. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11132112	28	3.8	A632XA619	FINE	1.0	25.40	5
21132112	28	3.8	A632XA619	FINE	1.0	14.52	3
11132122	28	3.8	A632XA619	FINE	1.2	49.95	9
21132122	28	3.8	A632XA619	FINE	1.2	21.60	4
11132132	28	3.8	A632XA619	MIXED	1.0	10.78	2
21132132	28	3.8	A632XA619	MIXED	1.0	10.02	2
11132142	28	3.8	A632XA619	MIXED	1.2	10.38	2
21132142	28	3.8	A632XA619	MIXED	1.2	0.00	0
11132152	28	3.8	A632XA619	LARGE	1.0	9.64	2
21132152	28	3.8	A632XA619	LARGE	1.0	0.00	0
11132162	28	3.8	A632XA619	LARGE	1.2	26.35	5
21132162	28	3.8	A632XA619	LARGE	1.2	15.18	3
11132212	28	3.8	B57XB14A	FINE	1.0	42.16	8
21132212	28	3.8	B57XB14A	FINE	1.0	49.52	8
11132222	28	3.8	B57XB14A	FINE	1.2	58.86	9
21132222	28	3.8	B57XB14A	FINE	1.2	35.04	6
11132232	28	3.8	B57XB14A	MIXED	1.0	10.06	2
21132232	28	3.8	B57XB14A	MIXED	1.0	61.38	9
11132242	28	3.8	B57XB14A	MIXED	1.2	4.85	1
21132242	28	3.8	B57XB14A	MIXED	1.2	0.00	0
11132252	28	3.8	B57XB14A	LARGE	1.0	25.50	5
21132252	28	3.8	B57XB14A	LARGE	1.0	31.56	6
11132262	28	3.8	B57XB14A	LARGE	1.2	15.12	3
21132262	28	3.8	B57XB14A	LARGE	1.2	0.00	0

TABLE F-5. CORN EMERGENCE EXPERIMENT TEMPERATURE - 18C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11211111	18	2.5	A632XA619	FINE	1.0	147.06	9
21211111	18	2.5	A632XA619	FINE	1.0	169.30	10
11211121	18	2.5	A632XA619	FINE	1.2	121.00	10
21211121	18	2.5	A632XA619	FINE	1.2	145.00	10
11211131	18	2.5	A632XA619	MIXED	1.0	161.40	10
21211131	18	2.5	A632XA619	MIXED	1.0	163.40	10
11211141	18	2.5	A632XA619	MIXED	1.2	149.00	10
21211141	18	2.5	A632XA619	MIXED	1.2	152.90	10
11211151	18	2.5	A632XA619	LARGE	1.0	163.30	10
21211151	18	2.5	A632XA619	LARGE	1.0	155.20	10
11211161	18	2.5	A632XA619	LARGE	1.2	119.80	10
21211161	18	2.5	A632XA619	LARGE	1.2	119.00	10
11211211	18	2.5	B57XB14A	FINE	1.0	151.60	10
21211211	18	2.5	B57XB14A	FINE	1.0	149.13	9
11211221	18	2.5	B57XB14A	FINE	1.2	131.90	10
21211221	18	2.5	B57XB14A	FINE	1.2	117.45	9
11211231	18	2.5	B57XB14A	MIXED	1.0	158.60	10
21211231	18	2.5	B57XB14A	MIXED	1.0	153.90	10
11211241	18	2.5	B57XB14A	MIXED	1.2	139.50	10
21211241	18	2.5	B57XB14A	MIXED	1.2	144.90	10
11211251	18	2.5	B57XB14A	LARGE	1.0	152.80	10
21211251	18	2.5	B57XB14A	LARGE	1.0	154.10	10
11211261	18	2.5	B57XB14A	LARGE	1.2	131.40	10
21211261	18	2.5	B57XB14A	LARGE	1.2	128.61	9

TABLE F-5. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11212111	18	3.8	A632XA619	FINE	1.0	155.80	10
21212111	18	3.8	A632XA619	FINE	1.0	138.24	9
11212121	18	3.8	A632XA619	FINE	1.2	133.00	10
21212121	18	3.8	A632XA619	FINE	1.2	128.10	10
11212131	18	3.8	A632XA619	MIXED	1.0	142.70	10
21212131	18	3.8	A632XA619	MIXED	1.0	149.20	10
11212141	18	3.8	A632XA619	MIXED	1.2	126.10	10
21212141	18	3.8	A632XA619	MIXED	1.2	129.00	10
11212151	18	3.8	A632XA619	LARGE	1.0	136.50	10
21212151	18	3.8	A632XA619	LARGE	1.0	151.70	10
11212161	18	3.8	A632XA619	LARGE	1.2	99.81	9
21212161	18	3.8	A632XA619	LARGE	1.2	126.10	10
11212211	18	3.8	B57XB14A	FINE	1.0	154.40	10
21212211	18	3.8	B57XB14A	FINE	1.0	138.00	10
11212221	18	3.8	B57XB14A	FINE	1.2	130.40	10
21212221	18	3.8	B57XB14A	FINE	1.2	107.28	9
11212231	18	3.8	B57XB14A	MIXED	1.0	130.80	10
21212231	18	3.8	B57XB14A	MIXED	1.0	145.30	10
11212241	18	3.8	B57XB14A	MIXED	1.2	137.30	10
21212241	18	3.8	B57XB14A	MIXED	1.2	102.48	8
11212251	18	3.8	B57XB14A	LARGE	1.0	131.49	9
21212251	18	3.8	B57XB14A	LARGE	1.0	119.79	9
11212261	18	3.8	B57XB14A	LARGE	1.2	146.07	9
21212261	18	3.8	B57XB14A	LARGE	1.2	124.40	10

TABLE F-5. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11221111	23	2.5	A632XA619	FINE	1.0	175.40	10
21221111	23	2.5	A632XA619	FINE	1.0	177.10	10
11221121	23	2.5	A632XA619	FINE	1.2	165.70	10
21221121	23	2.5	A632XA619	FINE	1.2	156.60	10
11221131	23	2.5	A632XA619	MIXED	1.0	174.30	10
21221131	23	2.5	A632XA619	MIXED	1.0	169.40	10
11221141	23	2.5	A632XA619	MIXED	1.2	165.90	10
21221141	23	2.5	A632XA619	MIXED	1.2	159.70	10
11221151	23	2.5	A632XA619	LARGE	1.0	162.80	10
21221151	23	2.5	A632XA619	LARGE	1.0	178.60	10
11221161	23	2.5	A632XA619	LARGE	1.2	154.00	10
21221161	23	2.5	A632XA619	LARGE	1.2	155.60	10
11221211	23	2.5	B57XB14A	FINE	1.0	181.40	10
21221211	23	2.5	B57XB14A	FINE	1.0	174.80	10
11221221	23	2.5	B57XB14A	FINE	1.2	163.30	10
21221221	23	2.5	B57XB14A	FINE	1.2	124.80	8
11221231	23	2.5	B57XB14A	MIXED	1.0	150.30	9
21221231	23	2.5	B57XB14A	MIXED	1.0	154.90	10
11221241	23	2.5	B57XB14A	MIXED	1.2	168.40	10
21221241	23	2.5	B57XB14A	MIXED	1.2	156.80	10
11221251	23	2.5	B57XB14A	LARGE	1.0	159.30	10
21221251	23	2.5	B57XB14A	LARGE	1.0	168.20	10
11221261	23	2.5	B57XB14A	LARGE	1.2	152.70	10
21221261	23	2.5	B57XB14A	LARGE	1.2	151.10	10

TABLE F-5. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11222111	23	3.8	A632XA619	FINE	1.0	166.90	10
21222111	23	3.8	A632XA619	FINE	1.0	164.80	10
11222121	23	3.8	A632XA619	FINE	1.2	152.10	10
21222121	23	3.8	A632XA619	FINE	1.2	159.30	10
11222131	23	3.8	A632XA619	MIXED	1.0	158.20	10
21222131	23	3.8	A632XA619	MIXED	1.0	168.40	10
11222141	23	3.8	A632XA619	MIXED	1.2	151.40	10
21222141	23	3.8	A632XA619	MIXED	1.2	156.20	10
11222151	23	3.8	A632XA619	LARGE	1.0	159.60	10
21222151	23	3.8	A632XA619	LARGE	1.0	149.60	10
11222161	23	3.8	A632XA619	LARGE	1.2	147.50	10
21222161	23	3.8	A632XA619	LARGE	1.2	149.20	10
11222211	23	3.8	B57XB14A	FINE	1.0	163.10	10
21222211	23	3.8	B57XB14A	FINE	1.0	160.30	10
11222221	23	3.8	B57XB14A	FINE	1.2	136.17	9
21222221	23	3.8	B57XB14A	FINE	1.2	154.30	10
11222231	23	3.8	B57XB14A	MIXED	1.0	142.47	9
21222231	23	3.8	B57XB14A	MIXED	1.0	165.90	10
11222241	23	3.8	B57XB14A	MIXED	1.2	157.20	10
21222241	23	3.8	B57XB14A	MIXED	1.2	109.71	9
11222251	23	3.8	B57XB14A	LARGE	1.0	158.10	10
21222251	23	3.8	B57XB14A	LARGE	1.0	134.91	9
11222261	23	3.8	B57XB14A	LARGE	1.2	131.20	10
21222261	23	3.8	B57XB14A	LARGE	1.2	135.27	9

TABLE F-5. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11231111	28	2.5	A632XA619	FINE	1.0	156.90	10
21231111	28	2.5	A632XA619	FINE	1.0	178.90	10
11231121	28	2.5	A632XA619	FINE	1.2	173.60	10
21231121	28	2.5	A632XA619	FINE	1.2	169.20	10
11231131	28	2.5	A632XA619	MIXED	1.0	170.90	10
21231131	28	2.5	A632XA619	MIXED	1.0	174.40	10
11231141	28	2.5	A632XA619	MIXED	1.2	165.70	10
21231141	28	2.5	A632XA619	MIXED	1.2	166.20	10
11231151	28	2.5	A632XA619	LARGE	1.0	164.60	10
21231151	28	2.5	A632XA619	LARGE	1.0	171.90	10
11231161	28	2.5	A632XA619	LARGE	1.2	140.04	9
21231161	28	2.5	A632XA619	LARGE	1.2	169.00	10
11231211	28	2.5	B57XB14A	FINE	1.0	178.70	10
21231211	28	2.5	B57XB14A	FINE	1.0	175.10	10
11231221	28	2.5	B57XB14A	FINE	1.2	145.35	9
21231221	28	2.5	B57XB14A	FINE	1.2	159.10	10
11231231	28	2.5	B57XB14A	MIXED	1.0	162.20	10
21231231	28	2.5	B57XB14A	MIXED	1.0	160.60	10
11231241	28	2.5	B57XB14A	MIXED	1.2	155.60	10
21231241	28	2.5	B57XB14A	MIXED	1.2	155.50	10
11231251	28	2.5	B57XB14A	LARGE	1.0	164.50	10
21231251	28	2.5	B57XB14A	LARGE	1.0	174.80	10
11231261	28	2.5	B57XB14A	LARGE	1.2	158.60	10
21231261	28	2.5	B57XB14A	LARGE	1.2	140.22	9

TABLE F-5. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11232111	28	3.8	A632XA619	FINE	1.0	157.30	10
21232111	28	3.8	A632XA619	FINE	1.0	141.80	10
11232121	28	3.8	A632XA619	FINE	1.2	156.30	10
21232121	28	3.8	A632XA619	FINE	1.2	159.20	10
11232131	28	3.8	A632XA619	MIXED	1.0	155.30	10
21232131	28	3.8	A632XA619	MIXED	1.0	160.30	10
11232141	28	3.8	A632XA619	MIXED	1.2	151.70	10
21232141	28	3.8	A632XA619	MIXED	1.2	153.10	10
11232151	28	3.8	A632XA619	LARGE	1.0	142.80	10
21232151	28	3.8	A632XA619	LARGE	1.0	162.60	10
11232161	28	3.8	A632XA619	LARGE	1.2	148.50	10
21232161	28	3.8	A632XA619	LARGE	1.2	164.20	10
11232211	28	3.8	B57XB14A	FINE	1.0	161.60	10
21232211	28	3.8	B57XB14A	FINE	1.0	144.81	9
11232221	28	3.8	B57XB14A	FINE	1.2	146.90	10
21232221	28	3.8	B57XB14A	FINE	1.2	163.30	10
11232231	28	3.8	B57XB14A	MIXED	1.0	151.40	10
21232231	28	3.8	B57XB14A	MIXED	1.0	112.80	10
11232241	28	3.8	B57XB14A	MIXED	1.2	151.70	10
21232241	28	3.8	B57XB14A	MIXED	1.2	141.93	9
11232251	28	3.8	B57XB14A	LARGE	1.0	150.80	10
21232251	28	3.8	B57XB14A	LARGE	1.0	129.24	9
11232261	28	3.8	B57XB14A	LARGE	1.2	149.80	10
21232261	28	3.8	B57XB14A	LARGE	1.2	129.52	8

TABLE F-6. CORN EMERGENCE EXPERIMENT TEMPERATURE - 26C

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11311111	18	2.5	A632XA619	FINE	1.0	276.30	10
21311111	18	2.5	A632XA619	FINE	1.0	282.00	10
11311121	18	2.5	A632XA619	FINE	1.2	250.90	10
21311121	18	2.5	A632XA619	FINE	1.2	187.60	10
11311131	18	2.5	A632XA619	MIXED	1.0	300.60	10
21311131	18	2.5	A632XA619	MIXED	1.0	264.10	10
11311141	18	2.5	A632XA619	MIXED	1.2	331.50	10
21311141	18	2.5	A632XA619	MIXED	1.2	199.10	10
11311151	18	2.5	A632XA619	LARGE	1.0	246.20	10
21311151	18	2.5	A632XA619	LARGE	1.0	261.70	10
11311161	18	2.5	A632XA619	LARGE	1.2	235.30	10
21311161	18	2.5	A632XA619	LARGE	1.2	218.30	10
11311211	18	2.5	B57XB14A	FINE	1.0	279.20	10
21311211	18	2.5	B57XB14A	FINE	1.0	212.58	9
11311221	18	2.5	B57XB14A	FINE	1.2	109.06	7
21311221	18	2.5	B57XB14A	FINE	1.2	134.55	9
11311231	18	2.5	B57XB14A	MIXED	1.0	260.70	10
21311231	18	2.5	B57XB14A	MIXED	1.0	275.20	10
11311241	18	2.5	B57XB14A	MIXED	1.2	225.09	9
21311241	18	2.5	B57XB14A	MIXED	1.2	255.80	10
11311251	18	2.5	B57XB14A	LARGE	1.0	257.94	9
21311251	18	2.5	B57XB14A	LARGE	1.0	259.40	10
11311261	18	2.5	B57XB14A	LARGE	1.2	227.50	10
21311261	18	2.5	B57XB14A	LARGE	1.2	201.50	10

TABLE F-6. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11312111	18	3.8	A632XA619	FINE	1.0	239.40	9
21312111	18	3.8	A632XA619	FINE	1.0	264.30	10
11312121	18	3.8	A632XA619	FINE	1.2	99.54	9
21312121	18	3.8	A632XA619	FINE	1.2	209.10	10
11312131	18	3.8	A632XA619	MIXED	1.0	262.50	10
21312131	18	3.8	A632XA619	MIXED	1.0	238.90	10
11312141	18	3.8	A632XA619	MIXED	1.2	292.00	10
21312141	18	3.8	A632XA619	MIXED	1.2	219.06	9
11312151	18	3.8	A632XA619	LARGE	1.0	250.30	10
21312151	18	3.8	A632XA619	LARGE	1.0	259.50	10
11312161	18	3.8	A632XA619	LARGE	1.2	184.50	10
21312161	18	3.8	A632XA619	LARGE	1.2	222.60	10
11312211	18	3.8	B57XB14A	FINE	1.0	246.70	10
21312211	18	3.8	B57XB14A	FINE	1.0	214.32	8
11312221	18	3.8	B57XB14A	FINE	1.2	162.47	7
21312221	18	3.8	B57XB14A	FINE	1.2	161.84	8
11312231	18	3.8	B57XB14A	MIXED	1.0	270.90	10
21312231	18	3.8	B57XB14A	MIXED	1.0	250.10	10
11312241	18	3.8	B57XB14A	MIXED	1.2	241.20	10
21312241	18	3.8	B57XB14A	MIXED	1.2	213.90	10
11312251	18	3.8	B57XB14A	LARGE	1.0	246.90	10
21312251	18	3.8	B57XB14A	LARGE	1.0	224.20	10
11312261	18	3.8	B57XB14A	LARGE	1.2	211.80	10
21312261	18	3.8	B57XB14A	LARGE	1.2	242.10	10

TABLE F-6. CONTINUED

PLOT IDENT.	MOISTURE %--DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11321111	23	2.5	A632XA619	FINE	1.0	331.40	10
21321111	23	2.5	A632XA619	FINE	1.0	257.60	8
11321121	23	2.5	A632XA619	FINE	1.2	274.60	10
21321121	23	2.5	A632XA619	FINE	1.2	279.81	9
11321131	23	2.5	A632XA619	MIXED	1.0	294.57	9
21321131	23	2.5	A632XA619	MIXED	1.0	323.40	10
11321141	23	2.5	A632XA619	MIXED	1.2	312.10	10
21321141	23	2.5	A632XA619	MIXED	1.2	265.50	10
11321151	23	2.5	A632XA619	LARGE	1.0	335.40	10
21321151	23	2.5	A632XA619	LARGE	1.0	321.70	10
11321161	23	2.5	A632XA619	LARGE	1.2	301.30	10
21321161	23	2.5	A632XA619	LARGE	1.2	288.50	10
11321211	23	2.5	B57XB14A	FINE	1.0	323.20	10
21321211	23	2.5	B57XB14A	FINE	1.0	258.50	10
11321221	23	2.5	B57XB14A	FINE	1.2	253.17	9
21321221	23	2.5	B57XB14A	FINE	1.2	308.30	10
11321231	23	2.5	B57XB14A	MIXED	1.0	300.00	10
21321231	23	2.5	B57XB14A	MIXED	1.0	319.30	10
11321241	23	2.5	B57XB14A	MIXED	1.2	266.10	10
21321241	23	2.5	B57XB14A	MIXED	1.2	299.90	10
11321251	23	2.5	B57XB14A	LARGE	1.0	255.87	9
21321251	23	2.5	B57XB14A	LARGE	1.0	301.80	10
11321261	23	2.5	B57XB14A	LARGE	1.2	326.50	10
21321261	23	2.5	B57XB14A	LARGE	1.2	274.50	10

TABLE F-6. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11322111	23	3.8	A632XA619	FINE	1.0	317.60	10
21322111	23	3.8	A632XA619	FINE	1.0	280.80	10
11322121	23	3.8	A632XA619	FINE	1.2	290.10	10
21322121	23	3.8	A632XA619	FINE	1.2	295.50	10
11322131	23	3.8	A632XA619	MIXED	1.0	296.00	10
21322131	23	3.8	A632XA619	MIXED	1.0	306.90	10
11322141	23	3.8	A632XA619	MIXED	1.2	291.00	10
21322141	23	3.8	A632XA619	MIXED	1.2	279.60	10
11322151	23	3.8	A632XA619	LARGE	1.0	351.10	10
21322151	23	3.8	A632XA619	LARGE	1.0	293.20	10
11322161	23	3.8	A632XA619	LARGE	1.2	282.30	10
21322161	23	3.8	A632XA619	LARGE	1.2	295.80	10
11322211	23	3.8	B57XB14A	FINE	1.0	312.00	10
21322211	23	3.8	B57XB14A	FINE	1.0	293.00	10
11322221	23	3.8	B57XB14A	FINE	1.2	288.20	10
21322221	23	3.8	B57XB14A	FINE	1.2	288.20	10
11322231	23	3.8	B57XB14A	MIXED	1.0	281.10	10
21322231	23	3.8	B57XB14A	MIXED	1.0	265.41	9
11322241	23	3.8	B57XB14A	MIXED	1.2	284.40	10
21322241	23	3.8	B57XB14A	MIXED	1.2	247.68	9
11322251	23	3.8	B57XB14A	LARGE	1.0	297.70	10
21322251	23	3.8	B57XB14A	LARGE	1.0	275.40	10
11322261	23	3.8	B57XB14A	LARGE	1.2	275.70	10
21322261	23	3.8	B57XB14A	LARGE	1.2	270.60	10

TABLE F-6. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11331111	28	2.5	A632XA619	FINE	1.0	321.80	10
21331111	28	2.5	A632XA619	FINE	1.0	324.30	10
11331121	28	2.5	A632XA619	FINE	1.2	314.60	10
21331121	28	2.5	A632XA619	FINE	1.2	281.43	9
11331131	28	2.5	A632XA619	MIXED	1.0	320.30	10
21331131	28	2.5	A632XA619	MIXED	1.0	321.60	10
11331141	28	2.5	A632XA619	MIXED	1.2	310.30	10
21331141	28	2.5	A632XA619	MIXED	1.2	308.20	10
11331151	28	2.5	A632XA619	LARGE	1.0	339.20	10
21331151	28	2.5	A632XA619	LARGE	1.0	316.80	10
11331161	28	2.5	A632XA619	LARGE	1.2	299.80	10
21331161	28	2.5	A632XA619	LARGE	1.2	314.80	10
11331211	28	2.5	B57XB14A	FINE	1.0	328.00	10
21331211	28	2.5	B57XB14A	FINE	1.0	316.30	10
11331221	28	2.5	B57XB14A	FINE	1.2	265.05	9
21331221	28	2.5	B57XB14A	FINE	1.2	307.20	10
11331231	28	2.5	B57XB14A	MIXED	1.0	251.64	9
21331231	28	2.5	B57XB14A	MIXED	1.0	327.70	10
11331241	28	2.5	B57XB14A	MIXED	1.2	309.40	10
21331241	28	2.5	B57XB14A	MIXED	1.2	269.19	9
11331251	28	2.5	B57XB14A	LARGE	1.0	327.00	10
21331251	28	2.5	B57XB14A	LARGE	1.0	307.20	10
11331261	28	2.5	B57XB14A	LARGE	1.2	283.50	10
21331261	28	2.5	B57XB14A	LARGE	1.2	316.20	10

TABLE F-6. CONTINUED

PLOT IDENT.	MOISTURE %-DRY B.	DEPTH CM	VARIETY	AGGR. SIZE	DENSITY G/CC	EMERGENCE RATE 100 P./D.	TOTAL EMERGED PLANTS
11332111	28	3.8	A632XA619	FINE	1.0	233.37	9
21332111	28	3.8	A632XA619	FINE	1.0	223.52	8
11332121	28	3.8	A632XA619	FINE	1.2	305.70	10
21332121	28	3.8	A632XA619	FINE	1.2	281.10	10
11332131	28	3.8	A632XA619	MIXED	1.0	270.18	9
21332131	28	3.8	A632XA619	MIXED	1.0	322.00	10
11332141	28	3.8	A632XA619	MIXED	1.2	288.00	10
21332141	28	3.8	A632XA619	MIXED	1.2	293.20	10
11332151	28	3.8	A632XA619	LARGE	1.0	317.90	10
21332151	28	3.8	A632XA619	LARGE	1.0	313.50	10
11332161	28	3.8	A632XA619	LARGE	1.2	294.00	10
21332161	28	3.8	A632XA619	LARGE	1.2	298.80	10
11332211	28	3.8	B57XB14A	FINE	1.0	262.71	9
21332211	28	3.8	B57XB14A	FINE	1.0	261.36	9
11332221	28	3.8	B57XB14A	FINE	1.2	231.75	9
21332221	28	3.8	B57XB14A	FINE	1.2	285.40	10
11332231	28	3.8	B57XB14A	MIXED	1.0	297.00	10
21332231	28	3.8	B57XB14A	MIXED	1.0	307.80	10
11332241	28	3.8	B57XB14A	MIXED	1.2	264.87	9
21332241	28	3.8	B57XB14A	MIXED	1.2	275.60	10
11332251	28	3.8	B57XB14A	LARGE	1.0	241.20	9
21332251	28	3.8	B57XB14A	LARGE	1.0	231.39	9
11332261	28	3.8	B57XB14A	LARGE	1.2	235.04	8
21332261	28	3.8	B57XB14A	LARGE	1.2	298.00	10