THE INFLUENCE OF CULTIVATION AND HERBICIDE APPLICATIONS ON CERTAIN SOIL PROPERTIES AND YIELD OF FIELD CORN

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Donald E. Herr

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THE INFLUENCE OF CULTIVATION AND HERBICIDE APPLICATIONS ON CERTAIN SOIL PROPERTIES AND YIELD OF FIELD CORN

By

Donald E. Herr

AN ABSTRACT

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Donald E. Herr

Field studies designed to determine the effect of cultivation on certain soil properties and the yield of corn were performed on a fine textured soil during 1960 and 1961. Determinations were made of bulk density and total porosity of soil that received varying amounts of cultivation. The effect of cultivation on height and yield of corn as well as the nutrient content of corn leaves was determined. Investigations were made on the influence of varying weed populations on yield of corn obtained by chemical and cultural methods.

When weeds were controlled with pre-emergence herbicides cultivation decreased the yield of corn. Increased yield resulted from adequate cultivation when weeds were not controlled by chemical methods. Cultivation by itself did not affect the nitrogen, phosphorus or potassium content of corn leaves. Plant height measurements revealed that uncultivated corn had attained a greater height than cultivated corn on two of the three dates it was measured.

There was no difference in the bulk density of soil beneath that stirred by one or four cultivations or under the rear wheel track made by the tractor during one cultivation. A higher bulk density resulted where the rear wheel of the tractor had passed four times during cultivation.

The soil beneath that stirred by one and four cultivations had the same total porosity. However, one pass of the tractor wheel during the cultivation lowered total porosity and four passes caused an additional decrease in this soil property.

Weed populations of only one to two per square foot reduced the per cent of nitrogen in corn leaves but did not affect the

per cent of phosphorus or potassium present.

The experimental areas used both years had light natural infestations of weeds. However, weeds caused significant reductions of corn yields in 1961. A destructive hail storm in mid-July 1960 nearly erased yield differences making it impossible to draw conclusions on yield data from this experiment.

Liquid and granular forms of 2-chloro-4-ethylamino-6-isopropylamino-s-traizine (atrazine) and 2,4-dichlorophenyoxyacetic acid (2,4-D) applied pre-emergence at recommended rates provided satisfactory control of annual weeds.

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INTRODUCTION

The growing of corn as a crop has required the help of man to reduce the pressure of competitive plants. Aztec, Maya and Inca Indians were growing corn before Columbus discovered America and weeds were probably removed by pulling or with crude instruments.

Early settlers in America learned the methods of growing corn from the Indians and it constituted much of their food supply. With the development of the country and the introduction of other food crops, particularly wheat, corn soon became our most important livestock feed rather than being used for human food.

Early in the 19th Century crude cultivators were built, and for the first time man used a machine in helping to control weeds in corn. The use of horse-drawn machines in corn culture necessitated planting in rows three to three and one-half feet apart, a practice that has persisted to the present.

With the development of the tractor in the 1920's, cultivating gradually shifted from the horse-drawn units to tractor-mounted cultivators. In spite of the continued improvement of cultivators in terms of adjustment, control and shovel equipment available, it has been and still is difficult to satisfactorily control weeds in the corn row by mechanized cultural methods alone.

The development of the selective phenoxy-type herbicides in the mid 1940's brought in chemical weed control as an aid to cultural weed control practices on a commercial scale. A recent survey by the United States Department of Agriculture indicates that herbicides are now being used on approximately twenty per cent of the corn acreage in this country and 2,4-D is still the most widely used herbicide. The primary purpose in the use of 2,4-D has been to supplement rather than replace cultural methods of weed control.

Recently a series of s-triazine derived herbicides have been developed which when applied pre-emergence to corn have given outstanding control of annual weeds throughout the entire growing season. With these herbicides available at economical prices, the value of cultivation becomes questionable to the commercial corn producer.

The aim of the present experiment was to study the effects of cultivation on certain soil properties and yield of corn in conjunction with various herbicide treatments.

REVIEW OF LITERATURE

The literature is voluminous on the control of weeds by chemical and cultural methods. This review will include only selected references dealing with the effects of cultivation and specific herbicides on the physical properties of soil and yield of corn.

Effects of Cultivation on Yield of Corn

Some experiments were started at Urbana, Illinois as early as 1888 to determine the value of depth and frequency of cultivation. These experiments were continued until 1893 and according to Wimer and Harland (36) Gardner concluded that there seemed to be no advantage in cultivating any more frequently than required to destroy weeds. The yield in those plots that received no cultivation, but where weeds were controlled by scraping with a hoe, was 96.9 per cent of that of plots cultivated shallow four to five times. In six years of experiments with corn Mosier and Gustafson (20) found the average yield from uncultivated plots on various soil types was 98.9 per cent that of similar cultivated plots. Cates and Cox (6) concluded that cultivation was not beneficial to the corn plant except that weeds were removed. They also reviewed work at New York, Missouri and South Carolina concluding that there were no significant differences for cultivation of corn over hand cutting of weeds with a hoe at any of these stations. In 1925 Wimer and Harland (36) published results of six years work where uncultivated plots, except with weeds controlled by scraping with a hoe, yielded 104.3 per cent of cultivated plots.

Borst and McClure (5) of Ohio concluded that on Miami silty clay loams and other soils which pack, bake or become crusted, cultivation has a beneficial action in addition to controlling weeds. On these soils cultivation to maintain a broken condition of the soil surface may result in increased yields of corn. On Brookston silty clay loam soils, well aggregated and supplied with organic matter, the chief purpose of cultivation is weed control and that stirring the soil will not in itself increase the yield of corn. Similar views were reported by Mooers (18) when he found that on granular soils no cultivation with weed growth controlled by scraping or very shallow cutting with a hoe gave unsurpassed yields. On soils with a high per cent of silt no cultivation resulted in decidedly reduced yields. Swanson and Jacobson (27) working on Cheshire loam in Connecticut found that cultivation had beneficial effects in addition to controlling weeds. Cultivation would be essential for maximum yields in seasons having high-intensity rains which result in puddling and packing of the soil, especially if this is followed by a hot period. In seasons where the soil surface does not crust or on light textured or well aggregated soils the benefits of cultivation would be fewer. Blake and Aldrich (2) studied the effect of cultivation on corn yields and reported that where weeds were effectively controlled with herbicides a minimum cultivation still gave better yields of corn than no cultivation.

Meggitt (16) investigating the influence of cultivation on corn yields when weeds were controlled with herbicides found that one and in some cases two cultivations were needed to provide maximum corn yields on most soil types with the exception of those which are of a light texture and are in excellent tilth as a result of previous cropping. In most cases there was no advantage of additional cultivations beyond one. There were no differences between the one cultivation made early in the growth of the plant or at lay-by as long as weeds were adequately controlled early in the season.

Another aspect of cultivation, affecting the yield of corn, is the possibility of root pruning. Williams and Welton (34) reported that cultivation to a depth of four inches gave a decreased yield every season but one, as compared with a similiar cultivation to a depth of one and one-half inches. The average decrease per acre was four bushels of grain and 183 pounds of fodder. In Missouri, Helm (10) reported that deep cultivation compared with shallow reduced the yield of corn six and one-half to thirteen bushels per acre.

Russell and Associates (23) studied the absorption of soil moisture at a shallow depth directly beneath the corn hills. The zone of absorption extended laterally until most of the available moisture at that depth was depleted. The lateral expansion of the moisture absorption zone occurred at successively lower depths as the growing season progressed. Mosier and Gustafson (20) found that the harmful effects of cultivation are always more pronounced during years of drought which would support the findings of Russell (23).

Effects of Cultivation on Soil Moisture

Musgrave and Free (21) investigated the effects of cultivation on the infiltration of water in Marshall silt loam and found that for a three and one-half hour period infiltration was as follows: without cultivation .78 inch per hour; with four-inch cultivation .99 inch per hour; and with six-inch cultivation 1.23 inches per hour. During the first thirty minutes following application of water the effects were quite pronounced. After this initial period, however, the effects of increased porosity induced by cultivation diminished rapidly. There were no significant effects of treatment found on three-hour wet runs made forty-eight hours after the initial runs. Pillsbury (22) was unable to get conclusive data on the effects of cultivation on infiltration of water on Yolo loam. He concluded that the principal effect of hand cultivation on infiltration was decidedly temporary in nature.

Wiese and Army (33) studied the effect of chemical and cultural weed control practices on soil moisture storage and losses on a calcareous reddish chestnut soil in the great plains and concluded that "when weeds were properly controlled the efficiency of moisture storage under chemical fallow was equal to that under subsurface tillage." Mosier and Gustafson (20), in a series of experiments from 1907-1914, recorded the average yields of corn. Plots uncultivated, but where weeds controlled by scraping, yielded 45.9 bushels per acre, plots cultivated shallow three times yielded 39.2 bushels and plots cultivated three times and irrigated averaged 47.7 bushels. These investigators concluded that the uncultivated corn produced so well in comparison with the other treatments that cultivation for conservation of moisture was a very secondary consideration.

Wimer (35) compared first and second year corn yields of plots cultivated versus scraping and found that cultivation increased the yield but once during the four years when rainfall was below the nine-year average. Even though this increase amounted to 14.8 bushels per acre it was more than offset by the seven remaining cases where yield reduction totaled 58.8 bushels.

Moore (19) found that capillary conductivity is at a maximum near saturation and decreases rapidly with the moisture content to about moisture equivalent. At moisture equivalent, conductivity is very low and remains practically constant as the moisture content is further decreased due to the breaking of water films on the soil particles. Since most soils become plastic at moisture contents near the moisture equivalent, cultivation to conserve soil moisture cannot be done until the moisture leaving the soil by capillary conductivity has been lost.

Veihmeyer (29) studied the loss of water through evaporation under a wide range of conditions and found that a dust mulch did not conserve a significant amount of soil water.

Effects of Cultivation on Physical Properties of Soil

According to Baver (1) the air supply to plant roots as well as soil microorganisms is augmented by cultivation. Cultivation decreased the bulk density of the soil and total porosity was increased. Moreover, the percentage of large pores was increased to a greater extent than the total pore space. As a result, the total volume of air within the seedbed was raised. Supporting views were expressed by Swanson and Jacobson (27) who studied the effects of soil hardness and compaction on corn growth and found that breaking of the soil crust permitted free movement of air in the soil.

Blake and Aldrich (2) in a study of levels of cultivation on physical properties of soils, reported virtually no difference in air space though volume weights were lowest in the noncultivated soil.

The composition of soil air is dependent on the extent of biological processes taking place in the soil and the ease with which atmospheric air diffusion can take place. In poorly aerated soils, a decrease in oxygen content is accompanied by an increase in carbon dioxide because the conditions that restrict oxygen diffusion also restrict removal of carbon dioxide produced by roots and microorganisms. As a result it is difficult to distinguish the relative effects of low oxygen and high carbon dioxide in a poorly aerated soil. The influence of the composition of soil air on plant processes is illustrated by Chang and Loomis (7) who found that bubbling carbon dioxide through water cultures for ten minutes out of each hour reduced the absorption of water by roots by fourteen to fifteen per cent. The effect of carbon dioxide seemed to be associated with the water-absorption mechanism rather than transpiration, a conclusion also reached by Kramer (11). Gingrich and Russell (9) investigated the effect of soil moisture tension and oxygen concentration on growth of corn roots and found, when the effects were averaged over all moisture tensions, each successive increase in oxygen produced a significant increase in radical elongation, fresh weight and dry weight.

Lawton (12) studied the effects of soil aeration on growth and absorption of nutrients by corn plants and found that increasing the soil moisture content reduced the growth of tops and roots of corn. Under the same conditions the per cent potassium, nitrogen, calcium, magnesium and phosphorus absorbed by the plants decreased. When air was forced through the soils held at high moisture the growth rate of tops and roots increased.

Blake and Aldrich (2) used the amount of sodium, potassium and calcium absorbed in potato leaves as an indicator of soil aeration. They found when potatoes were cultivated zero, one, two and six times, each of the three nutrients was lowest in potatoes cultivated six times. Cultivation reduced total porosity both years it was measured.

Weaver and Jamison (32) investigated the effect of moisture on tractor wheel compaction of soil. The greatest increase in bulk density occurred during the first four passes of the tire where a maximum of ten passes were imposed. The average bulk density of Cecil clay increased from 1.22 to approximately 1.40 at a depth of 2.75 to 5.25 inches below the bottom of the wheel track. This data was taken below the lower plastic limit in the moisture range considered optimum for working the soil. Bodman and Rubin (3) studied the effects of compression and shear on Yolo silty clay loam at three moisture levels. At the high moisture content of twenty-seven per cent which is practically equal to the moisture equivalent, pore space was reduced from sixty-six per cent to virtually zero by an applied pressure of 21.3 pounds per square inch. The reduction in pore space decreased with moisture but still was considerable at moisture contents favorable for cultivation and at pressures exerted by farm tractors. According to Baver (1) the work of Renk illustrates the importance of pore space where coarse sand with a pore volume of 55.5 per cent was 1000 times more permeable to air than sand with a pore volume of 37.9 per cent. Blake and Aldrich (2) reported that differences in bulk densities of potato plots cultivated five to seven times were not significant, but there was a tendency for these plots to have higher bulk densities than plots cultivated only once.

Veihmeyer and Henrickson (30) studied the effect of soil density and root penetration and concluded that the density above which roots fail to penetrate was not the same for all soils. No roots were found at densities of 1.9 or above and in several cases densities of 1.7 or 1.8 inhibited the penetration of sunflower roots. There was no penetration of sunflower roots in clay soils when densities reached values of 1.6 or 1.7. The lowest density in which roots failed to penetrate was 1.46.

Effect of Weeds on Yields of Corn

Wimer and Harland (36) reported the six-year average yield of corn where weeds were allowed to grow was only 13.7 per cent of similar plots cultivated with shovels. Corn on plots where weeds were not controlled yielded 15.6 per cent of plots receiving three shallow cultivations.

Results were cited by Bondarenko (4) where a band of pigweeds in the corn row reduced the yield 30.2 bushels per acre. Corn yield reductions of 22.9 bushels per acre were reported when an average of 54 giant ragweed plants were growing per foot of corn row. As the population of each of the two weeds was reduced, corn yields became progressively higher, approaching that of the weed free checks. Vangris et al. (31) reported that even at high nutrient levels weeds suppressed the growth of corn and resulted in decreased yields. He also presented data indicating that many weeds are more efficient in nutrient uptake than corn.

Characteristics and Effectiveness of Herbicides Used on Corn

Lovely and Staniforth (15) found that granular 2,4-dichlorophenoxyacetic acid (2,4-D) applied pre-emergence was about as effective as liquid. Slightly better control was obtained with 2,4-D at rates below two pounds per acre with liquid formulations than with granules. Granular applications, in conjunction with shallow cultivation, when corn was at the one-to-three leaf stage were equal to or better than spray.

Liden (14) applied 2,4-D pre- and post-emergence and compared these with the same treatments supplemented with cultivation. The treatments with cultivation outyielded those without at two out of three locations. He concluded that 2,4-D pre-emergence applications should be supplemented with cultivation for maximum yields and that 2,4-D applied pre-emergence at one pound per acre with two cultivations gave good results both in yield of corn and value returned for treatment.

Meggitt (17) concluded from a test involving several herbicides applied pre-emergence on corn that 2-chloro-4-ethylamine-6-isopropylamino-s-triazine (atrazine) at two pounds per acre provided excellent weed control throughout the season without injury or reduction in yield of field corn. Stroube (26) reported that a granular formulation of atrazine applied pre-emergence at recommended rates gave results equal to the corresponding wettable powder formulation where uniform distribution of granules was obtained.

Schneider (25) showed that atrazine was taken up by roots when a sufficient amount of moisture was present to carry the herbicide to the root zone. To obtain best results soil moisture should be adequate at the time of application and rainfall or over-head irrigation within two weeks was necessary to carry the herbicide to the root zone. Generally at least one-half inch in one shower was required although the rapidity of evaporation and soil moisture at time of application affects the amount required. Information reported by Schneider (24) indicated that atrazine as a post-emergence herbicide was more effective against broadleaf than grassy weeds. Atrazine performed favorably when applied at two pounds of active material per acre on an overall basis to broadleaf and grassy weeds which were not more than one and one-half to two inches high at the time of application. 2-chloro-4, 6-bis-(ethylamino)-s-triazine (simazine) at recommended rates will give longer control than atrazine in areas heavily infested with barnyard grass, several species of Panicum and crabgrass. Although controlled early in the season by atrazine, these species will sometimes reappear before fall as they have been observed to tolerate higher rates of atrazine than simazine.

In regard to the soil residual activity of atrazine as a selective herbicide, Stroube (26) reported that most rotational crops can be planted and grown one year after an application of atrazine at the recommended rates. Tillage practices such as plowing, harrowing and cultivating will reduce the possibility of adverse soil residual effects. However, the possibility exists that small grains seeded in the fall after corn harvest may be injured.

Bondarenko (4) reported 2 chloro-N, N diallylacetamide (CDAA) is especially effective in controlling annual grasses in corn. Best results were obtained when slight to moderate rains followed application. Rainfall of three-fourths inch or more shortly after application reduced the effectiveness of this herbicide considerably. The effectiveness of CDAA was also affected by temperature and in cool moist weather CDAA failed to control foxtail, a common annual grass in Ohio.

MATERIALS AND METHODS

This study was conducted during the 1960 and 1961 growing seasons on the Northwestern Substation of the Ohio Agricultural Experiment Station located at Hoytville, Ohio. The soil type was Hoytville silty clay loam and the topography level. Mechanical analysis of this soil type in the A horizon (zero to nine-inch depth) was as follows: sand 20.6 per cent, silt 41.8 per cent and clay 37.6 per cent. The areas used for the 1960 and 1961 experiments were surface drained and had underground tile drainage systems with laterals spaced fifty and forty-two feet apart respectively.

The 1960 experiment followed corn removed as silage. The area was fall plowed and the following spring 100 pounds of nitrogen was applied previous to the secondary tillage operations. The 1961 experiment followed an alfalfa-timothy sod that was seeded in oats in the spring of 1959. This area received an application of sixty pounds of nitrogen and 330 pounds of 0-20-20 prior to spring plowing on May 17, 1961.

Secondary tillage on the 1961 site consisted of twice over with a double disk and cultipacker pulled by a track-type tractor at right angles to planting direction. Care was exercised so that all areas received identical tillage treatment. Soil consistency at the time of the tillage operation was hard and a minimum tilled seedbed resulted.

In 1960, Ohio W 64 was planted on May 24 in 42-inch rows with a row application of 300 pounds of 4-16-16. The following year Ohio K 62 was planted on June 6 with a row application of 165 pounds of 5-10-10 per acre.

A split-plot design with four replications was used in the 1960 experiment. The following cultural treatments made up the main plots which were four rows wide.

A. Cultivated once, at three-leaf stage with sweeps.

B. Cultivated twice, same as A and 10 days later.

C. Cultivated four times, the first two the same as in A and B, with the last two cultivations at further ten-day intervals.

D. Check, no cultivation.

E. Cultivated once, same time as A, with shovels.

F. Cultivated twice, same time as B, with shovels.

G. Cultivated four times, same time as C, with shovels.

H. Check, no cultivation.

The sub-plots, fourteen feet wide and twenty-eight feet long, were made up of the following chemical treatments:

1. Atrazine 80 W, pre-emergence, two pounds per acre.
2. Atrazine 8 G, pre-emergence, two pounds per acre.
3. Atrazine 80 W, post-emergence (four-six leaf stage) two pounds per acre.
4. 2,4-D, low volatile ester, pre-emergence, two pounds per acre.
5. 2,4-D granular pre-emergence, two pounds per acre.
6. 2,4-D amine, post emergence, ½ pound per acre.
7. No herbicide.

In 1961, a partially balanced incomplete block with four replications was used. Plots were four 40-inch rows wide and twenty-eight feet long. Each replication contained sixteen treatments made up of all combinations of each of the following cultural and chemical variables.

Cultural Variables

A. No cultivation.

B. Cultivated one time at three-leaf stage with sweeps.

C. Cultivated two times, same time as B, and ten days later.

D. Cultivated four times, same time as B and C, with last two cultivations at further ten-day intervals.

Chemical Variables

1. Atrazine, 80W pre-emergence, three pounds per acre.

2. CDAA, pre-emergence, two pounds per acre.

3. 2,4-D amine post-emergence, one-half pound per acre.

4. No herbicide.

All rates of 2,4-D are expressed on an acid equivalent basis, and rates of atrazine and CDAA are in terms of active ingredient. All liquid formulations were applied with a hand boom delivering thirty-four gallons of solution per acre. Granular forms used in 1960 were applied with a 40-inch Gandy spreader. All herbicides were applied overall both years.

In 1960 all pre-emergence treatments were applied on May 25, the day following planting. Post-emergence applications were made on June 20 when the corn plants were in the five-leaf stage. Pre-emergence applications in 1961 were made on June 7 and the 2,4-D post-emergence treatment was applied on July 6 and repeated on August 4.

The cultivation in both experiments was performed with a mounted two-row cultivator. This cultivator was equipped with eight shanks on the front rigs and three on the rear. For the cultivation with sweeps in 1960 and all cultivations in 1961 the four shanks adjacent to the two rows were equipped with cultiguards and the remaining four equipped with ten-inch sweeps. Three 12-inch sweeps were mounted on the rear shanks equipped with cultilevelers to level the soil surface behind the large sweeps.

In 1960 the cultivation with shovels was performed with the same cultivator except that spear-point shovels were installed on the front rigs and narrow bull-tongue shovels on the rear.

The cultivations with shovels stirred the soil to a depth of two to three inches while the cultivation with sweeps worked the soil from one to one and one-half inches deep. In all cases the first cultivation was closest to the corn row with succeeding cultivations further from the row.

During 1960 the four cultivations were made on June 16, June 27, July 5, and July 12. In 1961, the dates were June 22, June 30, July 10, and July 21.

Each year stand counts were made and the entire experiment was thinned to a common stand. In 1960 poor stands were obtained and in order to have the same population in all plots the corn was thinned to 12,000 plants per acre on July 2. The corn in the 1961 experiment was thinned to a population of 15,170 plants per acre on July 11.

The total number of broadleaf and grassy weeds growing on eighty square feet of area between the rows were counted on each plot

of the 1960 experiment. In addition, weed counts were made in an eight-inch band fifty-six feet long centered on the corn row. Similar counts were made in 1961 on all plots receiving no cultivation and on all plots receiving no herbicide.

Measurements were made from the soil surface to the tip of the tallest leaf extended on thirty-five marked plants in each cultural treatment on July 6, 12 and 18, 1960. No plant height measurements were taken in 1961.

Leaf samples, from the leaf below the ear from ten plants selected at random, were analyzed for nitrogen, phosphorus and potassium in 1961. Samples were obtained from all plots treated with atrazine and all other plots receiving no and one cultivation.

By the use of the platinum microelectrode method (13) the rate of oxygen diffusion was measured in 1961 on one plot each where it was not cultivated, cultivated once and cultivated four times. Readings were taken on July 24, 25, 26, 28, August 18, September 10 and 26, with the electrodes placed four inches below the soil surface.

On September 3, 1961 nine soil cores were obtained from plots treated with atrazine in each of the following areas: one cultivation in and outside the rear wheel track made by the tractor during cultivation and four cultivations in and outside the wheel track. The number of blows of a twelve pound hammer on the core sampler required to obtain a core were recorded. Bulk density and per cent porosity were determined from the cores.

Plots in both experiments were trimmed to twenty-five feet and the center two rows hand harvested for yield determination on

October 17, 1960 and October 16, 1961. Per cent moisture in the corn at harvest was determined by gravimetric methods.

RESULTS AND DISCUSSION

All data presented in this section is the average of four replications unless otherwise mentioned. Duncan's (8) multiple range test of statistical significance at the five per cent level was used to determine the means significantly different when an analysis of variance indicated differences existed.

Weed counts were expressed as weeds per square foot and corn yields as bushels per acre at 15.5 per cent moisture.

Effect of Cultivation on Yield of Corn

The effect of cultivation on yield of corn can be determined by examining the yields in Table 1 from plots where weeds were controlled with atrazine.

Table 1. Effect of cultivation on yield of corn when weeds were controlled with atrazine, 1961.

Cultural Treatment	Yield in bushels per acre*
No cultivation	119.9 a
One cultivation	116.5 b
Two cultivations	112.7 c
Four cultivations	109.5 c

*Means not significantly different are indicated by similar lower case letters.

Under proper management this soil type has good structural qualities and remains in a friable condition throughout the growing season. Because of this characteristic no benefit was obtained from stirring the soil as is usually the case on coarser textured soils.

Root pruning and its interference with the absorption of moisture as well as the adverse effects of cultivation on soil properties could be factors responsible for the reduction in yields resulting from cultivation.

Effects of Cultivation on Height of Corn

Plant height measurements from the soil surface to the tallest leaf are given in Table 2.

Table 2. Average height of corn plants on three dates as affected by various cultural treatments, 1960.

Cultural Treatment	Average Plant Height in Inches*		
	July 6	July 12	July 18
No cultivation	41.57 a	54.83 a	67.81 a
Four shovel cultivations	40.21 a	53.43 b	65.63 b
One sweep cultivation	39.85 a	52.70 b	65.49 b
Two sweep cultivations	40.00 a	52.49 b	64.91 b c
One shovel cultivation	39.58 a	52.42 b	64.85 b c
Two shovel cultivation	39.51 a	52.40 b	64.12 b c
Four sweep cultivations	39.45 a	52.02 b	63.39 c

*Means not significantly different are indicated by similar lower case letters.

Increased bulk densities and lower porosity of soil incurred by the tractor during cultivation and the effect of these properties on processes essential to plant growth are probable causes of reduced height of corn.

Results of corn leaf samples indicate significant differences in the amount of nitrogen present in the various treatments. See Table 3.

Table 3. Per cent of nitrogen in corn leaves from combinations of chemical and cultural treatment, 1961.

Treatments		
Chemical	Cultural	Per cent nitrogen*
Atrazine	two cultivations	2.97 a
Atrazine	none	2.95 a
Atrazine	one cultivation	2.91 a b
None	one cultivation	2.89 a b c
CDAA	one cultivation	2.87 a b c
Atrazine	four cultivations	2.80 a b c
2,4-D	none	2.77 a b c
2,4-D	one cultivation	2.77 a b c
None	none	2.70 b c
CDAA	none	2.67 c

*Means not significantly different are indicated by similar lower case letters.

The presence or absence of weeds was the major influence on the amount of nitrogen present in the corn leaves. In Table 3 the two treatments with the highest per cent nitrogen were essentially weed free and contained a significantly greater amount of nitrogen than the last two treatments which had the greatest infestation of weeds. Cultivation by itself had no effect on the per cent of nitrogen.

No significant differences were obtained in the amount of phosphorus and potassium present in the leaf samples. A routine soil test of the area occupied by the experiment made in January 1960 indicated high amounts of phosphorus and potassium present. Apparently this reserve plus bulk and row applications in 1961 provided sufficient amounts of these two elements.

Effects of Cultivation on Soil Properties

The effects of cultivation on some physical properties of the soil are shown in Table 4. Before the cores were taken the soil through which the cultivator had passed was removed so that the cores contained soil immediately below the cultivated layer. A total of nine cores were taken on September 3, 1961 from each of the areas sampled.

Table 4. Bulk density, total porosity and blows required to obtain a core, from various areas of three cultural treatments, 1961.

Area of Cultural Treatment	Bulk Density*	Total Porosity*	Blows*
No cultivation, no wheel track	———	———	13.2 a
Four cultivations, no wheel track	1.142 a	49.62 a	27.9 b
One cultivation, no wheel track	1.225 a	48.30 a	31.3 b
One cultivation, in wheel track	1.220 a	44.70 b	28.0 b
Four cultivations, in wheel track	1.450 b	41.13 c	82.4 c

*Means not significantly different are indicated by similar lower case letters.

Soil from the no cultivation treatment was very friable and either fell from the core when the sampler was removed or while the core was being trimmed to length. Consequently, bulk density and total porosity were not determined from this treatment.

Analysis of the data in Table 4 indicates that repeated pressure exerted by even small farm tractors results in increased bulk densities. The resulting increase in density occurs deep in the plow layer considerably below that stirred during cultivation.

Taylor et al. (28) determined some physical properties of Hoytville silty clay loam at the Northwestern Substation in 1956 and reported a bulk density of 1.29 at the zero to nine inch depth and 1.45 at the nine to 18 inch depth. Results obtained in this study show that four passes over a given area with the rear wheel of a tractor resulted in a plow layer bulk density equal to that normally encountered nine to eighteen inches below the soil surface.

Cultivation by itself had no effect on the bulk density or total porosity of the area immediately below the plow layer, however, one pass with the tractor wheel significantly lowered porosity and four passes of the tractor wheel again lowered porosity a significant amount. The major portion of the reduction in total porosity probably took place as a result of a reduction in non-capillary pores. These pores are especially important in heavy soil as they provide the most direct route for the exchange of oxygen and carbon dioxide with the atmosphere.

Although the number of blows does not indicate any specific soil property it does provide a relative indication of the condition of the soil in the areas sampled. Analysis of this data in Table 4 indicates that only between the three center treatments were the number of blows required not significantly different. The other two means indicate the extreme variation in penetration resistance encountered by the core sampler.

The appearance of the two extremes of compaction after the cultivated layer of soil had been removed is shown in Figures 1 and 2.

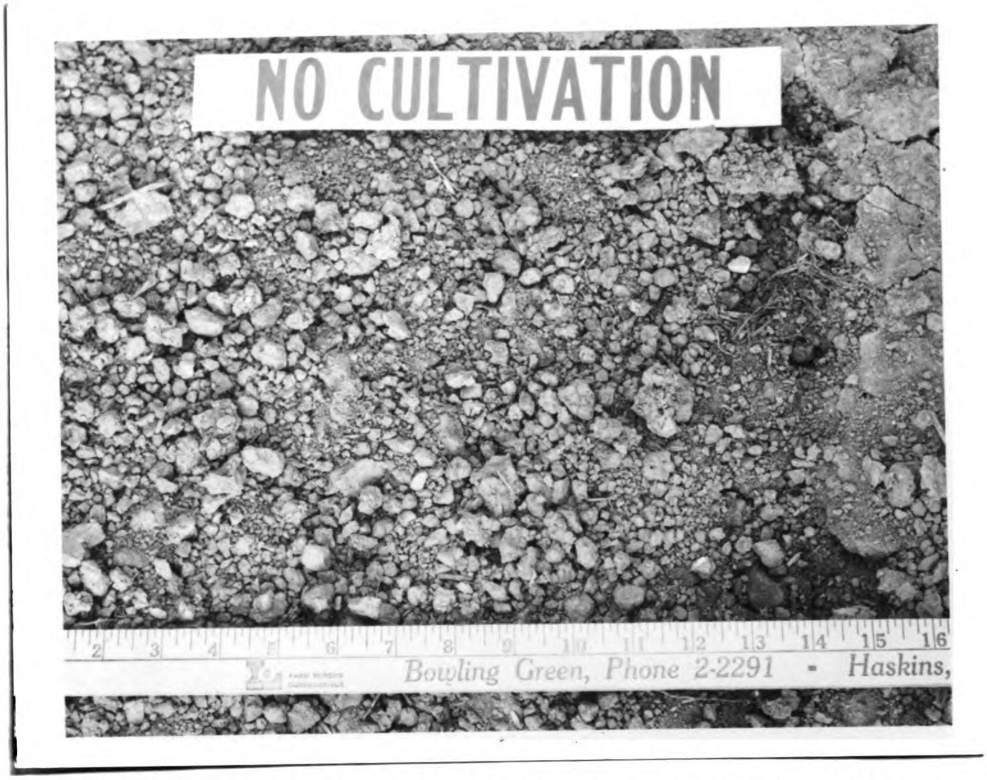

Figure 1. Appearance of uncultivated area that required an average of 13.2 blows to obtain core.

Data in Table 4 indicates that the properties of soil are drastically changed by repeated pressures exerted by farm tractors. In order to provide as near an ideal environment as possible for corn roots the number of operations performed after plowing should be kept

Figure 2. An average of 82.4 blows were required to obtain a core in this area over which the rear wheel of tractor had passed four times during the cultivation.

to a minimum. Minimum seedbeds that require less secondary tillage and often eliminate the need of rotary hoeing to facilitate emergence is a practice that results in fewer operations performed and consequently less compaction of the soil. Other helpful management techniques are the application of pre-emergence herbicides from planter attached equipment and if additional weed control operations are necessary that it be done with equipment that will run in tracks made during planting.

An observation apparent during late summer was the amount of cracking of the soil in the treatments receiving zero, one, two and four cultivations. Figures 3, 4, 5 and 6 are photographs taken September 12, 1961 of this phenomena.

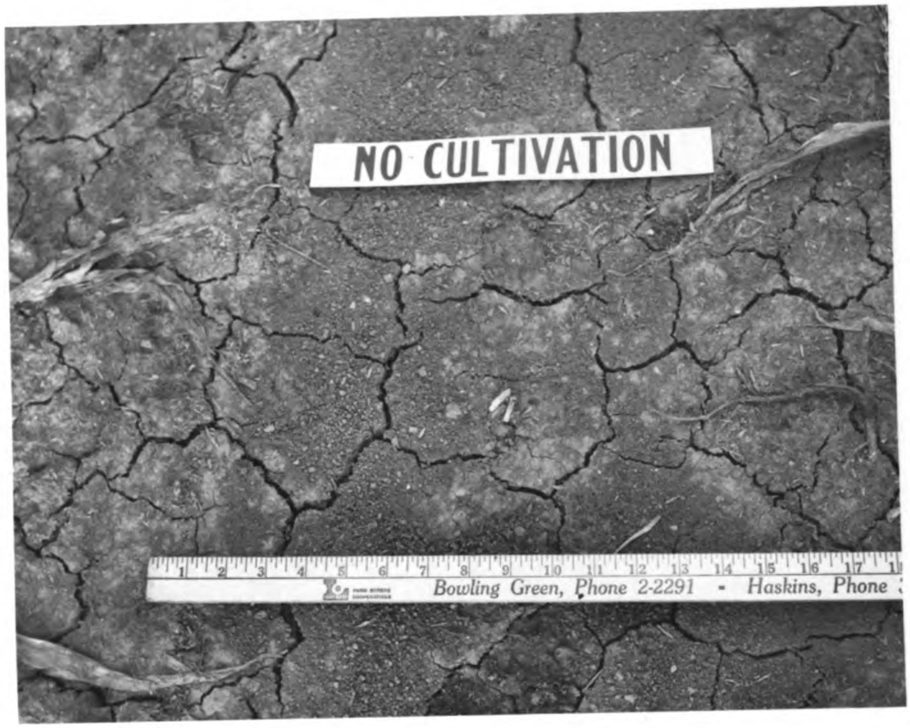

Figure 3. Soil surface of plot receiving no cultivation.

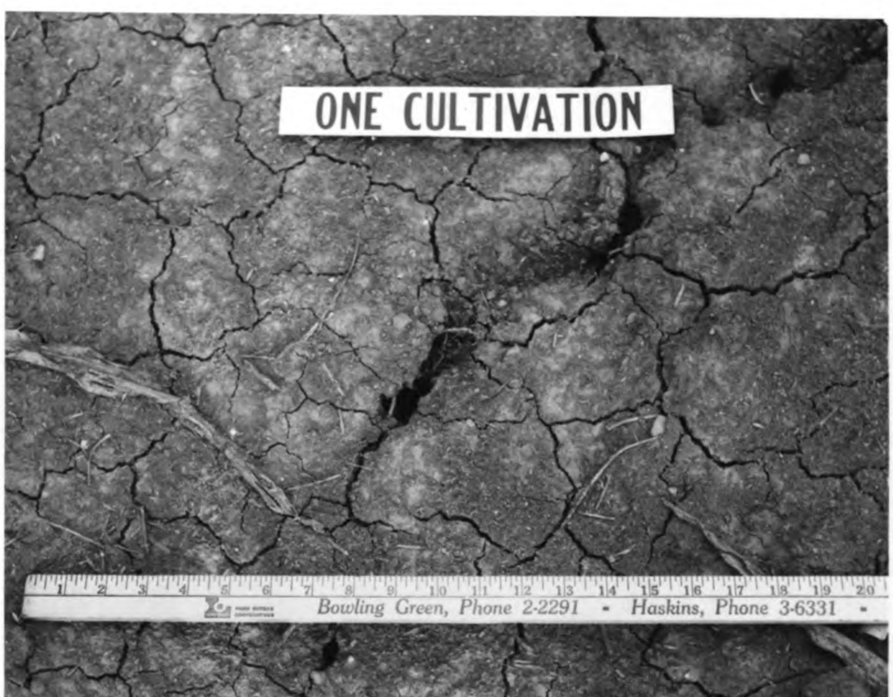

Figure 4. Soil surface of plot receiving one cultivation.

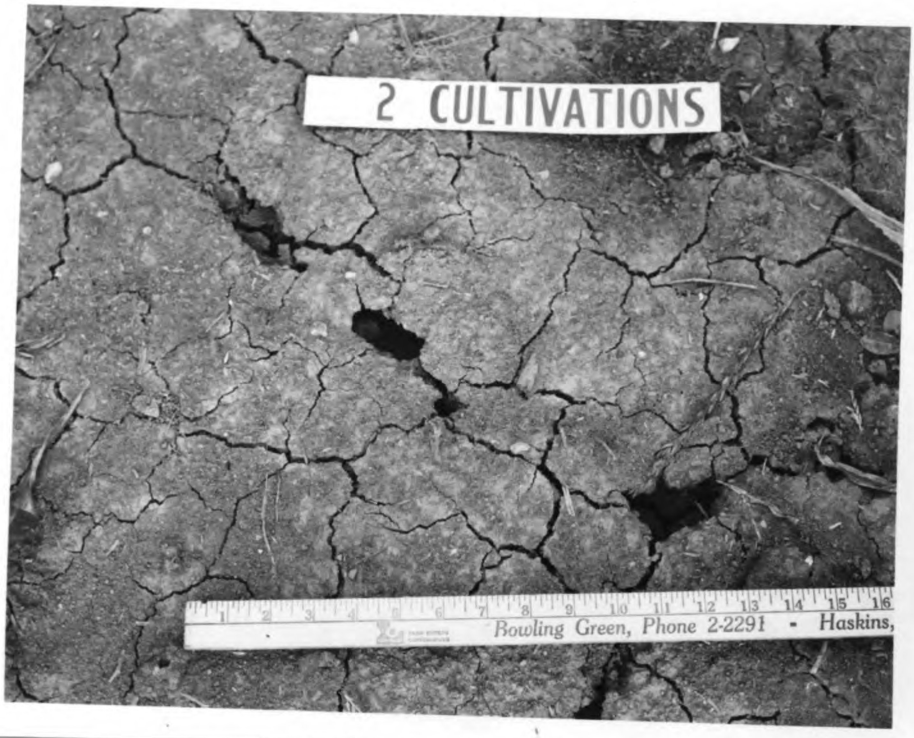

Figure 5. Soil surface of plot receiving two cultivations.

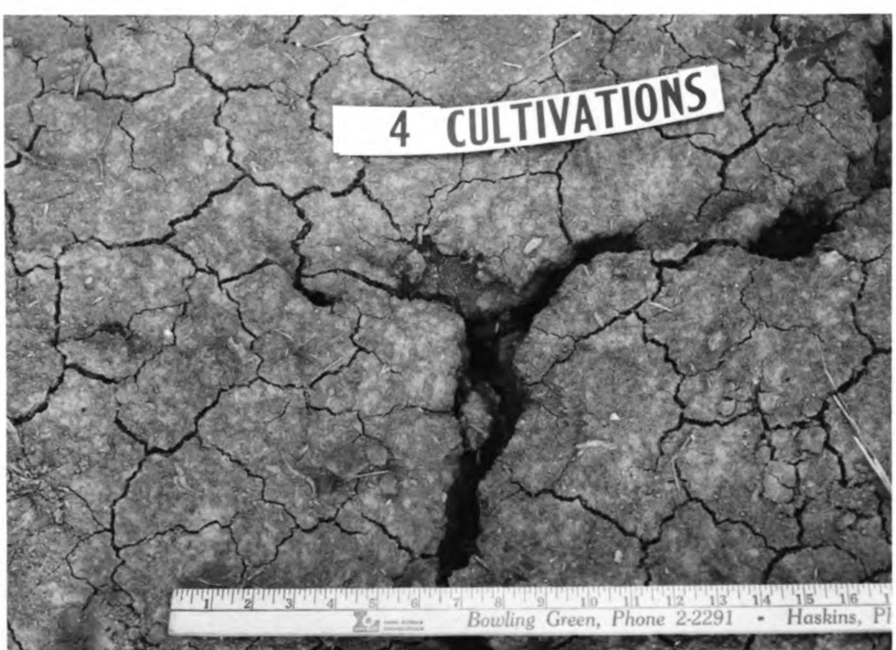

Figure 6. Soil surface of plot receiving four cultivations.

By use of the platinmum microelectrode method (13) the rate of oxygen diffusion was determined on plots treated with atrazine that were not cultivated, cultivated once and cultivated four times. The readings obtained were in microamperes and resulted from the flow of electrons through the circuit as oxygen is reduced at the electrode. Therefore the readings are proportional to the rate of oxygen diffusion into the immediate vicinity of the electrode. A total of 39 readings were taken per plot on each date with the electrodes four inches below the soil surface. Table 5 lists the means of these readings.

Table 5. Rates of oxygen diffusion in microamperes on several dates in soil that had received varying amounts of cultivations, 1961.

	Dates						
No. of Cultivations	7-24	7-25	7-26	7-28	8-18	9-10	9-26
No cultivation	6.37	5.93	5.98	6.07	5.42	5.84	1.49
One cultivation	5.61	4.68	5.79	5.85	4.82	6.39	1.61
Four cultivations	4.83	5.28	5.36	5.64	5.50	5.99	1.41
	*	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.

Wide variation of readings within a treatment resulted in a large error term, consequently, only the means obtained on July 24 were significantly different. The sequence of readings in late July was interrupted by a rain on July 29. However, the means obtained July 24 indicates that the rate of oxygen diffusion was slightly higher in the uncultivated plot with one and four cultivations following in that order.

Effectiveness of Chemical Treatments Used in Controlling Weeds

The effectiveness of the various herbicides used in the 1960 experiment on the control of grassy and broadleaf weeds is indicated in Table 6.

Table 6. The effects of several herbicides on the control of broadleaf and grassy weeds in corn, 1960.

Herbicide	Rate lb/A	Time*/	Weeds per square foot** Broadleaf	Grassy
Atrazine, 80 W	2	pre-emergence	.01	.11
2,4-D L.V.E.	2	pre-emergence	.19	.09
2,4-D Granular	2	pre-emergence	.19	.12
Atrazine, 8 G	2	pre-emergence	.11	.21
Atrazine 80 W	2	post-emergence	.19	.30
2,4-D Amine	½	post-emergence	.48	.45
Check, no herbicide			.74	.30

*All pre-emergence treatments applied May 25.
/Post-emergence applications made June 20.
**Weed counts made July 5.

Rainfall during the week following application of herbicides was: May 27, .55; May 28, .33; May 29, .01; and May 30, .28 inch. Rainfall following post-emergence treatments was: June 22, 1.52; and June 24, .02 inch.

Results with atrazine applied as a spray and in granular form were essentially equal.

Figure 7. Control of annual weeds was obtained with atrazine 80 W, 1960.

Figure 8. Granular form of atrazine was as effective as the wettable powder.

A light natural infestation of weeds on the 1960 experimental site made a critical evaluation of the herbicides impossible. However, pre-emergence applications of the herbicides in liquid and granular form were slightly more effective than post-emergence applications.

Total rainfall during June and July 1960 was 3.94 inches and 6.47 inches respectively. In some plots treated with atrazine, infestations of barnyard grass (Echinochloa crusgalli) averaging one-half plant per square foot, occurred in late July. Apparently this shallow rooted grass germinated in the surface soil from which the atrazine had been leached by the high amount of rainfall.

The herbicides used in 1961 were selected with the intent to create different types of weed populations: i.e. atrazine to control all annual weeds, 2,4-D post-emergence to control only broadleaf and CDAA to control only grasses.

The effectiveness of the herbicides used in 1961 is indicated in Table 7.

Table 7. The effects of three herbicides on the control of broadleaf and grassy weeds in corn, 1961.

Herbicide	Rate lb/A	Time*/	Weeds per square foot** Broadleaf	Grassy
Atrazine 80 W	3	pre-emergence	.07	.04
2,4-D amine	½	post-emergence	.19	.42
CDAA	2	pre-emergence	.85	.49
Check, no herbicide			1.31	.69

*Pre-emergence treatments applied June 7.
/Post-emergence treatment applied July 6 and repeated August 4.
**Weed counts were made on July 25.

Rainfall during the week following application of the pre-emergence herbicides was: June 8, .34; June 13, 1.09; and June 14, .99 inch. Following the two post-emergence applications precipitation was as follows: June 13, .05; July 14, .45; August 5, 1.10; August 6, .22; August 10, .07; and August 11, .07 inch.

Atrazine 80 W gave good control of annual weeds. Satisfactory control of broadleafs was obtained with 2,4-D amine post-emergence. Broadleaf weeds in the 2,4-D plots were upright spotted spurge (Euphorbia maculata), common milkweed (Asclepias syriaca) and horse nettle (Solanum carolinense). Heavy rainfall following application of CDAA reduced its effectiveness considerably as evidenced by the presence of annual grasses in these plots. Annual grasses in the plots treated with CDAA consisted primarily of yellow foxtail (Setaria lutescens). Infestations in the check plots consisted of all the weeds mentioned above in addition to lambsquarter (Chenopodium album), red root (Amarenthus retroflexus), smartweed (Polygonum pennsylvanicum), ground cherry (Physalis subglabrata) and green foxtail (Setaria viridis).

Effectiveness of Cultural Methods in Controlling Weeds

In the 1960 experiment the use of shovels and sweeps were included as cultural variables as shown in Table 8.

Weeds were not a serious problem on the site of the 1960 experiment, however, the data in Table 8 indicates that sweeps on the cultivator were more effective in controlling weeds than shovels. The added width of the sweeps compared with shovels made it more difficult for weeds to slip by the sweeps without being destroyed.

Table 8. The degree of weed control obtained in corn with one, two, and four cultivations using sweeps and spear-point shovels, 1960.

Treatment	Weeds per square foot between the row Broadleaf	Grassy
SWEEPS		
No cultivation	.74	.30
One cultivation	.03	.02
Two cultivations	.00	.00
Four cultivations	.00	.00
SHOVELS		
No cultivation	.74	.30
One cultivation	.14	.09
Two cultivations	.13	.03
Four cultivations	.01	.00

Sweeps were used on the cultivator for the cultural treatments in 1961. The natural infestation of weeds on the site of the 1961 experiment while not heavy was greater than in the 1960 experiment.

Table 9. Degree of weed control attained in corn with one, two and four cultivations using sweeps, 1961.

	Weeds per square foot between the row		Weeds per square foot in the row	
Treatment	Broadleaf	Grass	Broadleaf	Grass
No cultivation	1.31	.69	1.31	.69
One cultivation	.62	.07	.91	.26
Two cultivations	.35	.01	.70	.14
Four cultivations	.00	.00	.64	.26

The degree of weed control attained in 1961 by cultural methods is indicated in Table 9.

In spite of the light infestation of weeds it was evident that as the number of cultivations increased the number of weeds in the area cultivated decreased. The difficulty of controlling weeds in the row by cultural methods even with several cultivations is also indicated by the data. Weeds in the row not covered during the first cultivation usually are too large to be covered by subsequent cultivations.

Effect of Weeds on Corn

The presence of weeds influenced the yield of corn significantly even though the maximum number present was only two per square foot. The weeds grew vigorously due to lack of competition and by late summer many specimens of Redroot (Amaranthus retroflexus) and Velvet Leaf (Abutilon theophrasti) had attained heights in excess of five feet. These weeds were competing for moisture during late August when the ears were developing. The effect of these weeds and supplemental cultivation on corn yield is presented in Table 10.

The no cultivation treatments had the heaviest infestation of weeds and comparatively low yields of corn resulted. The low yield of the treatment no cultivation with CDAA was caused by one unexplainable yield more than ten bushels below the yield of the other plots that made up this mean. Treatments receiving one cultivation had essentially the same yields as the no cultivation treatments. Apparently the weeds left in the row plus those that germinated after cultivation held these yields close

to the no cultivation yields.

Table 10. Effect of supplemental cultivation on yield of corn when weeds were not satisfactorily controlled with herbicides, 1961.

	Chemical Treatments	
Cultural Treatment	No Herbicide Yield Bu/A.	CDAA Yield Bu/A.
No cultivation	104.5	99.9
One cultivation	105.4	105.9
Two cultivations	114.9	113.6
Four cultivations	108.3	111.4

On treatments where weeds were not eliminated by herbicides two cultivations controlled weeds to the extent that maximum yields were obtained. Additional cultivation beyond two resulted in lower yields due to the adverse effects of cultivation already mentioned.

Combined Effects of all Factors on Corn Yields

The previous discussion had indicated that cultivation is beneficial only insofar as it controls weeds and the presence of weeds decreases the yield of corn. These two facts largely explain the yields obtained from all treatments in the 1961 experiment, as shown in Table 11.

In Table 11 treatments with high comparative yields were weed free. This condition was obtained either by herbicides alone or a combination of herbicides and adequate cultivation. This fact emphasizes that one of the primary prerequisites for maximum corn yields is effective control of weeds. When adequate weed control was obtained by use of herbicides without the aid of cultivation the highest yield resulted. Weeds in this treatment were killed as they emerged thus eliminating early competition, a factor operating in all but those treated with atrazine. The highest yield from the atrazine treatment and no cultivation also indicates that cultivation on this soil type is beneficial only to the extent that it controls weeds.

Table 11. Average yields of corn from all combinations of chemical and cultural variables included in 1961 experiment.

Herbicide	Rate lb/A.	Time of Application	Number of Cultivations	Yield Bu/A.*
Atrazine 80 W	2	pre-emergence	0	119.9 a
Atrazine 80 W	2	pre-emergence	1	116.5 b
2,4-D	½	post-emergence	2	116.0 b c
No herbicide	-	-------------	2	114.9 b c
CDAA	2	pre-emergence	2	113.6 b c d
Atrazine	2	pre-emergence	2	112.7 c d e f
CDAA	2	pre-emergence	4	111.4 g d e f
2,4-D	½	post-emergence	4	111.0 g e f
2,4-D	½	post-emergence	0	110.6 g e f
Atrazine	2	pre-emergence	4	109.5 g f
2,4-D	½	post-emergence	1	109.4 g h f
No herbicide	-	-------------	4	108.3 g h i
CDAA	2	pre-emergence	1	105.8 h i j
No herbicide	-	-------------	1	105.4 i j
No herbicide	-	-------------	0	104.5 j
CDAA	2	pre-emergence	0	99.9 k

*Means not significantly different are indicated by similar lower case letters.

Around the median yield are treatments that have acceptable yields but significantly lower than the treatments just discussed due primarily to cultivation in excess of that necessary to control weeds.

Low comparative yields resulted from treatments where weeds were not satisfactorily controlled with herbicides or adequate cultivation.

Results of the 1960 experiment were influenced by a destructive hail storm on July 19. This storm seriously defoliated the corn plants which reduced total yields and largely erased differences between various treatments. The damage resulting from this storm is illustrated in Figure 9.

Figure 9. Damage to corn resulting from hail storm, July 19, 1960.

The influence of the cultivation variables that made up the cultural whole plots in 1960 on the yield of corn is presented in Table 12.

Table 12. Effect of varying amounts of cultivation on yield of corn using sweeps and spear-point shovels, 1960.

Cultural Treatments	Yield Bu/A.*
One cultivation with sweeps	81.5 a
Two cultivations with shovels	80.8 a b
Four cultivations with sweeps	80.0 a b
Four cultivations with shovels	78.4 a b c
Two cultivations with sweeps	77.8 a b c
One cultivation with shovels	76.6 b c d
Check, no cultivation	75.1 c d
Check, no cultivation	72.8 d

*Means not significantly different are indicated by similar lower case letters.

No consistent trend was established by the cultural whole plots in the 1960 experiment.

In 1960 various herbicide treatments made up the split plots. The effect of these herbicide treatments on corn yields is indicated in Table 13.

Differences in yield of corn between the herbicide treatments were not great, however, treatments with the lowest yields had the greatest infestations of weeds.

Table 13. Effect of pre-emergence and post-emergence herbicide treatments on yield of corn, 1960.

Herbicide Treatment	Yield Bu/A.*
Atrazine 8 G, pre-emergence	80.0 a
Atrazine 80 W, pre-emergence	79.5 a
2,4-D granular, pre-emergence	79.4 a
2,4-D L.V.E., pre-emergence	77.9 a
Atrazine 80 W, post-emergence	77.3 a b
No herbicide	76.7 a b
2,4-D Amine, post-emergence	74.2 b

*Mean not significantly different are indicated with similar lower case letters.

Analysis of the yield data showed a highly significant herbicide X culture interaction indicating that both the presence of weeds and the effect of cultivation were influencing corn yields.

SUMMARY

The effect of cultivation on the yield of corn and some physical properties of soil were investigated. In addition the effectiveness of several herbicides was determined in controlling weeds in corn, with varying amount of supplemental cultivation using sweep and spear-point shovels. The effect of weeds on the yield of corn and the influence of supplemental cultivation on the height and nutrient content of corn leaves was determined in this study.

These investigations may be summarized as follows:

1. When weeds were controlled with herbicides, cultivation did not increase and in some cases decreased the yield of corn.

2. No significant difference existed in the bulk density of the soil beneath that stirred by one or four cultivations or under the rear wheel track made by the tractor during one cultivation. The bulk density of soil over which the rear wheel of the tractor had passed four times during cultivation was significantly higher.

3. No difference existed in the per cent total porosity to the soil directly beneath that cultivated one or four times. The soil beneath the wheel track made by one cultivation had a significantly lower porosity and four passes of the tractor wheel during cultivation lowered the porosity an additional significant amount.

4. Cultivation by itself did not affect the nitrogen, phosphorus or potassium content of corn leaves.

5. The height of corn plants on uncultivated plots was significantly greater than corn on cultivated plots on two of the

three dates it was measured.

6. On treatments where weeds were not controlled by herbicides, cultivation to the extent that weed control was obtained increased corn yields.

7. The yield of corn was inversely proportional to the population of weeds present except where yields were decreased by excessive cultivation.

8. The presence of weeds significantly decreased the per cent of nitrogen in the corn leaves, however, there was no significant difference in the amount of phosphorus and potassium present in any of the treatments sampled.

9. A tractor-mounted cultivator equipped with sweeps was more effective in controlling weeds than one equipped with spear point shovels. However, neither satisfactorily controlled weeds in the corn row.

10. Atrazine 80 W applied pre-emergence at recommended rates gave virtually 100 per cent control of annual weeds. Acceptable results were also obtained with 2,4-D, L.V.E., 2,4-D granular and atrazine 8 G when applied pre-emergence at recommended rates.

BIBLIOGRAPHY

1. Baver, L. D. Soil physics, third edition. New York, New York, John Wiley and Sons. 1956.

2. Blake, G. R., R. J. Aldrich. Effects of cultivation on soil physical properties and crop yields. Soil Science Society of America Proceedings 19:400-403. 1955.

3. Bodman, G. B., J. Rubin. Soil puddling. Soil Science Society of America Proceedings 13:27-36. 1948.

4. Bondarenko, D. D. Weed control by herbicides. Agricultural Extension Service, Ohio State University, Bulletin 39[illegible]. 1960.

5. Borst, H. L., G. M. McClure. Cultivation of corn. Ohio Agricultural Experiment Station, Bimonthly Bulletin 162: 75-77. 1933.

6. Cates, J. S., H. R. Cox. The weed factor in cultivation of corn. United States Department of Agriculture Bulletin 257. 1912.

7. Chang, H. T., W. E. Loomis. Effect of CO_2 on absorption of water and nutrients by roots. Plant Physiology 20:220-232. 1945.

8. Duncan, D. B. Multiple range and multiple F tests. Biometrics 2:1-4. 1955.

9. Gingrich, J. R., M. B. Russell. Effect of soil moisture tension and O_2 concentration on growth of corn roots. Agronomy Journal 48:517-520. 1956.

10. Helm, C. A. Corn in Missouri. Missouri Agricultural Experiment Station Bulletin 185. 1921.

11. Kramer, P. J. Causes of decreased absorption of water by plants in poorly aerated media. American Journal of Botany 27: 216-220. 1949.

12. Lawton, K. The influence of soil aeration on the growth and absorption of nutrients by corn plants. Soil Science Society of America Proceedings 10:263-269. 1945.

13. Lemon, E. R., A. E. Erickson. The measurement of oxygen diffusion in the soil with a platinum microelectrode. Soil Science Society of America Proceedings 16:160-163. 1952.

14. Liden, C. H. Weed control using various combinations of cultivation, 2,4-D, and calcium cyanamid. Proceedings Northeastern Weed Control Conference 6:209-216. 1952.

15. Lovely, W. G., D. W. Staniforth. Granular herbicide formulations for weed control in corn. Proceedings of Joint meeting North Central Weed Control Conference and Western Canadian Weed Control Conference. 1959.

16. Meggitt, W. F. The influence of cultivation on corn yields when weeds are controlled by herbicides. Proceedings of the 14th Annual Meeting of the Northeastern Weed Control Conference. 1960.

17. Meggitt, W. F. Progress report on herbicides for weed control in corn and soybeans. Proceedings 14th Annual Meeting of the Northeastern Weed Control Conference. 1960.

18. Mooers, C. A. Depth and method of soil preparation and cultivation for corn and cotton. Tennessee Agricultural Experiment Station Bulletin 191. 1944.

19. Moore, R. C. Water conduction from shallow water tables. Hilgardia 12:383-426. 1939.

20. Mosier, J. G., A. F. Gustafson. Soil moisture and tillage for corn. University of Illinois, Agricultural Experiment Station Bulletin 181. 1915.

21. Musgrave, G. W., G. R. Free. Some factors which modify the rate and total amount of infiltration of field soils. Agronomy Journal 28:727-739. 1936.

22. Pillsbury, A. F. Factors influencing infiltration rates into Yolo loam. Soil Science 64:171-181. 1947.

23. Russell, M. B., F. E. Davis, R. A. Bair. The use of tensiometers for following soil moisture conditions under corn. Agronomy Journal 32:922-930. 1940.

24. Schneider, E. O. Comparison of simazine and atrazine for weed control in corn. Proceedings of Joint meeting North Central Weed Control Conference and Western Canadian Weed Control Conference. 1959.

25. Schneider, E. O. Simazine and related triazine herbicides. Proceedings 15th Annual Meeting, North Central Weed Control Conference 10-11. 1958.

26. Stroube, E. W. Herbicides to control weeds in field crops. Agricultural Extension Service Leaflet L-75. 1962.

27. Swanson, C. L., H. G. Jacobson. Effect of soil hardness and compaction on corn growth. Soil Science Society of America Proceedings 20:161-167. 1956.

28. Taylor, G. S., T. Goins, N. Holowaychak. Drainage characteristics of Toledo and Hoytville soils. Ohio Agricultural Experiment Station Research Bulletin 876. 1961.

29. Veihmeyer, F. J. Some factors affecting the irrigation requirements of deciduous orchards. Hilgardia 2:125-284. 1927.

30. Veihmeyer, F. J., A. H. Hendrickson. Soil density and root penetration. Soil Science 65:487-493. 1948.

31. Vengris, J., W. G. Cobly, M. Drake. Plant nutrient competition between weeds and corn. Agronomy Journal 47:213-216. 1955.

32. Weaver, H. A., V. C. Jamison. Effects of moisture on tractor wheel compaction of soil. Soil Science 71:15-23. 1951.

33. Wiese, A. F., T. J. Army. Effect of tillage and chemical weed control practices on soil moisture storage and losses. Agronomy Journal 50:465-468. 1958.

34. Williams, C. G., F. A. Welton. Corn experiments. Ohio Agricultural Experiment Station Bulletin 282. 1915.

35. Wimer, D. C. Why cultivate corn? University of Illinois Extension Service Circular 597. 1946.

36. Wimer, D. C., M. B. Harland. The cultivation of corn. Illinois Agricultural Experiment Station Bulletin 259. 1925.

APPENDIX A

Analysis of Variance on 1960 data

Yield of Corn

Source	SS	df	MS	F
Total	13,705.27	223		
Whole plot				
Reps.	1,282.05	3		
Culture	1,728.25	7	246.89	4.311**
Error a	1,202.69	21	57.27	
Split plot				
Herbicides	817.25	6	136.21	3.429**
H x C	2,955.75	42	70.38	1.772**
Error b	5,719.28	144	39.72	

Height of Plants on July 6

Source	SS	df	MS	F
Total	40,725.90	195		
Whole plot				
Reps.	1,968.38	3		
Culture	2,315.13	6	385.86	2.411 n.s.
Error a	2,880.60	18	160.03	
Split plot				
Herbicides	5,224.67	6	870.78	5.318**
H x C	7,704.16	36	214.00	1.307 n.s.
Error b	20,632.96	126	163.75	

Height of Plants on July 12

Source	SS	df	MS	F
Total	54,340.98	195		
Whole plot				
Reps.	6,458.45	3		
Culture	3,756.01	6	626.00	4.346**
Error a	2,592.87	18	144.05	
Split plot				
Herbicides	4,273.40	6	712.23	3.315**
H x C	10,192.44	36	283.12	1.318 n.s.
Error b	27,067.81	126	214.82	

Height of Plants on July 18

Source	SS	df	MS	F
Total	67,244.96	195		
Whole plot				
Reps.	7,162.46	3		
Culture	7,067.35	6	1,177.89	5.073**
Error a	4,179.35	18	232.19	
Split plot				
Herbicides	3,236.31	6	539.39	2.025 n.s.
H x C	12,038.05	36	334.39	1.255 n.s.
Error b	33,561.44	126	266.36	

APPENDIX B

Analysis of Variance on 1961 data

Yield of Corn

Source	SS	df	MS	F
Total	2,748.15	63		
Reps.	195.93	3		
Treatments	1,558.37	15	103.89	4.704**
Error	993.85	45	22.09	

Corn Leaf Analysis for Nitrogen

Source	SS	df	MS	F
Total	96.57	39		
Reps.	8.37	3		
Treatments	39.38	9	4.3756	2.420**
Error	48.82	27	1.8081	

Corn Leaf Analysis for Phosphorus

Source	SS	df	MS	F
Total	11.686	39		
Reps.	2.294	3		
Treatments	2.438	9	.27089	1.052 n.s.
Error	6.954	27	.25756	

Corn Leaf Analysis for Potassium

Source	SS	df	MS	F
Total	59.50	39		
Reps.	5.19	3		
Treatments	22.08	9	2.4533	2.055 n.s.
Error	32.23	27	1.1937	

Blows Required to Obtain a Core

Source	SS	df	MS	F
Total	27,616.20	44		
Between	25,463.90	4	6,365.97	118.32**
Error	2,152.30	40	53.80	

Percent Porosity

Source	SS	df	MS	F
Total	634.70	35		
Between	377.90	3	125.9	15.70**
Error	256.80	32	8.0	

Bulk Density

Source	SS	df	MS	F
Total	.591	35		
Between	.472	3	.157	42.31**
Error	.119	32	.00371	

Rate of Oxygen Diffusion on July 24

Source	SS	df	MS	F
Total	411.87	116		
Between	30.63	2	15.31	4.58*
Error	381.24	114	3.34	

Rate of Oxygen Diffusion on July 25

Source	SS	df	MS	F
Total	320.02	116		
Between	12.54	2	6.27	2.33 n.s.
Error	307.48	114	2.69	

Rate of Oxygen Diffusion on July 26

Source	SS	df	MS	F
Total	366.77	116		
Between	5.39	2	2.69	.84 n.s.
Error	361.38	114	3.17	

Rate of Oxygen Diffusion on August 18

Source	SS	df	MS	F
Total	314.19	116		
Between	8.73	2	4.36	1.62 n.s.
Error	305.46	114	2.76	

Rate of Oxygen Diffusion on September 10

Total	494.85	116		
Between	6.22	2	3.11	.72 n.s.
Error	488.63	114	4.28	

Rate of Oxygen Diffusion on September 26

Total	25.95	116		
Between	.83	2	.41	1.86 n.s.
Error	25.12	114	.22	

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