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MODE OF RESPONSE OF WEED-FREE CORN
TO POST-PLANTING CULTIVATION

DISSERTATION

Presented in Partial Fulfillment of the Requirements for the
Degree Doctor of Philosophy in the Graduate School of
The Ohio State University

By

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* * * * *

The Ohio State University
1965

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This dissertation is dedicated to my wife, Mohinder, and our children, Ajit and Jaspal, who willingly went through the hardship of separation and all that goes with it.

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PUBLICATIONS

1. Effect of continuous application of farmyard manure and inorganic fertilizers on crop yields and properties of soil. I. Chemical properties. J. Indian Soc. Soil Sci., 10, 109-120, 1962.
2. Effect of continuous application of manures and fertilizers on some physical properties of Punjab soils. J. Indian Soc. Soil Sci. 10, 243-247, 1962.

FIELDS OF STUDY

Major Field: Agronomy

Studies in Soil Physics, Classification and Conservation. Professors G. S. Taylor, N. Holowaychuk, D. J. Hoff and G. O. Schwab

Studies in Soil Chemistry and Tracer Techniques.
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Studies in Physics. Professors C. E. Neilsen and
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Studies in Physical Chemistry. Professors G. E.
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Studies in Plant Physiology. Professors C. A. Swanson,
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INTRODUCTION

Increased crop yield is the objective of most of the agronomic practices all the world over. Post-planting cultivation of row crops has long been practiced to eradicate weeds. Weeds, if not destroyed, compete with the main crop for nutrients, moisture and light (29, 48, 49) and reduce economic yields. Recently herbicides have been introduced which permit weed control without disturbing the soil. However, cultivation in weed-free corn (weeds controlled by herbicides) on some soils has still resulted in an increase in yield. Blake and Aldrich (4) reported an increase of 16 bushels per acre (3 years average) in corn yields from cultivated plots on Sassafras loam when compared with effective chemical weed control. In Ohio as a four years' average (1960-64) cultivation, in the absence of weeds, increased corn yields by 7.5 and -1.5 bushels per acre on "crusting" and "non-crusting" soils respectively (unpublished data).

The causes of favorable response from cultivation in the absence of weeds are somewhat obscure. Early investigators utilizing scraping weeds off of the soil surface with a sharp hoe (5, 32) to simulate weed-free con-

ditions, attributed yield increases associated with cultivation to greater water availability (5, 36) and other undefined useful functions (30). However, scraping may have simulated cultivation, and the magnitude of effects may not have been sufficient to permit proper interpretation of the data.

Additional benefits from cultivation of crusting soils are likely to accrue from its effect on breaking the surface soil crust and thus increasing water infiltration. Besides, cultivation lowers bulk density, increases air filled pore space in the surface layer and affects aeration. Some researchers (5, 37) pointed out that cultivation may increase nitrification, but none of them obtained any significant differences in the nitrate level in soil as a result of cultivation. Merkle and Irvin (27) in Pennsylvania found that biological activity as shown by nitrate production was not increased by intertillage.

Despite much work having been done on the effect of cultivation to row crops, it is not definitely known why cultivation is necessary on some soils when weeds are controlled with chemicals. The purpose of this study is to see how cultivation benefits weed-free corn and how much each factor involved contributes towards increased yields.

LITERATURE REVIEW

One of the functions of cultivation is to break the soil crust, which affects physical properties of the surface layer. The change in soil properties is reflected in plant growth. The literature reviewed, therefore, is discussed under two subheads as follows:

I. Crusts. Their Cultivation and Soil Properties

A. Cultivation and Aeration

Soil crusts are those hard layers that form on the surface as a result of the beating action of raindrops and the subsequent drying of compacted layers of oriented particles (25), characterized by high bulk densities (20, 23).

In Marshall silt loam soil pore space increased from 52.8 percent to 55.8 and 57.4 percent and bulk density decreased from 1.25 to 1.17 and 1.13 as a result of 4 inches and 6 inches deep cultivation respectively (31). Swanson and Jacobson (37) observed 35 percent higher macropores, 9 percent higher total porosity, and 7 percent lower volume weight as a result of cultivation in their corn plots. Dreibelbis and Nair (10) conducted some studies with corn-wheat and two years meadow rotation on

Muskingham silt loam on ploughed and disked plots of approximately 20 percent slope. Half of the plots received 2-4-D for weed control and in the other half weeds were controlled by cultivation. Disked and cultivated plots had more porosity than disked 2-4-D plots in 1-4" layer. Disked 2-4-D plots had maximum porosity in 0-1" layer.

The influence of surface crust on soil aeration appears to depend upon the soil moisture tension to a great extent. Oxygen diffusion studies with platinum microelectrode method of Lemon and Erickson (21) indicated that the relation between oxygen diffusion rate and air space is almost linear over the moisture range in which the microelectrode is valid (18), which is at or below tensions required to maintain complete moisture films around soil particles.

In a very wet condition (9) surface crust may provide an effective seal against diffusion at the time when aeration is most critical, such as a short time after rain or irrigation. Erickson and VanDoren (12) using platinum microelectrode method (21) for measuring soil aeration obtained similar results. It was seen that there is a continuous variation in oxygen diffusion rate depending upon precipitation, extraction of moisture by crops, cultivation, etc. They pointed out that the oxygen deficient times are only few in cultivated conditions and such occurrences are usually only after major rains and for

a short period. It was observed that a short period of oxygen deficiency may reduce growth and yield of crops.

In air dry silt loam degree of crusting did not influence gaseous diffusion (9). It was postulated that unless the surface is completely impervious, the rate of diffusion through the soil profile did not depend solely on the properties of this dry surface layer.

B. Cultivation and Moisture Relations

An adequate amount of moisture in the soil during the growing season is a prerequisite for good crop production. Soil gains moisture through intake of rain water and loses it through runoff, evaporation, transpiration, and penetration to deeper layers where roots cannot use it.

Early research workers held the view that losses by evaporation in a growing corn crop were very low. Cates and Cox (7) indicated that presence of a maze of living roots prevents loss of water by evaporation at the surface. Weidman (45) suggested that before the corn plant is very large, the root system so completely fills the feeding area of the soil that there is very little chance for water moving up from below to reach the surface where it can be lost through evaporation.

More recent quantitative studies of soil moisture losses have revealed that evaporation accounts for a considerable part of the total loss by evapotranspiration in the growing corn crop. Tanner and associates (39) who

used energy balance to compute water losses, observed that evaporation from soil under corn drilled in rows 40 inches apart may constitute about 30 percent of total evapotranspiration from fully grown (silking complete) corn planted at 13 kiloplants per acre, when the corn plant has not suffered from water deficiencies and 40 percent when corn growth has been limited by water deficiency. Harold et al. (19), Letey and Peters (24), Peters and Russell (34) used plastic covers to eliminate evaporation and reported that evaporation comprised approximately 50 percent of the evapotranspiration. Peters (33) used an approach similar to Tanner et al. (39) and concluded that evaporation accounted for as much as 50 percent of total water used by corn where the soil surface was frequently wetted from summer rains.

Cultivation produces a thin layer of dry soil at the surface which acts as a mulch. The effect of this layer in reducing losses due to evaporation by cutting down capillary movement of water from lower layers has always been a matter of controversy. Widtsoe (46), from a pot culture study at Utah, reported a saving of 34 percent, 13 percent and 63 percent water from sand, sanpete clay and clay respectively as a result of one inch cultivation. On College loam, cultivation resulted in a loss of soil moisture compared with no cultivation treatment. The soils were maintained at 15 to 30 percent saturation

depending on texture. Cultivation did result in a lesser amount of water being used for production of unit dry matter.

Recently Benoit and Kirkham (3) studied evaporation as affected by soil surface conditions in 3" diameter 15" deep soil cores under carefully controlled conditions of air movement and radiation. Soil under dust mulch lost approximately 0.5 grams moisture per hour against 2 grams per hour for no mulch treatment as an average for 200 hours. After 640 hours run, mulched soil had about twice as much water as the unmulched soil below the soil-mulch interface. There was a sharp break in the moisture distribution curve between soil and the mulch.

Lemon (22) presented a review of some Russian literature and discussed the potentialities for decreasing soil moisture losses by evaporation. He emphasized the importance of dry and rough layer which acts as a barrier to the quick vapor transfer and is expected to cut down losses by evaporation.

Hellaire (17) has shown that the applicability of equation for diffusion of liquid moisture in soil $\left\{ \frac{dQ}{dt} = \lambda \frac{dH}{dz} \right\}$ is very limited. In this equation Q, H, Z and t stand for amount of evaporation, soil water content, depth and time respectively while λ is a constant. It is pointed out that

in the following cases this equation does not yield accurate results:

1. When evaporation is determined in soils having differently structured and textured horizons.
2. When some layer has a tendency to increase in water content at the expense of another layer.

At the time of beginning of soil desiccation, water movement is due to the movement of the entire system of water films under the influence of cohesive forces. The relation between evaporation 'u' and depth 'z' was expressed by the exponential curve $u = u_0 \exp(-az)$. In this equation constant 'a' varies from 0 to 1 depending on the configuration of pore space and evaporation at a given depth. This coefficient represents the probability of the disruption of water films. Creation of a loose layer is expected to yield a high value for 'a' and thus a lower value for 'u.'

Borst and McLure (5) observed an evidence of higher moisture content in cultivated plots on Miami soil. On five years average cultivated plots had 16.1 percent moisture as compared to 14.7 percent in scraped plots. It is, however, hard to say from these results whether this difference in moisture is the result of difference in evaporation, transpiration, infiltration or all of them. The same holds for Sach (36) who concluded that deep cultivation, at least to the deepest depth used (4-6"),

increased the average moisture during the critical period of growth of corn.

Willis (47) from his studies on evaporation from layered soils indicated that for many practical purposes, the inhomogeneities may be of little consequence when water table is relatively deep.

Call and Sewell (6) reported that cultivation did not result in any saving of moisture in their diked plots. McCall (26) concluded that when individual rains are insufficient to fully penetrate the mulch, the latter inhibits the absorption by increasing the amount of current evaporation in the newly fallen moisture. The volume weight of stirred soil being less than that of the unstirred soil, the moisture content of the former immediately after rain is higher (on % weight basis). When conditions are favorable for evaporation, the result is a greater total loss from mulched soil. Weidman (45) asserted that ploughed soil is more valuable as feeding area than it is as a mulch to prevent evaporation of water. Also, when a soil gets dry enough, it will normally form a protective layer at the surface which will serve the same purpose in preventing evaporation as a mulch with cultivation.

Cultivation greatly influences infiltration of water into the soil. A higher water infiltration for three and a half hours initial run in experiments on Marshall and

Shelby silt loam soils was attributed to increased pore space resulting from cultivation (31). The differences disappeared in the first thirty minutes of the run. The thin compact layer that forms on the surface of bare soils during rain has a greater effect on intake of water than has the soil type, slope, moisture content or profile characteristics (11). The infiltration rate increased from 0.25 to 1.6 inches per hour as a consequence of removing 0.3 inches of crusted soil surface. A loose, rough surface assists rain water in entering the soil (45).

Meyer and Mannering (28) reported that in a 60 minute dry run, the infiltration rate was 50 percent higher in the minimum tillage cultivated plots than in the minimum tillage uncultivated plots.

II. Cultivation and Corn Growth

In the previous section it is seen that cultivation of soil affects its bulk density, pore space, water infiltration, evaporation and water content, which consequently could influence crop growth. Oven dry weight of roots has been reported to have a high positive correlation ($r = 0.993$, significant at $P < .001$) with corn yield at various levels of compaction and fertility (35). Any soil factor that limits root development is, therefore, important in plant growth.

In artificially layered pots, root penetration ceased when critical bulk density exceeded values of 1.75 grams per cubic centimeter for sands and 1.46-1.63 grams per cubic centimeter for clays (44). More recently, however, (40, 44) data have been presented to show that soil strength, not soil bulk density, is the critical impedance factor controlling root penetration in sandy soils of southern great plains. A negative correlation coefficient of -0.96 between soil strength as measured by a penetrometer and cotton tap root penetration was reported by Taylor and Gardner (44). The soil strength increased as the bulk density and soil moisture tension increased. Evidence has been presented to show that there does not exist any critical bulk density, but the bulk density at which no roots penetrated depended on the soil moisture content.

Gill and Miller (16), while developing an apparatus for the simultaneous study of the effects of aeration and mechanical impedance observed that the rate of growth of unimpeded roots declines when the oxygen content falls below 10 percent, whereas the growth of impeded roots is seriously reduced under these conditions. Earlier Gill and Bolt (15) presented a review of work done by Pfeffer (1893) on the root growth pressures exerted by plants and pointed out that the root has plastic properties. Its path will generally be along the line of least resistance. Further support to this idea is provided by the results

obtained by Taylor and Gardner (41). These authors used wax substrates of various rigidities for simulated plastic pans and studied the penetrating ability of roots of corn seedlings. As the ASTM penetration number increased from 30 to 60, the roots penetrated
seeds germinated value for corn seedlings increased from 0.3 to 1.2, for bulk density of 1.2 grams per c. c. of soil layer at top of wax substrates. The corresponding increase in this value for bulk density of 0.8 grams per c. c. of the top soil layer was 0.2 to 0.9. Corn seedling root penetration and root length within the wax also increased with the penetration number. They postulated that greater axial pressures exerted by the roots as the radial pressures increased due to higher bulk density of soil layer covering the wax were the cause for increased root penetration.

In a series of experiments conducted by Swanson and Jacobson (38) on Cheshire fine sandy loam a highly significant negative correlation ($r = -0.77$) existed between the corn yields and the number of strokes required to drive core sampler $3 \frac{3}{8}$ inches deep. In another set of data, reported by Phillips and Kirkham (35) from their trial including three levels of compactness and two levels of fertility, it was shown that mechanical impedance as measured by bulk density and a needle type penetrometer was the property most highly correlated with reduction in growth and yield of corn. As the direct measurements of

oxygen content of soil water were not included, the authors felt that their experiments did not prove that mechanical impedance was the only factor responsible for reduced growth.

MATERIAL AND METHODS

Sets of experiments conducted during 1961-62 and 1963-64 are described separately:

1. 1961-62 experiments. In an attempt to estimate the maximum possible effects of cultivation on yield due to infiltration and "other effects," a set of experiments was conducted on Wooster silt loam during 1961 and '62. Among other things, these experiments included the following treatments replicated four times in plots 11 ft. 4" long and 10 ft. 6" wide:

1. No cultivation and runoff allowed.
2. Cultivation and runoff allowed.
3. No cultivation and runoff not allowed.
4. Cultivation and runoff not allowed.

General management. The whole area was plowed and the seed-bed was prepared with a disk and other conventional tillage tools. Four hundred lbs. per acre of 0-20-20 fertilizer and 400 lbs. per acre of ammonium nitrate was plowed down before planting. Active atrazine and active simazine @ 2 lbs. of each per acre was used for weed control during 1961, while only atrazine was used during 1962. K-62 and W-64 hybrid corn was hand planted during the first half of May during 1961 and 1962, respectively. Two to three kernels per hill were planted at

eight-inch intervals in rows 42" apart. Each plot had four rows. The crop was thinned to one plant per hill after the plants were 6-8 inches tall.

Ears and stalks from the six central plants (harvest plants) in each of the two middle rows in the plot were harvested for yield estimates.

Runoff was controlled with metallic frames (Fig. 2) driven two inches deep into the soil.

2. 1963-64 experiments. In 1963 and 1964 field experiments were conducted to explore the additional benefits from cultivation, apart from infiltration. Only the following three treatments with eight and nine replications during 1963 and 1964 respectively were included:

- A. Cultivation with runoff not allowed.
- B. No cultivation with runoff not allowed.
- C. No cultivation with runoff allowed.

Plot size and row spacings were the same as in 1961 and 1962. There were 18 plants in each row. Six central plants in each of the two middle rows were taken as harvest plants. A seven foot border surrounded all plots (Fig. 1). In the center of the border a dead furrow was left for surface drainage. Water could run off a plot if conditions permitted, but water could not run onto a plot. All borders were planted to corn at the same row spacing and population as plot areas.

General management. The whole area was plowed leaving no dead furrows. The seedbed was then prepared with

a disk. During 1963, 300 pounds of 0-20-20 fertilizer and 450 pounds of ammonium nitrate were disked down at the time of preparing the seedbed. In 1964, 300 pounds of a 0-20-20 fertilizer and 200 pounds of ammonium nitrate were disked at the time of planting, and 200 pounds of ammonium nitrate was side dressed when the crop was two feet tall. Active atrazine was applied at planting time for weed control. Weeds were controlled by paraquat and 2-4-D sprays in 1963 and 1964 respectively.

W-64 hybrid corn was hand planted in the first week of May during both years. Two kernels per hill were used during 1963 and thinned to one plant per hill when the plants were six to eight inches tall. Germination in treatment C was not 100 percent and the missing hills were replanted. In 1964 three kernels were used per hill and thinning was done twice. The first thinning was done when the plants were six to eight inches tall when only one plant was pulled out. The second thinning was done when the plants were approximately twenty inches tall and only one plant per hill was left in the field.

Runoff control and measurement. Runoff in treatment A and B was prevented with the help of metallic frames (Fig. 2) driven approximately two inches in the soil so as to leave no gaps between the soil and frames. This arrangement did not allow any runoff from these plots. All the rain water ponded in the frames and infiltrated

into the soil. Runoff control frames were installed immediately after planting in 1963 and after emergence in 1964.

On all the plots in treatment C, rectangular, runoff-measuring frames (average area = 13.75 square feet) were installed. Runoff water was led through a trough on the side of the frame and a pipe laid along the slope to a plastic bag (Fig. 3). Soil and water losses from each plot were measured to the nearest gram and tenth of a pound respectively, after each rain.

Cultivation. Treatment A was cultivated with a hand hoe to a depth of 2-2½ inches after each crusting rain until late July in 1963 and late June in 1964. Cultivations were given on May 23, June 13, June 21, July 16, and July 30 during 1963, and May 16, May 20, May 29, June 9, and June 25 during 1964.

Growth measurements. Plants removed at thinning were collected separately from each plot, washed, oven dried and weighed. The dry weight per plant was taken as an index of early growth. When the remaining plants were more than 60 centimeters tall, the ones selected for harvest were measured for plant height with tallest leaf fully extended. Corn ears were removed from all twelve harvest plants per plot, dried, shelled and weighed for grain yield. The stalks from these plants were cut, dried and weighed for corn fodder yield. Grain and fodder yields per acre were computed from yield per plant.

Fig. 2. Runoff Control Frames

Fig. 3. Runoff Measuring Frames

Oxygen diffusion measurements. Rate of oxygen diffusion was measured at 4 inch depth with a platinum microelectrode (21) after 1.98 inch of cumulative rainfall on July 27 to 29 in 1963. There was 0.33 inch additional rain on August 1 and 0.34 inch on August 3. In 1964, measurements were made on May 25, 26 and 29 following a rainfall of 0.94 inch on May 23 and 24. There was a rain of 0.38 inch after the measurements were taken on May 26. On May 29, the oxygen diffusion measurements were taken immediately after cultivation. More measurements were taken on July 22, 1964, following a rain storm of 2.7 inches on July 20, 1964.

Soil moisture measurements. Moisture measurements were made with neutron depth probe (43) below 6 inches depth and with surface moisture probe in the top 0-12 inch layer. During 1963, half of the neutron access tubes were located in the row and the other half between corn rows. During 1964 the access tubes were installed in three locations: 1. in the row, 2. $10\frac{1}{2}$ inches west of the row, 3. half way between the rows. Moisture was periodically measured with neutron depth probe at depths of 12 inches, 24 inches and 36 inches to represent water content in the 6-18 inch, 18-30 inch, and 30-42 inch soil layers respectively.

Evaporation cans. Cans 6 inches in diameter and 10 inches deep were filled with Wooster silt loam to get a

soil column nine inches deep with a bulk density of 1.2 grams per cubic centimeter. These cans were then installed in holes made at $10\frac{1}{2}$ inches and 21 inches distance west of the row in treatments A and B in 1964. These holes were lined with tar paper on the sides and metallic discs were placed at the bottom to prevent the soil from sticking to the bottom of the can. The depth of the hole was adjusted to leave the can $\frac{3}{4}$ inch above the soil surface so that rain water would not flow into the can. The cans fitted loosely into the lined holes and could be taken out easily and replaced. Crusts were obtained in these cans by sprinkler irrigation. Average initial water content was 27 percent by weight. The soil on the sides of the can was pressed whenever any shrinking was noticed. Periodic losses due to evaporation were determined by weighing the cans to the nearest gram. Cans were covered with lids against rain.

Water distribution in top 6" of cultivated and uncultivated bare soil. Moisture was also determined gravimetrically in samples taken by one inch thickness in top 6 inch layer of three bare cultivated and uncultivated 3 foot x 3 foot plots on level land. The plots were cultivated on August 26 and samples taken on September 8, 1964, after 13 days of rainless period after cultivation.

Root distribution study. A row of corn in a rather level portion of the field adjacent to the main trial was

cultivated on one side and left uncultivated on the other side. In four out of eight replications cultivation was done north of the row while in the other four replications the south side was cultivated. This crop was planted on June 4 and received two cultivations with a hand hoe on June 24 and July 13. Since it was intended to study the distribution in the top 15 inches of soil, the samples were taken a week prior to tasseling when most of the roots are growing in the upper soil (13).

Root samples were obtained by using metal frames to remove slabs of soil of desired thickness. The samples were taken perpendicular to the row and extended to the mid-point between rows. The frame was first driven vertically into soil to the desired depth and a metal plate was then horizontally driven along the lower rim of the frame. This arrangement permitted removal of the slab of desired thickness from a certain location. The samples were collected laterally from 0-3 inch, 3-9 inch, 9-15 inch and 15-21 inch zones and sectioned vertically at 0-3 inches, 3-9 inches and 9-15 inches (Fig. 4). Roots were washed over a screen with a gentle spray of water, picked up with tweezers, oven dried and weighed.

Fig. 4. Sampling Scheme for Root Distribution Study

WEATHER CONDITIONS

From the data given in Table 1, it is seen that rainfall for 1961 nearly equalled the mean rainfall and was well distributed throughout the growing season. In 1962 the months of May and August were very dry and the total rainfall was very low. The year 1963 was drier than normal during the corn growing season. In 1964 the total rainfall for the entire season approached the mean rainfall and monthly averages exceeded the monthly means during May, July and August. Two significant features are that there was a long dry spell in 1963 from June 11 to July 13, and during July, 1964, 2.7 inches of rain came in a single storm.

Mean monthly temperatures for May were lower than the 77 year mean during 1961 and 1963, and higher than the mean during 1962 and 1964. June and July temperatures were about the same in all years and slightly below the mean. Mean temperatures for the month of August were close to normal during 1961 and '62 and below normal in 1963 and '64. September was hotter than normal during 1961 and slightly cooler than normal in 1962-1964.

TABLE 1
WEATHER DATA FOR THE CORN GROWING SEASONS

Year	May	June	July	August	Sept.	Total
Rainfall						
1961	3.22	4.86	4.24	2.81	2.41	17.54
1962	1.97	2.15	3.06	1.12	3.58	11.88
1963	2.59	2.48	3.55	2.13	0.70	11.45
1964	4.53	2.20	5.03	4.45	0.56	16.77
77 year mean	3.78	4.00	4.01	3.50	3.02	18.31
Mean Monthly Temperature--F°						
1961	52.7	64.1	69.6	70.2	66.5	-
1962	63.5	65.7	69.4	68.9	59.0	-
1963	54.7	66.4	69.1	65.4	59.2	-
1964	60.0	66.6	70.9	66.4	61.6	-
77 year mean	58.5	67.5	71.6	69.8	63.7	-

EXPERIMENTAL RESULTS

1. 1961 and 1962

Magnitude of infiltration effects. From 1961 and 1962 data it is possible to compute the order of magnitude of infiltration effects due to cultivation. These computations are shown in Table 2 below.

TABLE 2
CORN YIELDS IN DIFFERENT TREATMENTS IN 1961 AND 1962

Treatment	Corn Grain Yield Bushels/Acre			Incrs. Over Check	% of Max. Incrs.
	1961	1962	Total		
1. No cultivation and runoff allowed	113.0	79.8	192.8	-	-
2. Cultivation and runoff allowed	125.0	104.0	229.0	36.2	70.6
3. No cultivation and runoff not allowed	122.0	93.5	215.5	22.7	43.9
4. Cultivation and runoff not allowed	137.0	107.1	244.1	51.3	100.0

It is seen that on two years average, infiltration alone accounted for only 43.9 percent of the maximum possible increase in corn yield due to cultivation com-

bined with runoff not allowed. The rest of the increase is due to other effects of cultivation. Evidently cultivation without runoff control frames did not result in infiltration of total rainfall and gave only 70.6 percent of the maximum possible increase in corn yield.

2. 1963 and 1964

Runoff and erosion. Since no runoff was allowed in treatments A and B, the infiltration in these treatments exceeded that where runoff was allowed by at least 0.83 inches and 4.03 inches in the years 1963 and 1964 respectively (Table 3). The computed runoff for 1963 is expected to be considerably lower than the actual runoff because some of the runoff collecting bags leaked due to insect damage. In 1964, no leaking was noticed. In 1963, thus, at least 18 percent of the rainfall was lost as runoff while in 1964, 36 percent of the total 11.22 inches of rain ran off the plots. Each inch of runoff water took with it 1.67 and 1.93 tons of soil during 1963 and 1964 respectively. However, the soil erosion estimates with this technique are at best very crude.

Early growth. In 1963 dry weight per plant on June 21 was significantly higher in treatments where runoff was not allowed than where runoff was allowed. As already mentioned, the runoff control frames were installed before emergence in "runoff not allowed" treatments. There

TABLE 3
RUNOFF LOSSES IN TREATMENT C DURING 1963 AND 1964

Date			Amount of Precipitation (Inches)	Runoff (Inches)	Soil Loss Tons/Acre
June	5	1963	0.67	0.25	0.36
June	7, 9, 10	1963	1.39	0.28	0.56
July	27, 28	1963	0.90	0.17	0.30
August	1, 3	1963	0.61	0.02	0.04
August	9	1963	0.38	0.06	0.01
Sept.	11, 12	1963	0.65	0.05	0.12
TOTAL			4.60	0.83	1.39
May	23, 24	1964	0.94	0.29	1.13
May	26	1964	0.38	0.09	0.07
June	7	1964	0.51	0.25	0.55
June	14, 15	1964	0.58	0.05	0.16
June	21	1964	0.23	0.03	0.09
June	23	1964	0.53	0.26	1.48
July	15	1964	0.52	0.15	0.28
July	20	1964	2.70	1.14	1.67
July	28	1964	0.59	0.15	0.36
August	2, 3	1964	1.59	0.65	0.86
August	11	1964	1.82	0.86	0.90
August	20, 21	1964	0.83	0.11	0.24
TOTAL			11.22	4.03	7.79

was an inch of rainfall during the interval between planting and emergence. The result was only 75 percent emergence in plots where runoff was allowed against 100 percent in other two treatments (A and B). Additional water seems to have benefited the early growth in treatments without runoff. Nevertheless, cultivation gave higher dry weight per plant than no cultivation.

In 1964, early in the season on June 8, no differences in growth were shown by the dry weight per plant. But at the time of second sampling dry weight per plant was significantly higher in treatments A and B compared with treatment C. A and B were not different.

Plant height. In 1963, plants in no runoff plots were higher than those where runoff was allowed, up to mid-July (Table 4). After that the height differences in three treatments disappeared. It appears that in the latter part of the growing season the replants in "runoff allowed" treatment (C) did not provide as much competition as was present in the no runoff treatments. Lack of competition resulted in better growth of the harvest plants in treatment C.

In 1964, treatment A resulted in taller corn plants than both B and C during the entire growing season. Also, treatment B was significantly better than treatment C throughout the season.

TABLE 4
EFFECT OF CULTIVATION ON CROP GROWTH AND YIELD

Treat- ment	Av. Dry Wt. Per Plant (Grams)		Mean Plant Height (Cm.)					Av. No. of Harvest Plants	Yield	
	June 21	--	July 2	July 9	July 17	July 25	Aug. 5		Grain Bu/A	Fodder T/A
1963										
A	3.15	--	109	128	147	173	182	12	106	2.02
B	2.82	--	96	114	131	162	182	12	98	1.82
C	2.07	--	88	106	126	161	186	9	107*	2.04
L.S.D.@5%	.28	--	7.1	4.9	6.3	7.1	N.S.		6.7	0.16
1964										
	June 8	June 22	June 29	July 6	July 13	July 20	July 28			
A	0.87	7.48	128	154	173	203	217	12	125	2.65
B	0.82	7.41	119	138	153	180	198	12	105	2.24
C	0.78	6.15	109	127	142	170	184	12	91	2.01
L.S.D.@5%	N.S.	1.13								
1%			7.3	8.0	9.6	8.6	10.7		10.3	0.15

*Yield from replants was only negligible and not considered. When computed on equivalent area grain yield in treatment C is only 80 bushels per acre.

Yield. In 1963 treatment C outyielded treatments B and A for the reasons already given. Treatment A, however, gave an increase of 8 bushels per acre over B. The conditions in the latter two treatments were comparable. The fodder yields seem to follow the same trend as the grain yields.

During 1964 cultivation and runoff not allowed (A) resulted in 20 bushels per acre increase over runoff not allowed alone (B), and 34 bushels per acre increase over no cultivation and runoff allowed (C). Results of fodder yield also showed that treatment A was better than B and B was better than C.

Oxygen diffusion. No differences were noticed in the rates of oxygen diffusion (Table 5) through soil water films between cultivation and no cultivation where runoff was not allowed.

TABLE 5
OXYGEN DIFFUSION RATES* IN VARIOUS TREATMENTS

Treatment	1963				1964			
	7/30	7/31	8/1	8/6	5/25	5/26	5/29	7/22
A	37	54	48	52	22	34	33	35
B	37	56	48	53	25	36	37	34
C	48	54	49	53	33	43	43	56
L.S.D. 5%	10.8	N.S.	N.S.	N.S.	6.7	N.S.	9.2	6.2

*Grams O₂ x 10⁻⁸ cm⁻² min⁻¹.

Oxygen diffusion rates were significantly higher in treatment C than in A and B immediately after rain. The differences disappeared within 24 hours.

Moisture content in the surface six inches. During a dry period in 1963 from June 28 to July 26 the moisture content in the surface 6 inches in treatment A was slightly lower than in B and C (Table 6). It rained on July 27 and the moisture content thereafter was about the same in treatments A and B. Lower moisture contents in treatment C on July 31 to August 6 are the result of runoff from this treatment from July 27 and July 28 rain.

During 1964 treatment A had the same amount of moisture as B during most of the season except on June 16 when it had a lower moisture content than B. Treatment C was always lower than B and A except that it was about the same as A on June 16.

Distribution of water in the profile below six inches. Comparison of various treatments during 1963 (Table 7) reveals that in 6"-30" layer, as an average for the whole season, cultivation and runoff not allowed (treatment A) had only 0.15 inch more moisture between rows than in the row itself whereas no cultivation plots with runoff not allowed and allowed (treatments B and C) had 0.60 inch and 0.29 inch more water respectively between rows than in the row. Similar computations for the entire

TABLE 6

MOISTURE CONTENT IN SURFACE SIX INCHES DURING
1963 AND 1964 GROWING SEASONS

Treatment	Percent H ₂ O by Volume									
	6/28	7/18	7/26	7/31	8/1	8/6	8/15	8/22	8/28	9/5 - 1963
A	16.0	15.4	6.3	21.5	19.5	13.9	11.2	13.6	6.8	5.8
B	17.0	17.5	7.5	20.9	18.6	13.0	10.5	13.8	7.0	5.7
C	17.5	17.0	9.4	18.0	16.4	12.1	10.7	14.0	7.3	6.2
L.S.D. at 5%	--	--	--	--	N.S.	2.4	--	--	--	--
	5/26 6/9 6/16 6/30 7/7 7/13 8/11 - 1964									
	5/26	6/9	6/16	6/30	7/7	7/13	8/11			
A	30.7	21.4	23.3	9.2	7.5	16.1	15.1			
B	30.0	22.8	26.4	11.7	8.9	17.8	16.4			
C	24.2	20.5	23.6	10.1	6.3	15.3	12.2			
L.S.D. at 5%	3.2	N.S.	2.0	N.S.	N.S.	--	2.3			

TABLE 7
DISTRIBUTION OF WATER IN THE PROFILE UNDER DIFFERENT
TREATMENTS DURING 1963

Date	Soil Layer	Percent Moisture by Volume								
		Cultivation - Runoff Not Allowed (A)			No Cultivation - Runoff not allowed (B)			No Cultivation Runoff Allowed (C)		
		I	III	D*	I	III	D	I	III	D
June 19, '63	6"-18"	29.0	28.6	-0.4	27.4	27.9	0.5	28.4	27.2	-1.2
	18"-30"	24.6	26.1	1.5	24.6	27.8	3.2	25.5	26.8	1.3
July 4, '63	6"-18"	24.3	25.1	0.8	22.9	24.9	2.0	23.6	25.1	1.5
	18"-30"	23.5	25.2	1.7	24.3	26.9	2.6	24.0	26.7	2.7
July 15, '63	6"-18"	21.6	20.0	-1.6	19.0	21.3	2.3	20.4	22.4	2.0
	18"-30"	21.7	23.3	1.6	21.5	24.6	3.1	22.6	24.1	1.5
July 24, '63	6"-18"	15.3	17.9	2.6	15.9	19.1	3.2	18.0	19.3	1.3
	18"-30"	19.7	20.4	0.7	19.5	22.6	3.1	21.7	22.9	1.2
Aug. 21, '63	6"-18"	16.7	17.5	0.8	14.8	18.3	3.5	16.4	17.6	1.2
	18"-30"	17.2	17.8	0.6	16.7	19.5	2.8	17.4	18.5	1.1
Aug. 28, '63	6"-18"	15.6	16.0	0.4	14.1	17.5	3.4	14.7	16.3	1.6
	18"-30"	16.8	16.6	-0.2	16.3	18.3	2.0	16.6	17.5	0.9
Sept. 4, '63	6"-18"	13.8	14.6	0.8	13.1	16.3	3.2	14.0	15.2	1.2
	18"-30"	15.7	15.8	0.1	15.5	17.1	1.6	15.5	16.3	0.8
Sept. 18, '63	6"-18"	13.7	14.7	1.0	13.3	15.5	2.2	13.5	14.8	1.3
	18"-30"	15.0	14.8	-0.2	15.2	16.1	0.9	14.7	15.2	0.5
Avr. all dates	6"-30"	19.0	19.6	0.6	18.4	20.9	2.5	19.2	20.4	1.2

*I = Access tubes in the row; III = Access tubes between rows; D = III - I.

1964 growing season (Table 8) show that in the 6-30 inch layer there was no difference in the water contents in the row and between rows in treatment A, while in treatments B and C there was 0.43 inch and 0.53 inch more water respectively between rows than in the row. Apart from this, there was more water between rows in treatment B than in A during both the years. Treatment C had more water than A between rows during 1963 only. This shows that in treatment A there was greater uptake of water between rows when compared with treatments B and C.

In 1963 from June 19 to July 15, there was only 0.78 inch of rain, the bulk of which, 0.67 inch, came on July 14 when the surface was very dry. It is assumed that this rain did not penetrate beyond 6 inches depth. Similar conditions existed in 1964 for the period July 1 to July 9 during which there was a total 0.20 inch of rain, which was received in three showers on different dates. The water uptake pattern during these periods will be taken as indicative of the pattern of root growth.

Data in Table 9 show that from June 19 to July 15, 1963, cultivated plots (treatment A) lost more moisture from the 6-18 inch soil layer, half way between the corn rows, than treatments B and C. In the row, moisture depletion differences were non-significant. Furthermore, treatment A lost significantly less water in the row than between rows. Overall, there was no treatment effect on

TABLE 8
DISTRIBUTION OF WATER IN THE PROFILE UNDER DIFFERENT
TREATMENTS DURING 1964

Date	Layer	Percent moisture by Volume											
		Cultivation and Runoff not Allowed (A)				No Cultivation Runoff not Allowed (B)				No Cultivation Runoff Allowed (C)			
		I	II	III	D*	I	II	III	D*	I	II	III	D*
6/10/64	6"-18"	27.2	24.6	21.5	-2.1	25.3	24.5	24.5	-0.8	22.9	23.2	25.5	2.6
	18"-30"	24.3	24.1	23.0	-1.3	23.4	23.1	24.6	1.2	21.9	22.6	22.9	1.0
6/17/64	6"-18"	25.5	23.5	24.9	-0.6	23.3	23.7	23.5	0.2	23.2	22.1	24.3	1.1
	18"-30"	24.5	23.4	23.3	-1.2	23.4	22.9	23.6	0.2	22.0	22.3	22.4	0.4
7/1/64	6"-18"	21.4	20.4	23.0	1.6	19.4	20.7	21.3	1.9	18.7	19.3	21.9	3.2
	18"-30"	23.2	22.8	22.1	-1.1	22.6	21.9	23.6	1.0	21.3	21.7	21.6	0.3
7/9/64	6"-18"	16.1	16.1	19.3	3.2	13.8	17.0	19.0	5.2	15.1	16.0	19.9	4.8
	18"-30"	21.7	21.6	21.7	0.0	21.1	20.3	22.1	1.0	20.0	20.2	21.5	1.5
7/14/64	6"-18"	15.0	14.5	19.0	4.0	13.1	16.6	18.0	4.9	14.9	15.4	18.9	4.0
	18"-30"	21.3	20.8	21.2	-0.1	20.1	19.8	21.9	1.8	19.4	19.6	21.3	1.9
8/15/64	6"-18"	21.0	18.9	20.0	-1.0	19.2	20.5	21.7	2.5	12.6	14.2	14.8	2.2
	18"-30"	19.5	18.9	18.9	-0.6	18.5	17.8	20.6	2.1	14.4	15.8	18.2	3.8
Avr. for all dates 6"-30"		21.7	20.8	21.8	0.1	20.2	20.7	22.0	1.8	18.9	19.4	21.1	2.2

*I = Access tubes in row; II = Access tubes 10½" from the row; III = Access tubes 21" from the row; D = III - I.

TABLE 9
SOIL MOISTURE DEPLETION (INCHES) FROM 6-18 INCH SOIL
LAYER IN VARIOUS TREATMENTS

Period	Treat- ment	Location			Treat- ment Means
		I	II	III	
June 19 to July 15, 1963	A	0.89	-	1.03	0.96
	B	0.97	-	0.92	0.95
	C	0.96	-	0.58	0.77
	Mean	0.94	-	0.84	-
July 1 to July 9, 1964	A	0.64	0.52	0.44	0.53
	B	0.67	0.44	0.28	0.46
	C	0.43	0.40	0.24	0.36
	Mean	0.58	0.45	0.32	-
Period	For	Differences Nec- essary for Signi- ficance at 5%			
June 19 to July 15, 1963	Treatment means	N.S.			
	Location means	N.S.			
	Treatment x location means	0.101			
July 1 to July 9, 1964	Treatment means	0.23			
	Location means	0.23			
	Treatment x location means	N.S.			

I = Access tubes in the row; II = Access tubes 10½" away from the row; III = Access tubes half way between rows.

moisture depletion from the 6-18 inch layer. Contrary to 1963, in 1964 the location means for water depletion from July 1 to July 9 were significantly different. More water was lost in the row compared with $10\frac{1}{2}$ inches and 21 inches away from the row. Treatment A tended to lose more water compared with the other two, but the differences were not significant. The treatment x location interaction is non-significant.

Comparative evaporation from cultivated and uncultivated cans. The average daily loss for the days studied amounted to 0.05 and 0.08 inches per day for cultivated and uncultivated cans respectively (see Appendix). Cans located $10\frac{1}{2}$ inches and 21 inches west of the north-south rows in the same treatment did not differ in amounts of water lost (Table 10). It can be seen from the data that loss of water from uncultivated cans was much greater than from cultivated cans. The difference between total water lost from cultivated and uncultivated cans for the dates studied are very highly significant ($P = .001$).

The overall slopes of the lines obtained by joining 5/25 to 5/30 points and 6/12 to 7/3 (Fig. 5) points are very much alike for the two treatments (cans were rewetted on June 11). But the shapes of curves are different and the line for uncultivated cans runs higher in both the cases. This shows that after a lapse of sufficient time the initially different rates of evaporation may equalize

TABLE 10

EVAPORATIVE LOSSES FROM CULTIVATED AND UNCULTIVATED
CANS EMBEDDED IN RESPECTIVE PLOTS

Treatment	Total Water Loss (Grams per Can)		Mean
	10 $\frac{1}{2}$ " from Row	21" from Row	
Cultivated	325	347	336
Uncultivated	601	622	612
Mean	463	484	

L.S.D. at 1% for treatment means = 207

Location means = N.S.

Treatment x location = N.S.

Fig. 5. Evaporative Losses from Cans (Cans rewetted on 6/11)

from the cultivated and uncultivated cans. However, for the periods studied uncultivated cans lost more moisture than the cultivated cans.

Moisture distribution in the top six inches of bare cultivated and uncultivated plots. Table 11 shows percent moisture (by weight) in the top 6 inches, by one inch layers, in cultivated and uncultivated treatments. The plots cultivated on August 26 had significantly lower moisture content in the top one-inch layer than the corresponding layer in the uncultivated plots. The treatments did not differ in water content below this layer. In cultivated plots percent moisture was significantly higher in all the lower layers than in 0-1 inch layer. The rise in water content with depth was gradual in the uncultivated plots.

TABLE 11

MOISTURE DISTRIBUTION IN THE TOP SIX INCHES
OF CULTIVATED AND UNCULTIVATED BARE SOIL
AFTER THIRTEEN DAYS EVAPORATION

Treatment	Depth						Mean
	0"-1"	1"-2"	2"-3"	3"-4"	4"-5"	5"-6"	
	(% moisture by weight)						
Cultivated	12.0	19.5	20.5	20.3	20.7	20.3	18.9
Uncultivated	15.7	17.6	18.7	18.1	18.5	18.9	17.9
Mean	13.8	18.5	19.6	19.2	19.6	19.6	
L.S.D. at 5%	For treatment means				N.S.		
	For depth means				2.25		
	For treatment x depth				2.25		

Moisture distribution for cultivated soil shows a sharp break at 1-inch depth whereas in uncultivated soil the distribution is more uniform.

Root distribution. Dry weight of roots in different sections of the rooting volume obtained from individual observations are shown in Appendix while the averages are given in Table 12.

Due to unequal volumes of the various sections, it is not possible to statistically interpret the data as such, for variations in rooting density in the vertical and horizontal directions. To permit valid comparisons for rooting density, the root weights were computed for equal volumes at each location X depth combination before statistically analyzing the data. This conversion, however, invalidates the data for comparison between main treatment by differential magnification of individual observations which disturbs the ratio of computed means to the observed means for treatment totals. The effects of treatment, depth and locations on root distribution are, therefore, discussed separately as follows.

Treatment comparisons. Total root weights for the total rooting volume studied were computed in all the eight blocks for cultivated and uncultivated treatments

TABLE 12
ROOT DISTRIBUTION AS INFLUENCED BY CULTIVATION

Vertical Distance	Dry Weight of Roots in Grams*							
	Distance from Row (Cultivation)				Distance from Row (No Cultivation)			
	0"-3"	3"-9"	9"-15"	15"-21"	0"-3"	3"-9"	9"-15"	15"-21"
0"-3"	0.837	0.154	0.065	0.043	0.678	0.083	0.088	0.006
3"-9"	1.069	1.267	0.649	0.387	0.973	0.820	0.381	0.216
9"-15"	0.127	0.135	0.130	0.076	0.090	0.195	0.100	0.009

*Average of eight observations in 0"-3" and 3"-9" layers, and four observations in 9"-15" layer.

and analyzed statistically. The means are shown below:

<u>Treatment</u>	<u>Mean Root Weight (Grams)</u>
Cultivation	4.82
No cultivation	3.46
L.S.D. at 1%	1.29

Cultivation resulted in a significant increase of 40 percent in root growth over no cultivation treatment.

Vertical distribution of roots. Root density is significantly higher in the 3-9 inch layer, compared with the 0-3 inch and 9-15 inch layers (Table 13).

TABLE 13

DISTRIBUTION OF CORN ROOTS WITH DEPTH IN
CULTIVATED AND UNCULTIVATED PLOTS

Distance Down	Calculated Mean Root Weight per 1/6 Cu. Ft.				Depth Means
	Cultivation		No Cultivation		
0-3"	2.20	ab	1.55	ab	1.87
3"-9"	3.38	a	2.39	ab	2.88
9"-15"	0.67	b	0.59	b	0.63

Difference Necessary for Significance at 5%

For depth means (L.S.D.)	0.70
For treatment x depth means (by Duncan's multiple range test) $P = 5$	2.28

The 0-3 inch layer is significantly denser in roots than the 9-15 inch layer. Also by Duncan's multiple range root

density in cultivated plots is higher in the 3-9 inch layer compared with the 9-15 inch layer, which is not true for the uncultivated treatment.

Lateral distribution of roots. Root density in the top 15 inch soil layer for cultivated and non-cultivated treatments as a function of distance from the row is shown in Figure 6. Also, root densities for different horizontal locations in the 3-9 inch vertical soil layer which had the highest amount of roots are shown in Table 14.

TABLE 14

LATERAL ROOT DISTRIBUTION IN THE 3-9 INCH
SOIL LAYER AS INFLUENCED BY CULTIVATION

Mean Dry Weight of Corn Roots in Grams per 1/6 cu. ft.					
Distance from Row	Cultivation		No Cultivation		Means for Location
0 - 3"	2.14	a	1.95	a	2.05
3 - 9"	1.27	ab	0.82	b	1.05
9 - 15"	0.65	b	0.38	b	0.52
15 - 21"	0.39	b	0.22	b	0.31

Differences Necessary for Significance at 5%

For location means 0.28

For treatment x location means
(by Duncan's multiple range test ($P = 3$)) 0.99

Clearly the root densities vary significantly among locations except that the densities in the 9-15 inch and 15-21

Fig. 6. Lateral Root Distribution in the Top 15 Inches Soil Layer as Influenced by Cultivation

inch portions do not differ significantly. Also, Duncan's multiple range test reveals that in cultivation treatment the root densities in the 0-3 inch and 3-9 inch layers are not significantly different whereas in no cultivation treatment root density in the 3-9 inch layer was significantly lower than in the 0-3 inch layer.

DISCUSSION

Disregarding the anomalous behavior of treatment C during 1963 for the reason given on page 29, it is seen that in absence of cultivation runoff not allowed resulted in 13.3 percent increase in grain yield (average for 1961, 1962 and 1964) over runoff allowed. Cultivation with runoff not allowed yielded 30.7 percent higher than no cultivation and runoff allowed. Thus the increased infiltration resulting from post-planting cultivation at best accounts for approximately 43 percent of the maximum yield increase. What causes the remaining 57 percent increase in yield resulting from cultivation?

In an effort to find out the benefits of cultivation through influence on oxygen diffusion rates, platinum microelectrode method (21) was used. Where the runoff was not allowed, no differences in oxygen diffusion rates between cultivation and no cultivation were observed at 4" depth after heavy rains. The plots where runoff was allowed showed higher oxygen diffusion rates immediately after rain compared with those where runoff was not allowed. These results show that post-planting cultivation of the soil type under investigation does not improve soil aeration. An increase in oxygen diffusion rates with time

after rain indicates that diffusion depends on water content rather than the presence or absence of crust. Similar results have also been reported from earlier investigations (9, 12). It appears that the Wooster silt loam has a good internal drainage. The rain water percolates rapidly in the soil and the air-filled pore space soon builds up.

Since yield increases due to cultivation cannot be explained in terms of aeration, it is necessary to explore the effects of cultivation on surface evaporation and physical properties like bulk density and penetrability of soil. A number of workers (35, 38, 42, 44) have related root growth to properties like bulk density and soil strength. Root growth is known to be related to yields (35). Also, the pattern of root distribution is related to pattern of water uptake from the soil (14). These findings may be used to investigate the effects of cultivation on yield through its influence on root growth.

In general, more water lost between rows from "cultivation and runoff not allowed" treatment than "no cultivation" with or without runoff allowed is indicative of greater root proliferation throughout the soil with cultivation. Although water uptake is a good index of root distribution, yet this observation alone is not sufficient to establish difference in rooting. It is not certain that the difference in uptake of water half way between

the corn rows in the cultivated and uncultivated plots is entirely due to more water transpiring from plants in cultivated plots. If the difference in moisture depletion was due to more evaporation from cultivated plots, no difference in rooting would have been expected. The data from evaporation cans in the respective plots revealed that cultivation reduced evaporative losses from the soil. Higher evaporative loss from uncultivated cans than that from the cultivated ones means that actual difference in the water transpiring through the plants in cultivated and uncultivated plots was probably even greater than that computed in Table 9.

From these data it is postulated that where the crust was broken by cultivation after rain there was greater lateral root growth in the 6-18 inch layer than where crust was not broken. From the moisture estimates obtained by surface moisture probe, it is hard to make similar conclusions as the moisture measurements were taken only at one location. Considering, however, that total water losses from cultivated and uncultivated plots were about equal and the evaporative losses were higher in uncultivated plots, it appears that surface layer in cultivated plots has more roots than uncultivated plots.

The actual root study (Table 12) has clearly brought out that cultivation affects root distribution. Samples taken a week prior to tasseling, when most roots are con-

fined to the upper soil layers (13) revealed that in the top 15 inch layer the cultivated side of the corn row contained 40 percent more roots than the uncultivated side. More roots were found in samples towards the middle of rows where cultivation was done than where cultivation was not done. The bulk of the roots in both cases was confined to the 3-9 inch layer at the time of sampling. Samples taken from the 3-9 inch depth vertically and 15-21 inches distant from the row on the cultivated side had 80 percent more roots than those from corresponding locations on the uncultivated side.

A side observation substantiates this point further. Early in the growing season when the corn plants were 14-16 inches tall, it was observed that the average acute angle which the root makes with the vertical was larger in cultivated rows than in uncultivated rows (Figure 7). Fifty-five observations gave an average root angle of 42 degrees for cultivated and 30.8 degrees for uncultivated plants. Roots subtending a large angle with the vertical are capable of tapping more soil volume in the upper soil layer than those subtending a smaller angle. This is reflected in plant growth as the upper soil layers are richer in available plant food, have better soil structure, and hence better soil-water relationships.

Having observed more roots in the cultivated plots in the top 15 inches compared with uncultivated plots, it

A. Cultivated

B. Uncultivated

Fig. 7. Pattern of Root Growth as Influenced by Cultivation

is worthwhile to consider why the root growth is enhanced with cultivation. It may be a result of more water being available to roots in the cultivated plots as evidenced by reduction in evaporation by cultivation. Root growth is also likely to be affected by soil physical properties which determine the resistance of soil to root penetration. The root requires energy to overcome the resistance offered by the soil (1). Furthermore, root has plastic properties and follows the path of least resistance (15).

The strength of soils depends quite generally on their water content (1, 42). The experiments which interpret changes in root growth in soil at different moisture contents in terms of availability of water, may also be interpreted in terms of changing magnitude of resistance offered to the growing root (1).

Cultivation creates a loose dry layer at the surface called mulch. The soil layer above the soil-mulch interface has lower bulk density and greater penetrability. Also, the soil below the interface has less cohesion because of more water (2, 8) than corresponding layers in uncultivated soil (Table 11). A decrease in cohesion of clay containing soils decreases the overall soil strength. It is postulated that reduction in soil strength caused by cultivation may facilitate greater root proliferation.

SUMMARY AND CONCLUSIONS

Two series of replicated field microplot experiments were conducted on Wooster silt loam with K-62 and W-64 hybrid corn during 1961 and '62, and 1963 and '64. Nineteen sixty-one and '62 experiments among others included the following treatments which permitted the computation of the magnitude of infiltration effects due to cultivation:

1. No cultivation and runoff allowed
2. Cultivation and runoff allowed
3. No cultivation and runoff not allowed
4. Cultivation and runoff not allowed

Runoff was controlled by metallic frames with 14" x 14" divisions driven 2 inches deep into the soil. Infiltration alone accounted for only 43 percent of the maximum possible increase in corn yield. The remaining 57 percent increase was attributed to "other effects" due to cultivation. Cultivation with runoff allowed resulted in 70.6 percent of the maximum increase.

An exploration of other effects due to cultivation was attempted in the 1963 and '64 experiments. Three treatments were tried:

- A. Cultivation and runoff not allowed
- B. No cultivation and runoff not allowed
- C. No cultivation and runoff allowed

Oxygen diffusion rates measured with platinum micro-

electrode after heavy rains in cultivated and uncultivated plots, where runoff was not allowed, were not different. Moisture computations from differentially located neutron access tubes from rainless periods during 1963 and '64 showed greater evapotranspiration losses in cultivated than uncultivated plots, midway between the rows in the 6-18 inch soil layer. Evaporation losses from 6-inch diameter cans with a 9-inch column of Wooster silt loam, embedded in the respective plots, showed greater evaporation losses from uncultivated cans than cultivated cans. This means that the differences due to transpiration in the cultivated and uncultivated plots were actually greater than those computed from neutron moisture measurements.

Oven dry root weights in samples taken a week before tasseling from the top 15 inch soil layer were 40 percent higher on the cultivated side of the row compared with the uncultivated side. Greater root growth with cultivation is attributable to increased water availability or decreased soil strength or both.

It is concluded that post-planting cultivation of corn on Wooster silt loam does not improve aeration. Assuming 100 percent runoff control with cultivation, infiltration accounts for only 43 percent of the maximum increase in yield. The remaining 57 percent increase appears to be the result of greater root growth with cultivation.

APPENDIX

APPENDIX TABLE 1

CORN YIELDS IN BU/ACRE @ 15.5% MOISTURE.
FODDER IN TONS/ACRE OF DRY MATTER

Treatment Rep.	No. Plants/ Plot*	Bu/Acre	Tons/Acre (Fodder)
a. 1963			
A	1	120	2.35
	2	101	1.85
	3	103	1.91
	4	109	1.94
	5	107	2.06
	6	85	1.99
	7	116	2.08
	8	<u>103</u>	<u>1.99</u>
	Total	844	16.17
	Avg.	105.5	2.02
B.	1	108	1.99
	2	98	1.81
	3	101	1.93
	4	89	1.75
	5	94	1.82
	6	95	1.89
	7	95	1.64
	8	<u>101</u>	<u>1.76</u>
	Total	781	14.59
	Avg.	97.6	1.82

APPENDIX TABLE 1--Continued

Treatment Rep.	No. Plants/ Plot*	Bu/Acre	Tons/Acre (Fodder)	
a. 1963--continued				
C	1	7	122	2.63
	2	8	102	1.74
	3	6	113	1.86
	4	10	97	1.91
	5	10	106	1.94
	6	10	96	1.87
	7	10	122	2.29
	8	<u>10</u>	<u>104</u>	<u>2.11</u>
	Total	71	862	16.35
Avg.	9	107.8	2.04	
	L.S.D. 5%	6.7	.16	
	C.V.	6.0%	7.6 %	
b. 1964				
A	1	12	129.3	2.62
	2	12	114.9	2.61
	3	12	131.5	2.69
	4	12	105.7	2.40
	5	12	136.9	2.86
	6	12	119.0	2.66
	7	12	127.8	2.65
	8	12	127.6	2.77
	9	<u>12</u>	<u>134.3</u>	<u>2.60</u>
Total	108	1127.0	23.86	
Avg.	12	125.2	2.65	
B	1	12	93.2	1.94
	2	12	108.0	2.34
	3	12	102.2	2.29
	4	12	101.6	2.19
	5	12	108.6	2.35
	6	12	104.7	2.21
	7	12	108.1	2.21
	8	12	119.2	2.48
	9	<u>12</u>	<u>103.1</u>	<u>2.18</u>
Total	108	948.7	20.19	
Avg.	12	105.4	2.24	

APPENDIX TABLE 1--Continued

Treatment Rep.	No. Plants/ Plot*	Bu/Acre	Tons/Acre (Fodder)	
b. 1964--continued				
C	1	12	83.2	1.98
	2	12	89.6	1.97
	3	12	97.1	2.20
	4	12	92.8	2.05
	5	12	82.8	2.00
	6	12	90.8	1.94
	7	12	93.5	2.07
	8	12	102.7	2.04
	9	<u>12</u>	<u>90.2</u>	<u>1.82</u>
	Total	108	822.7	18.07
	Avg.	12	91.4	2.01
	L.S.D. at 1%		10.3	0.15
	C.V. %		7.0	4.8

*Actual number of plants harvested per plot. In most cases there was a plant every 8 inches, but many had been replanted and were not harvested. In fact there were so many replants in treatment C that there was not an equivalent competition as in A and B. Treatment C should not be compared with A and B during 1963.

APPENDIX TABLE 2

DIFFUSION CURRENTS IN MICROAMPERES TO 4 MM. OF
22 GAUGE PLATINUM WIRE*-4 INCH DEPTH IN SOIL

Treatment Reps.		7/30/63 (AM)	7/31/63 (PM)	8/1/63 (AM)	8/6/63 (AM)
a. 1963					
A	1	5.30	8.48	7.74	8.50
	2	5.83	8.60	8.48	8.35
	3	5.60	11.18	8.32	8.74
	4	7.00	9.20	7.92	9.22
	5	<u>8.00</u>	<u>8.40</u>	<u>7.91</u>	<u>9.36</u>
	Total	31.73	45.86	40.37	44.17
	Avg.	6.3	9.2	8.1	8.8
B	1	6.45	8.40	8.63	9.44
	2	4.60	8.60	7.60	8.85
	3	6.50	9.40	7.75	8.36
	4	7.91	10.44	8.20	9.47
	5	<u>5.73</u>	<u>10.00</u>	<u>7.67</u>	<u>8.50</u>
	Total	31.19	46.84	39.85	44.62
	Avg.	6.2	9.4	8.0	8.9
C	1	6.70	7.75	7.47	8.32
	2	7.90	9.98	7.20	9.20
	3	9.07	9.87	8.29	8.96
	4	8.82	9.88	9.41	8.56
	5	<u>7.90</u>	<u>8.24</u>	<u>9.44</u>	<u>9.50</u>
	Total	40.39	45.72	41.81	44.54
	Avg.	8.1	9.1	8.3	8.9

APPENDIX TABLE 2--Continued

Treatment Reps.		5/25/64 (PM)	5/26/64 (PM)	5/29/64 (PM)	7/22/64 (AM)
b. 1964					
A	1	2.7	4.7	4.8	3.8
	2	2.9	4.1	4.1	6.3
	3	5.3	7.0	6.4	7.3
	4	3.8	5.9	6.4	6.4
	5	4.0	6.3	6.1	6.2
	6	<u>4.3</u>	<u>6.0</u>	<u>4.9</u>	<u>5.3</u>
	Total	23.0	34.0	32.7	35.3
	Avg.	3.8	5.7	5.5	5.9
B	1	3.9	8.6	7.9	5.0
	2	4.4	6.0	6.3	7.0
	3	4.3	4.8	6.0	5.7
	4	4.3	6.1	6.2	4.9
	5	4.9	5.7	5.3	6.3
	6	<u>3.2</u>	<u>5.2</u>	<u>5.2</u>	<u>5.5</u>
	Total	25.0	36.4	36.9	34.4
	Avg.	4.2	6.1	6.2	5.7
C	1	2.6	5.7	5.3	10.2
	2	5.7	8.3	7.3	9.5
	3	7.4	7.4	7.2	9.2
	4	6.0	6.9	7.0	9.7
	5	6.2	8.0	7.9	9.3
	6	<u>5.9</u>	<u>7.2</u>	<u>8.8</u>	<u>9.3</u>
	Total	33.8	43.5	43.5	57.2
	Avg.	5.6	7.3	7.3	9.5
L.S.D. 5%		1.13	N.S.	1.56	1.04

*Current in microamperes x 5.92 equals oxygen diffusion rates ($\text{g. O}_2 \times 10^{-8} \text{ cm}^{-2} \text{ min}^{-1}$).

APPENDIX TABLE 3

MOISTURE CONTENT OF SOIL SURFACE (NEUTRON SURFACE PROBE)
% WATER BY VOLUME

Treat. Reps.		6/28	7/18	7/26	7/31	8/1
a, 1963						
A	1	14.6	18.5	7.7	23.7	21.6
	2	16.0	16.7	6.5	22.3	19.4
	3	18.5	12.3	6.3	22.5	20.1
	4	15.5	11.1	6.1	18.9	15.8
	5	17.4	17.2	6.3	23.4	24.2
	6	14.6	16.9	5.4	20.6	18.8
	7	16.8	16.0	6.7	21.5	21.8
	8	<u>14.4</u>	<u>14.4</u>	<u>5.3</u>	<u>19.2</u>	<u>14.5</u>
	Avg.	16.0	15.4	6.3	21.5	19.5
B	1	18.1	18.4	6.2	25.4	18.1
	2	18.5	18.9	8.6	24.3	23.5
	3	16.8	15.3	6.2	16.9	14.9
	4	13.5	16.0	6.6	18.4	16.8
	5	17.0	21.2	10.1	19.8	20.9
	6	18.9	16.3	7.0	18.5	17.6
	7	15.1	17.2	7.5	22.1	17.5
	8	<u>18.4</u>	<u>16.9</u>	<u>7.8</u>	<u>21.5</u>	<u>19.6</u>
	Avg.	17.0	17.5	7.5	20.9	18.6
C	1	19.1	21.3	9.2	19.5	17.7
	2	18.5	17.0	10.4	18.0	17.5
	3	15.3	17.7	9.6	14.9	14.8
	4	18.1	18.2	9.3	20.0	19.7
	5	17.6	19.0	8.9	19.5	16.1
	6	18.2	20.3	9.7	18.1	15.0
	7	18.0	17.1	10.0	17.1	17.1
	8	<u>15.3</u>	<u>15.0</u>	<u>7.6</u>	<u>17.1</u>	<u>13.4</u>
	Avg.	17.5	18.2	9.3	18.0	16.4

APPENDIX TABLE 3--Continued

Treat. Reps.		8/6	8/15	8/22	8/28	9/5	Mean
a. 1963							
A	1	16.0	11.9	18.7	9.1	6.6	14.8
	2	14.1	10.6	17.0	7.3	5.7	13.6
	3	14.8	10.0	10.6	6.0	5.8	12.7
	4	13.1	11.2	14.7	6.0	5.1	11.8
	5	16.4	11.7	13.3	7.4	6.9	14.4
	6	11.7	12.1	10.7	5.4	4.6	12.1
	7	13.2	11.5	13.2	7.0	6.3	13.4
	8	<u>11.6</u>	<u>10.9</u>	<u>10.9</u>	<u>6.0</u>	<u>5.7</u>	<u>11.3</u>
	Avg.	13.9	11.2	13.6	6.8	5.8	13.0
B	1	12.7	10.4	15.4	7.2	6.7	13.9
	2	16.1	11.1	16.5	7.5	6.2	15.1
	3	9.9	7.7	13.8	5.2	4.0	11.1
	4	11.5	8.9	12.0	6.2	3.9	11.4
	5	15.8	12.5	15.4	10.1	8.5	15.1
	6	11.7	9.0	12.0	5.9	6.0	12.3
	7	13.4	12.1	12.8	7.1	5.2	13.0
	8	<u>13.3</u>	<u>12.1</u>	<u>12.4</u>	<u>6.5</u>	<u>5.1</u>	<u>13.4</u>
	Avg.	13.0	10.5	13.8	7.0	5.7	13.2
C	1	13.8	12.5	17.8	11.0	7.8	15.0
	2	12.1	9.2	12.5	7.0	5.9	12.8
	3	7.9	9.7	12.3	6.1	5.0	11.3
	4	11.0	7.0	17.9	7.4	5.2	13.4
	5	11.9	14.9	13.4	9.5	8.9	14.0
	6	13.2	7.8	12.4	8.5	9.0	13.2
	7	12.0	10.4	11.7	7.5	8.7	13.0
	8	<u>14.9</u>	<u>13.9</u>	<u>13.8</u>	<u>8.4</u>	<u>7.0</u>	<u>12.6</u>
	Avg.	12.1	10.7	14.0	8.2	7.2	13.2

APPENDIX TABLE 3--Continued

Treat. Reps.		5/26	6/9	6/16	6/30	7/7	8/11
b. 1964							
A	1	28.0	20.0	25.0	11.0	9.3	18.0
	2	33.0	25.0	25.5	9.0	10.0	17.7
	3	26.7	20.5	23.0	7.3	8.5	16.0
	4	33.5	22.2	24.0	10.2	6.3	16.5
	5	29.6	22.0	25.1	11.0	8.5	16.0
	6	31.5	22.5	20.5	11.0	6.0	15.5
	7	30.8	20.0	24.5	11.0	3.8	14.8
	8	33.7	21.3	20.5	8.5	-	12.0
	9	<u>29.7</u>	<u>19.0</u>	<u>21.5</u>	<u>4.0</u>	<u>-</u>	<u>9.2</u>
	Avg.	30.7	21.4	23.3	9.2	7.5	15.1
B	1	33.0	20.0	28.0	14.5	11.5	20.5
	2	28.6	22.0	27.5	10.5	6.5	15.8
	3	31.2	22.2	23.7	11.5	9.0	15.5
	4	29.0	23.5	25.3	9.5	7.0	18.3
	5	32.5	25.5	26.2	16.5	11.0	14.5
	6	31.6	25.0	28.0	12.5	8.0	17.0
	7	27.0	24.0	26.5	9.0	9.3	13.6
	8	29.0	19.7	22.5	8.0	-	13.7
	9	<u>27.3</u>	<u>23.7</u>	<u>29.8</u>	<u>13.7</u>	<u>-</u>	<u>18.5</u>
	Avg.	30.0	22.8	26.4	11.7	8.9	16.4
C	1	33.0	27.0	28.0	14.5	10.5	14.2
	2	23.0	19.0	26.5	8.7	7.5	8.3
	3	25.7	18.5	22.2	10.0	10.0	12.2
	4	25.4	21.5	22.3	9.7	6.0	13.0
	5	21.0	21.5	21.2	11.0	7.7	12.0
	6	18.5	17.0	22.0	9.0	10.0	16.5
	7	23.7	16.5	24.0	7.5	5.2	13.3
	8	24.7	20.0	24.5	12.0	-	11.6
	9	<u>23.2</u>	<u>23.7</u>	<u>21.3</u>	<u>8.5</u>	<u>-</u>	<u>8.5</u>
	Avg.	24.2	20.5	23.6	10.1	6.3	12.2
L.S.D. 5%		3.2	N.S.	2.0	N.S.	N.S.	2.3

APPENDIX TABLE 4

MOISTURE DISTRIBUTION IN THE SOIL PROFILE

6"-18"				18"-30"			30"-42"		
a. 1963									
6/19/63									
Reps.	A	B	C	A	B	C	A	B	C
1 *	29.8	27.8	27.5	25.3	29.5	27.1	21.4	23.0	22.6
2	30.0	30.9	28.5	28.0	26.8	26.2	20.3	21.0	21.5
3 *	29.6	27.8	25.8	31.3	27.5	27.1	22.0	20.1	21.2
4	29.1	26.2	31.2	23.8	25.5	27.9	22.6	20.7	24.2
5 *	25.5	29.5	29.1	22.7	26.5	25.3	23.3	23.0	22.2
6	30.5	27.2	30.2	25.0	24.1	26.6	20.8	19.4	23.4
7 *	29.5	26.6	26.5	25.1	27.5	27.5	20.6	23.7	22.9
8	<u>26.5</u>	<u>25.1</u>	<u>23.5</u>	<u>21.5</u>	<u>21.8</u>	<u>21.1</u>	<u>20.7</u>	<u>22.5</u>	<u>21.9</u>
Avg.	28.8	27.6	27.8	25.3	26.2	26.1	21.5	21.7	22.5
7/4/63									
1*	26.8	25.6	24.9	25.9	29.4	26.9	22.8	24.4	22.0
2	25.1	24.7	24.0	24.7	24.5	24.0	20.1	20.3	19.9
3 *	27.3	24.2	25.9	29.5	26.6	27.6	21.6	21.3	20.1
4	25.1	21.2	25.6	22.6	26.5	26.3	22.4	21.1	22.5
5 *	21.5	26.7	27.2	22.8	25.1	25.1	23.7	22.4	22.5
6	23.0	22.0	23.8	23.5	23.1	25.0	19.9	18.4	22.5
7 *	24.6	23.1	22.4	22.6	26.5	27.3	20.0	23.6	23.1
8	<u>23.8</u>	<u>23.7</u>	<u>20.9</u>	<u>23.0</u>	<u>23.0</u>	<u>20.7</u>	<u>22.5</u>	<u>22.8</u>	<u>22.3</u>
Avg.	24.7	23.9	24.3	24.3	25.6	25.4	21.6	21.8	21.9

APPENDIX TABLE 4--Continued

	6"-18"			18"-30"			30"-42"		
7/15/63									
Reps.	A	B	C	A	B	C	A	B	C
1 *	20.3	21.8	24.6	21.8	26.6	24.3	20.9	23.0	18.1
2	23.1	20.2	23.5	23.4	23.1	24.4	19.1	20.7	19.5
3 *	23.0	22.4	23.5	28.4	25.1	24.4	21.8	19.9	19.5
4	21.8	19.6	20.8	21.2	22.3	23.7	21.1	20.8	22.0
5*	16.2	22.6	22.2	21.3	23.5	23.6	20.9	21.5	21.2
6	20.5	18.4	21.6	21.4	20.1	22.5	20.2	18.9	21.4
7 *	20.6	18.2	19.3	21.7	23.1	24.2	18.3	21.6	21.2
8	<u>21.1</u>	<u>17.7</u>	<u>15.6</u>	<u>20.7</u>	<u>20.4</u>	<u>19.7</u>	<u>20.7</u>	<u>22.1</u>	<u>21.6</u>
Avg.	20.8	20.1	21.4	22.5	23.0	23.7	20.4	21.1	20.6
7/24/63									
1 *	19.1	19.9	20.5	19.0	23.9	22.2	20.8	22.1	21.1
2	18.3	16.7	20.0	20.9	19.7	22.6	18.5	20.0	18.8
3 *	19.1	18.5	19.7	24.7	22.7	23.8	21.4	19.8	19.7
4	17.4	15.5	19.5	19.6	21.5	21.0	22.1	19.6	22.1
5 *	15.0	19.4	19.9	18.4	21.6	21.4	21.9	21.9	21.7
6	17.9	15.6	18.2	19.2	18.7	21.7	19.8	17.5	21.7
7 *	18.4	18.5	17.2	19.4	22.1	24.2	20.0	24.1	22.2
8	<u>17.5</u>	<u>15.8</u>	<u>14.2</u>	<u>19.0</u>	<u>18.2</u>	<u>18.5</u>	<u>21.4</u>	<u>22.7</u>	<u>22.1</u>
Avg.	17.8	17.5	18.6	20.0	21.0	21.9	20.7	21.0	21.2

APPENDIX TABLE 4--Continued

	6"-18"			18"-30"			30"-42"		
8/21/63									
Reps.	A	B	C	A	B	C	A	B	C
1 *	18.5	18.5	18.8	15.1	19.9	18.2	17.5	20.6	18.4
2	16.3	17.0	15.1	18.6	17.0	18.3	16.3	17.8	16.6
3 *	19.0	17.2	17.0	21.4	19.2	18.0	19.9	17.0	17.8
4	16.6	14.4	21.6	16.6	18.4	18.6	18.6	17.8	19.2
5 *	15.2	20.5	19.9	15.4	19.2	18.2	19.0	19.5	19.3
6	17.2	14.7	16.0	17.1	16.9	17.5	17.6	15.5	17.9
7 *	17.2	16.8	14.6	17.8	19.6	19.6	16.9	19.5	18.6
8	<u>16.5</u>	<u>13.2</u>	<u>11.7</u>	<u>16.4</u>	<u>14.6</u>	<u>13.5</u>	<u>18.2</u>	<u>18.1</u>	<u>16.7</u>
Avg.	17.1	16.5	16.8	17.3	18.1	17.7	18.0	18.2	18.1
8/28/63									
1 *	17.3	18.3	18.0	15.6	18.6	17.3	18.0	20.3	18.1
2	14.9	16.0	15.0	18.4	16.5	19.0	17.1	18.3	17.6
3 *	17.7	15.8	14.7	19.6	17.6	16.4	20.0	17.1	17.6
4	15.0	13.3	18.4	15.4	17.7	17.5	17.5	17.1	18.4
5 *	13.3	19.2	18.6	14.3	18.2	16.8	19.3	18.5	19.5
6	16.0	13.7	13.8	16.8	16.5	16.5	17.8	15.0	16.3
7 *	15.6	16.5	14.0	16.7	18.7	19.3	16.5	19.4	17.9
8	<u>16.5</u>	<u>13.2</u>	<u>11.7</u>	<u>16.4</u>	<u>14.6</u>	<u>13.5</u>	<u>18.2</u>	<u>18.1</u>	<u>16.7</u>
Avg.	15.8	15.8	15.5	16.6	16.7	17.0	18.1	18.0	17.8

APPENDIX TABLE 4--Continued

	6"-18"			18"-30"			30"-42"		
9/4/63									
Reps.	A	B	C	A	B	C	A	B	C
1 *	16.6	16.8	16.8	14.4	17.0	16.0	17.3	19.8	17.3
2	13.5	15.6	13.9	17.2	15.7	17.5	16.5	17.4	16.4
3 *	15.5	15.3	12.7	17.6	16.5	15.4	18.1	16.5	17.2
4	13.8	12.3	17.0	14.5	17.1	15.9	16.2	15.9	17.6
5 *	13.1	17.8	18.3	14.8	16.8	16.1	19.1	17.7	17.7
6	14.0	12.2	13.5	15.5	15.2	16.0	16.6	13.8	16.6
7 *	13.3	15.4	12.9	16.3	18.2	17.8	15.7	19.5	17.2
8	<u>14.0</u>	<u>12.1</u>	<u>11.5</u>	<u>15.5</u>	<u>13.8</u>	<u>12.7</u>	<u>18.0</u>	<u>17.7</u>	<u>16.6</u>
Avg.	14.2	14.7	14.6	15.7	16.3	15.9	17.2	17.3	17.1

*On these replications the access tube is between corn rows. The other four replications have the access tube in the corn row.

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀ *	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
b. 1964										
6/10/64										
6"-18"	I	24.8	24.4	21.8	24.2	22.7	23.3	23.2	21.2	25.1
	II	28.1	25.4	28.0	25.1	24.5	26.6	22.7	22.4	27.2
	III	<u>28.8</u>	<u>24.0</u>	<u>25.5</u>	<u>26.6</u>	<u>26.2</u>	<u>23.5</u>	<u>22.8</u>	<u>26.1</u>	<u>24.3</u>
	Avg.	27.2	24.6	25.1	25.3	24.5	24.5	22.9	23.2	25.5
18"-30"	I	23.2	24.2	22.6	24.3	22.4	24.5	22.4	22.7	24.0
	II	25.8	24.8	23.0	25.8	23.2	26.3	20.8	22.3	22.8
	III	<u>23.9</u>	<u>23.2</u>	<u>23.5</u>	<u>20.0</u>	<u>23.6</u>	<u>22.9</u>	<u>22.5</u>	<u>22.8</u>	<u>21.9</u>
	Avg.	24.3	24.1	23.0	23.4	23.1	24.6	21.9	22.6	22.9
30"-42"	I	21.4	23.2	19.8	22.2	22.3	22.0	23.3	23.2	22.5
	II	22.8	22.2	22.5	22.4	23.1	21.3	20.1	21.3	22.2
	III	<u>22.4</u>	<u>23.0</u>	<u>22.1</u>	<u>21.9</u>	<u>22.5</u>	<u>22.6</u>	<u>21.0</u>	<u>22.7</u>	<u>21.4</u>
	Avg.	22.2	22.8	21.5	22.2	23.0	22.0	21.8	22.4	22.0

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
6/17/64										
6"-18"	I	25.3	23.2	21.9	24.0	21.9	21.8	24.8	21.0	24.7
	II	25.8	25.3	27.3	23.1	24.2	26.4	21.8	21.8	26.0
	III	<u>25.4</u>	<u>22.1</u>	<u>25.6</u>	<u>21.7</u>	<u>25.0</u>	<u>22.2</u>	<u>22.9</u>	<u>23.4</u>	<u>22.3</u>
	Avg.	25.5	23.5	24.9	23.3	23.7	23.5	23.2	22.1	24.3
18"-30"	I	24.5	23.5	24.4	25.6	22.7	24.6	23.9	22.6	23.2
	II	26.2	24.2	22.6	24.7	22.3	24.8	20.1	22.7	22.8
	III	<u>22.8</u>	<u>22.5</u>	<u>22.8</u>	<u>20.0</u>	<u>23.7</u>	<u>21.3</u>	<u>22.1</u>	<u>21.6</u>	<u>21.1</u>
	Avg.	24.5	23.4	23.3	23.4	22.9	23.6	22.0	22.3	22.4
30"-42"	I	21.9	22.7	19.8	22.0	22.9	23.6	22.5	22.4	22.3
	II	23.2	22.4	22.0	22.9	23.6	21.4	20.1	21.4	21.7
	III	<u>20.7</u>	<u>21.7</u>	<u>21.4</u>	<u>20.3</u>	<u>21.6</u>	<u>21.8</u>	<u>21.8</u>	<u>21.6</u>	<u>20.7</u>
	Avg.	21.9	22.3	21.1	21.7	22.7	22.3	21.5	21.8	21.6

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
7/1/64										
6"-18"	I	22.2	19.0	21.2	20.6	20.3	17.9	19.6	20.6	21.6
	II	21.5	23.3	23.8	19.5	20.0	25.3	18.3	16.1	21.6
	III	<u>20.4</u>	<u>19.0</u>	<u>24.0</u>	<u>18.1</u>	<u>21.9</u>	<u>20.7</u>	<u>18.3</u>	<u>21.2</u>	<u>22.6</u>
	Avg.	21.4	20.4	23.0	19.4	20.7	21.3	18.7	19.3	21.9
18"-30"	I	23.0	22.5	22.0	23.7	21.8	23.2	22.0	22.0	21.3
	II	24.3	23.5	20.3	24.0	20.7	25.5	20.3	22.2	22.5
	III	<u>22.2</u>	<u>22.3</u>	<u>24.0</u>	<u>20.0</u>	<u>23.2</u>	<u>22.0</u>	<u>21.5</u>	<u>21.0</u>	<u>21.0</u>
	Avg.	23.2	22.8	22.1	22.6	21.9	23.6	21.3	21.7	21.6
30"-42"	I	20.6	22.0	20.7	22.1	22.1	23.0	21.5	24.2	20.8
	II	24.0	21.6	22.3	22.5	22.5	22.3	21.0	22.3	22.1
	III	<u>20.0</u>	<u>22.5</u>	<u>24.0</u>	<u>20.9</u>	<u>22.0</u>	<u>22.1</u>	<u>20.7</u>	<u>21.2</u>	<u>23.0</u>
	Avg.	21.5	22.0	22.3	21.8	22.2	22.5	21.1	22.6	22.0

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
7/9/64										
6"-18"	I	15.7	14.8	16.4	16.0	15.5	15.2	15.1	16.4	19.6
	II	15.6	19.8	19.2	13.8	17.0	23.3	14.6	14.3	20.0
	III	<u>17.1</u>	<u>13.6</u>	<u>22.2</u>	<u>11.5</u>	<u>18.6</u>	<u>18.6</u>	<u>15.6</u>	<u>17.2</u>	<u>20.0</u>
	Avg.	16.1	16.1	19.3	13.8	17.0	19.0	15.1	16.0	19.9
18"-30"	I	22.2	21.8	21.3	22.0	21.0	22.2	19.9	20.7	22.0
	II	22.5	22.4	21.8	22.8	17.8	23.0	18.6	20.5	22.2
	III	<u>20.5</u>	<u>20.6</u>	<u>22.1</u>	<u>18.6</u>	<u>22.0</u>	<u>21.1</u>	<u>20.4</u>	<u>19.5</u>	<u>20.3</u>
	Avg.	21.7	21.6	21.7	21.1	20.3	22.1	20.0	20.2	21.5
30"-42"	I	21.0	21.8	20.0	21.7	21.7	22.0	21.5	22.1	21.0
	II	22.5	21.8	21.0	22.4	21.5	21.5	20.1	22.0	22.0
	III	<u>21.1</u>	<u>21.8</u>	<u>22.4</u>	<u>20.5</u>	<u>22.0</u>	<u>22.0</u>	<u>21.1</u>	<u>21.0</u>	<u>20.4</u>
	Avg.	21.5	21.8	21.1	21.5	21.7	21.8	20.9	21.7	21.1

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
7/14/64										
6"-18"	I	14.4	13.0	16.0	15.2	14.8	14.2	15.4	16.5	19.0
	II	14.3	18.3	18.8	11.8	15.0	22.3	14.8	16.8	17.8
	III	<u>16.2</u>	<u>12.2</u>	<u>22.1</u>	<u>12.2</u>	<u>20.0</u>	<u>17.6</u>	<u>14.4</u>	<u>12.9</u>	<u>20.0</u>
	Avg.	15.0	14.5	19.0	13.1	16.6	18.0	14.9	15.4	18.9
18"-30"	I	21.5	21.5	20.5	21.0	20.5	21.8	20.2	19.8	21.8
	II	21.1	22.0	20.5	21.2	16.5	22.5	17.7	19.2	21.1
	III	<u>21.4</u>	<u>19.0</u>	<u>22.5</u>	<u>18.1</u>	<u>22.5</u>	<u>21.5</u>	<u>20.2</u>	<u>19.7</u>	<u>21.0</u>
	Avg.	21.3	20.8	21.2	20.1	19.8	21.9	19.4	19.6	21.3
30"-42"	I	21.0	21.7	19.9	21.2	20.3	20.8	20.2	22.4	21.0
	II	22.0	21.5	20.7	22.0	21.8	20.2	19.5	20.2	21.0
	III	<u>20.8</u>	<u>22.0</u>	<u>22.2</u>	<u>20.0</u>	<u>22.8</u>	<u>21.0</u>	<u>20.0</u>	<u>21.0</u>	<u>20.2</u>
	Avg.	21.3	21.7	20.9	21.1	21.6	20.6	20.2	21.2	20.4

APPENDIX TABLE 4--Continued

Depth	Repl.	A ₀	A ₁	A ₂	B ₀	B ₁	B ₂	C ₀	C ₁	C ₂
8/15/64										
6"-18"	I	21.7	19.4	20.0	23.7	20.0	19.0	13.8	14.5	14.6
	II	18.9	19.5	19.2	16.8	20.2	23.5	12.0	12.2	13.5
	III	<u>22.5</u>	<u>17.8</u>	<u>20.9</u>	<u>17.2</u>	<u>21.3</u>	<u>22.5</u>	<u>12.0</u>	<u>15.8</u>	<u>16.2</u>
	Avg.	21.0	18.9	20.0	19.2	20.5	21.7	12.6	14.2	14.8
18"-30"	I	20.4	18.6	20.0	21.0	19.2	20.1	16.4	15.2	19.5
	II	17.7	19.7	17.5	18.2	15.0	22.5	12.2	15.5	17.1
	III	<u>20.3</u>	<u>18.5</u>	<u>19.1</u>	<u>16.3</u>	<u>19.1</u>	<u>19.1</u>	<u>14.5</u>	<u>16.6</u>	<u>18.1</u>
	Avg.	19.5	18.9	18.9	18.5	17.8	20.6	14.4	15.8	18.2
30"-42"	I	21.1	20.0	20.0	21.5	20.8	20.0	17.0	19.8	19.7
	II	20.7	19.2	18.6	19.5	18.8	18.5	15.2	16.2	19.6
	III	<u>19.1</u>	<u>21.2</u>	<u>19.9</u>	<u>19.4</u>	<u>19.7</u>	<u>20.0</u>	<u>17.5</u>	<u>18.7</u>	<u>19.8</u>
	Avg.	20.3	20.1	19.5	20.1	19.8	19.5	16.6	18.2	19.8

*Subscripts 0, 1 and 2 are used to denote that neutron access tubes were located in the row, 10½" and 21" away from the row respectively.

APPENDIX TABLE 5

MOISTURE LOSS FROM SIX INCH DIAMETER CANS AS INFLUENCED
BY CULTIVATION DURING 1964

(Loss of Water in Grams Per Can)

Rep.	A ₂ *	A ₁	B ₂	B ₁	A ₂	A ₁	B ₂	B ₁
May 25 to 26 (1 day)					May 26 to 27 (1 day)			
1	55	46	77	70	26	19	46	69
2	80	56	79	78	26	28	72	94
3	48	53	78	80	17	26	70	97
4	92	41	79	83	79	18	99	94
5	42	90	79	85	24	70	93	104
6	78	48	81	82	47	9	95	102
7	68	44	84	85	41	26	69	76
8	61	76	80	84	38	32	98	108
9	<u>44</u>	<u>79</u>	<u>80</u>	<u>74</u>	<u>10</u>	<u>41</u>	<u>98</u>	<u>64</u>
Avg.	63	59	80	80	34	30	82	90
May 27 to 30 (2½ days)					June 12 to 15 (3½ days)**			
1	25	27	85	58	80	56	64	67
2	68	37	53	96	85	79	70	103
3	34	31	102	97	80	66	107	88
4	75	26	108	93	110	61	164	71
5	28	64	100	112	44	93	125	79
6	45	40	100	112	94	60	106	86
7	37	23	109	102	49	79	146	72
8	52	66	102	111	95	56	103	107
9	<u>39</u>	<u>66</u>	<u>77</u>	<u>56</u>	<u>63</u>	<u>67</u>	<u>51</u>	<u>76</u>
Avg.	45	42	93	93	78	69	104	83
June 22, 24 and 29 (3 days)					June 30 to July 3 (4 days)			
1	56	68	68	82	24	32	41	56
2	70	71	64	115	44	35	46	58
3	59	66	118	100	34	44	57	66
4	74	54	287	84	38	28	108	38

APPENDIX TABLE 5--Continued

Rep.	A ₂	A ₁	B ₂	B ₁	A ₂	A ₁	B ₂	B ₁
	June 22, 24 and 29 (3 days)--cont.				June 30 to July 3 (4 days)--cont.			
5	71	66	107	131	29	44	64	80
6	72	83	114	118	38	32	37	28
7	73	67	136	100	45	38	64	56
8	77	84	128	100	34	37	32	65
9	<u>68</u>	<u>76</u>	<u>95</u>	<u>89</u>	<u>36</u>	<u>32</u>	<u>41</u>	<u>43</u>
Avg.	69	71	124	102	36	36	54	54

*Subscripts 1 and 2 denote that cans were located at 10 $\frac{1}{2}$ " and 21" away from the row in the respective treatments.

**Cans were rewetted on June 11, 1964.

APPENDIX TABLE 6

DISTRIBUTION OF MOISTURE IN THE TOP SIX INCH SOIL IN
CULTIVATED AND UNCULTIVATED BARE PLOTS* DURING 1964

Depth	Rep. I		Rep. II		Rep. III		Average	
	A	B	A	B	A	B	A	B
0-1"	10.0	14.3	7.8	14.4	18.1	18.3	12.0	15.7
1"-2"	18.4	16.4	18.8	17.0	12.2	19.5	19.5	17.6
2"-3"	19.5	17.2	20.0	18.5	21.9	20.5	20.5	18.7
3"-4"	20.1	16.7	19.3	18.2	21.4	19.5	20.3	18.1
4"-5"	20.8	17.0	19.7	18.1	21.7	20.3	20.7	18.5
5"-6"	19.6	16.7	19.7	18.0	21.7	22.0	20.3	18.9

*Plots were cultivated on August 26 and sampled on September 8. There was no rain during this period.

APPENDIX TABLE 7

CORN ROOT DISTRIBUTION IN CULTIVATED AND UNCULTIVATED PLOTS

Depth	Repl.	Distance from Row				Distance from Row			
		0-3"	3"-9"	9"-15"	15"-21"	0-3"	3"-9"	9"-15"	15"-21"
		(Cultivated)				(Uncultivated)			
0-3"	1	1.073	0.220	0.097	0.086	0.713	0.221	0.014	0.009
	2	0.471	0.284	0.061	0.029	0.901	0.077	0.003	0.000
	3	1.354	0.243	0.224	0.098	0.868	0.058	0.016	0.012
	4	0.618	0.121	0.041	0.032	0.638	0.070	0.015	0.009
	5	1.159	0.140	0.056	0.037	0.805	0.083	0.000	0.000
	6	0.514	0.044	0.011	0.024	0.703	0.080	0.010	0.009
	7	0.916	0.109	0.032	0.005	0.310	0.009	0.009	0.000
	8	0.603	0.071	0.000	0.033	0.494	0.069	0.004	0.010
3"-9"	1	1.522	0.553	0.356	0.224	0.886	0.847	0.256	0.017
	2	1.180	1.328	0.641	0.194	0.923	0.977	0.474	0.064
	3	1.350	1.943	1.101	0.799	1.290	0.740	0.543	0.405
	4	0.888	1.404	0.820	0.498	1.414	0.734	0.304	0.417
	5	0.715	1.288	0.723	0.463	0.761	0.993	0.234	0.018
	6	1.253	1.080	0.484	0.361	0.997	0.502	0.600	0.345
	7	0.776	1.392	0.712	0.261	0.645	0.690	0.255	0.161
	8	0.872	1.156	0.386	0.304	0.872	1.080	0.386	0.304
9"-15"	1	0.073	0.122	0.021	0.038	0.161	0.097	0.057	0.009
	2	0.075	0.252	0.074	0.014	0.009	0.180	0.267	0.086
	3	0.257	0.124	0.321	0.140	0.190	0.301	0.098	0.041
	4	0.303	0.242	0.302	0.313	0.200	0.401	0.176	0.098

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