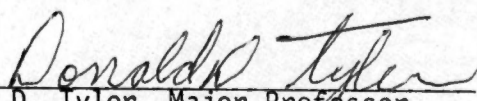
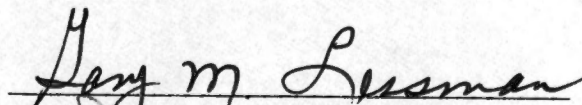
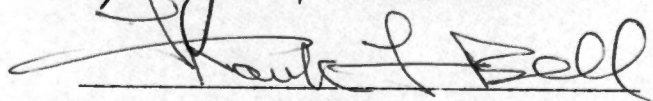


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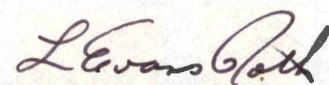
I am submitting herewith a thesis written by William E. Stevens entitled "Cover Crop, Tillage, and Nitrogen Effects on Corn." I have examined the final copy of this thesis for form and content and recommend that it be accepted in partial fulfillment of the requirements for the degree of Master of Science, with a major in Plant and Soil Science.


Donald D. Tyler, Major Professor

We have read this thesis
and recommend its acceptance:

Accepted for the Council:


Vice Chancellor
Graduate Studies and Research

Thesis
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COVER CROP, TILLAGE, AND NITROGEN
EFFECTS ON CORN

A Thesis

Presented for the

Master of Science

Degree

The University of Tennessee, Knoxville

William E. Stevens

June 1982

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ABSTRACT

Soil erosion and rapidly increasing nitrogen fertilizer costs are two major problems confronting West Tennessee corn producers. Cover crops grown during fall and winter can substantially reduce erosion especially if used in conjunction with no-till corn planting. Including nitrogen fixing legumes in cover crops could supply a part of the nitrogen needed for a succeeding corn crop. An objective of this experiment was to determine whether as much nitrogen is supplied to succeeding corn crops by the residues left on the soil surface in a no-tillage system as compared to incorporation in a conventional tillage system.

A field experiment using a split plot design was conducted to determine the effects of different cover crops, tillage systems, and nitrogen rates on corn. The four tillage-cover crop treatments consisted of conventional tilled no cover, conventional tilled wheat-vetch, wheat-vetch no-tillage, and wheat no-tillage. The four nitrogen rates used ranged from 0 to 168 kg N/ha. Conventionally tilled corn following a wheat-vetch cover crop significantly outyielded conventionally tilled corn following no cover crop in plots receiving 0 and 56 kg N/ha. Since the yields from the 112 and 168 kg N/ha were similar, differences in yields at the 0 and 56 kg N/ha rates were attributed to greater nitrogen availability in the wheat-vetch plots as compared to the no cover plots. Corn yields were significantly lower in no-tillage corn following a wheat cover crop than in no-tillage corn following a wheat-vetch cover crop at 0, 56, 112, and 168 kg N/ha nitrogen rates. Soil nitrate-nitrogen levels were lower in the wheat no-tillage plots than in the

wheat-vetch no-tillage plots. This may indicate that less soil nitrogen mineralization occurred in the wheat no-tillage plots as compared with the wheat-vetch no-tillage plots due to higher carbon:nitrogen ratios in the residues of the former. Corn following conventionally tilled wheat-vetch outyielded corn following no-tilled wheat-vetch at the 56, 112, and 168 kg N/ha rates.

Results from this experiment indicate that the availability of soil nitrogen to corn is influenced by tillage and cover crops. Soil nitrogen was more available to corn following wheat-vetch as compared to corn following wheat. Soil nitrogen was less available in no-tilled corn with wheat-vetch than conventionally tilled corn with wheat-vetch at the 0 and 56 kg N/ha rate. This indicates that more nitrogen fertilizer may be needed to produce corn yields in no-tillage systems comparable with conventionally tilled corn yields.

CRANE CREST

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CHAPTER I

INTRODUCTION

Technological advancements in corn production have resulted in the substitution of animal power with petroleum power and nitrogen from organic sources with commercial nitrogen fertilizer. However, rising petroleum prices are making the operation of petroleum-powered machinery and the application of nitrogen fertilizer increasingly expensive.

Using animal power to replace petroleum power as a means of avoiding high petroleum costs is impractical. The costs of the additional time and labor required would more than cancel out the savings from the reduced petroleum costs.

Many corn farmers are reducing both labor and petroleum expenses by using no-tillage systems. No-tillage is a procedure whereby a crop is planted into a seedbed which has not been tilled since the harvest of the previous crop (United States Department of Agriculture, 1975). No-tillage corn usually follows a winter cover crop which has been killed with herbicides.

A study conducted in Nebraska showed that 120.1 kWh/ha of power were required for tillage, planting, and harvesting when conventional tillage methods were used. When no-tillage methods were used 20.6 kWh/ha were needed (Lane et al., 1973). Ohio researchers found that pre-harvest labor requirements declined from 3.31 hours/ha under a conventional tillage system to 1.03 hours/ha under a no-tillage system (Rask et al., 1967). In addition, researchers have found that no-tillage corn yields can equal or exceed conventional tillage corn yields

(Blevins et al., 1977; Jones et al., 1969; Moschler et al., 1967; and Shanholtz and Lillard, 1969).

Reducing nitrogen fertilizer rates usually cannot be accomplished without reducing corn yields. If the price of corn rises with the prices of N fertilizer, farmers will probably be able to afford the high rates of nitrogen needed to attain high corn yields. However, nitrogen fertilizer prices are escalating so fast that this may not be possible in the future. In the period from May 1979 to May 1980, the price of anhydrous ammonia increased 30% (Economics, Statistics, and Cooperatives Service, 1980). Much of that increase was a result of increases in natural gas prices. Natural gas is a raw material used in the synthesis of ammonia.

A nitrogen source that is not a product of fossil fuels and that will perform satisfactorily with a no-tillage corn system is needed. Nitrogen from leguminous green manure crops may meet these requirements.

Nitrogen mineralized from turned under winter legumes was a major source of nitrogen for conventional tillage corn before World War II. Admittedly, corn yields were generally lower then than they are now, but one should consider that hybrid corn cultivars were not available then. Research is needed to evaluate leguminous green manuring in modern corn production. New developments such as hybrid corn cultivars and no-tillage planting systems have made information gathered before World War II of limited value today.

A study was conducted to monitor water and nitrate levels in the top 0 to 90 cm layer of a Memphis silt loam soil growing no-tillage and conventional tillage corn following a winter cover crop of wheat, and a

wheat-hairy vetch mixture. Rates of nitrogen fertilizer applied were 0, 56, 112, and 168 kg N/ha. The effects of tillage and cover crops on soil pH and soil organic matter in the top 0 to 15 cm were also determined. A Master's thesis by John Lyle, which will be completed in Spring 1982, will deal with the growth and nitrogen contents of corn plants in this experiment. A comparison of these two research projects will aid in understanding certain results in the present study. The primary objectives of this experiment were:

1. To determine the effect that tillage and cover crops have on soil water, nitrate, pH, and organic matter in a Memphis silt loam soil cropped to corn following a wheat-hairy vetch mixture.
2. To determine the amounts of nitrogen fertilizer that should be applied to corn grown in the various cover crop and tillage regimes for maximum economical yields.



CHAPTER II

LITERATURE REVIEW

Immobilization and Mineralization of Nitrogen

Soil microorganisms have a tremendous effect upon the amounts and forms of nitrogen that occur in soils. Unfortunately, they sometimes compete with higher plants for nitrate and ammonium ions, the two forms of nitrogen most available to plants.

Doryland (1916) concluded from his work that, when a substance high in "available energy" is added to soil, nitrogen can be extracted from the soil and assimilated into the bodies of the soil microorganisms feeding upon the substance. The term "immobilization" has been employed to describe the phenomenon that Doryland observed. Immobilization of soil nitrogen often occurs when a plant residue which contains a low percentage of nitrogen is added to a soil. Soil microorganisms consuming such residues take up mineral nitrogen from the soil to supplement in the building of their cell tissues. This results in a decline in the amount of soil mineral nitrogen that is available to higher plants.

In a greenhouse experiment, Pinck et al. (1946) compared the yields of sudangrass grown in control pots containing only soil to yields from pots receiving additions of wheat straw with various amounts of urea. They found that under certain conditions sudangrass from pots of soil containing wheat straw-urea mixtures with nitrogen contents below 1.37% did not yield as high as the sudangrass from the control

pots. The carbon to nitrogen ratio for the 1.37% nitrogen mixture was 30:1. Pinck et al. (1946) concluded that at the 30:1 carbon to nitrogen ratio, the nitrogen needs of the soil microflora are satisfied.

Allison and Klein (1962) reported that the carbon to nitrogen ratio of a wheat straw-sodium nitrate mixture was 25:1 when the nitrogen needs of the soil microorganisms are met. They compared their results to those obtained by Winsor and Pollard (1956) who used sucrose instead of straw as a high carbon energy source. Winsor and Pollard (1956) found that the nitrogen needs of the microorganisms consuming the sucrose are not met until the carbon to nitrogen ratio reached 11:1. Allison and Klein (1962) attributed the wide difference between their results and those of Winsor and Pollard (1956) to the fact that the straw which they had used contained lignin and hemicellulose which was more resistant to microbial attack than the sucrose which Winsor and Pollard (1956) had used.

The addition of some types of plant residues to the soil does not result in immobilization of nitrogen. Many times nitrogen is released to the soil as ammonia when microorganisms decompose certain residues. The process of converting an element from an organic form to an inorganic state as a result of microbial decomposition is called mineralization.

Bartholomew (1965) conducted an incubation study comparing the effects of legume and nonlegume residues on the inorganic nitrogen content of a soil. Pots of soil receiving alfalfa residues increased in an inorganic nitrogen relative to check pots which had no residue

addition. Pots receiving a nonlegume residue, corn stalks, declined in inorganic nitrogen.

A major factor determining whether nitrogen will be immobilized or mineralized when a plant residue is added to a soil is the percentage of nitrogen in the plant residue. Generally, legumes have a higher percentage of nitrogen than nonlegumes. The analysis of various crop residues showed that on a dry matter basis, alfalfa, hairy vetch, and Austrian winter peas contained from 3.0 to 4.0 percent nitrogen (Rogers and Giddens, 1957). Crimson clover contained 3.0 to 3.3 percent nitrogen, and red clover contained 2.8 to 3.2 percent nitrogen. Oats and rye, both nonlegumes, contained 1.2 to 1.4 percent nitrogen.

Numerous studies have shown that corn grown in the absence of inorganic nitrogen fertilizer often yields higher following a turned under leguminous green manure than a nonlegume green manure (Lyon, 1927; Obenshain and Gish, 1941; United States Agricultural Adjustment Administration, 1936).

Green Manuring in Continuous Conventional Tillage Corn

Much of our knowledge concerning the usage of leguminous green manures as a nitrogen source comes from research conducted before World War II. Prior to World War II, corn farmers in the United States obtained most of their nitrogen fertilizer from three sources--ammonium sulfate from the coking industry, nitrate of soda from Chilean deposits, and mineralized nitrogen from leguminous green manures. Of the three sources, the latter is the only one that is renewable. The widespread usage of green manures by farmers necessitated extensive research with them during the first four decades of the 20th Century.

The turning under of summer legumes for soil improvement is probably economically feasible only on the poorest of soils (Pieters and McKee, 1938). Often summer legumes are cut for hay or grazed by stock. Any soil improvement that occurs in such cases results from the residues of the summer legumes. Unlike summer legumes, winter legumes can be grown and turned under with no interference with regular summer crops such as corn.

Three important winter legumes used for green manures in the southeastern United States are bur clover, vetch, and Austrian winter peas. Bur clover is not hardy in Virginia and Tennessee but can be grown in other parts of the region (Pieters and McKee, 1938). Woolly podded, Hungarian, Monantha, and common vetches have been used as green manures, but hairy vetch is the most popular of the vetches. Austrian winter peas are usually able to survive winters as far north as Washington, D.C. (Pieters and McKee, 1938). With the exception of the Grey winter pea variety, all other field pea varieties are not winter-hardy in the southeastern United States.

The amount of winter legume growth varies from year to year and this may affect the amount of fixed nitrogen that is potentially mineralizable. In a 4-year test in Tennessee, the dry matter production of Austrian peas ranged from 1.12 to 3.32 metric tons/ha (Fribourg, 1963). Hairy vetch production ranged from 1.26 to 2.72 metric tons/ha.

A 6-year experiment at the Augusta County Substation in Virginia, comparing the effect of six leguminous green manure crops for corn production, showed that corn yielded highest following hairy vetch (Gish and Hutcheson, 1933). Corn following hairy vetch outyielded corn

following crimson clover in a 7-year test conducted at State College, Mississippi (Mississippi Agric. Expt. Sta., 1934). At Clemson, South Carolina, corn following Austrian peas outyielded corn following crimson clover or hairy vetch (Buie, 1929). Austrian peas were also the most effective green manure for corn in a 9-year experiment at Tifton, Georgia (Stephens, 1934).

Changes in Corn Production

For approximately three decades United States corn farmers have relied on synthetic nitrogen fertilizers produced by the Haber-Barch ammonia synthesis process. Cummings (1953) ranked the development of this process as "a great technological advance affecting the destiny of mankind" and proclaimed that it had "opened up an inexhaustible supply of fertilizer nitrogen." However, if supplies of natural gas, a raw material used in ammonia synthesis, continue to dwindle, our "inexhaustible" supply of nitrogen may be exhausted. Reverting back to using leguminous green manure for a part of the needed nitrogen is one alternative if synthetic nitrogen becomes scarce or too expensive. New research is needed to keep leguminous green manuring abreast with new developments in corn production.

The usage of no-tillage systems in corn production is expected to increase in the future. In 1975 the United States Senate Committee on Agriculture and Forestry predicted that 45% of planted cropland will be no-till planted by the year 2000 (United States Department of Agriculture, 1975).

No-tillage Effect on Erosion and Soil Water

No-tillage allows the residues of preceding crops to be left on the soil surface where they can provide protection against soil erosion (Harrold et al., 1967; Johnson et al., 1979) and reduce evaporation of soil water (Blevins et al., 1971; Jones et al., 1969; Shanholtz and Lillard, 1969; Thomas et al., 1973). In conventional tillage systems plant residues are incorporated into the soil surface layer where they are less effective protectors against soil erosion and soil water evaporation.

The soil water conserved by a mulched no-tilled soil surface may aid in the mineralization of nitrogen from residues in the dry years. Stanford and Eptein (1974) observed a near-linear increase in nitrogen mineralization rates in soils when soil water suctions were decreased from -15 to -0.1 bar tension.

No-tillage Effect on Soil Nitrogen

In Maryland Bandel et al. (1975) studied the effects of various rates of nitrogen fertilizer on no-tillage and conventional tillage corn planted after a wheat cover crop. They observed more visible nitrogen deficiency in the no-tillage corn than in the conventional tillage corn at the low and medium rates of nitrogen at two locations. Tillage did not affect corn yields at any nitrogen rate at one location, but no-tillage corn yields were lower than conventional tillage yields at the low and medium rates at the other location. Yields were similar for both tillage treatments at the optimum nitrogen rates at both locations.



Greater anion leaching rates in soils under no-tillage systems have been reported by McMahon and Thomas (1976); Quisenberry and Phillips (1976, 1978); Thomas et al., (1973); and Tyler and Thomas (1977).

Nitrate is an anion. Because most soil clay particles are negatively charged, nitrate is usually repelled and remains predominantly in the soil water.

Thomas et al. (1973) indicated that aggregate size is important in water and nitrate movement in soils. Generally soils with large aggregates also have large connected pores. Percolating water seeks paths of least resistance in its downward movement in the soil and can flow quickly through large connected pores that have not been destroyed by tillage. When such pores are absent, water tends to enter the soil matrix where water and nitrate movement is slower.

In Kentucky Quisenberry and Phillips (1976) found that water moved as a diffuse front in the tilled layer of a Huntington silt loam soil (Fluventic Hapludolls). Below 15 cm the water flowed in isolated channels. In plots where no tillage had occurred, water became channelized near the soil surface. Another investigator found similar results when disturbed and undisturbed columns from aggregated soils which had been leached with fluorescein dye were dissected (Tyler and Thomas, 1981).

Nitrogen deficiency in no-tillage corn is sometimes caused by volatilization of ammonia from nitrogen fertilizer. Since cultivation is not used in no-tillage corn, nitrogen fertilizers cannot be incorporated. Ernst and Massey (1960) found that mixing urea into the soil

reduced nitrogen volatilization as compared to surface applied urea. Meyer et al. (1961) reported lower ammonia losses when urea, ammonium nitrate, and a nitrogen solution were broadcast on a bare soil surface than when they were broadcast on a soil surface covered with plant residues. When fertilizers were mixed with the soil, less nitrogen was lost than when they were surface applied.

Meyer et al. (1961) also found that the magnitude of nitrogen volatilization as ammonia varied significantly between the types of fertilizer applied. Pots containing Crofton silty clay loam with straw residue on the surfaces were fertilized with the equivalent of 112 kg N/ha from four different nitrogen fertilizers and then incubated. Nitrogen losses as ammonia from the nitrogen solution, urea, ammonium sulfate, and ammonium nitrate were 21, 17, 10, and 5% respectively.

Bandel et al. (1980) compared the effects of ammonium nitrate, prilled and granular urea, and a urea-ammonium nitrate solution on total dry matter production and grain yields in no-tillage corn. Corn receiving ammonium nitrate was superior to corn receiving either of the other three nitrogen fertilizers. This is unfortunate considering the trends in nitrogen fertilizer production in the United States. In the period from 1975 to 1979, consumption of nitrogen from ammonium nitrate declined 10.7% (Bridges, 1979). During that same period consumption of nitrogen from nitrogen solutions and urea increased 30.9 and 45.8% respectively.

Differences in nitrogen availability under no-tillage and conventional tillage systems may also be due to differences in microbial activity in the soils. Microorganisms determine the rate of

mineralization or immobilization in a soil.

Microbial populations in the top 0 to 7.5 cm soil layer are usually greater under no-tilled systems than in conventional tilled systems (Doran, 1980). Doran (1980) indicated that a reverse relationship usually exists in the 7.5 to 15 cm soil layer. In Nebraska Dawson (1948) found 325,000 fungi/g soil in the 0 to 2.5 cm soil layer in sub-tilled plots and 290,000 fungi/g soil in the 2.5 to 15 cm soil layer. In plowed plots he found 199,000 fungi/g soil in the 0 to 2.5 cm soil layer and 385,000 fungi/g soil in the 2.5 to 15 cm soil layer. Sub-tillage refers to the practice of undercutting stubble and weeds with implements having staggered widesweep blades. It is similar to no-tillage in that most of the residues from previous crops are left on the soil surface. The reason that microorganisms are less concentrated at the soil surface in plowed soil than in no-tilled and subtilled soils is that the plant residues on which the microorganisms feed are incorporated in the plow layer.

In an incubation study Broadbent and Bartholomew (1948) measured carbon dioxide evolution from 25 grams of soil receiving various quantities of oat straw. The amount of carbon dioxide evolving was used as an indication of the rate of straw decomposition. They found that the rate of decomposition per gram of straw was lower in the samples receiving large residue additions than those receiving small additions. Broadbent and Bartholomew (1948) concluded that there must be physical and biotic factors restricting microbial development when large quantities of residues are applied to comparatively small volumes of soil. Plant residues in no-tilled soils only come in contact with soil at

the soil surface opposed to plowed soils where residues come in contact with soil in the 0 to 15 cm soil layer. Whether the quantities of residues commonly found on the surface of no-tilled soils are high enough to result in restricting microbial development is not known.

High rates of denitrification in no-tilled soils may be responsible for some of the reduction in nitrogen availability to no-tillage corn. Doran (1980) reported higher numbers of facultative anaerobes and denitrifiers to a depth of 15 cm in no-tilled soils than conventional tilled soils. Higher soil moisture contents in no-tillage soils may create more zones with low oxygen levels in the no-tillage soils. Lemon and Kristensen (1961) measured the rate of oxygen diffusion through soil water to a platinum electrode. Their results indicated that the rate of oxygen diffusion decreases with increases in soil water content. Doran (1980) reported higher soil water contents in the surface 0 to 7.5 cm under no-till than conventional tillage. Aggregate size differences between no-tillage soil and conventional tillage soil may be partly responsible for the higher number of facultative anaerobes and denitrifiers in the no-tilled soils. Oxygen diffusion rates to the center of small aggregates in a plow layer of conventional tillage soil would be higher than to the center of the larger aggregates of a no-tilled soil.

No-tillage Effects on Soil Organic Matter

One function of a green manure crop is to increase the organic content of a soil (Pieters and McKee, 1938). Both legumes and non-legumes can be used as green manures, but the former usually have the

added benefit of increasing the nitrogen content of a soil. Kamprath et al. (1958) and Obenshain and Gish (1941) reported higher organic matter contents in soils that had green manures incorporated into them than those that had not. The results of Hallam and Bartholomew (1953) have led many people to believe that green manuring can accelerate the decline of a soil's organic matter. Hallam and Bartholomew (1953) grew green manure crops in the presence of radioactive carbon dioxide so that, when the residues of the plants were incubated in soil samples, they would be able to distinguish carbon dioxide generated from the decomposition of the green manures from carbon dioxide resulting from the decomposition of the soil's native organic matter. They found high rates of residue addition can cause greater losses of native soil organic matter than low rates of residue addition. They concluded that green manuring may accelerate the decline of organic matter in soils that are high in organic matter. This conclusion was probably unfounded since their data showed that the net loss of organic matter in the soil samples receiving plant residues was usually less than samples receiving no residues.

The benefits associated with having high organic matter contents in cropped soils are well known. It is understandable that farmers are frustrated when the organic matter content of a soil that is high in organic matter content in the original virgin condition declines rapidly when the soil is brought into cultivation. Blevins et al. (1977) reported that a no-tillage system in an experimental area that had been in bluegrass (*Poa pratensis* L.) for 50 years most nearly preserved the soil characteristics as compared to uncropped untreated plots. Several

researchers have reported higher organic matter contents in no-tilled soils than corresponding conventional tilled soils (Blevins et al., 1977; Lal, 1976; Moschler et al., 1972). Blevins et al. (1977) attributed the greater decline in organic matter content in conventional tillage soil to a promotion in the oxidation of organic matter by tillage operations.

No-tillage Effects on Soil pH

Blevins et al. (1977) found significantly lower soil pH values in the upper 0 to 5 cm soil layer under no-tillage corn than under conventional tillage corn. Levels of exchangeable aluminum remained low under no-tillage despite the lower pH values. Based on the work conducted by Thomas (1975), and Blevins et al. (1977) attributed the suppression of exchangeable aluminum to the higher organic matter in the no-tillage plots. Moschler et al. (1973) and Triplett and Van Doran (1969) reported lower pH values in the surface layer of no-tilled soils.

Application of nitrogen fertilizers containing ammonia compounds often lowers soil pH. The oxidation of the ammonium to nitrate releases hydrogen into the soil. In conventional tillage corn nitrogen fertilizers are incorporated into the top 0 to 15 cm soil layer thus spreading the acidifying effect of the fertilizers over a large volume of soil. In no-tillage corn nitrogen fertilizer is usually surface broadcasted. The surface 0 to 5 cm soil layer in no-tillage corn receives the same amount of hydrogen from ammonia fertilizers as the top 0 to 15 cm soil layer under conventional tillage corn.

Green Manuring with Legumes in Continuous No-tillage Corn

Mitchell and Teel (1977) investigated the effectiveness of spring oats and rye grown alone and in combination with hairy vetch and crimson clover as winter cover crops for no-tillage corn. At the 0 kg N/ha rate, corn following the spring oats-legume mixtures produced yields comparable with corn receiving 112 kg N/ha. Rye produced larger amounts of top growth than spring oats. This caused the carbon to nitrogen ratios of the spring oats-legume mixtures to be lower than the rye-legume mixtures. At the low nitrogen rates, corn following rye-legume mixtures did not yield as high as corn following spring oats-legume mixtures. This was probably due to less nitrogen mineralization from the rye-legume mixture.

In Ohio, Triplett et al. (1979) compared corn grain yields and nitrogen contents of corn ear leaves from conventional tillage and no-tillage corn following alfalfa. Corn yields were increased by added nitrogen at the 56 kg N/ha rate only one year out of the 3-year duration of the experiment. The fundamental weakness of the experiment was that all of the treatments in the experiment followed alfalfa. Thus, there is no way of knowing whether the corn would have yielded as well had the alfalfa been absent.

Summary

A discrepancy exists in the literature as to the carbon to nitrogen ratio of plant residues that will cause immobilization rather than mineralization of nitrogen when the residues are added to soils. Nevertheless, the carbon to nitrogen ratio of a green manure is usually a satisfactory indicator of how the nitrogen status of a soil will be

affected by the green manure. Generally, green manures with carbon:nitrogen ratios above 35:1 cause nitrogen immobilization, and green manures with carbon:nitrogen ratios below 20:1 cause nitrogen mineralization. Legumes usually have lower carbon:nitrogen ratios than nonlegumes. For this reason, legumes are usually used as green manure crops when nitrogen for following crops such as corn is needed and the use of inorganic nitrogen fertilizer is not desired.

No-tillage corn yields can equal or exceed conventional tillage corn yields when optimum nitrogen rates are applied. When lower nitrogen rates are applied no-tillage yields may be lower due to greater nitrogen deficiency stress. Lower nitrogen levels in no-tillage corn may be caused by higher nitrate leaching, higher volatilization of nitrogen fertilizer, higher denitrification, and lower nitrogen mineralization rates.

Tillage may effect the pH and water contents of soils. Surface soil layers in no-tillage soils have been found to have lower pH values and higher water contents than conventional tillage soil surface layers.

Tillage operations have been shown to promote the oxidation of soil organic matter. There are pros and cons to having low organic matter decomposition rates. In no-tillage soils, where decomposition rates are lower than conventional tillage soils, higher organic matter contents in the soil surface have been reported. While no direct evidence is available showing how nitrogen mineralization is affected by using no-tillage methods, the lower rate of organic matter decomposition indicates that the nitrogen mineralization rate is probably slower in no-tillage soil. Whether green manuring with legumes in

no-tillage corn can supply the same amount of nitrogen as it does in conventional tillage corn is not known.

Considerable research has been conducted on green manuring and no-tillage methods separately but little has been reported on the results of combining the two practices. Perhaps this experiment will help solve several unanswered questions about green manuring in continuous no-tillage corn.



CHAPTER III

MATERIALS AND METHODS

The experiment was conducted on Memphis silt loam (a fine-silty, mixed, thermix Typic Hapludalf) on 0-2% slope at the Milan Experiment Station at Milan, Tennessee.

The test was arranged in a split-plot design. Nitrogen rates were the main plots and cover/tillage situations the sub-plots. The four nitrogen treatments were 0, 56, 112, and 168 kg N/ha. The four cover crop/tillage treatments were winter wheat-hairy vetch with conventional tillage, winter wheat with no-tillage, no cover with conventional tillage, and winter wheat-hairy vetch with no-tillage. The subplots were randomized within each main nitrogen plot. Subplots were 4.06 m wide by 9.14 m long, providing four rows of corn at 102 cm spacing. The experiment was replicated four times.

Cover crops were seeded October 27, 1979 and October 7, 1980. Subplots assigned to winter wheat-hairy vetch cover crops were surface broadcast with 40 kg/ha and 100 kg/ha winter wheat and hairy vetch seed, respectively. Wheat alone subplots received 100 kg/ha winter wheat seed. On April 30, 1980 all plots received applications of Roundup (N-phosphomethylglycine), atrazine (2-chloro-4-(ethylamino)-6-(isopropylamino)-s-triazine), and Lasso (2-chloro-2', 6'-diethyl-N-(methoxymethyl) acetanilide) at 1.68, 1.68 and 2.24 kg active ingredient/ha, respectively. On April 8, 1981 the entire test was sprayed with 0.56 kg active ingredient/ha Paraquat (1,1'-dimethyl-4,4'-bipyridinium dichloride) with X77 surfactant. Subplots designated to conventional

tillage culture were disc and roller harrowed prior to planting. A no-tillage planter was used to plant Pioneer brand 3184 hybrid corn treated with 11.2 kg Furaden/ha at approximately 20,000 kernels/ha. Ammonium nitrate was surface broadcast by hand to deliver 0, 56, 112, and 168 kg N/ha on the main plots.

Lime was applied to the test area at 2.24 metric tons/ha on October 25, 1979. On April 30, 1980 and October 7, 1980 phosphorus and potassium were broadcast at 39 and 74 kg/ha, respectively.

Soil samples were collected from the 0-5 cm, 5-10 cm, 10-15 cm, and 15-30 cm soil layers on December 16, 1979 and April 2, 1981 across all replications. Soil water pH was determined in a 1:1 soil water mixture. The percentage of soil organic matter was determined by the Walkley-Black potassium dichromate wet-oxidation method (Allison, 1965).

Soil samples were collected in 15 cm increments to the 90 cm depth of five dates in 1980 and three dates in 1981. Two sets of soil samples were collected from one replication on each of the sampling dates. The percentage of soil water on a dry-weight basis in each soil sample was determined gravimetrically with oven drying (Gardner, 1965). The percentage of water on a volumetric basis was calculated by multiplying the percentage of water on a dry-weight basis and the bulk density of the soil layer from which the sample was collected. The soil bulk density was determined by the core method (Blake, 1965). The percent soil water values reported are the means from two sets of soil samples taken at each depth within one replication on each sampling date. Soil samples were ground to pass through a 2 mm sieve and analyzed for ppm nitrate-nitrogen on soil basis with an Orion "nitrate

specific" ion electrode, Model 92-07 (Orion Research Incorporated, Cambridge, Massachusetts) paired with an Orion double junction reference electrode, Model 90-20 (Orion Research Incorporated, Cambridge, Massachusetts). The sample preparation procedure given in the Orion 98 series electrodes methods manual (Orion Research Incorporated, Cambridge, Massachusetts) was followed. The bulk densities were used to convert the ppm N values to kg N/ha on a soil volume basis. The nitrate-nitrogen levels reported are the means from two sets of soil samples at each depth on each date.

Corn grain yields were calculated from hand-harvested samples and reported on 15.5% moisture basis.

CHAPTER IV

RESULTS AND DISCUSSION

Soil Water Contents Under the Treatments

The 1980 growing season was one of the driest on record at the Milan Experiment Station as indicated by Table 1. The high temperatures which accompanied the drought prevented complete pollination of corn from taking place. This caused many cobs to have only a few kernels of corn at harvest (National Oceanic and Atmospheric Administration, 1980). Insufficient water and poor pollination resulted in lower than normal yields in 1980. The water conserving effect of the mulch in no-tillage treatments was probably not as effective in 1980 as it would have been in a more typical year since low rainfall resulted in no water to conserve in the surface soil layer in July and August. In the season of 1981 corn received more rainfall and produced larger yields.

In this thesis the term soil water deficit will refer to the difference in soil water content of a soil on a certain date and when it is at field capacity. Soil water was used by corn below 90 cm so the total soil water deficit was not measured. Hereinafter nc conv, wv conv, w no-till, wv no-till, and F.C. will be used as abbreviations for no cover with conventional tillage, wheat-vetch with conventional tillage, wheat with no-tillage, wheat-vetch with no-tillage, and field capacity, respectively.

May and June 1980 samplings showed minor differences in soil

Table 1. Precipitation in May, June, July, August and September 1980 at the Milan Experiment Station, Milan, Tennessee, and Average Monthly Precipitation from 30 Years at Milan, Tennessee.

	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm	30 yr/ cm
May Rainfall (cm)	13 2.90	15 0.08	16 0.08	17 0.76	18 0.18	19 0.20	23 1.32	24 0.03
May Rainfall (cm)	25 0.20	26 0.08	Total 5.83	30 yr. avg. 11.51				
June Rainfall (cm)	8 1.17	17 0.05	20 0.46	23 1.52	24 11.81	30 5.08	Total 20.09	30 yr. avg. 10.95
July Rainfall (cm)	3 0.91	4 0.58	22 1.27	23 0.15	Total 2.91	30 yr. avg. 9.83		
August Rainfall (cm)	4 0.33	6 0.23	12 0.18	15 0.28	16 0.86	19 0.56	Total 2.49	30 yr. avg. 9.19
September Rainfall (cm)	5 0.12	17 1.20	18 0.08	21 0.02	22 0.90	23 0.50	24 0.04	25 0.17
September Rainfall (cm)	26 0.24	28 0.04	29 0.13	Total 3.44	30 yr. avg. 9.19			

water contents between treatments (Appendix A). This was due to the low transpiration rates of the young corn plants and the frequent rainfall which replenished the soil water as it was lost (Table 1). Samples taken on July 8 from plots that received 0 and 56 kg N/ha indicated that the conventional tillage plots were lower in water content (Figures 1 and 2). This was not noticeable in the plots which had 0 kg N/ha applied (Figures 3 and 4). The lower water content in the conventional tillage plots can be explained three ways. The corn plants in the conventional tillage plots were larger than in the no-tillage plots (John Lyle, personal communication). This was attributed to a higher nitrogen availability in the conventional tilled plots as compared to no-tillage plots because at 112 and 168 kg N/ha rates differences were not present. The higher transpiration rate in the larger conventional tillage corn plants may have depleted the soil water faster than no-tillage corn plants. Conservation of surface soil water may have had some effect, but most of the water differences were not in the surface 0-15 cm soil layer. Less of the rainfall may have been lost to runoff in the no-tillage plots due to the surface mulches.

Indication of these runoff differences are shown by comparing the June 16 water deficits at the 0 and 168 kg N/ha to the July 3 deficits at the same rates (Table 2). No data was obtained for the 56 and 112 kg N/ha plots on July 3 because a thunderstorm terminated the sampling on that date. On June 16 the nc conv plots at the 0 kg N/ha rate had a 4.6 cm water deficit in the 0-90 cm soil depth (Table 2). The wv no-till plots had a 5.1 cm deficit. Between June 16 and July 3, 18.9 cm of rainfall occurred (Table 1). On July 3 the wv no-till plots at the

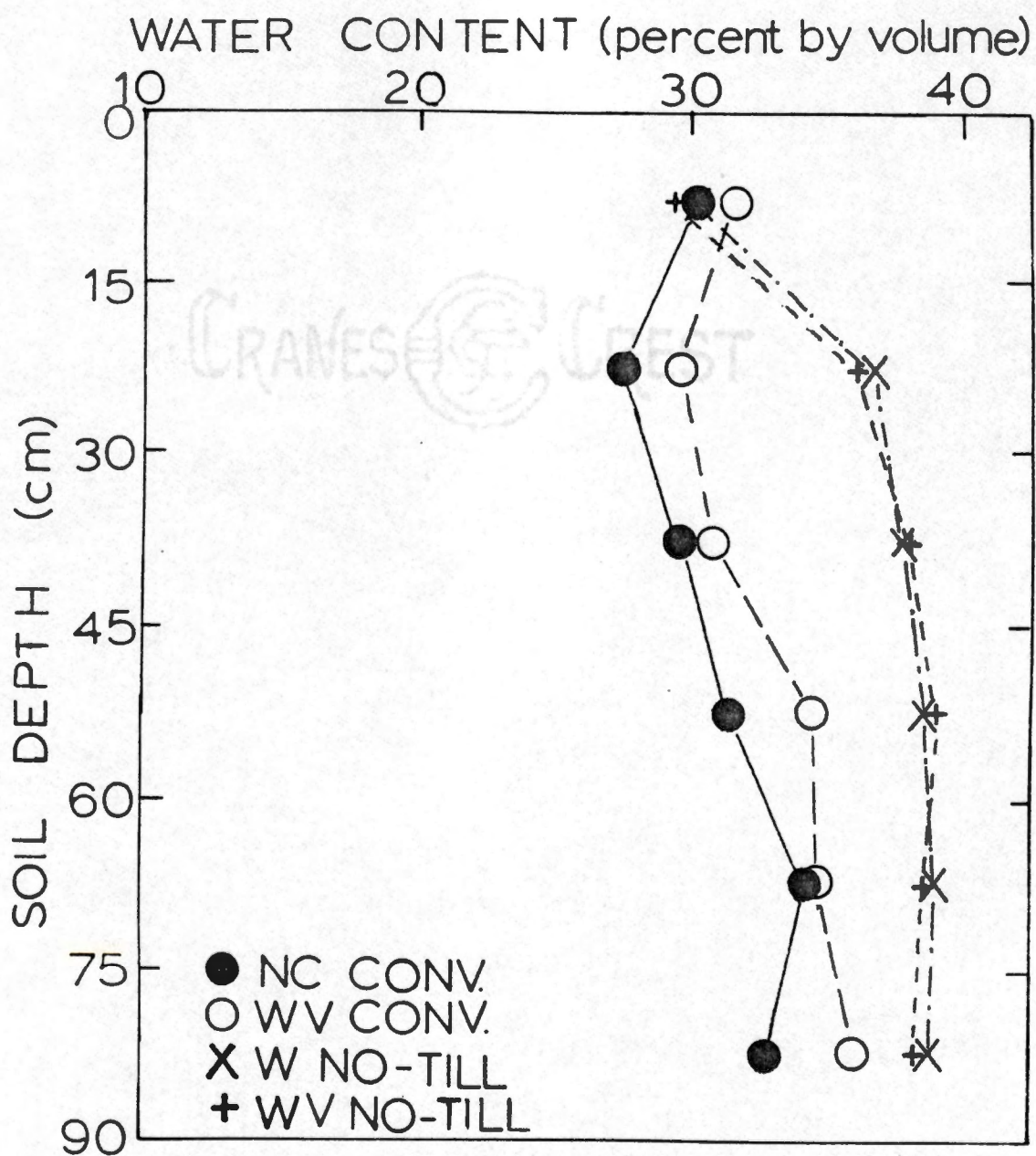


Figure 1. Soil water contents at the 0 kg N/ha rate on July 8, 1980.

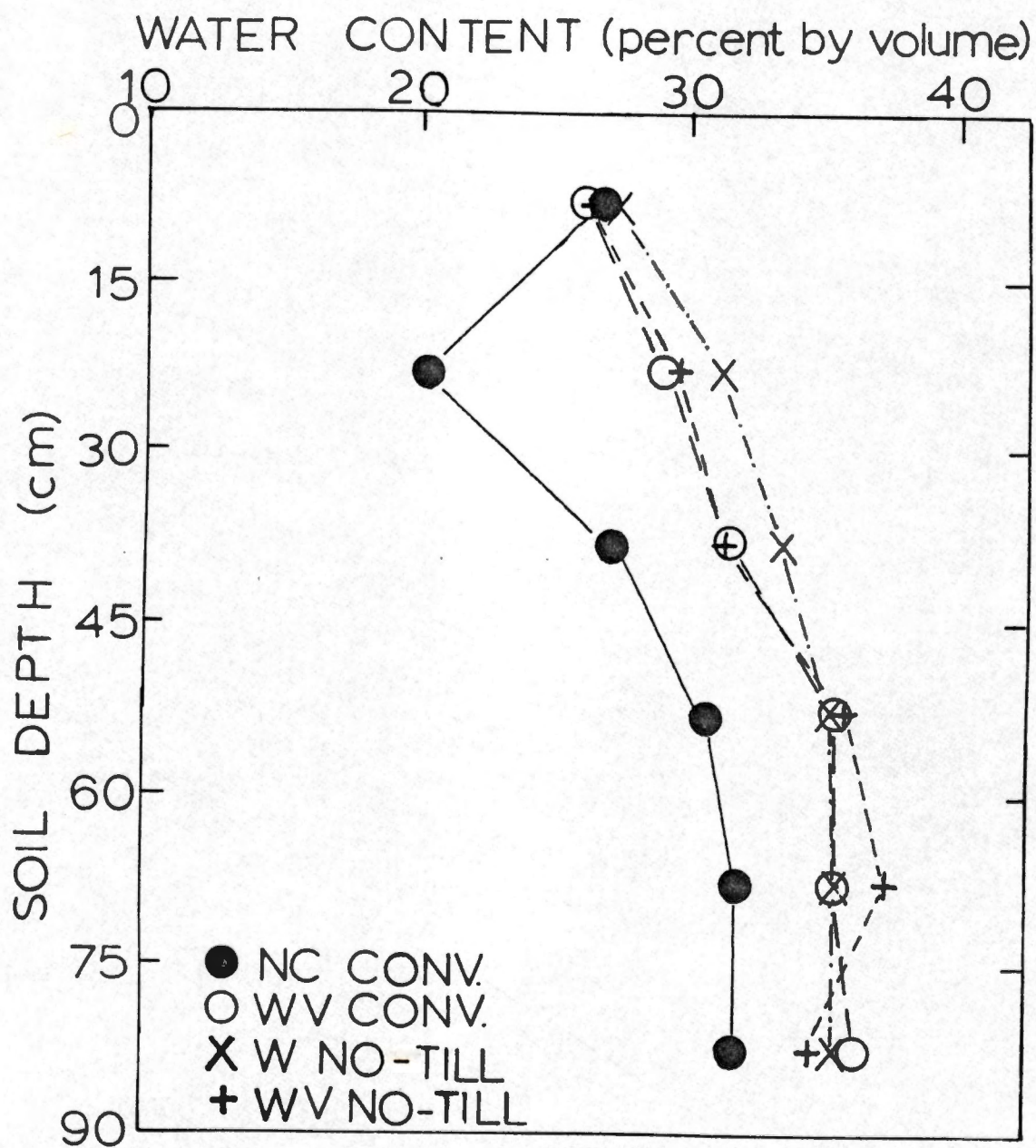


Figure 2. Soil water contents at the 56 kg N/ha rate on July 8, 1980.

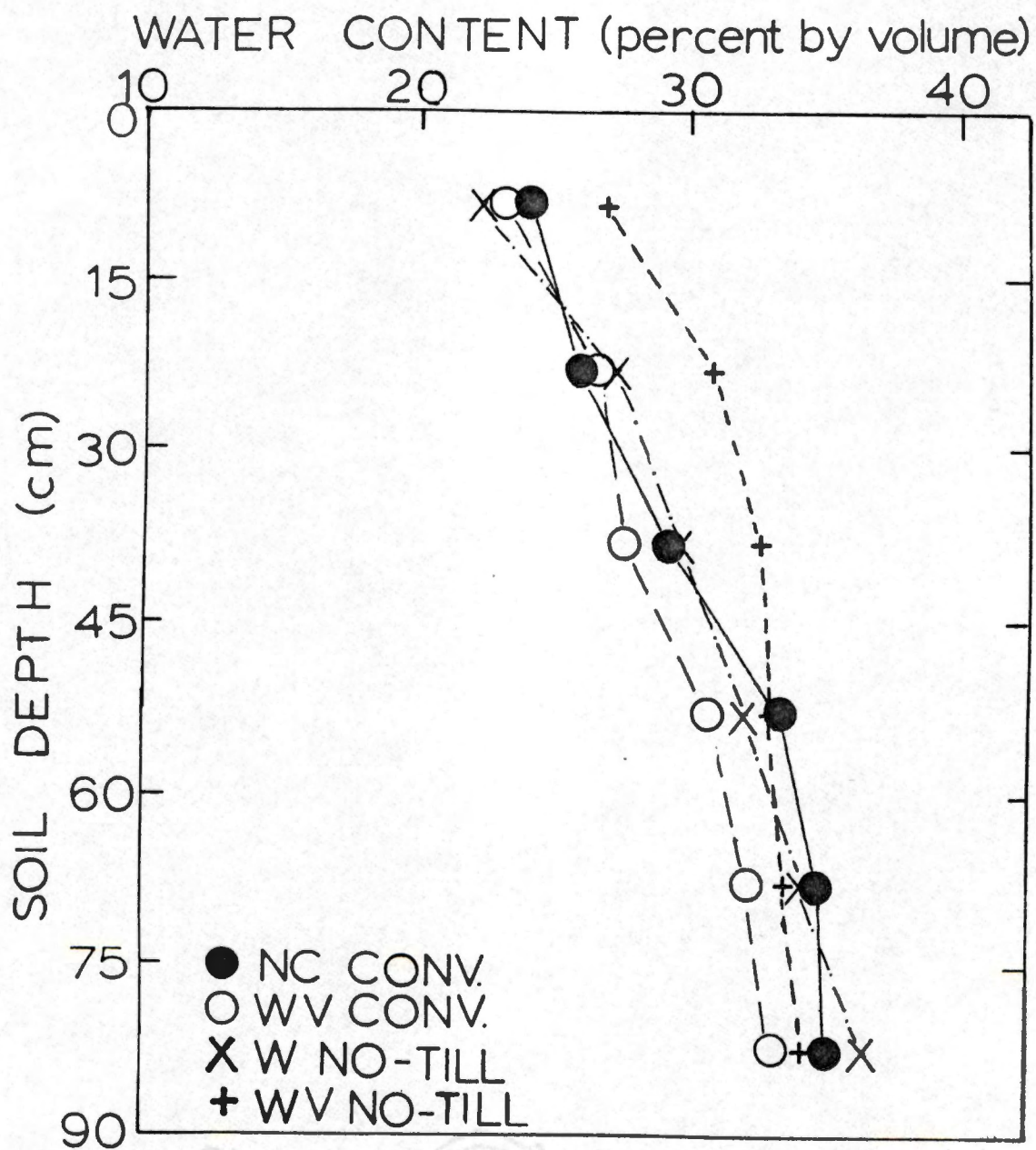


Figure 3. Soil water contents at the 112 kg N/ha rate on July 8, 1980.

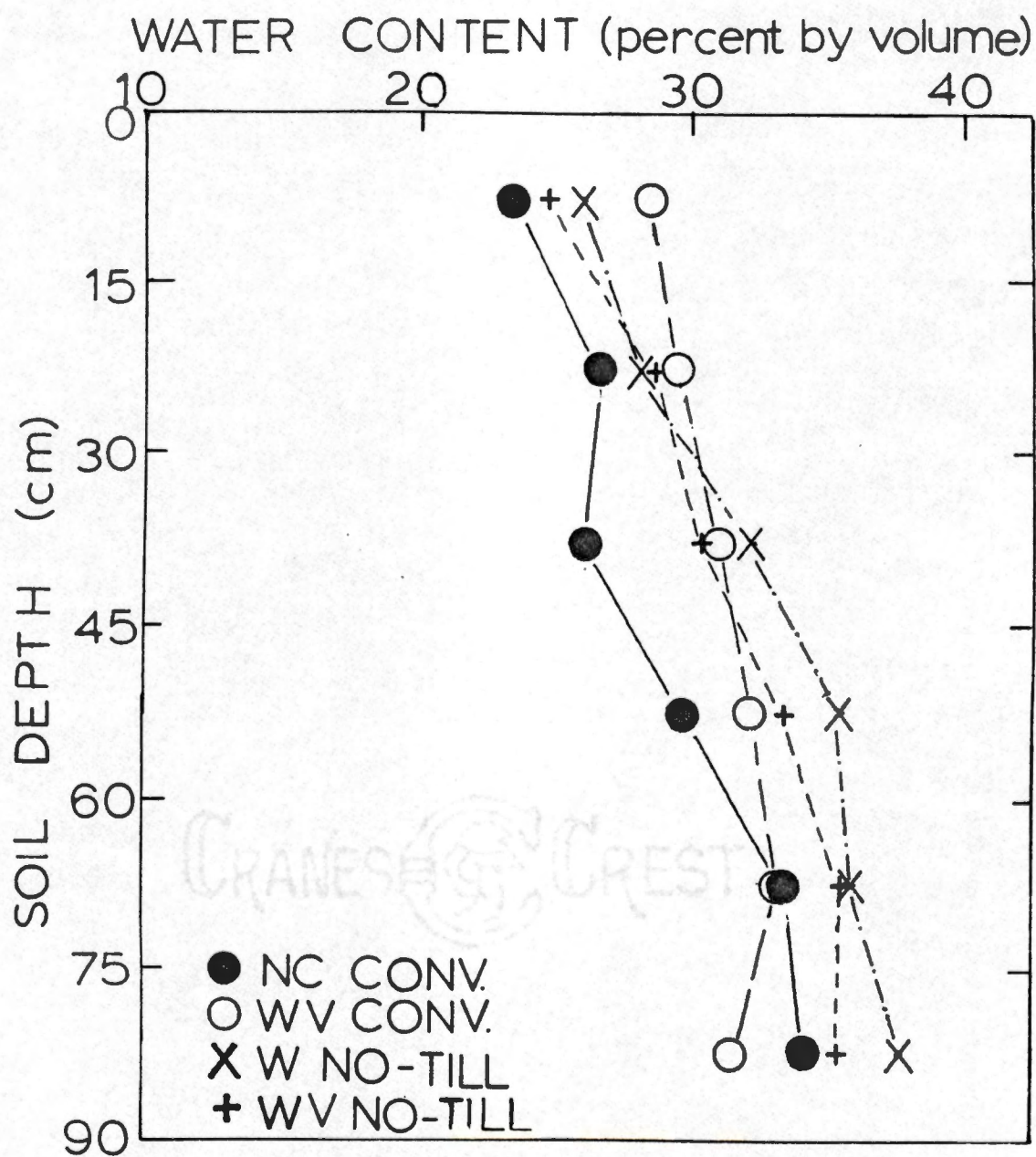


Figure 4. Soil water contents at the 168 kg N/ha rate on July 8, 1980.

Table 2. Centimeters of Soil Water Deficit in the 0-90 cm Soil Depth in 1980 and 1981 as Measured Under Various Treatments on Selected Dates at the Milan Experiment Station, Milan, Tennessee.

Date	Cover Crop	Nitrogen rate (kg N/ha)			
		0	56	112	168
5/8/80	nc conv	1.5	1.5	1.0	1.0
	w no-till	1.5	1.3	0.8	2.0
	wv no-till	3.8	3.3	2.5	3.6
	wv conv	2.5	1.3	1.8	2.0
5/21/80	nc conv	1.0	0.8	1.0	1.3
	w no-till	0.8	0.8	1.3	F.C.
	wv no-till	0.8	1.3	2.3	1.8
	wv conv	0.8	1.3	1.8	1.8
6/3/80	nc conv	1.8	2.5	2.3	1.8
	w no-till	1.0	0.8	1.8	1.8
	wv no-till	1.3	1.5	2.0	1.5
	wv conv	1.5	0.8	1.5	1.3
6/16/80	nc conv	4.6	6.6	9.1	6.4
	w no-till	2.5	4.3	6.4	5.6
	wv no-till	5.1	5.1	6.9	4.8
	wv conv	4.6	6.6	7.4	4.8
7/3/80	nc conv	4.6	*	*	5.1
	w no-till	1.5	*	*	>F.C.
	wv no-till	F.C.	*	*	1.0
	wv conv	0.8	*	*	3.3
7/8/80	nc conv	6.6	8.9	6.9	8.1
	w no-till	1.3	4.3	6.6	4.8
	wv no-till	1.3	5.1	5.6	5.8
	wv conv	3.2	5.1	7.9	6.1
7/25/80	nc conv	6.6	12.4	11.9	10.9
	w no-till	6.9	10.7	9.6	10.2
	wv no-till	6.4	8.4	9.4	8.1
	wv conv	10.2	11.4	9.1	11.4
8/6/80	nc conv	14.0	14.5	16.0	18.8
	w no-till	10.7	13.0	14.7	15.0
	wv no-till	9.1	12.2	13.0	13.7
	wv conv	14.0	15.0	16.0	15.2
8/18/80	nc conv	12.7	14.7	13.7	14.0
	w no-till	9.1	10.4	13.2	11.7
	wv no-till	9.4	12.4	15.7	13.5
	wv conv	8.9	11.7	13.2	14.5
6/11/81	nc conv	F.C.	1.0	F.C.	F.C.
	w no-till	>F.C.	0.5	0.5	0.3
	wv no-till	>F.C.	0.5	1.3	>F.C.
	wv conv	0.5	0.8	2.0	>F.C.
8/5/81	nc conv	7.1	10.9	13.2	13.0
	w no-till	3.8	4.8	7.1	8.1
	wv no-till	4.3	7.9	7.1	8.9
	wv conv	8.1	11.4	10.4	9.4
9/29/81	nc conv	3.8	3.8	5.1	6.6
	w no-till	3.8	2.5	3.6	4.1
	wv no-till	4.1	3.0	1.8	1.5
	wv conv	1.5	2.5	2.3	2.0

*Data not available

0 kg N/ha rate were at field capacity. The nc conv plots had a 4.6 cm water deficit in the top 0-90 cm. Part of this difference in water deficits may have been due to small differences in transpiration rates, but most of the difference was due to more infiltration of rain water into the no-tillage soils rather than being lost as runoff. In a dry year such as 1980 rewetting the soil in a short period of intense rainfall can be very important. Since rainfall was very low after the first week of July, the deficit differences found on July 3 affected the cumulative deficit for the rest of the 1980 growing season. On July 25 at the 0 kg N/ha rate (Figure 5), the wv conv treatment was significantly drier than the other treatments at the 30-90 cm depth. Larger corn plants in the wv conv plots (John Lyle, personal communication) resulted from nitrogen mineralized during the decomposition of the vetch residue. These larger, more adequately nitrogen supplied plants transpired more soil water. In the 56 kg N/ha rate on July 25 (Figure 6), a larger soil water deficit (10.7 cm) was present under w no-till as compared to wv no-till (8.4 cm). This occurred in spite of more vigorous corn growth under the wv no-till. The greater amounts of residue on the soil surface in the vetch plots (John Lyle, personal communication), may have conserved more water than the wheat no-tillage mulch. No apparent differences in water contents between treatments were observed at the 112 kg N/ha rate (Figure 7). Water contents as shown in Figure 8 indicated water conservation in wv no-till occurred.

In the 1981 growing season rainfall was more abundant and frequent (Table 3). Early seasonal differences observed in soil water content taken on June 11 were minor and inconsistent across the different nitrogen rates with the soil profile in all treatments close to field

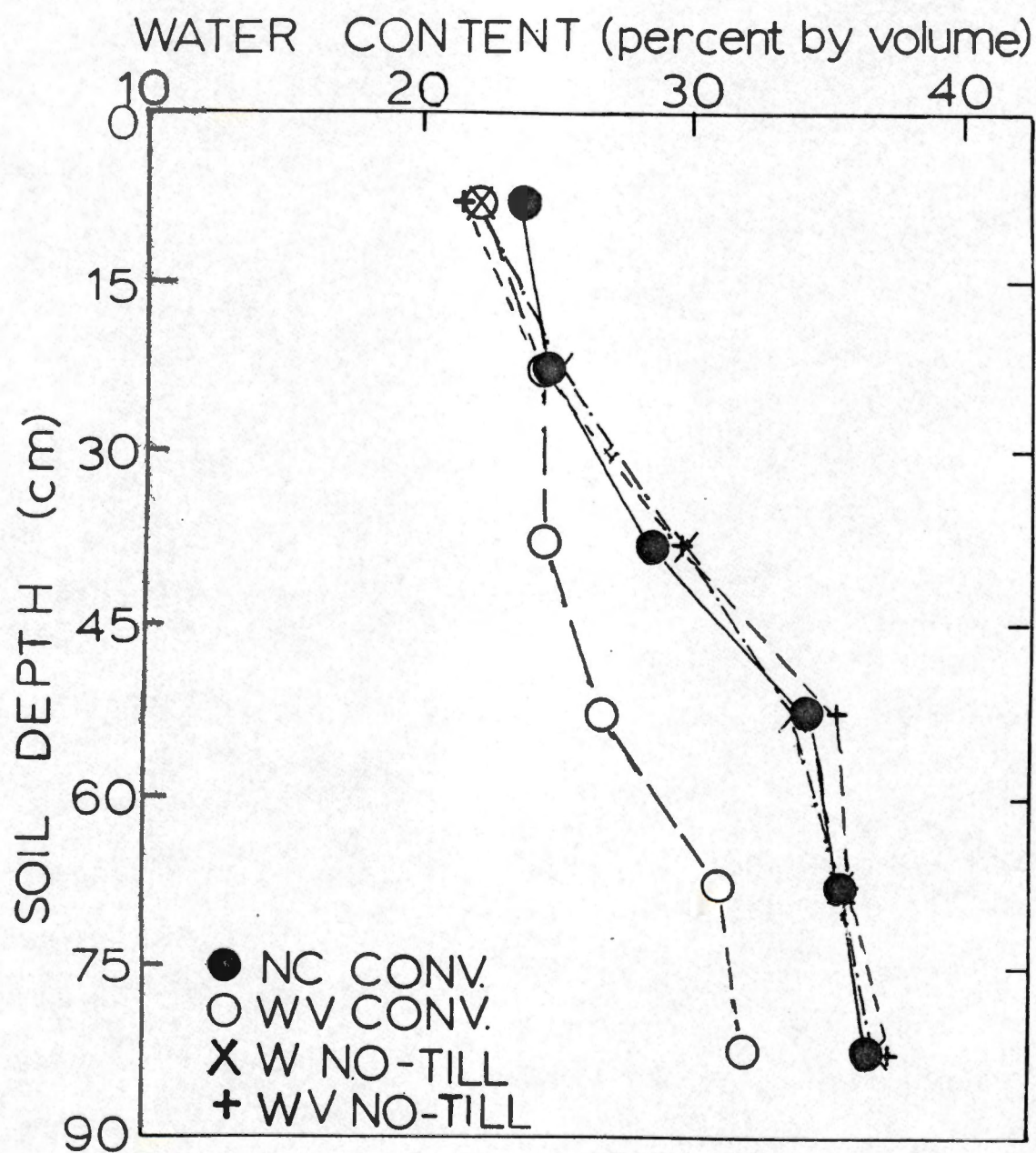


Figure 5. Soil water contents at the 0 kg N/ha rate on July 25, 1980.

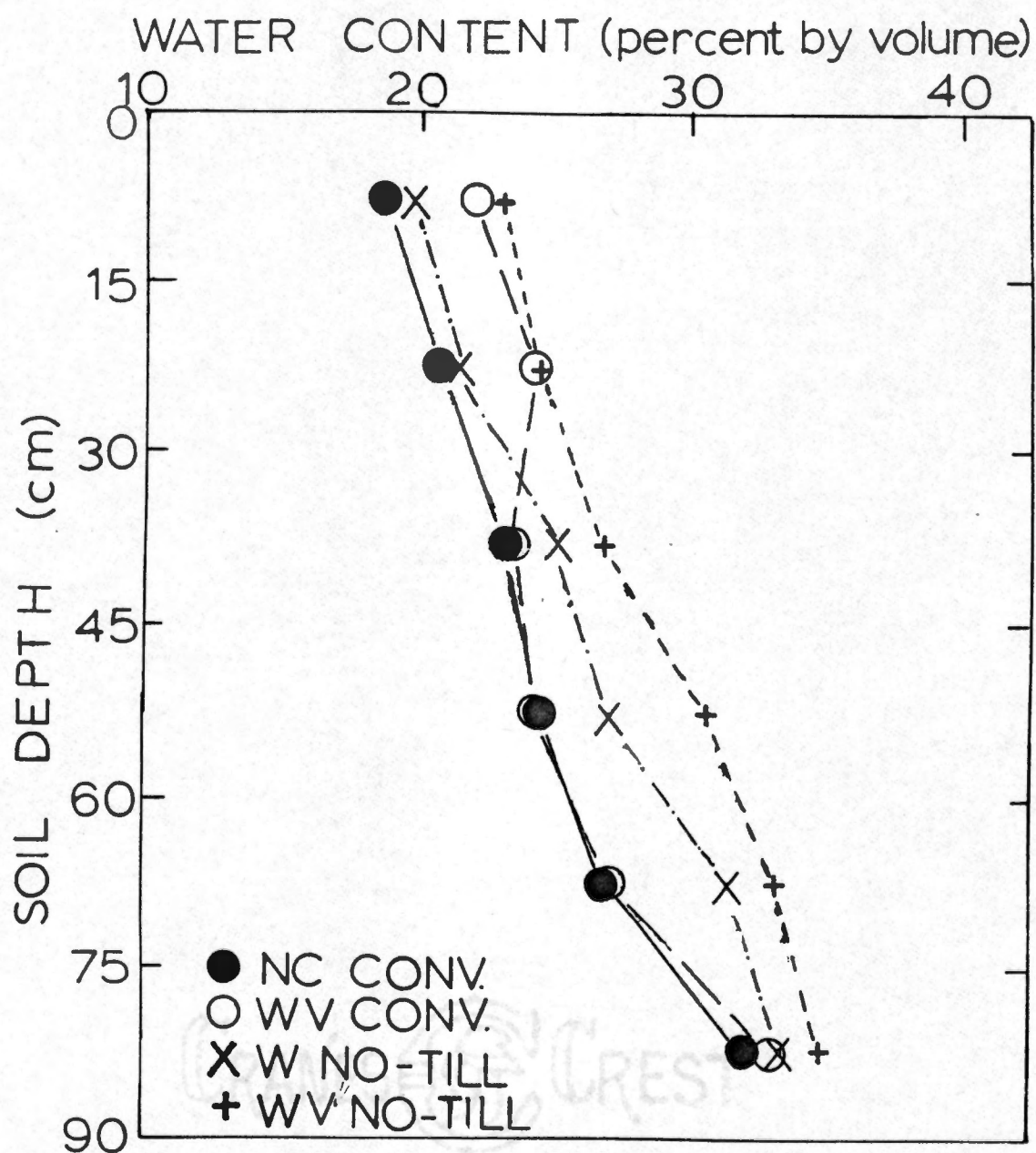


Figure 6. Soil water contents at the 56 kg N/ha rate on July 25, 1980.

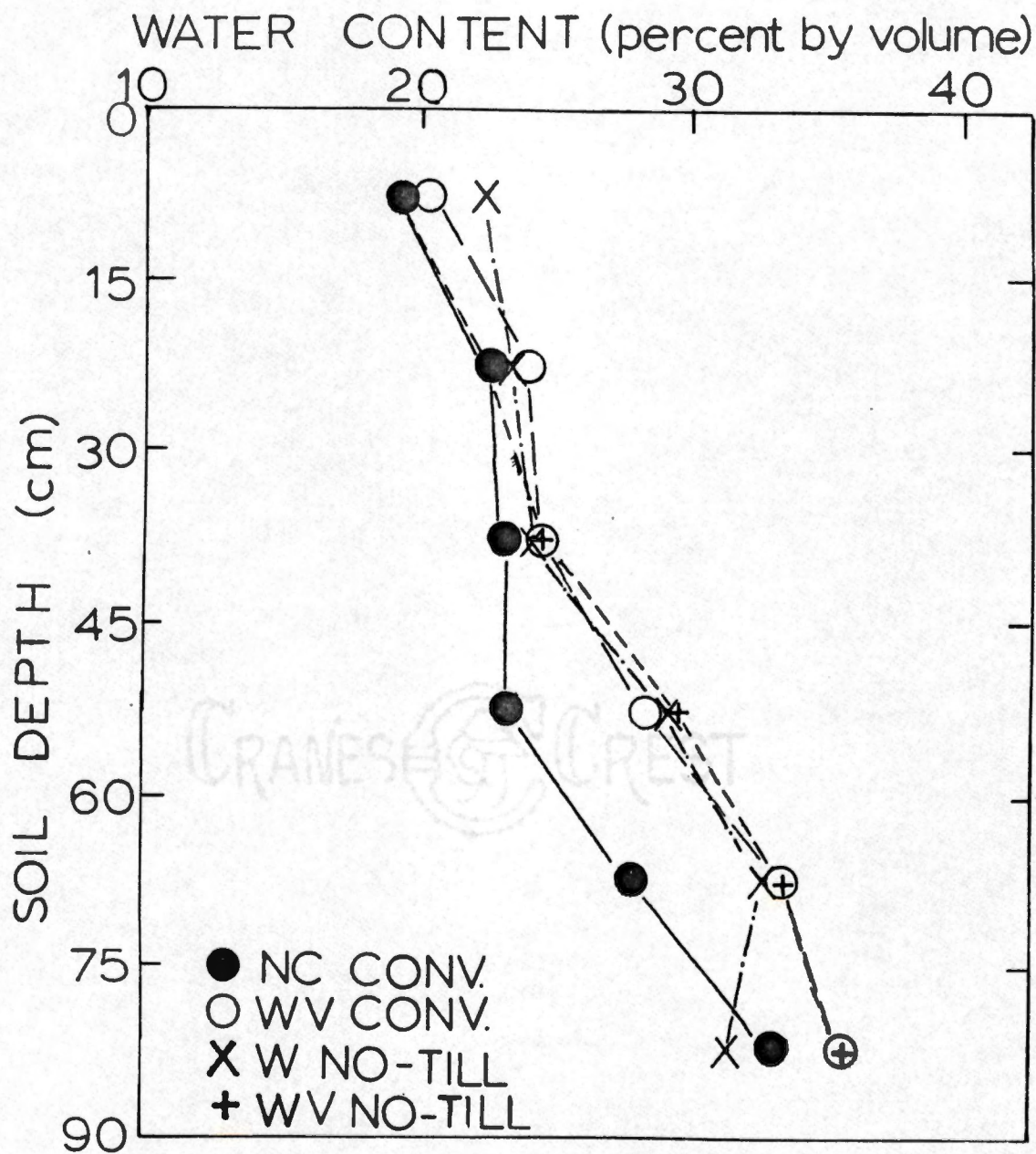


Figure 7. Soil water contents at the 112 kg N/ha rate on July 25, 1980.

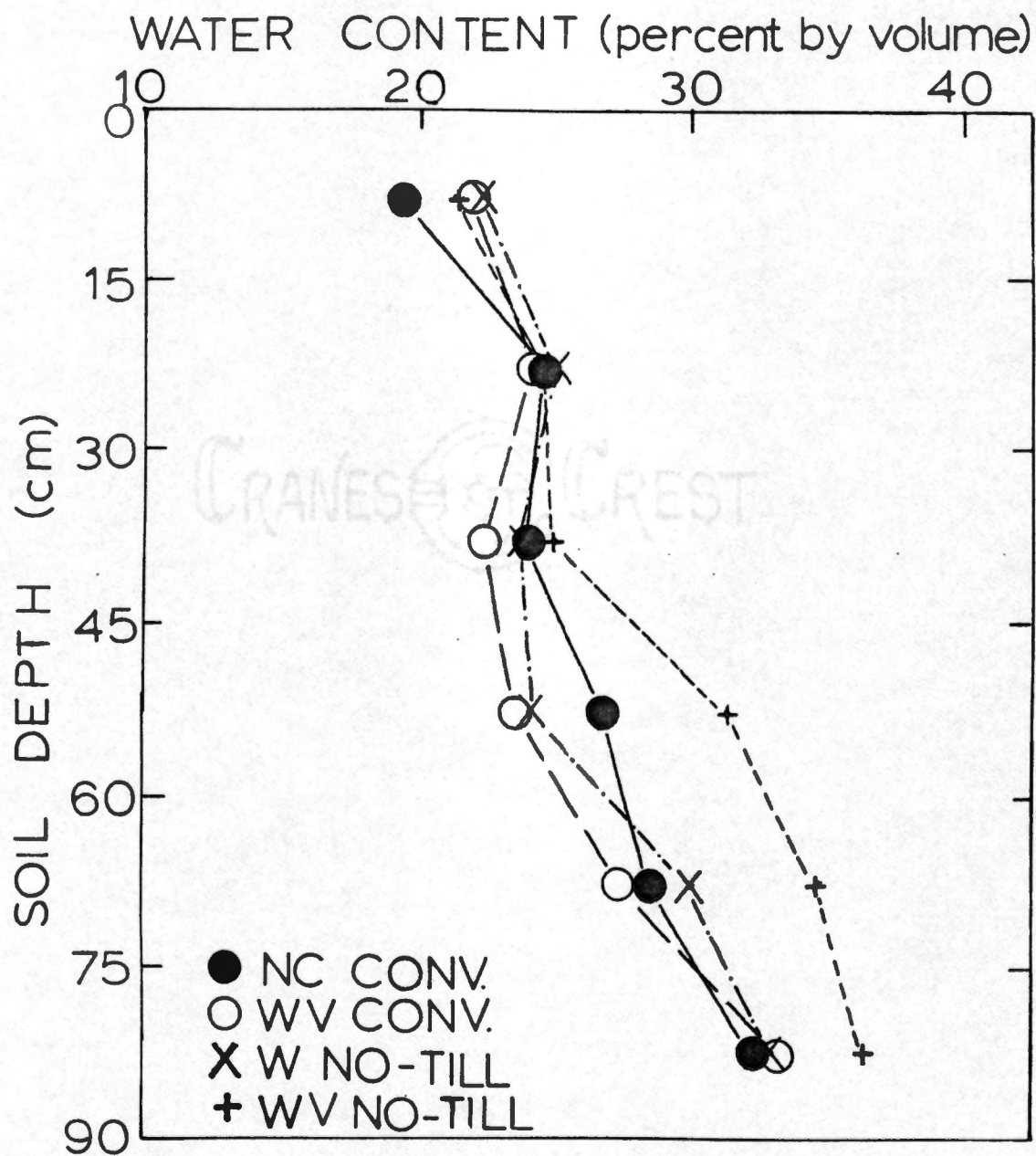


Figure 8. Soil water contents at the 168 kg N/ha rate on July 25, 1980.

Table 3. Precipitation in May, June, July, August and September 1981 at the Milan Experiment Station, Milan, Tennessee, and Average Monthly Precipitation from 30 Years at Milan, Tennessee.

	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm	Date/ cm
May Rainfall (cm)	10 0.61	11 0.10	14 1.27	15 0.14	17 0.28	18 0.46	19 0.46 25 0.28
May Rainfall (cm)	26 0.30	27 2.39	31 3.18	Total 9.47	30 yr. avg. 11.51		
June Rainfall (cm)	1 0.36	2 0.15	3 1.83	5 0.11	6 1.07	7 0.41	11 4.60 12 0.18
June Rainfall (cm)	17 0.18	19 0.05	20 0.81	23 0.15	Total 9.9	30 yr. avg. 10.95	
July Rainfall (cm)	1 0.25	5 3.10	6 0.28	7 0.51	11 0.46	15 0.15	16 0.28 18 0.56
July Rainfall (cm)	19 1.47	21 3.35	24 1.09	25 1.19	29 1.37	Total 14.06	30 yr. avg. 9.83
August Rainfall (cm)	7 2.44	8 0.05	16 1.47	17 0.86	18 1.12	19 0.08	27 1.60 28 2.01
August Rainfall (cm)	29 0.08	Total 9.71		30 yr. avg. 9.19			
September Rainfall (cm)	1 0.74	2 1.52	3 0.06	16 0.44	27 2.9	Total 2.9	30 yr. avg. 9.19

capacity (Appendix A). Water contents on August 5, 1981 indicated that a greater soil water deficit was present in the conventional tillage plots as compared to no-tillage plots (Figures 9-12). Since corn plants in the wv no-till plots and w no-till plots at the 0 kg N/ha rate and to some extent at the 56 kg N/ha rate were small with a resulting lower dry matter accumulation (John Lyle, personal communication), the smaller soil water deficit probably resulted from less transpiration. Some differences were present at the higher nitrogen rates but transpiration differences were probably less with the more adequate nitrogen supply. Because the resulting dry matter accumulation was more uniform, the differences in the treatments at 112 and 168 kg N/ha rates are probably more related to lower runoff and water conservation from mulches. Differences in soil water contents in the 0-30 cm layers of the treatments were observed at the September 29, 1981 sampling of the 0 kg N/ha plots (Figure 13). Visual observations late in the growing season indicated that some treatments were maturing later than others. This would have caused the later maturing treatments to continue transpiring water longer than the other treatments and have higher water deficits. This may have occurred in the treatments with the lower soil water contents at the 0 kg N/ha rate on September 29. Differences between treatments were minor at the 56 kg N/ha rate on September 29, 1981 (Figure 14). The lower water contents in the nc conv plots at the 112 kg N/ha and 168 kg N/ha rates on September 29 (Figures 15 and 16) are attributed to the absence of mulches which would have reduced the loss of rainfall to runoff and surface soil water to evaporation.

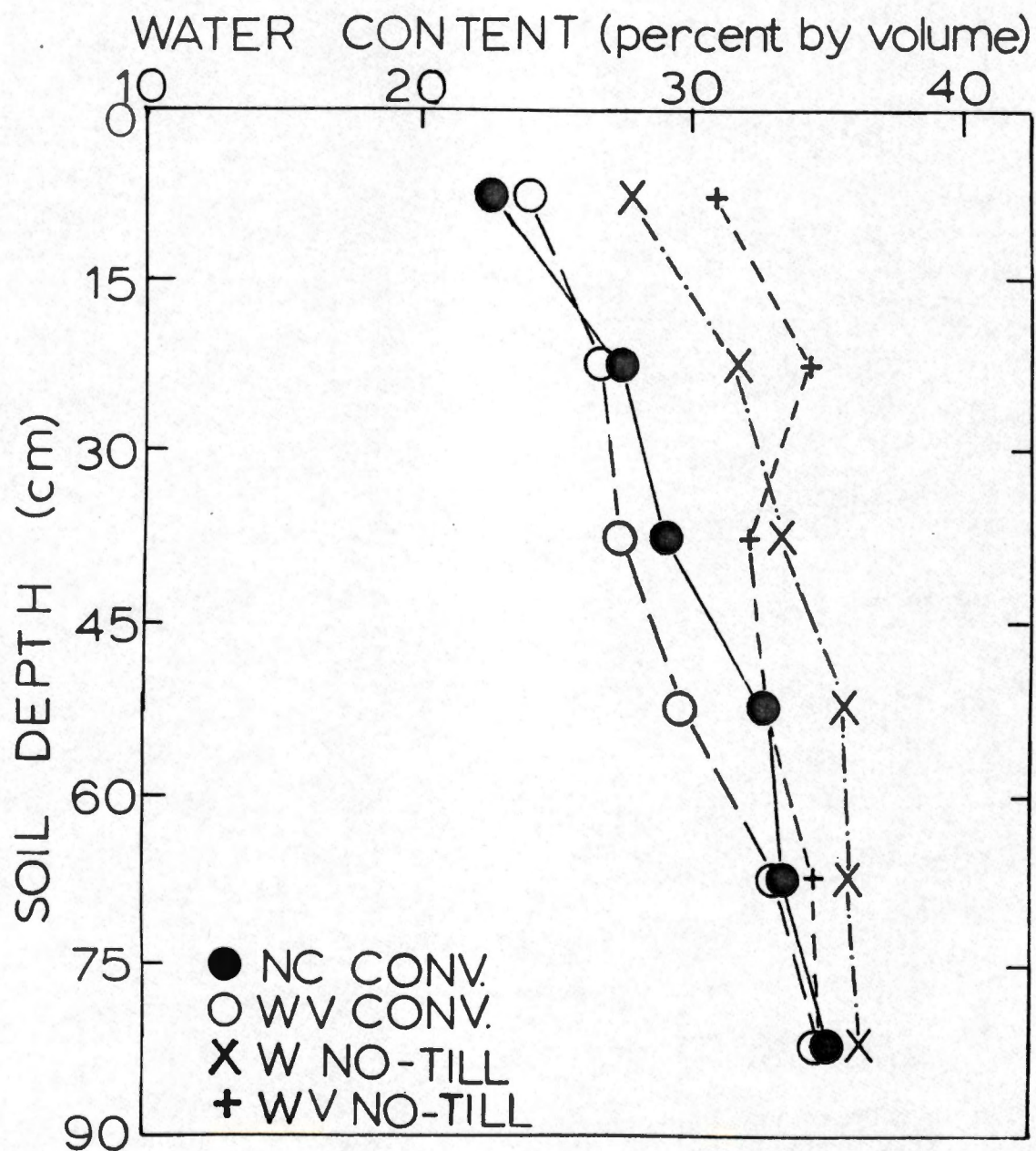


Figure 9. Soil water contents at the 0 kg N/ha rate on August 5, 1981.

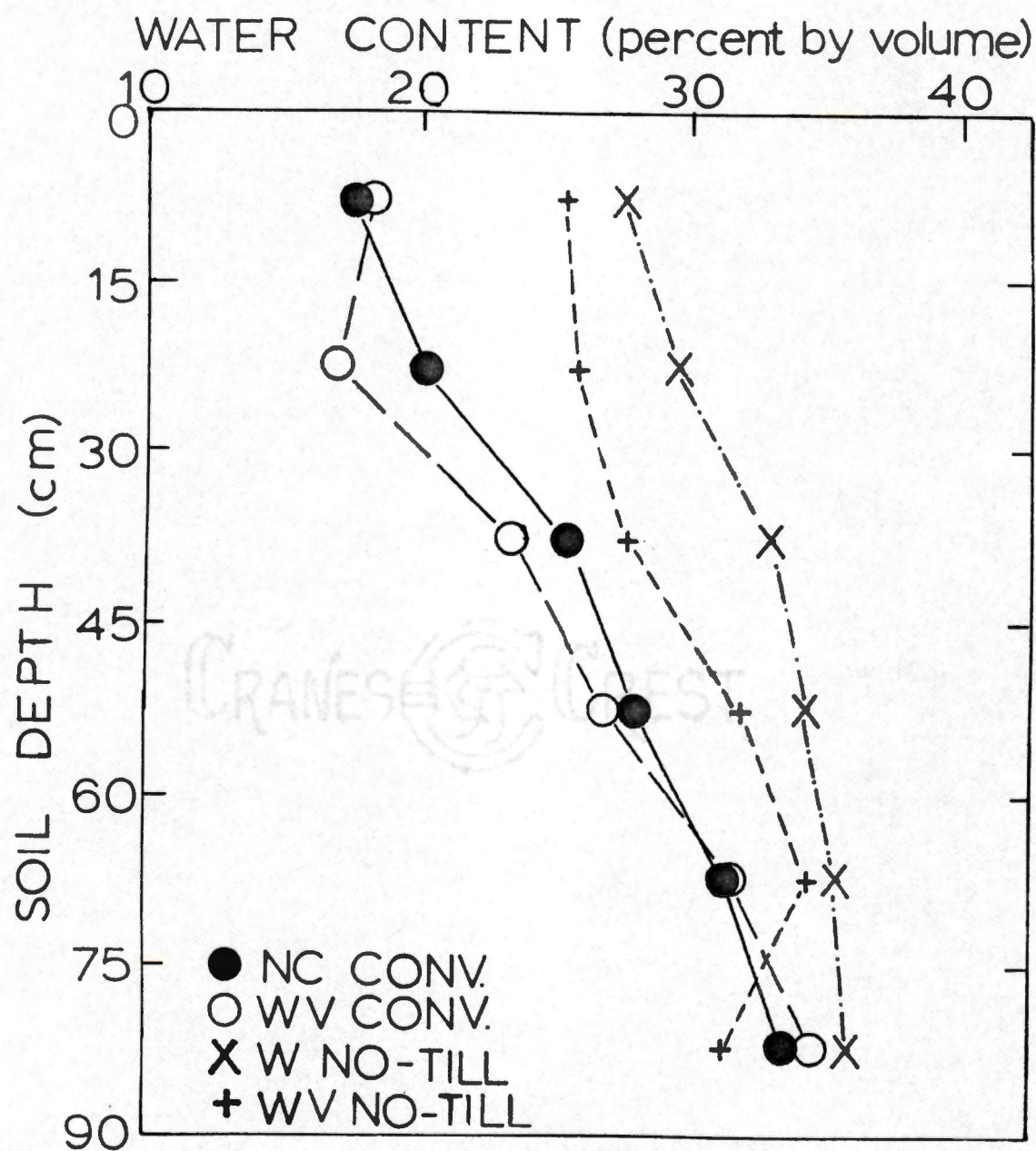


Figure 10. Soil water contents at the 56 kg N/ha rate on August 5, 1981.

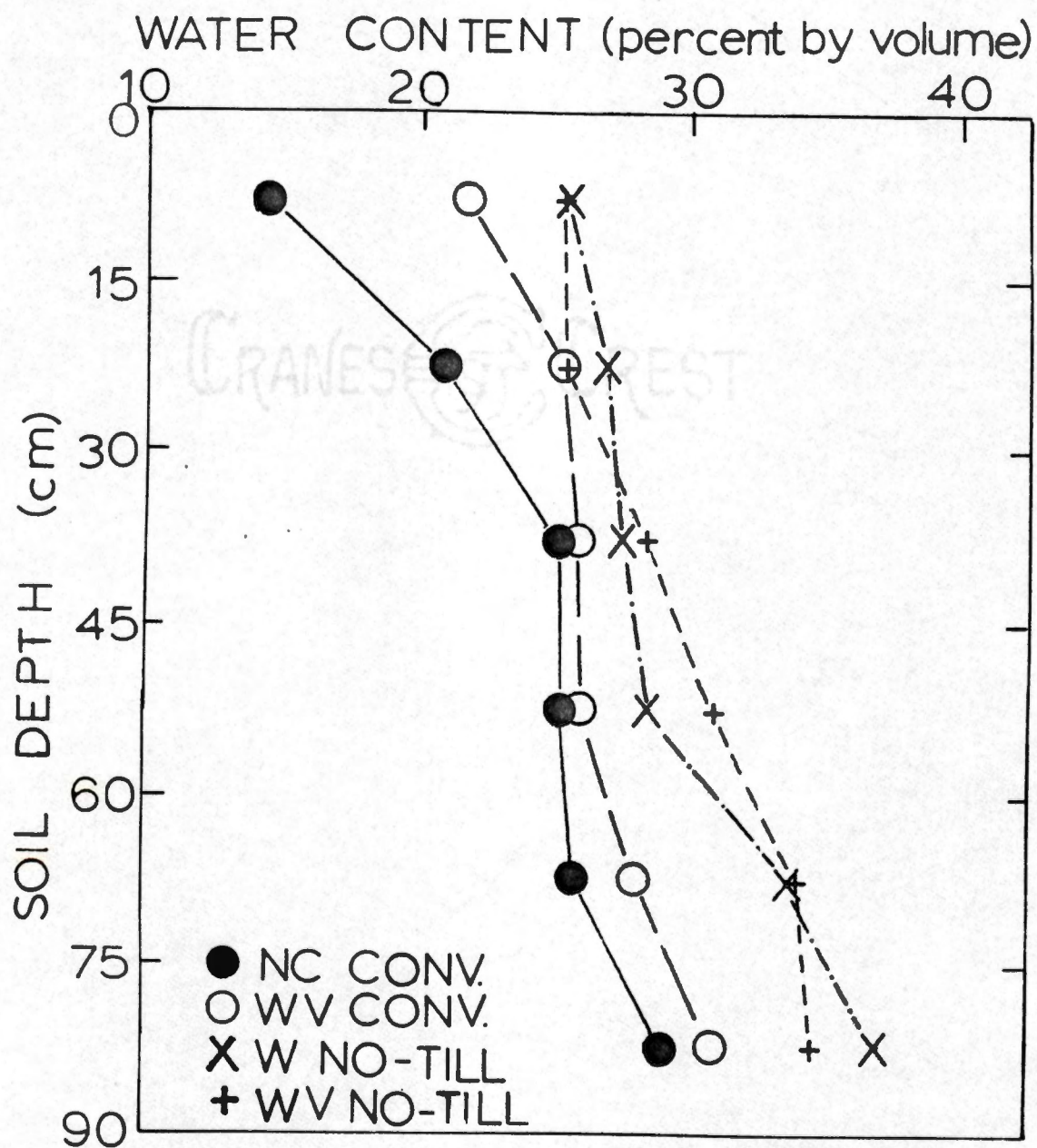


Figure 11. Soil water content at the 112 kg N/ha rate on August 5, 1981.

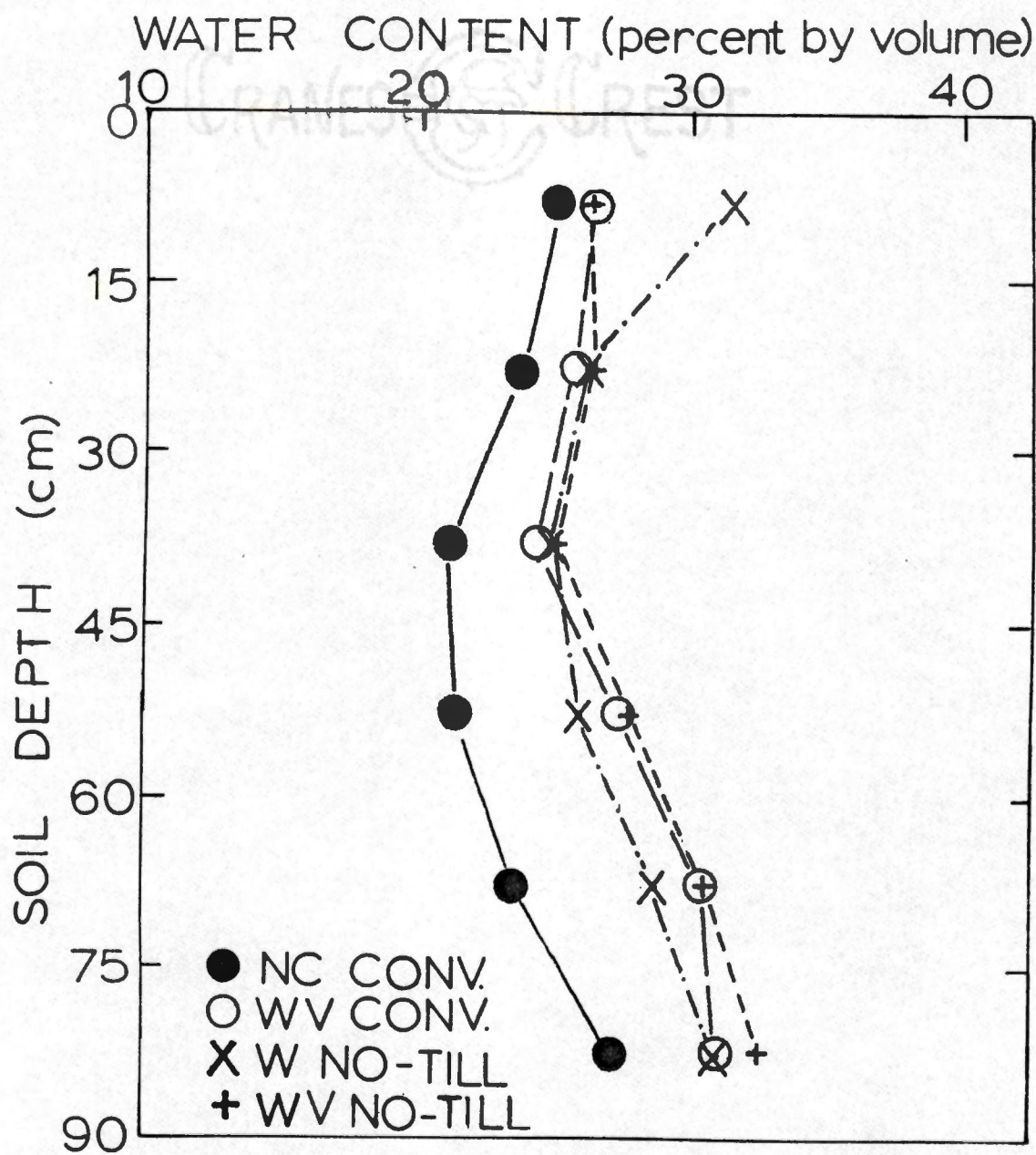


Figure 12. Soil water content at the 168 kg N/ha rate on August 5, 1981.

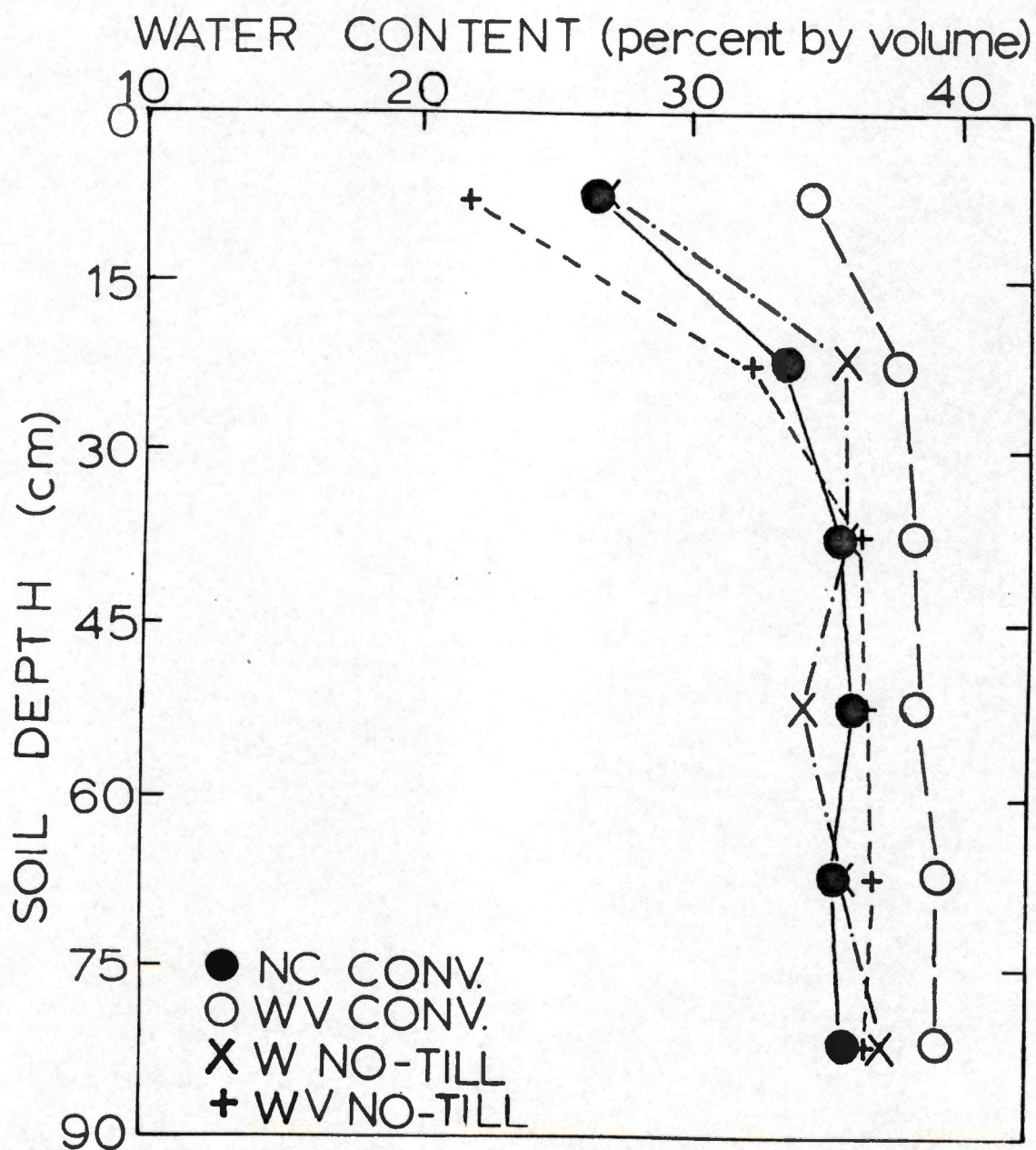


Figure 13. Soil water content at the 0 kg N/ha rate on September 29, 1981.

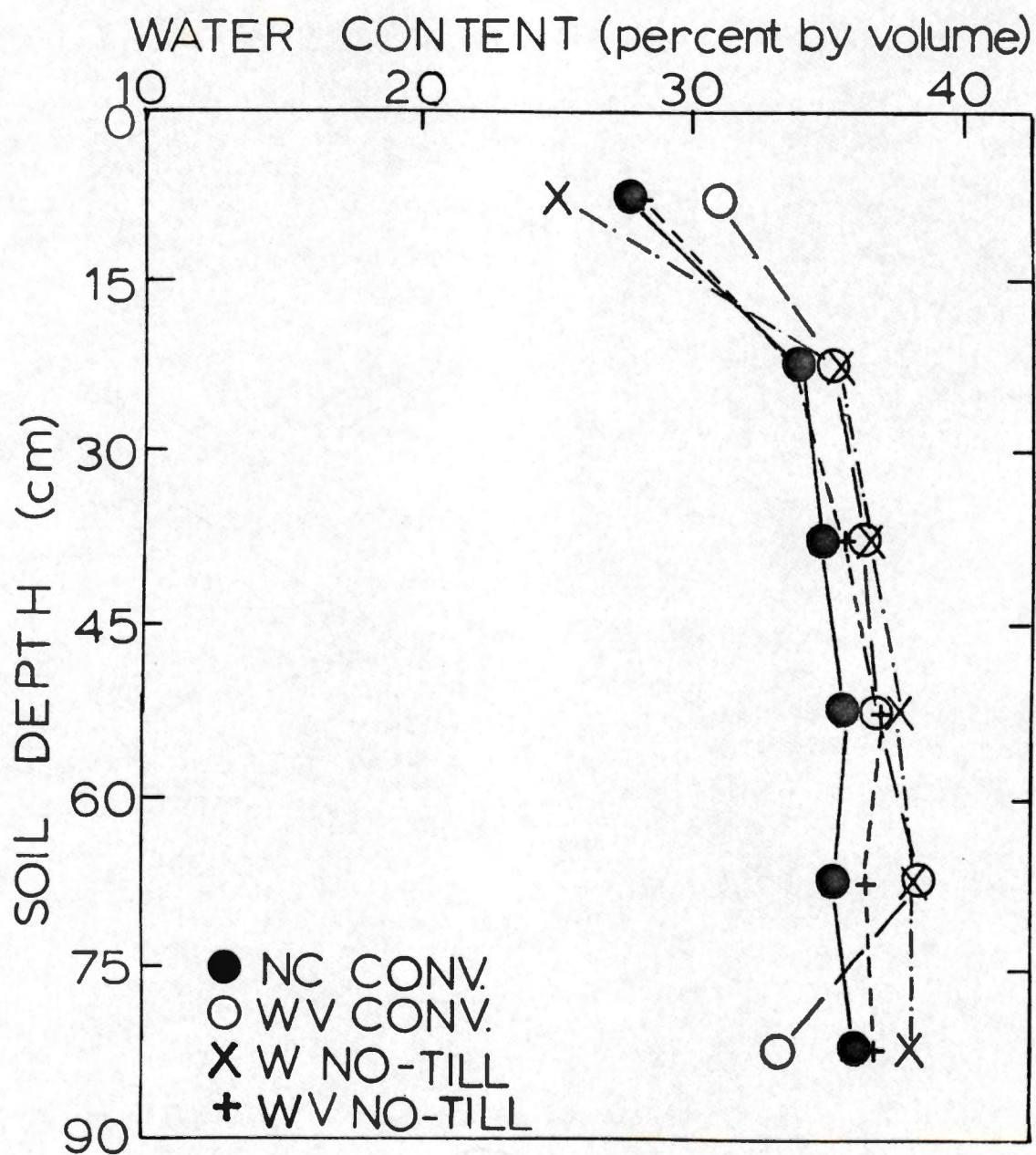


Figure 14. Soil water content at the 56 kg N/ha rate on September 29, 1981.

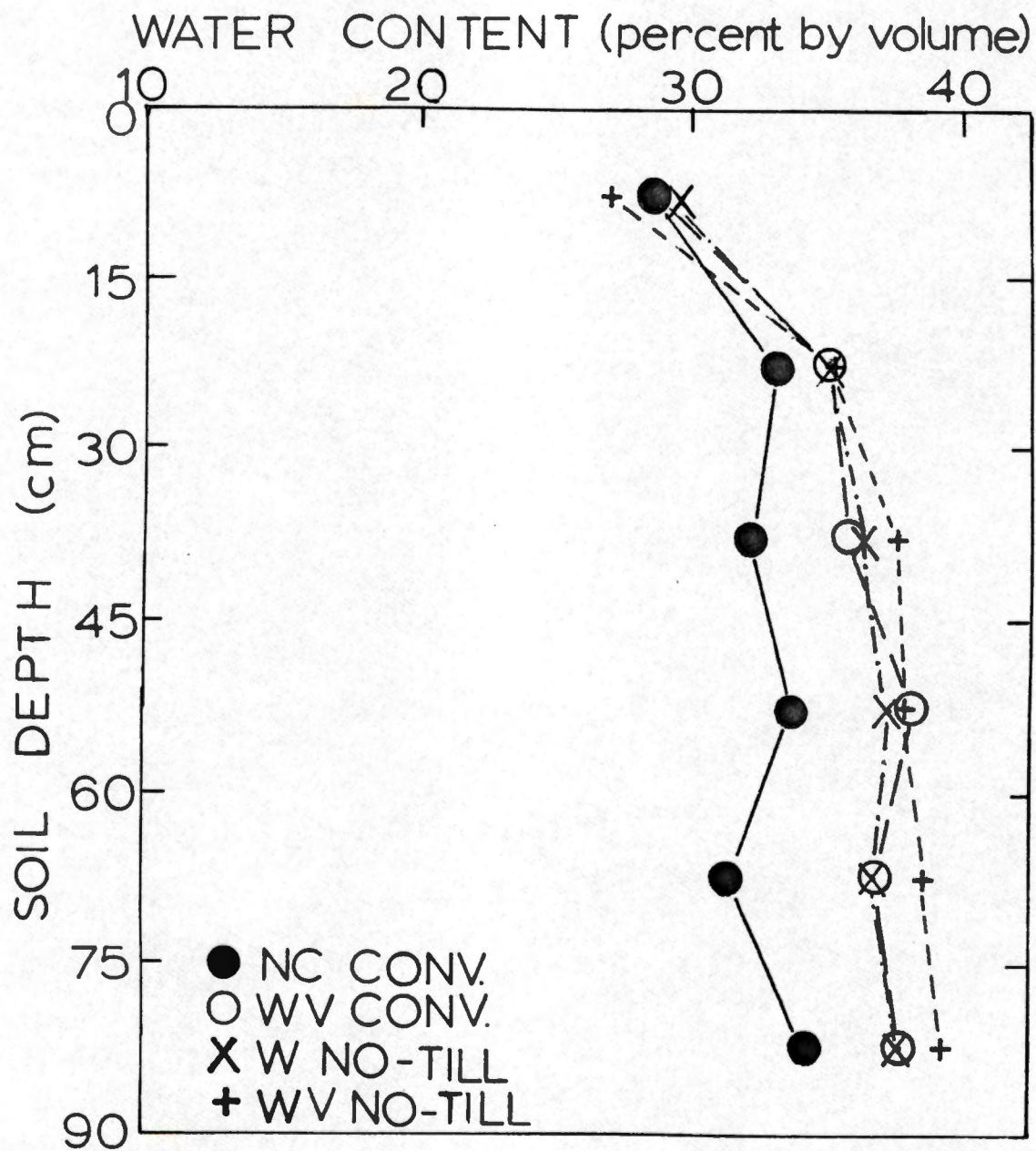


Figure 15. Soil water content at the 112 kg N/ha rate on September 29, 1981.

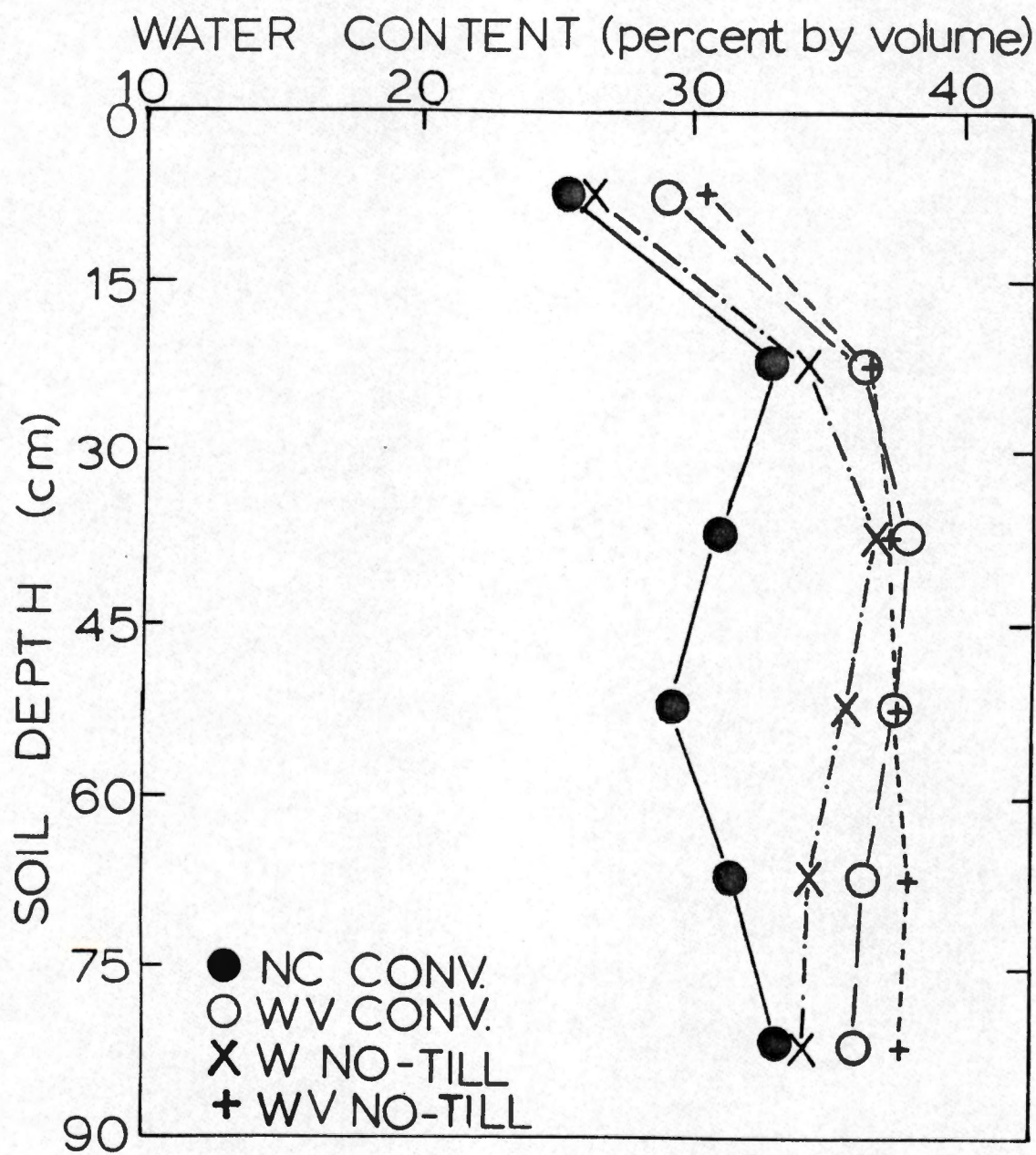


Figure 16. Soil water content at the 168 kg N/ha rate on September 29, 1981.

Nitrate-Nitrogen in the Soil

The distributions of nitrate-nitrogen in the 0-90 cm soil layer determined in each treatment for several dates in 1980 and 1981. All of the nitrogen applied as fertilizer in 1980 plus a small amount of native soil nitrogen was found in samples taken on May 21, 1980 (Figures 17-20). Mineralization at this early period in the growing season could have been coming from cover crop residue decomposition according to trends evident in Figure 18. This was not evident at the 112 and 168 kg N/ha rates (Figures 19 and 20). Nitrate levels in plots at the 0 kg N/ha rate on June 3 were higher in the wv conv plots than the other treatments (Figure 21). The nitrogen in the incorporated vetch residue had probably started decomposing. The much lower nitrate levels in the wheat-vetch no-tillage plot suggest that residues were not as easily decomposed when not incorporated. The nc conv plots had nitrate-nitrogen levels below the wv conv plots but slightly above the no-tillage treatments. At the 56 kg N/ha rate (Figure 22) less nitrate-nitrogen was present in the wheat no-till system. Differences in nitrate-nitrogen were minor and inconsistent at the 112 kg N/ha rate on June 3, 1980 (Figure 23). Nitrate-nitrogen levels in the soil profiles of the conventionally tilled plots at the 168 kg N/ha rate tended to be higher than in the no-tillage plots (Figure 24). Immobilization of nitrogen could have occurred when the high C:N ratio wheat residue decomposed. None of the cover crop-tillage treatments had nitrate-nitrogen levels in any 15 cm layer above 30 kg N/ha at the 0, 56 and 112 kg N/ha rate on July 8 (Figures 25-27). The wv conv and wv no-till plots at the 168 kg N/ha rate were higher in nitrate-nitrogen than the other two treatments (Figure 28). The difference apparently came from

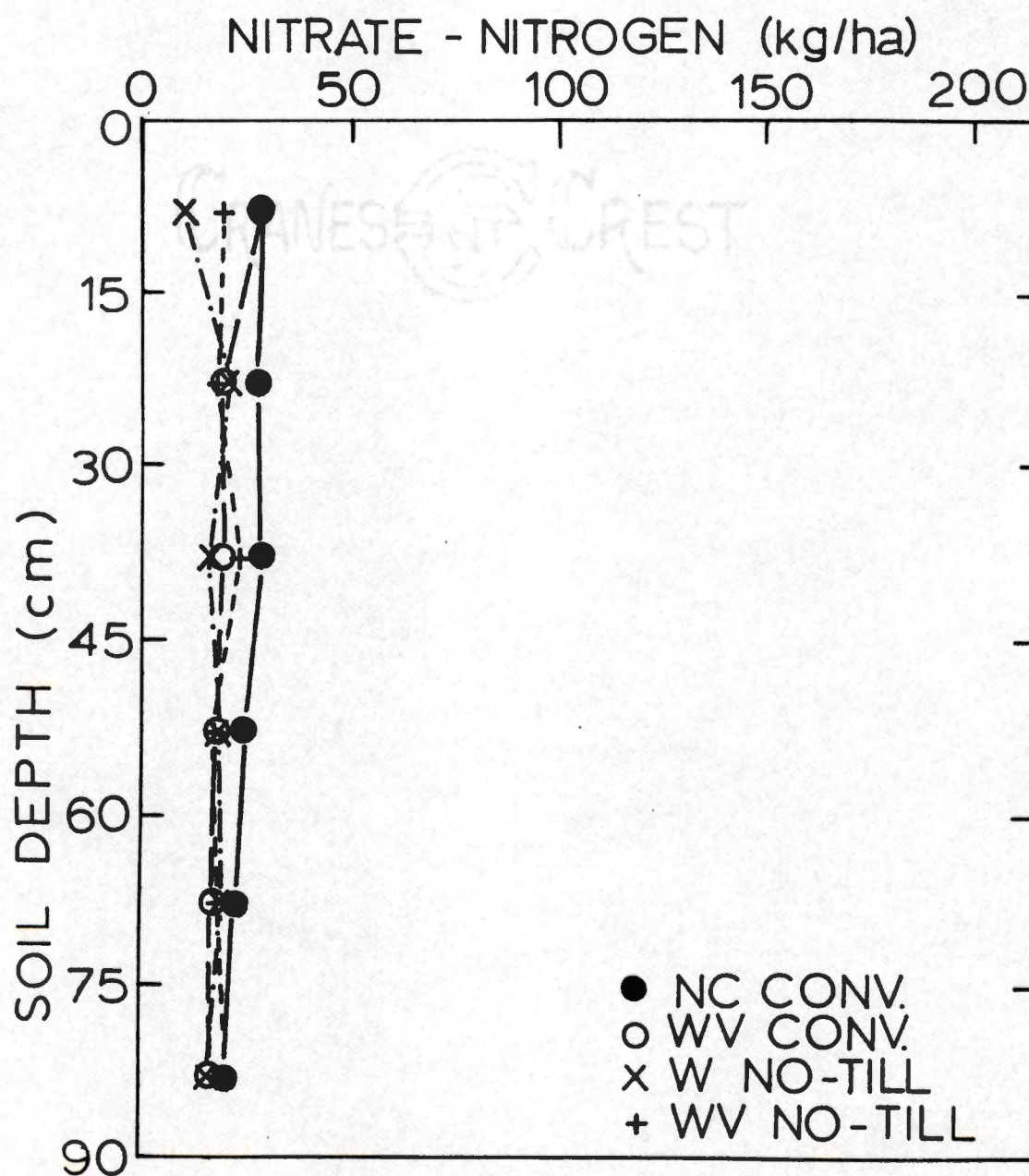


Figure 17. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on May 21, 1980.

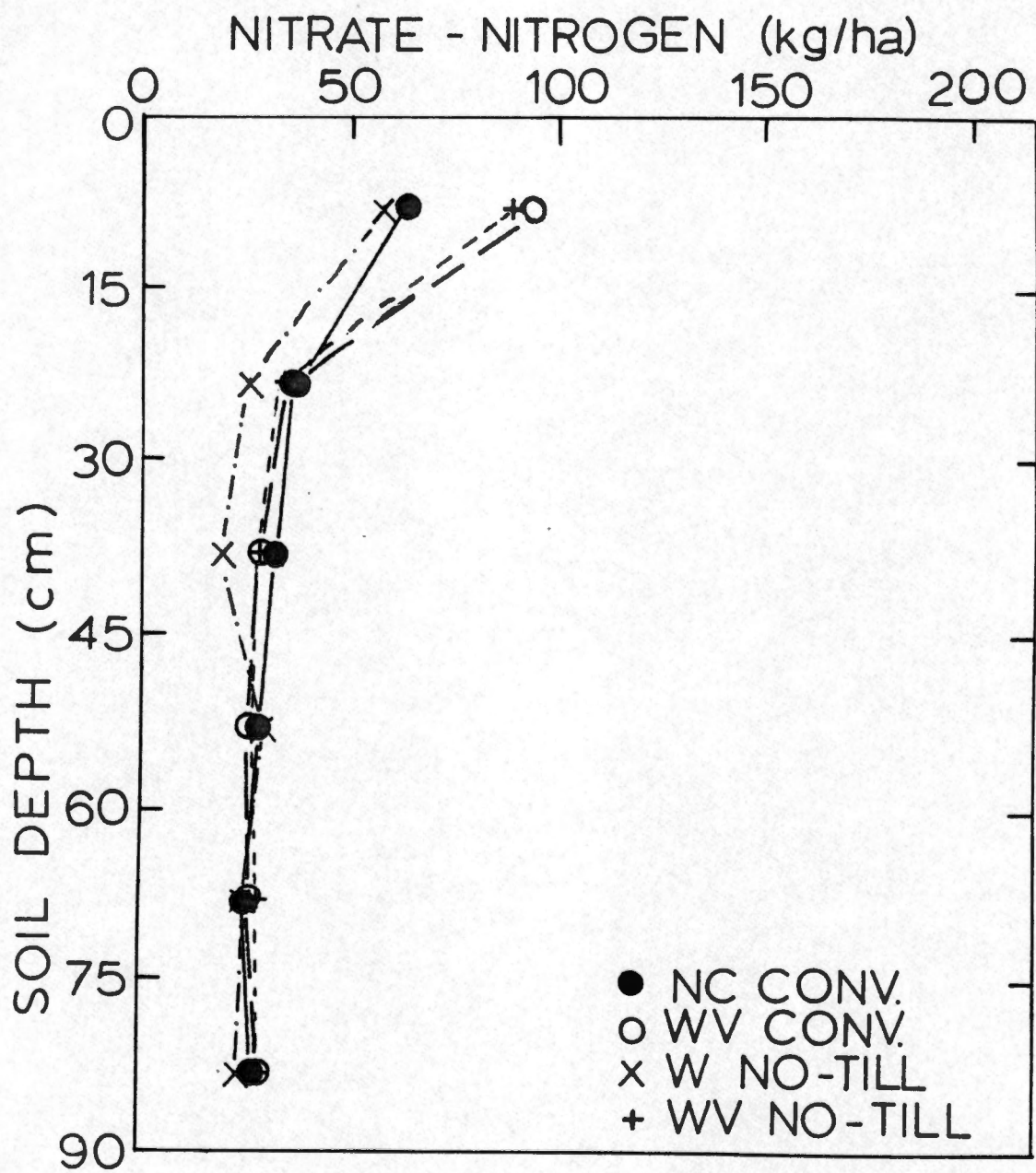


Figure 18. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on May 21, 1980.

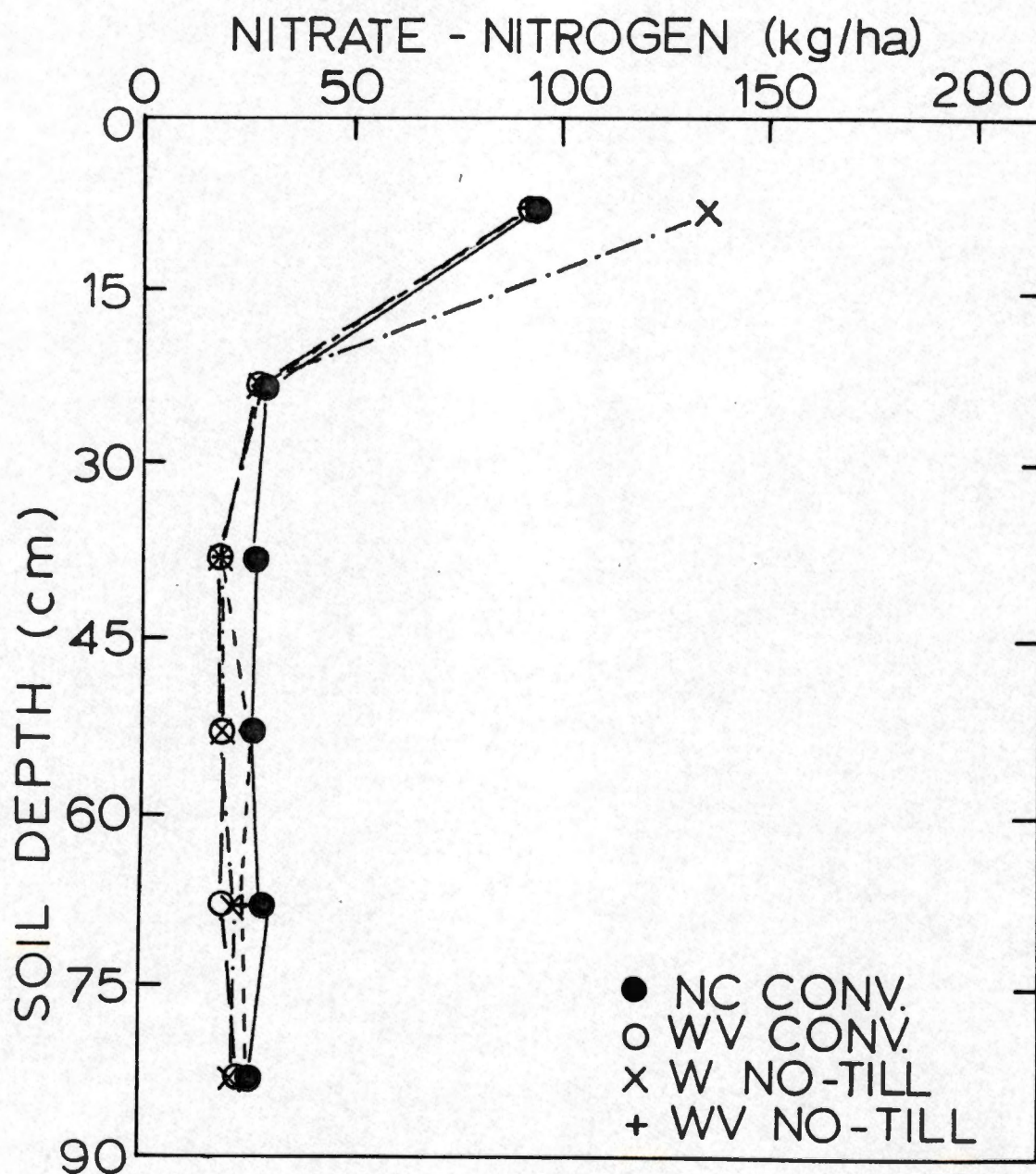


Figure 19. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on May 21, 1980.

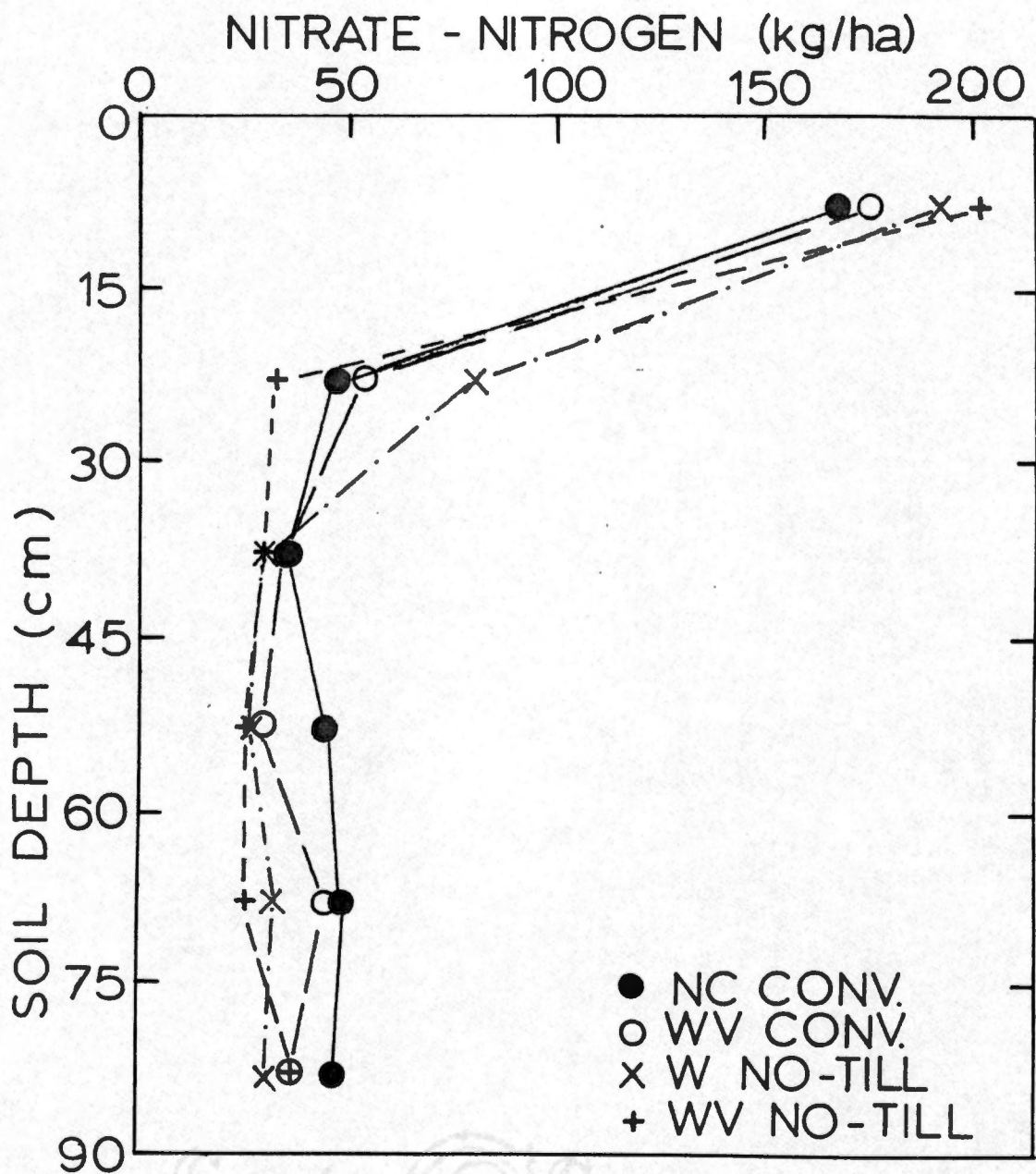


Figure 20. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on May 21, 1980.

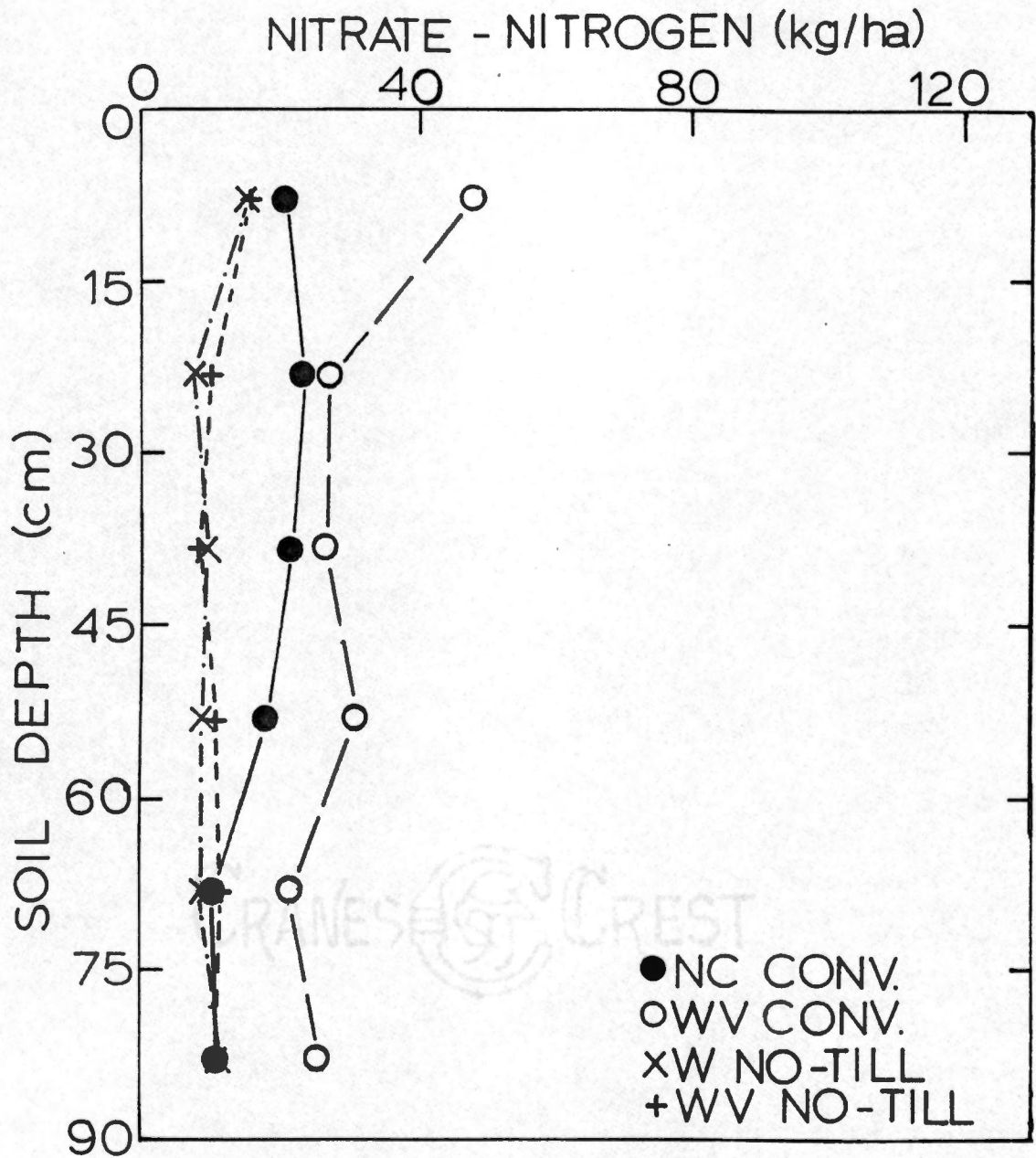


Figure 21. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on June 3, 1980.

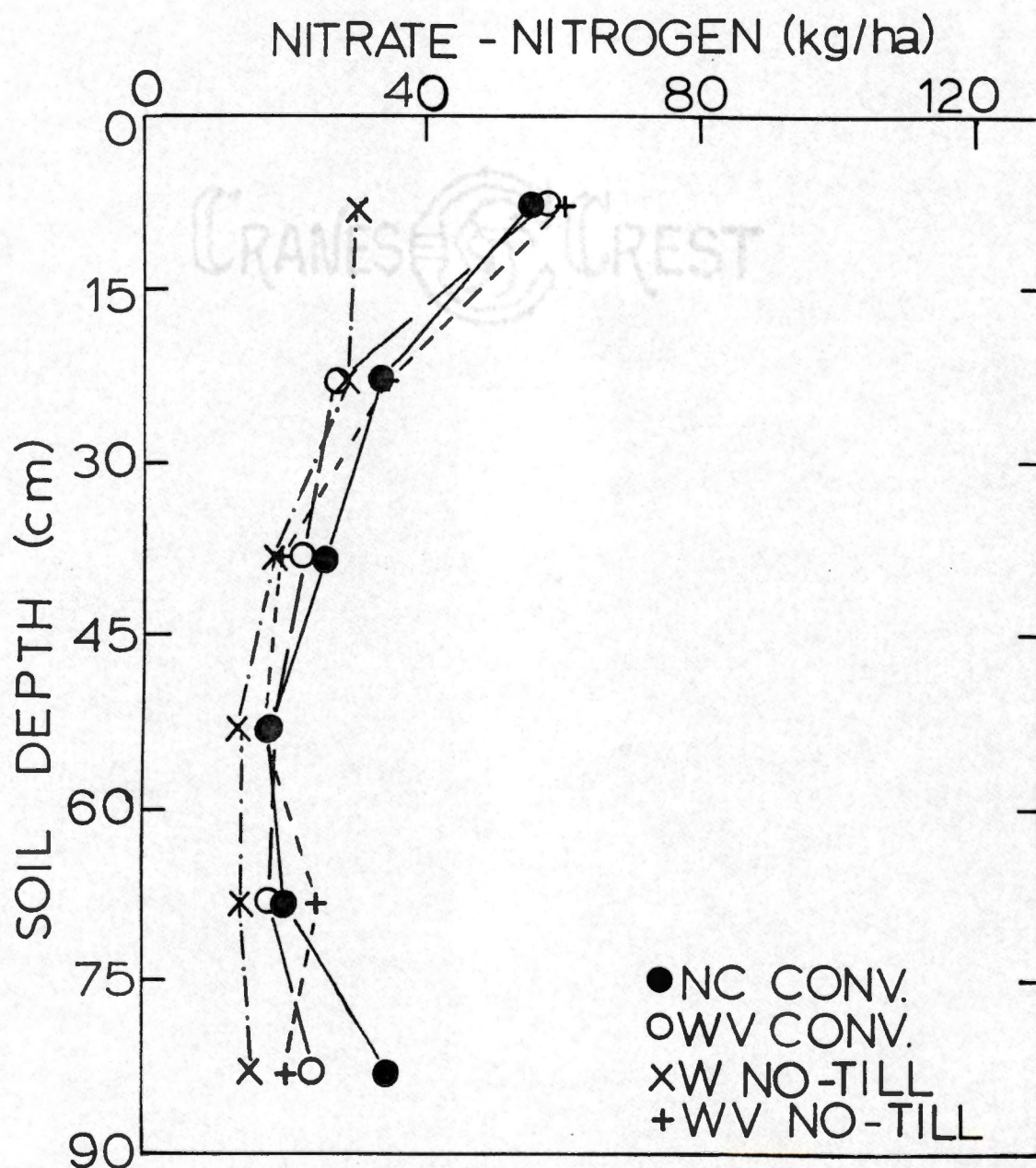


Figure 22. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on June 3, 1980.

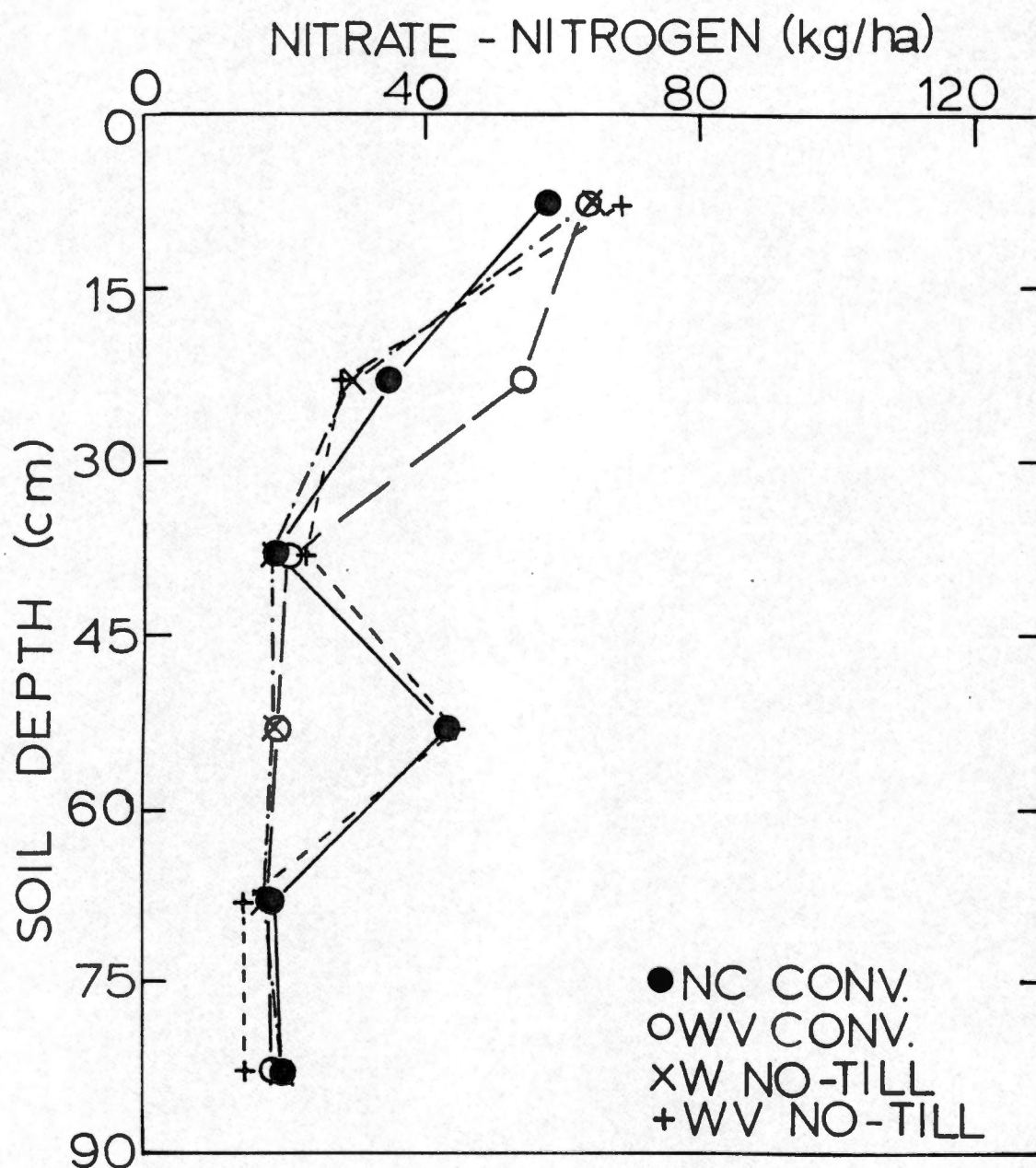


Figure 23. Soil nitrate-nitrogen distributions of the 112 kg N/ha rate on June 3, 1980.

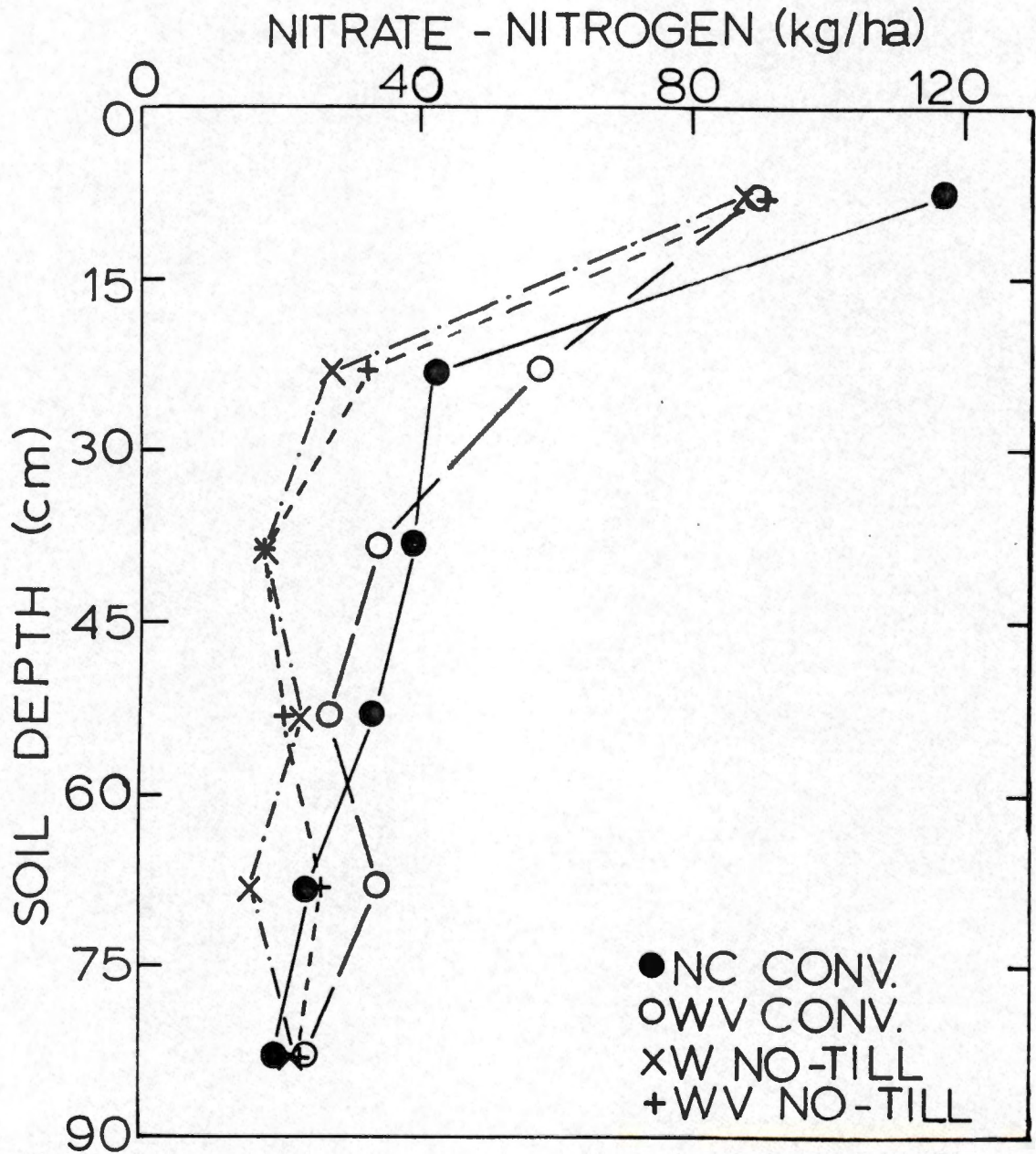


Figure 24. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on June 3, 1980.

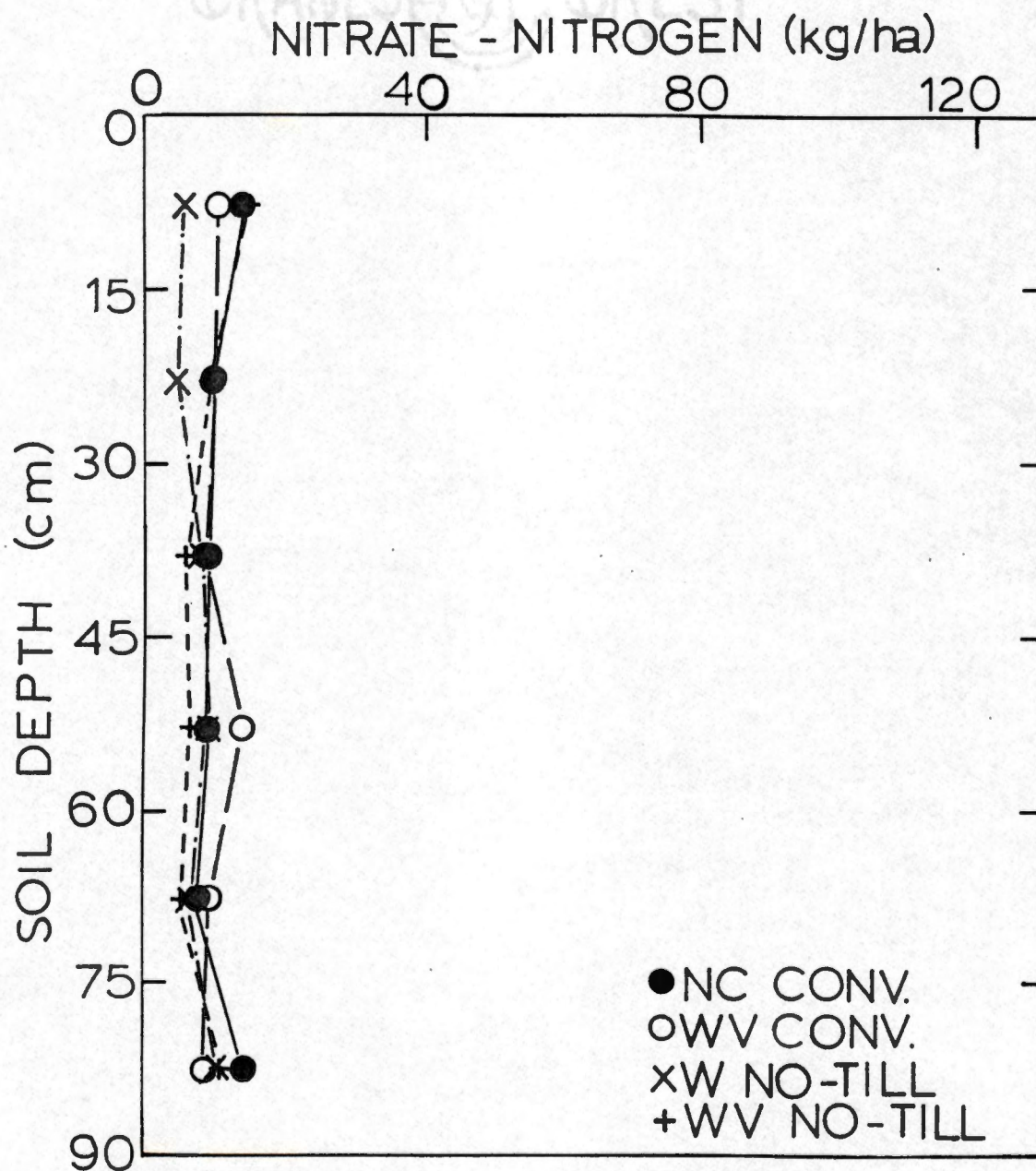


Figure 25. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on July 8, 1980.

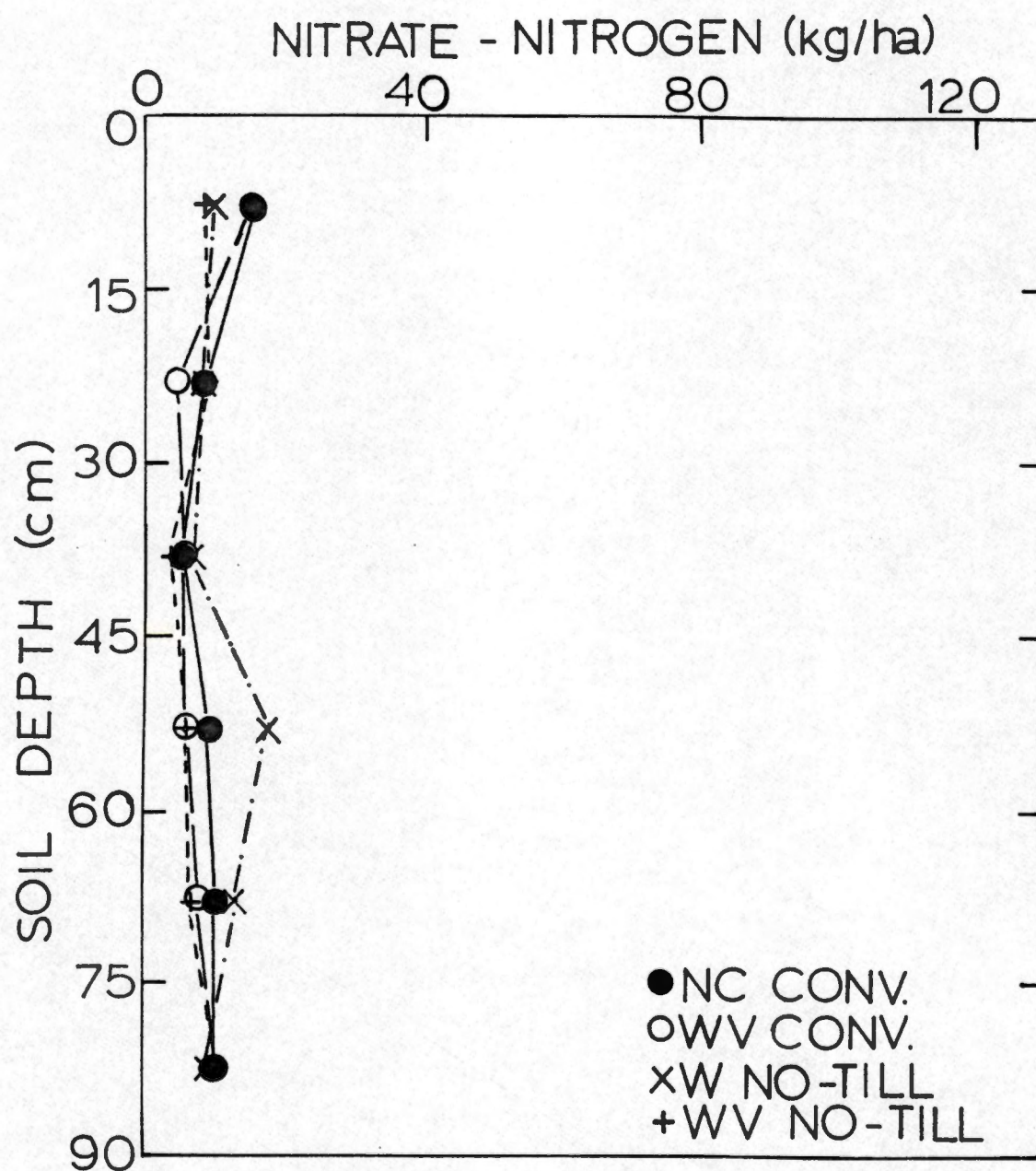


Figure 26. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on July 8, 1980.

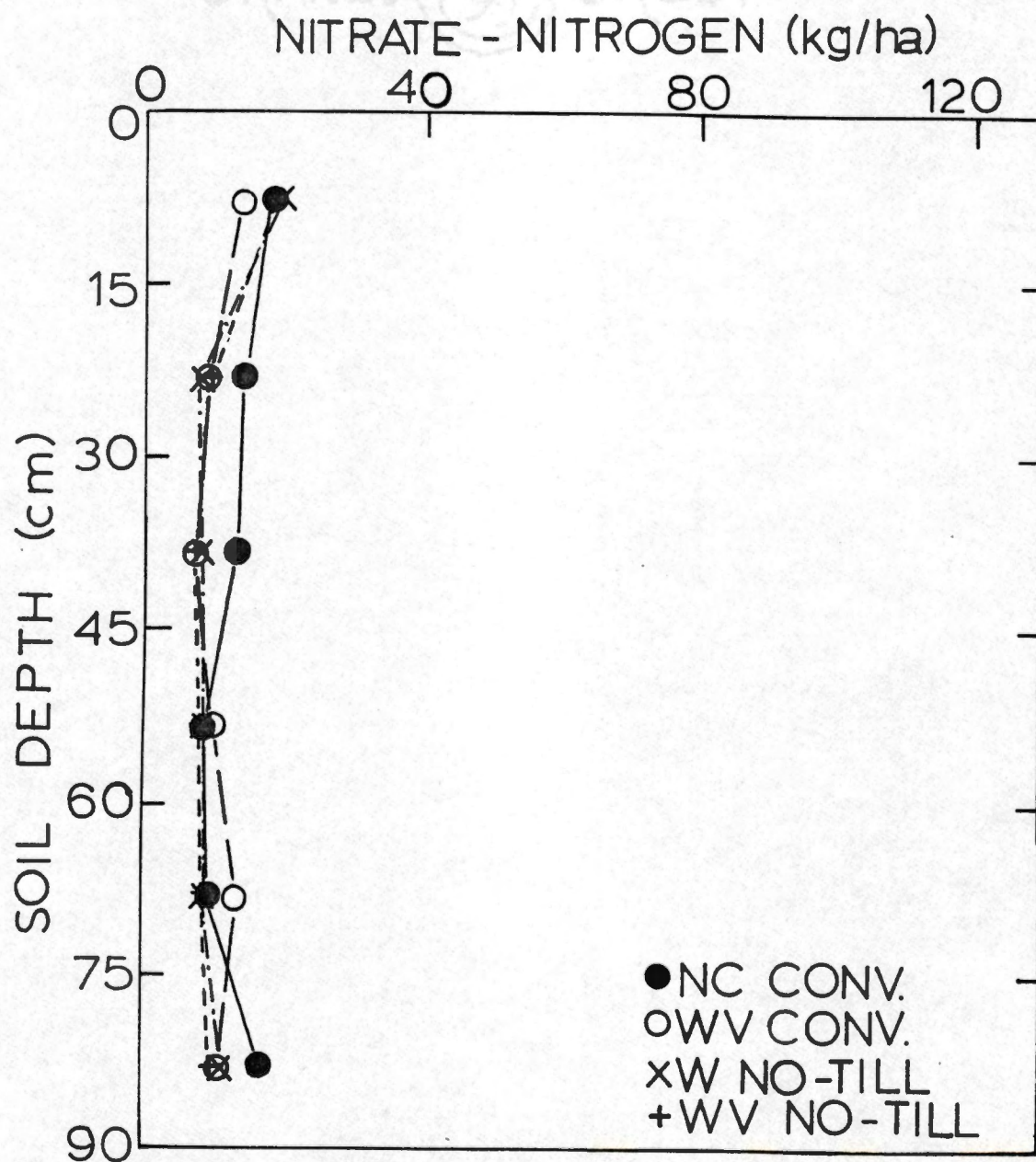


Figure 27. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on July 8, 1980.

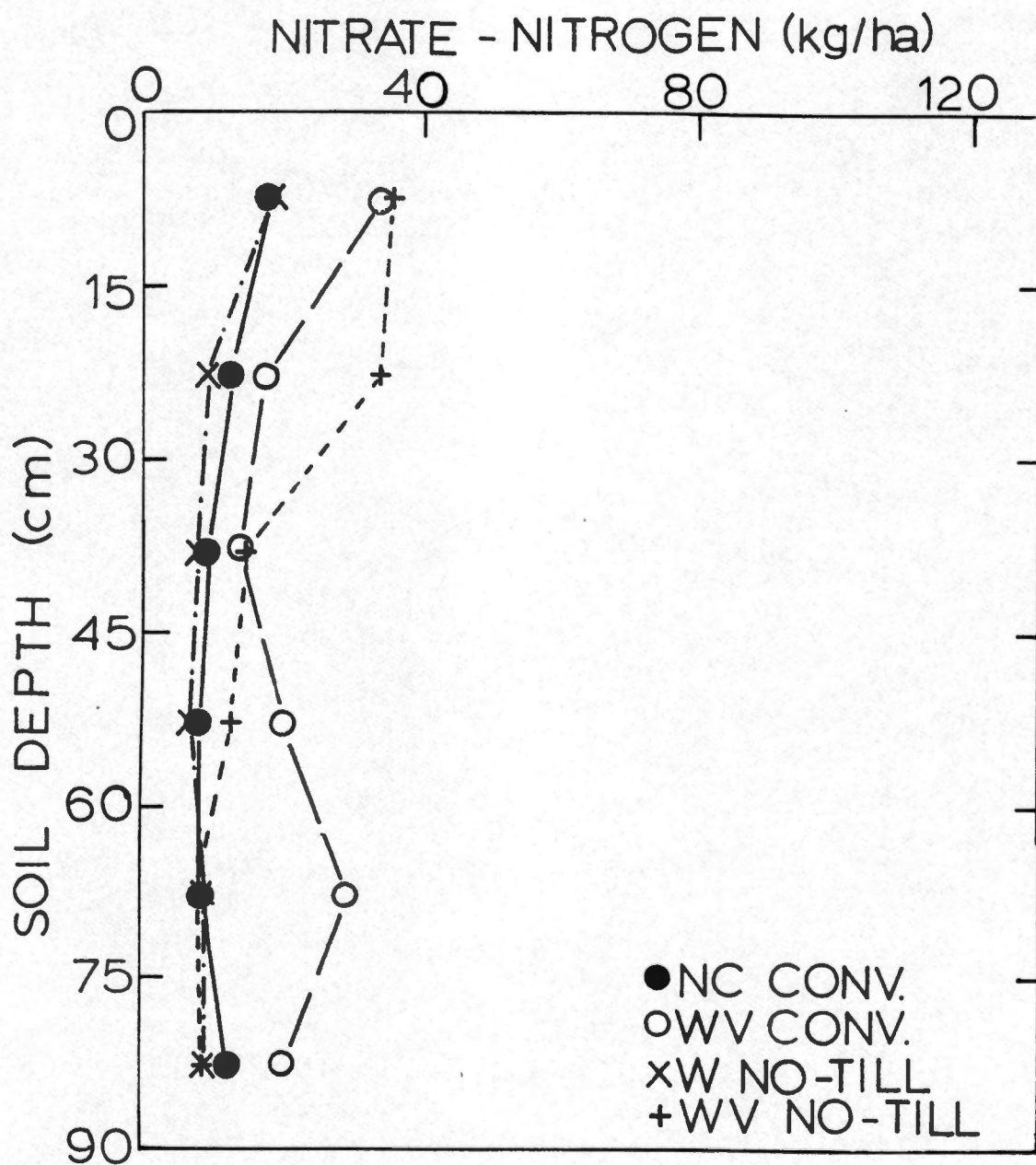


Figure 28. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on July 8, 1980.

nitrogen mineralized from vetch residue. The mineralization of nitrogen in the no-tillage plots may be slower in the beginning than in conventionally tilled plots but it did occur before the corn matured. Plots with 0, 56, 112 kg N/ha rates had nitrate-nitrogen levels below 20 kg N/ha at all 15 cm soil layers to 90 cm on July 25 (Figures 29-31). At the 168 kg N/ha rate the wv no-till was much higher in nitrate-nitrogen than the other treatments at the 0-15 cm soil layer (Figure 32). The wv conv may have decomposed earlier than the wheat-vetch with no-tillage. The nitrogen resulting from the decomposition of the vetch in the wv conv would have already been taken up by the corn and would not have been evident at this late date. This would explain the low nitrate-nitrogen levels in the wv conv plots at the 168 kg N/ha rate on July 25 (Figure 32). The same trends that existed on July 8 and July 25 were present on August 18 (Figures 33-36). The nitrate-nitrogen levels were low with no differences in plots where nitrogen fertilizer rates were below 168 kg N/ha. The nc conv plots at the 168 kg N/ha rate (Figure 36) was the highest in nitrate at the 0-15 cm soil layer but dropped off well below the wheat-vetch treatments at the 15-30 cm depth. The differences in nitrate distribution are probably a product of residue decomposition differences as a function of depth resulting from vetch nodule and root decay. In a normal year the nitrate levels would probably not have been as high as they were in August 1980 because the corn would have utilized the nitrogen as it was released. In 1980 lack of soil water reduced nitrogen uptake by the corn earlier than when corn matures in a normal growing season.

Samples taken on June 11, 1981 (Figures 37-40) indicated nitrogen mineralization from the decomposition of vetch residue in conventional

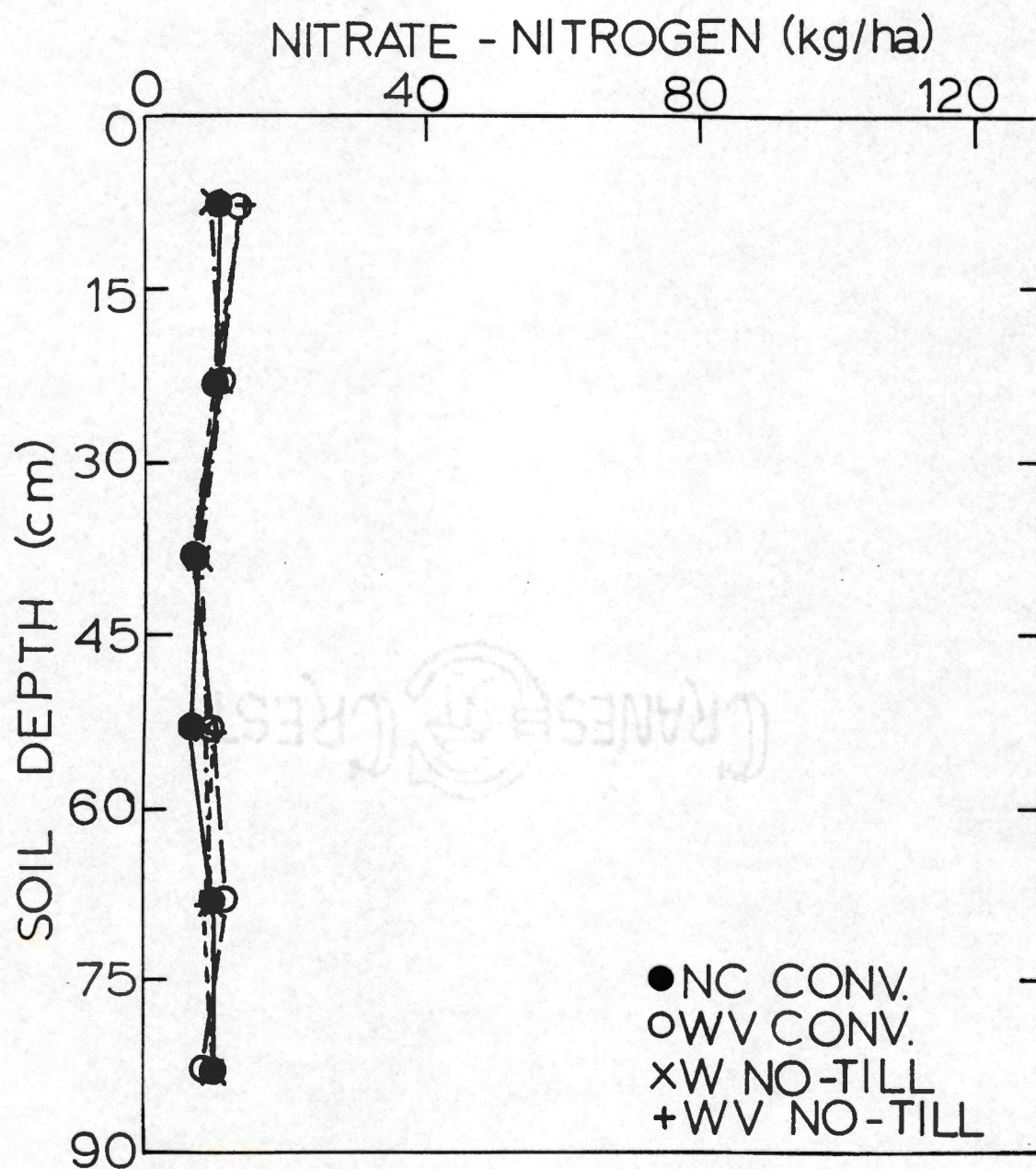


Figure 29. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on July 25, 1980.

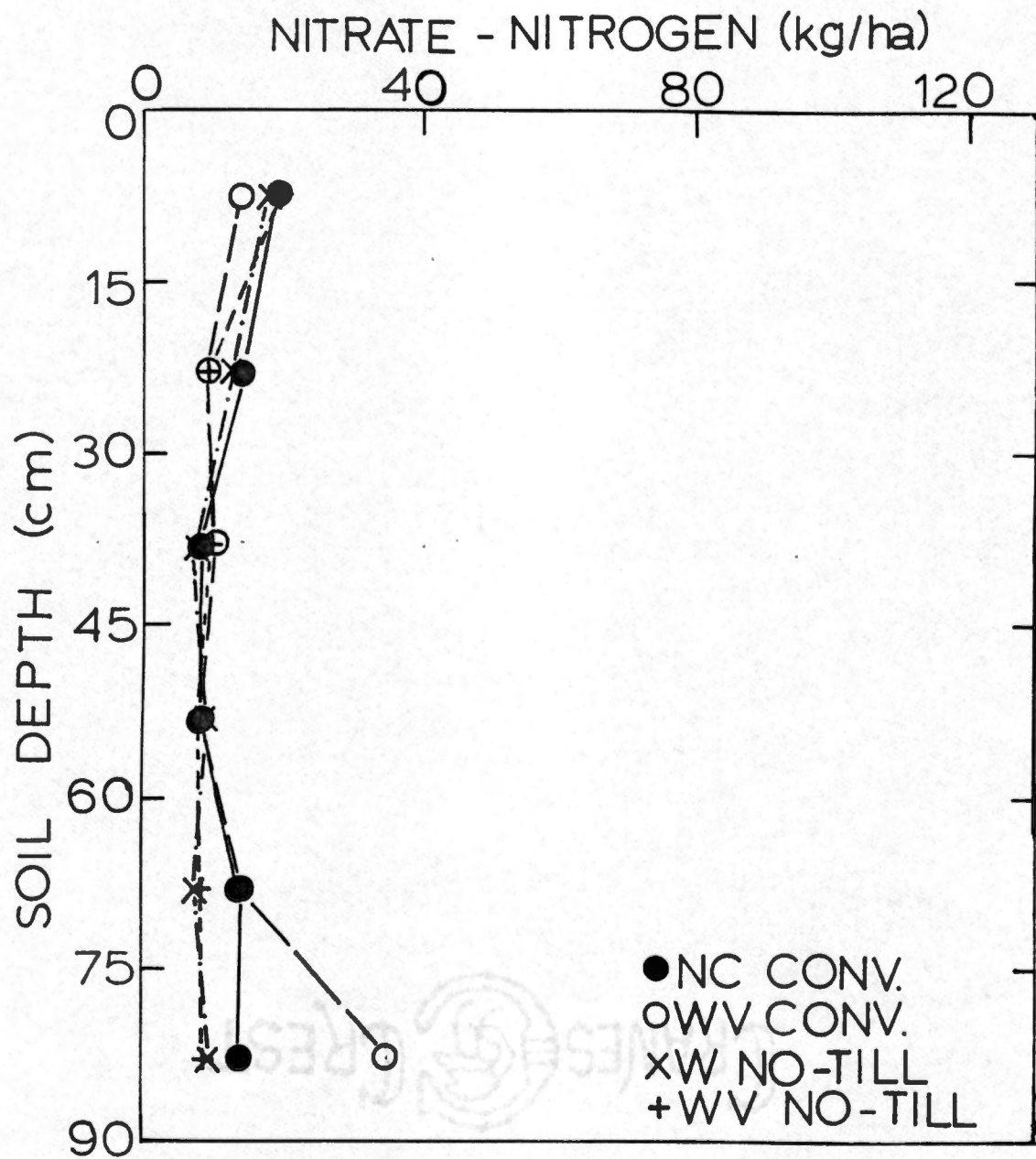


Figure 30. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on July 25, 1980.

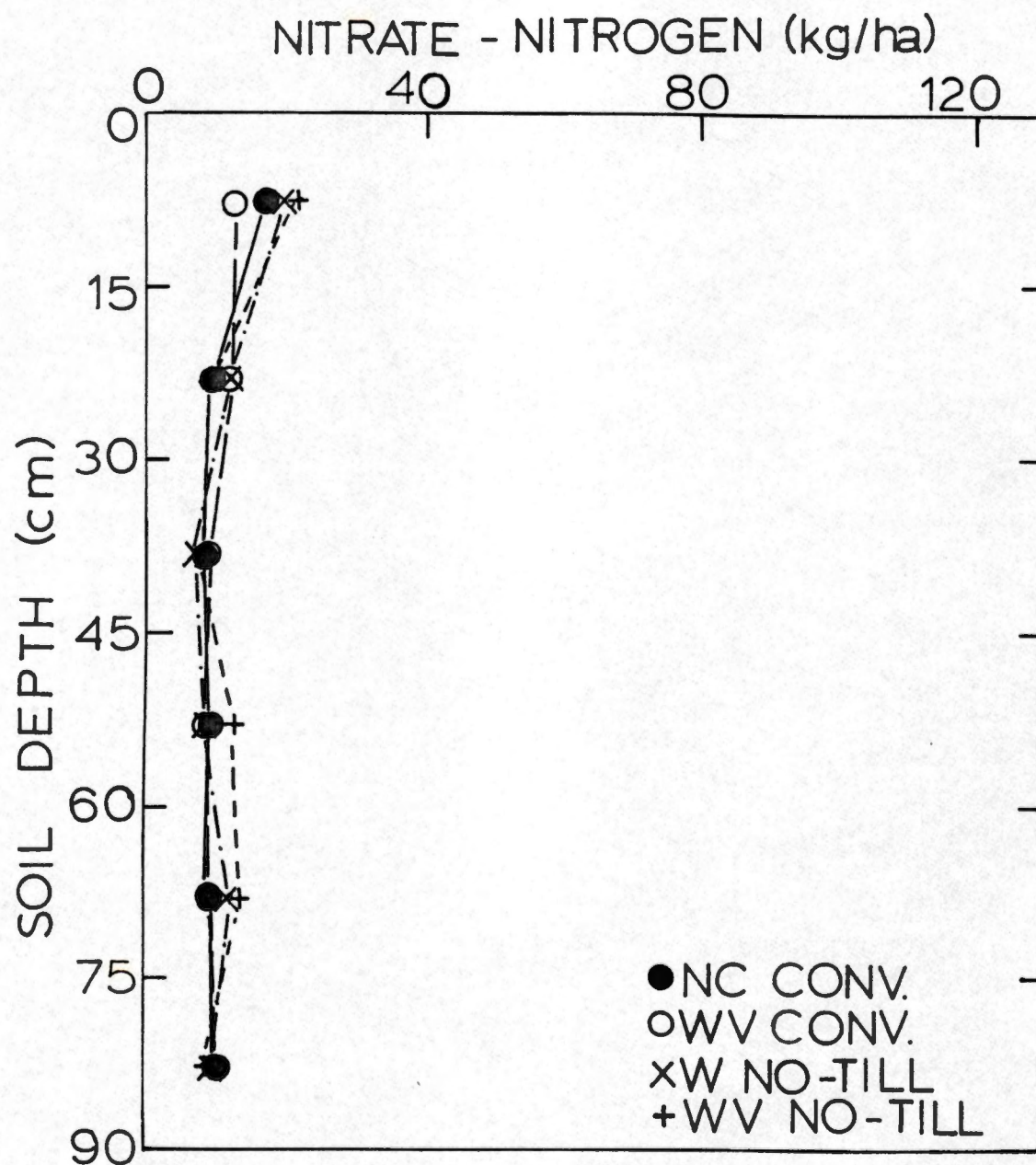


Figure 31. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on July 25, 1980.

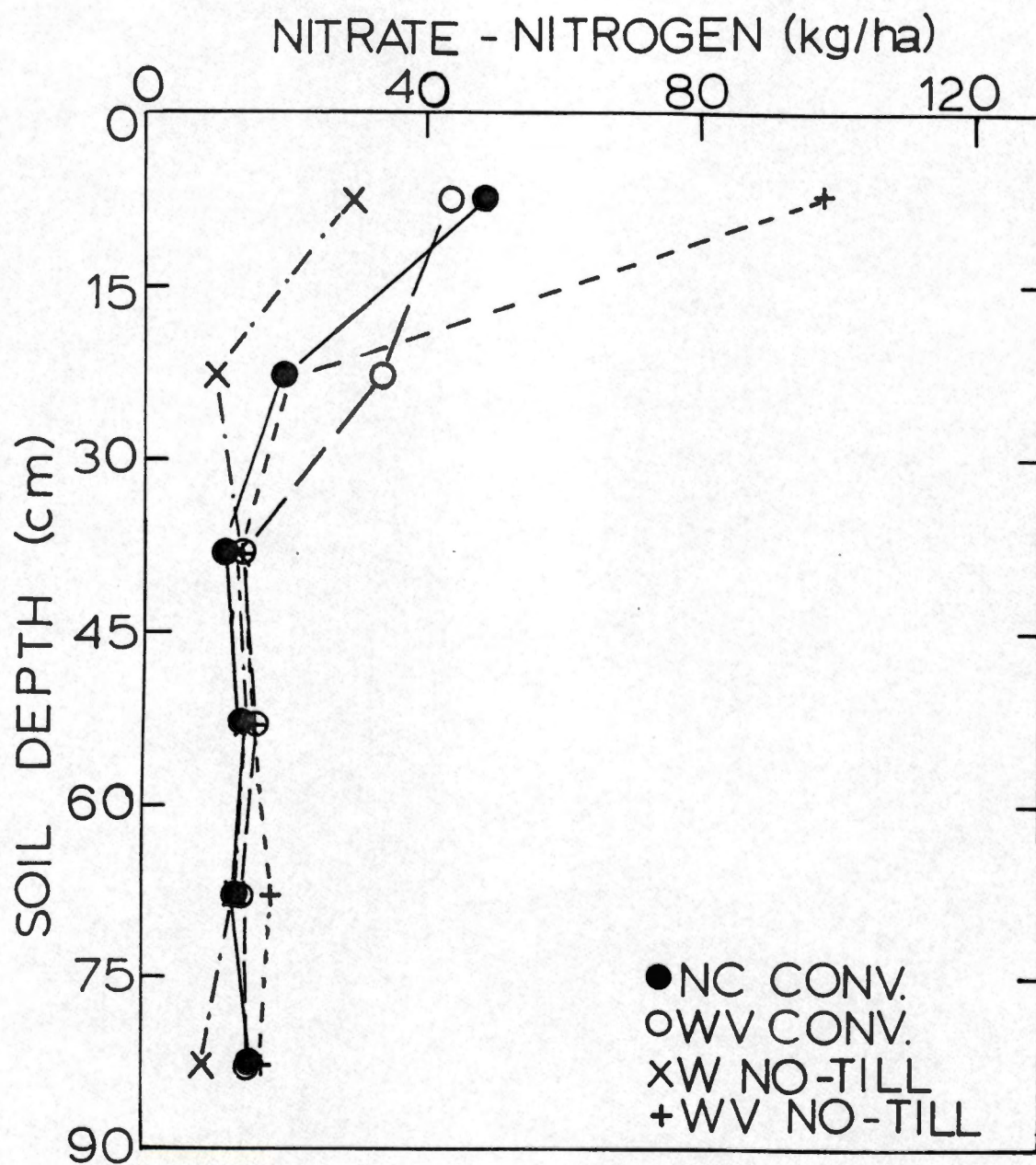


Figure 32. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on July 25, 1980.

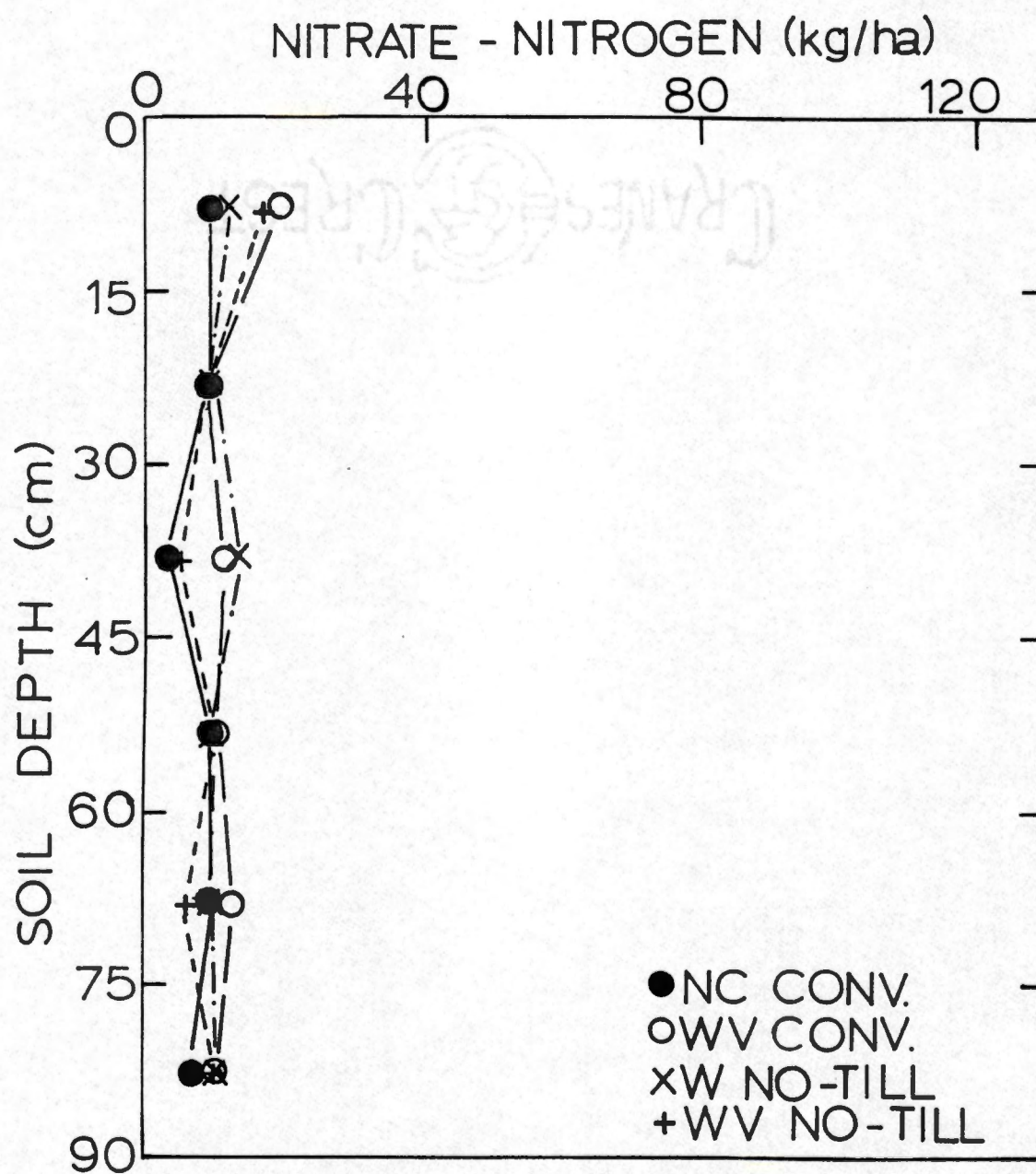


Figure 33. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on August 18, 1980.

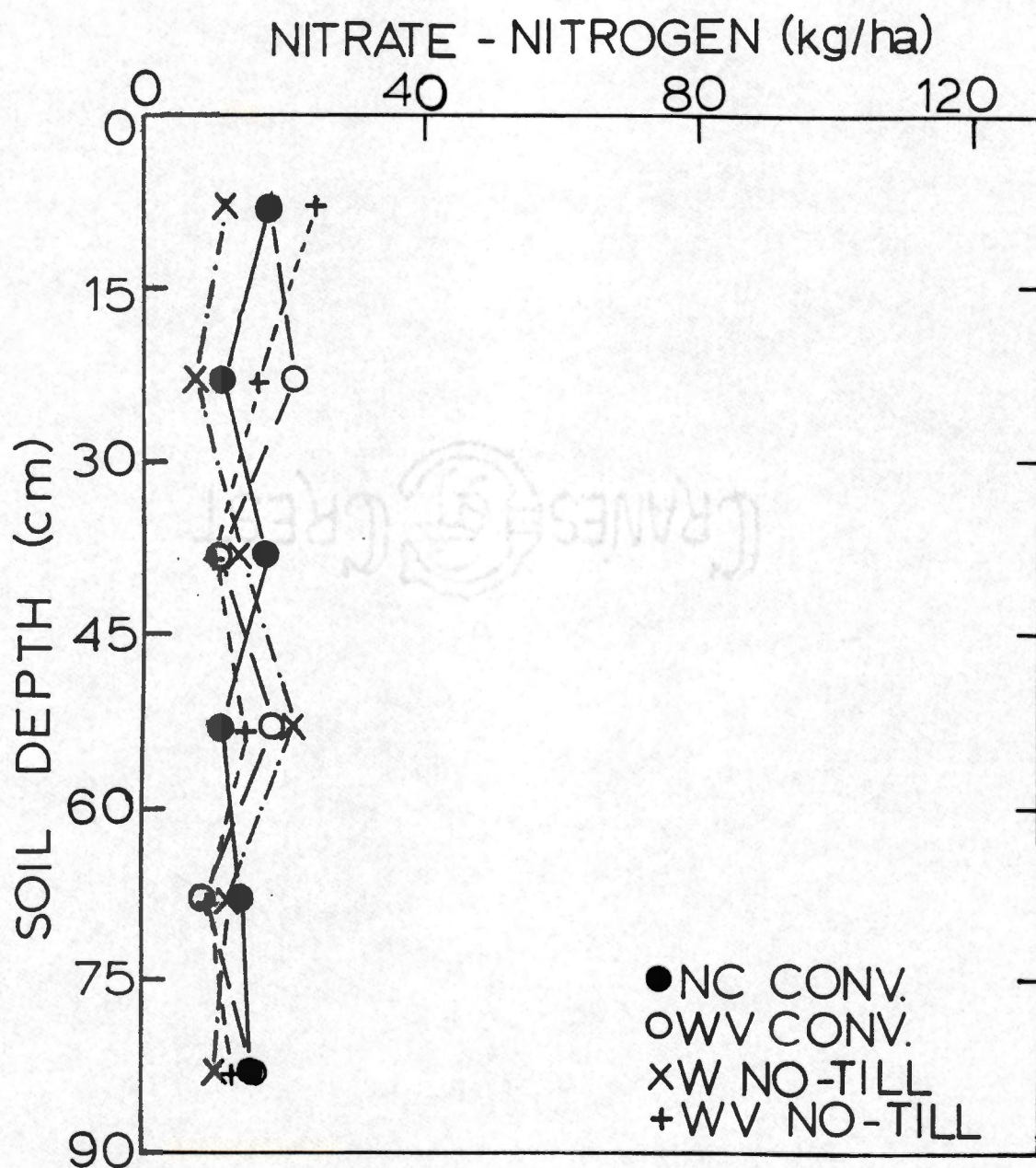


Figure 34. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on August 18, 1980.

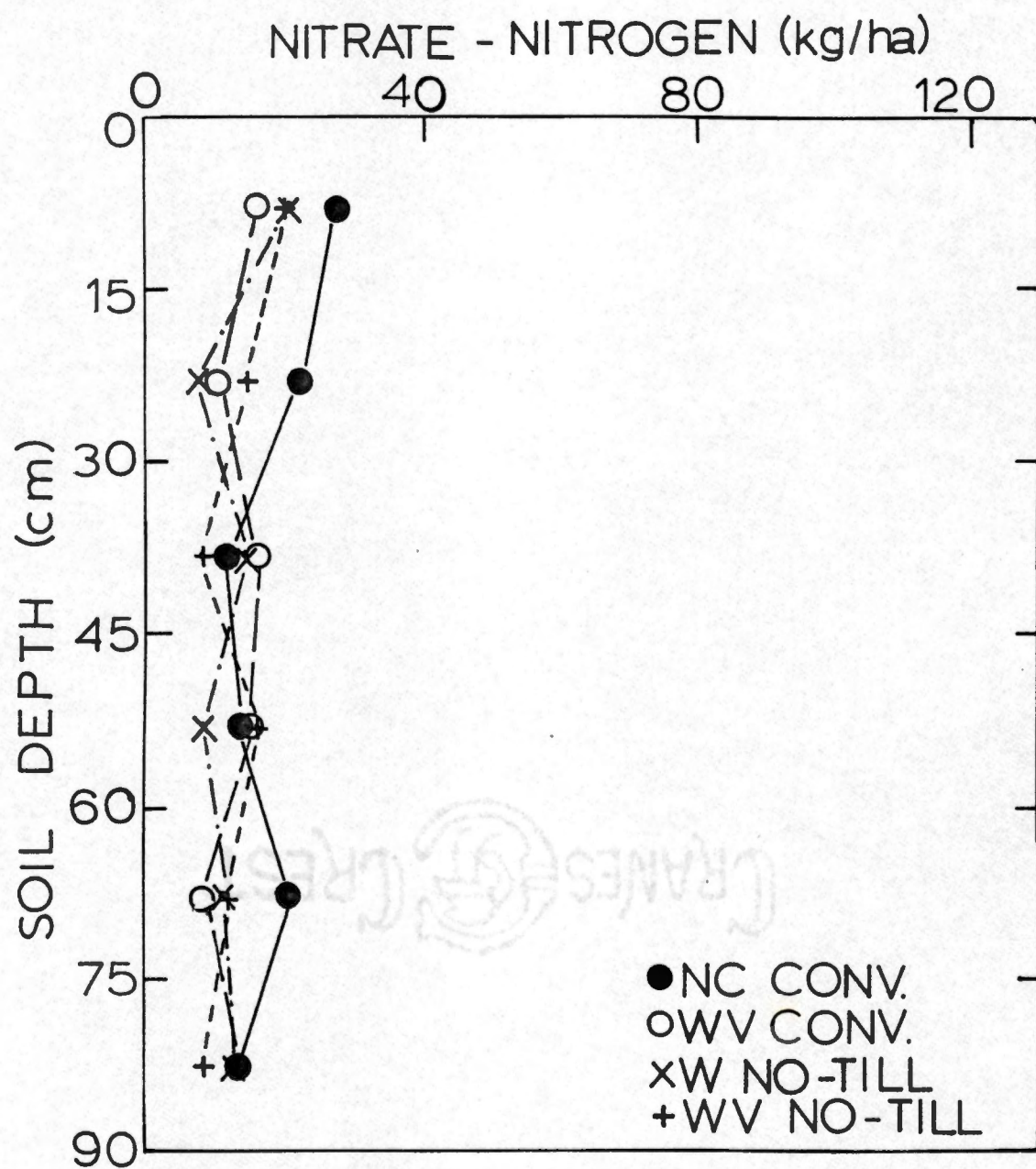


Figure 35. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on August 18, 1980.

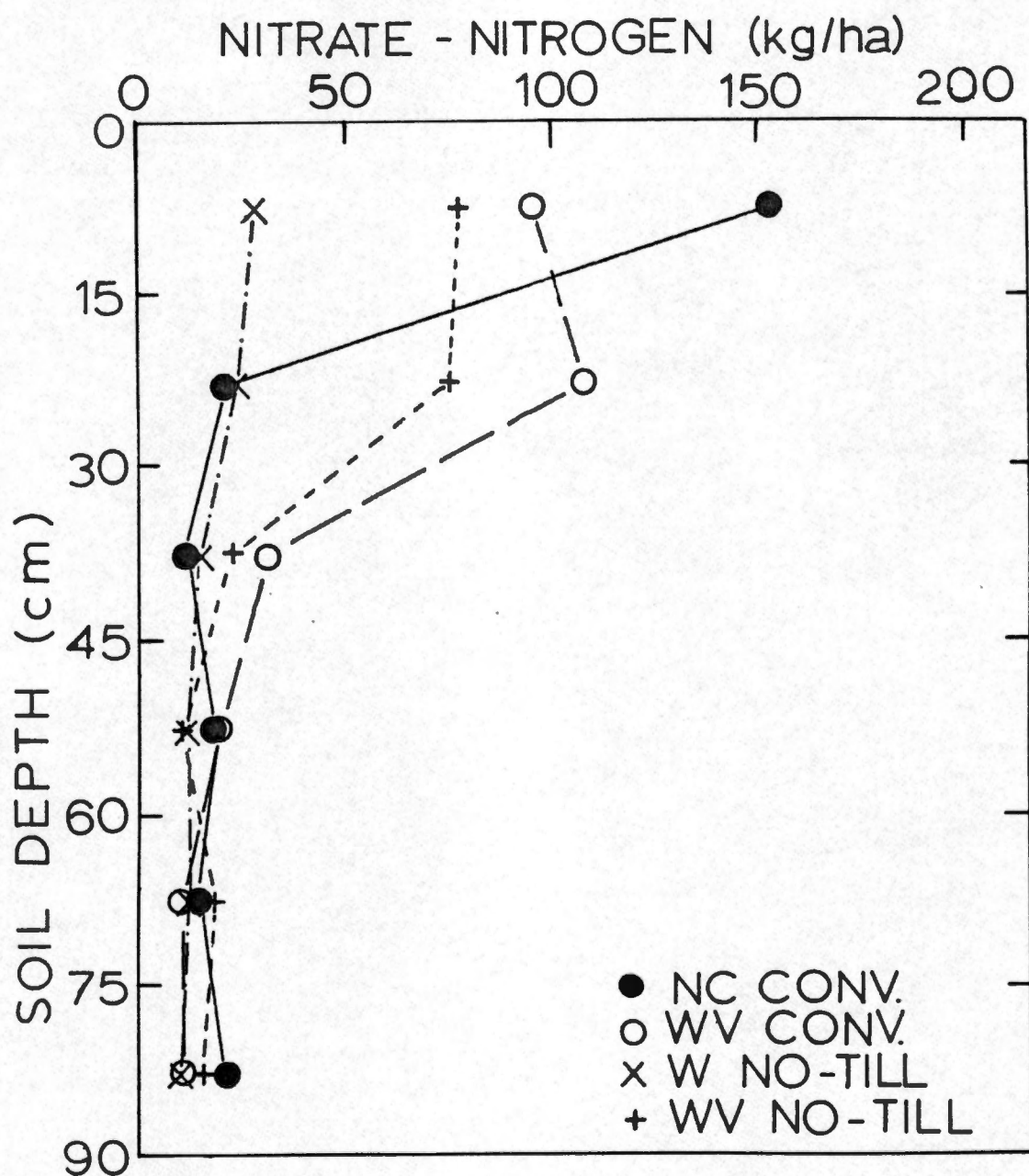


Figure 36. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on August 18, 1980.

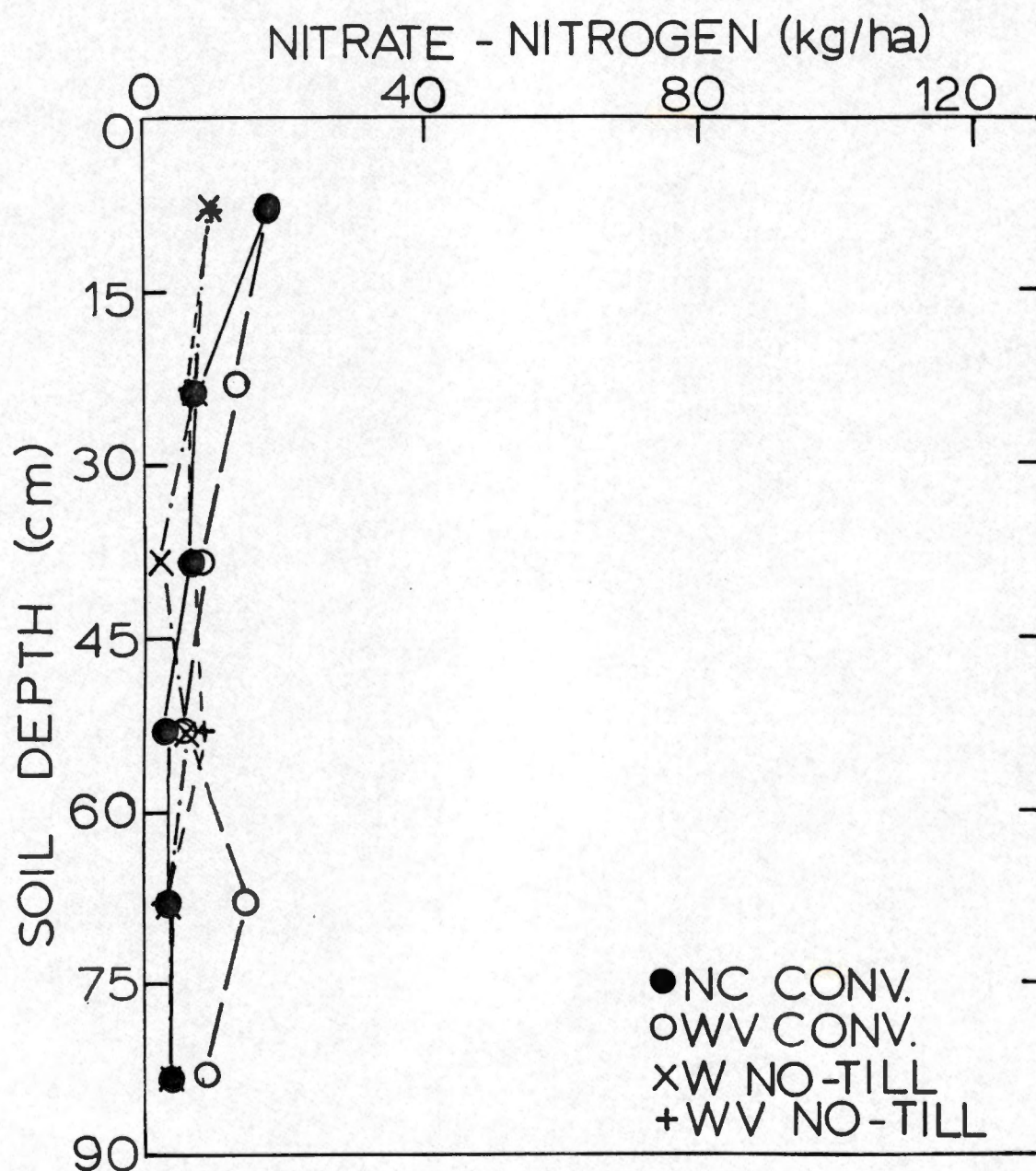


Figure 37. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on June 11, 1981.

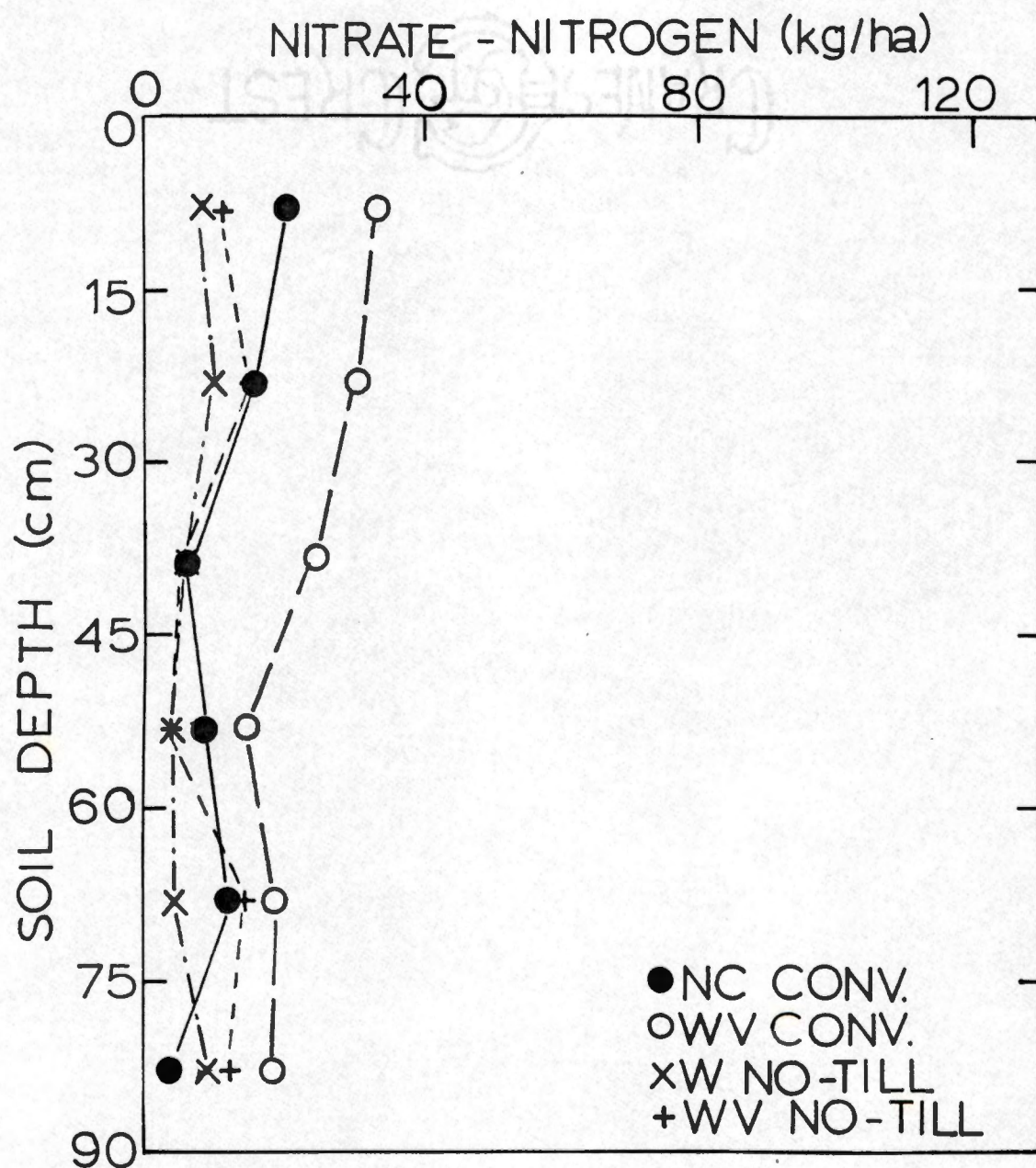


Figure 38. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on June 11, 1981.

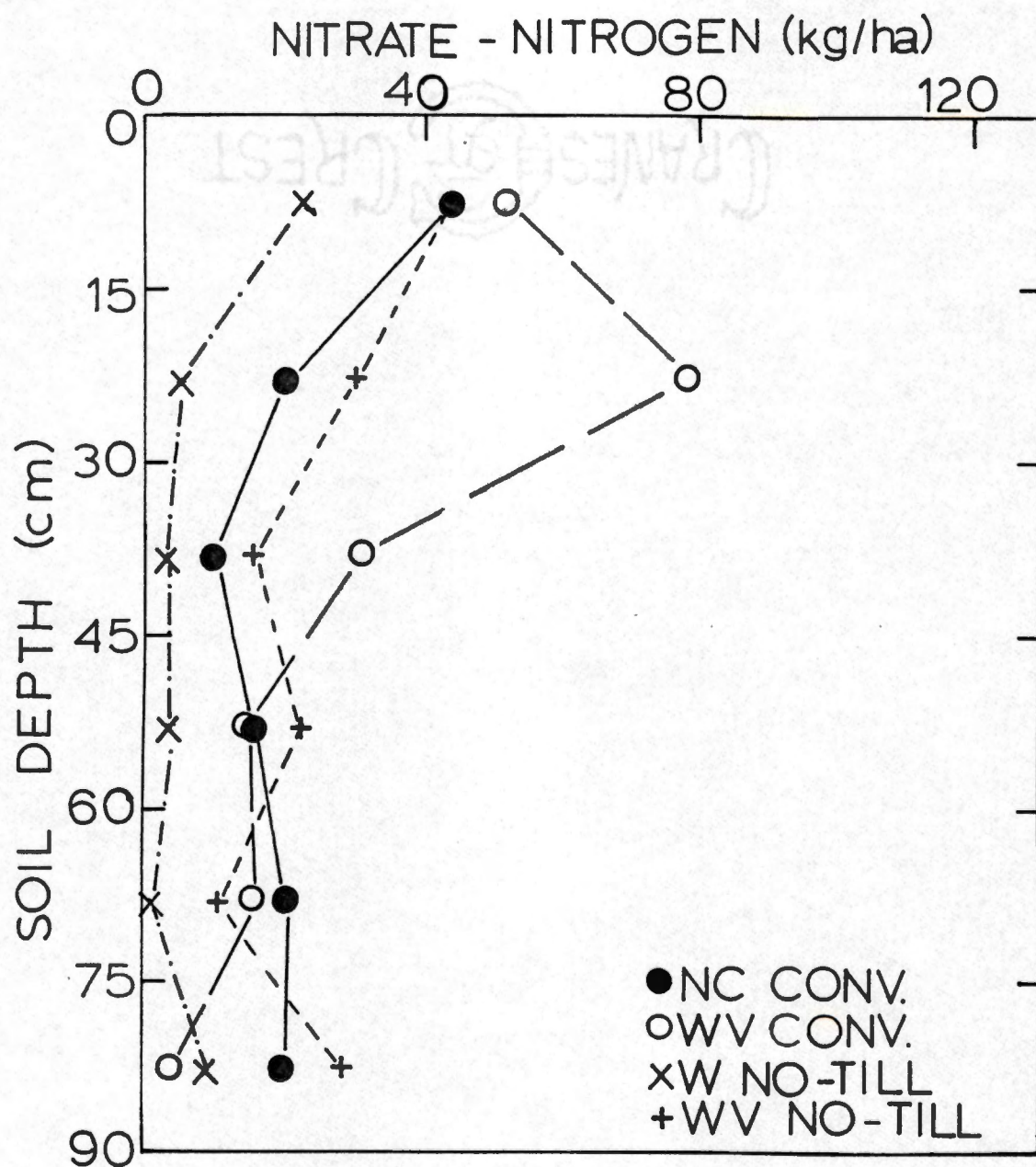


Figure 39. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on June 11, 1981.

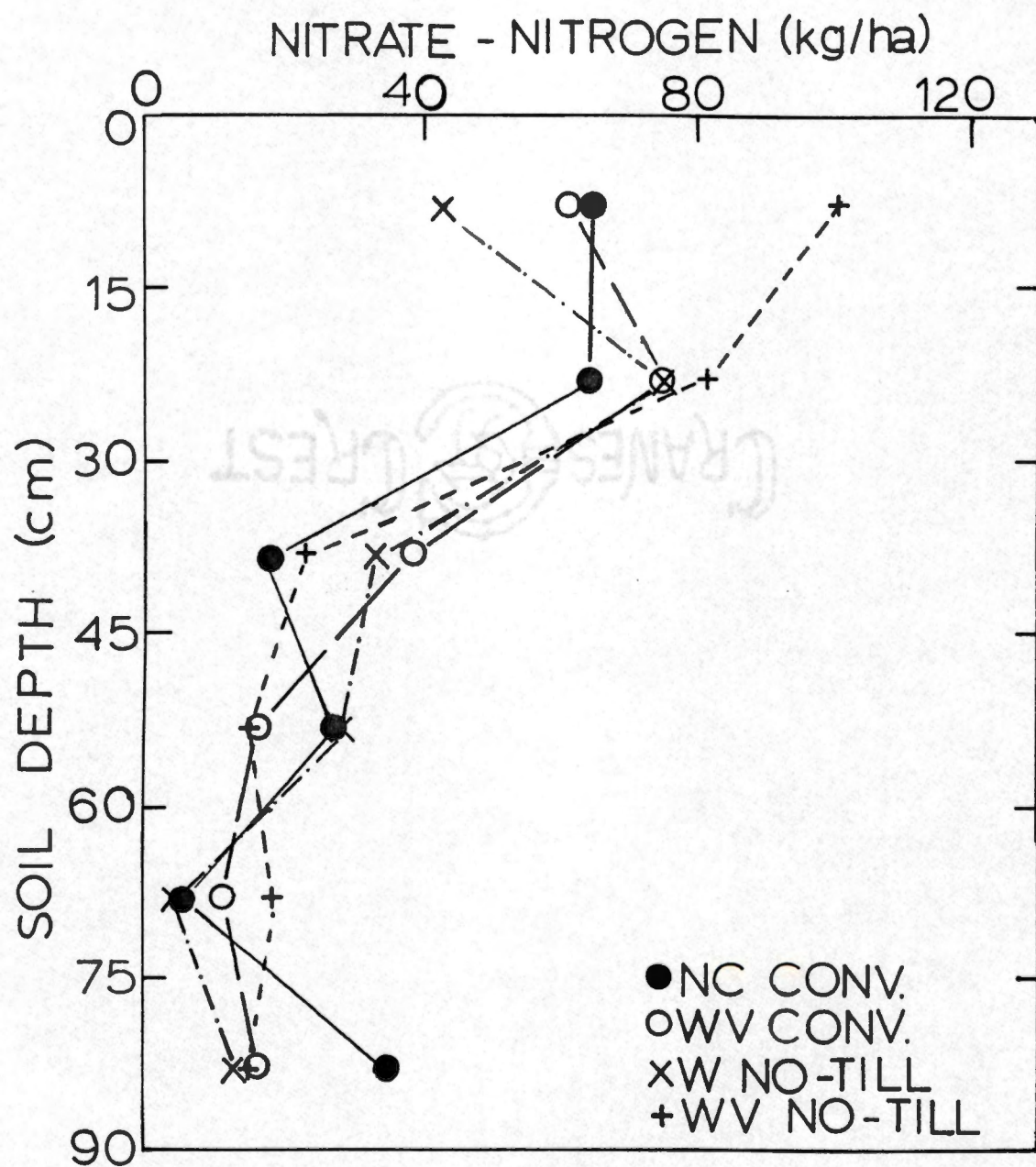


Figure 40. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on June 11, 1981.

tilled plots at the 56 and 112 kg N/ha rates had occurred. The absence of nitrogen mineralization in any of the treatments at the 0 kg N/ha rate may indicate that an application of inorganic nitrogen fertilizer may stimulate microorganisms to begin mineralizing nitrogen from organic sources such as vetch residue. Wheat-vetch with no-tillage plots showed signs of nitrogen mineralization at the 112 and 168 kg N/ha rates.

Nitrogen mineralization in the wv no-till plots was not observed until a later date in 1980. Since rainfall was more frequent and abundant in late May and early June in 1981 than late May and early June in 1980 (Tables 1 and 3, pages 22 and 34), the mulches in the no-tillage plots were wetter in 1981 resulting in possibly higher residue decomposition rates in no-tillage plots in 1981. This would cause higher mineralization or immobilization rates depending on the carbon-nitrogen ratio of the residue. The samples taken from the wheat no-tillage plots at the 112 kg N/ha rate on June 11, 1981 were much lower in nitrate-nitrogen than the other treatments indicating immobilization had occurred in the wheat no-tillage plots on analysis of the June 3, 1980 samples, but not nearly as much as in the June 11, 1981 samples.

Nitrate-nitrogen levels in samples taken on August 5, 1981 were below 15 kg N/ha in each 15 cm soil layer to the 90 cm depth at all the nitrogen rates (Figures 41-44). The contrast between the nitrate-nitrogen levels observed from the August 1980 sampling and August 1981 sampling is dramatic. In 1981 the corn matured later and was able to extract soil nitrogen as it was mineralized. In 1980 low water contents prevented the corn from extracting soil nitrogen present as applied fertilizer or that being mineralized from organic sources.

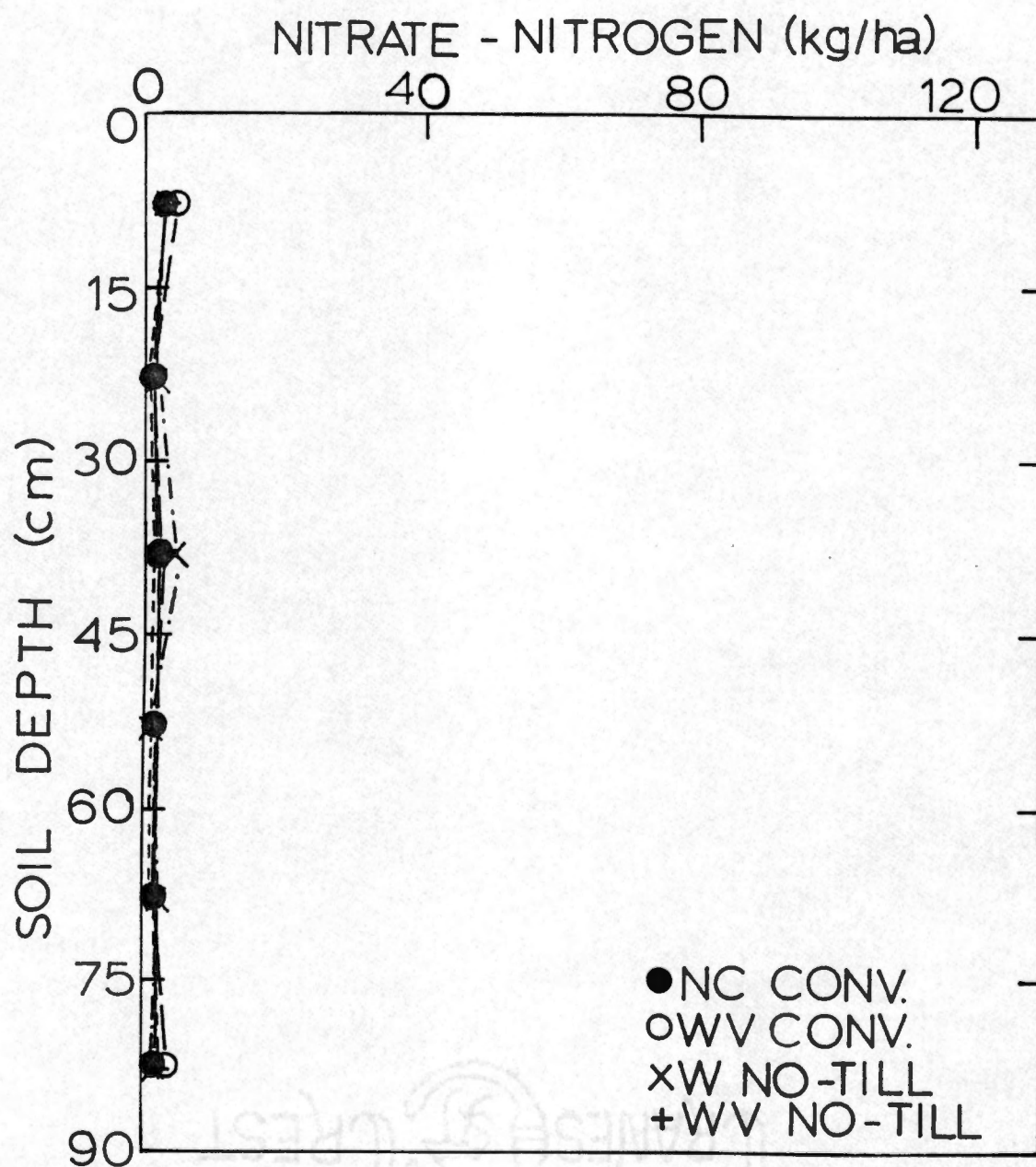


Figure 41. Soil nitrate-nitrogen distributions at the 0 kg N/ha rate on August 5, 1981.

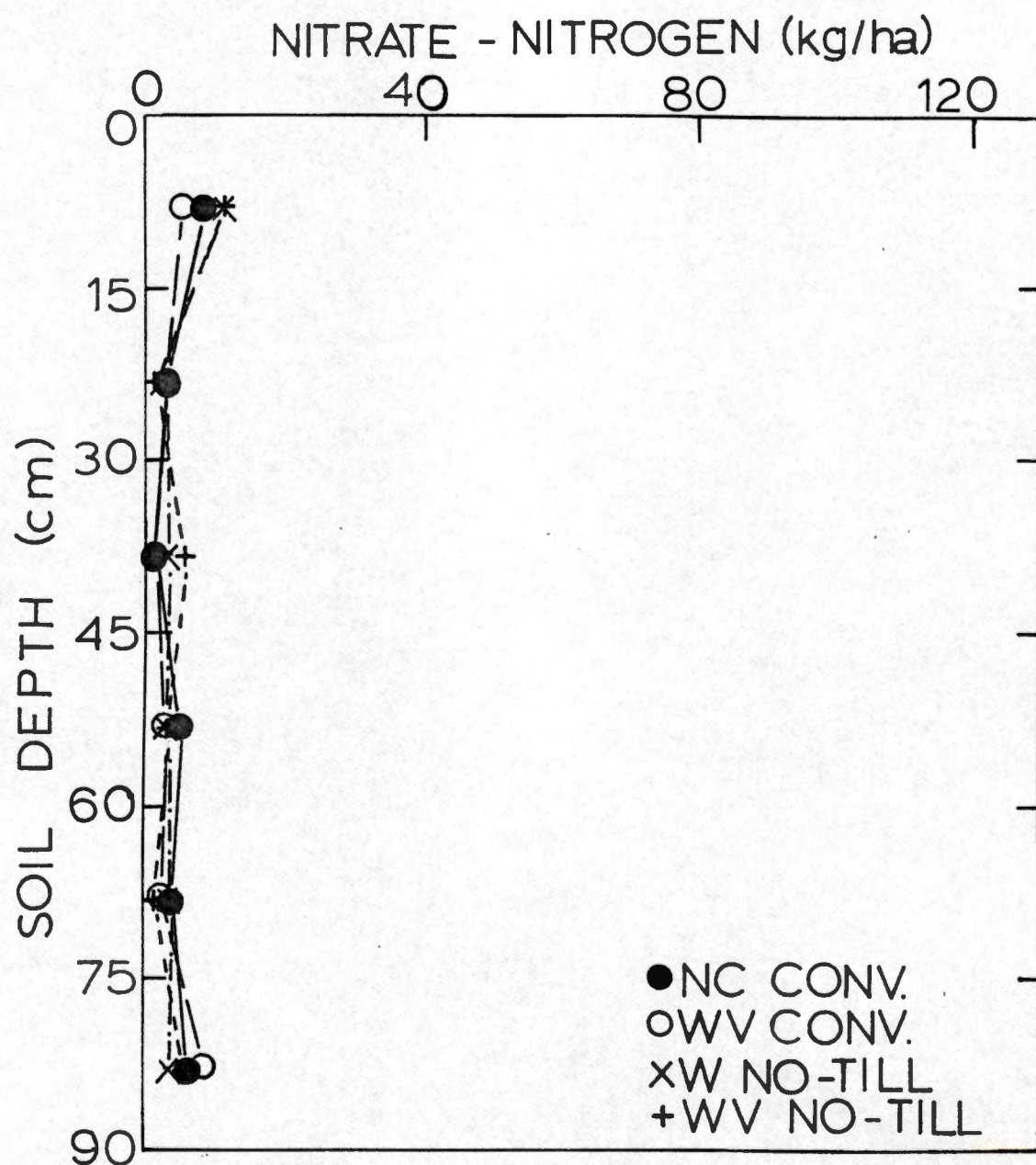


Figure 42. Soil nitrate-nitrogen distributions at the 56 kg N/ha rate on August 5, 1981.

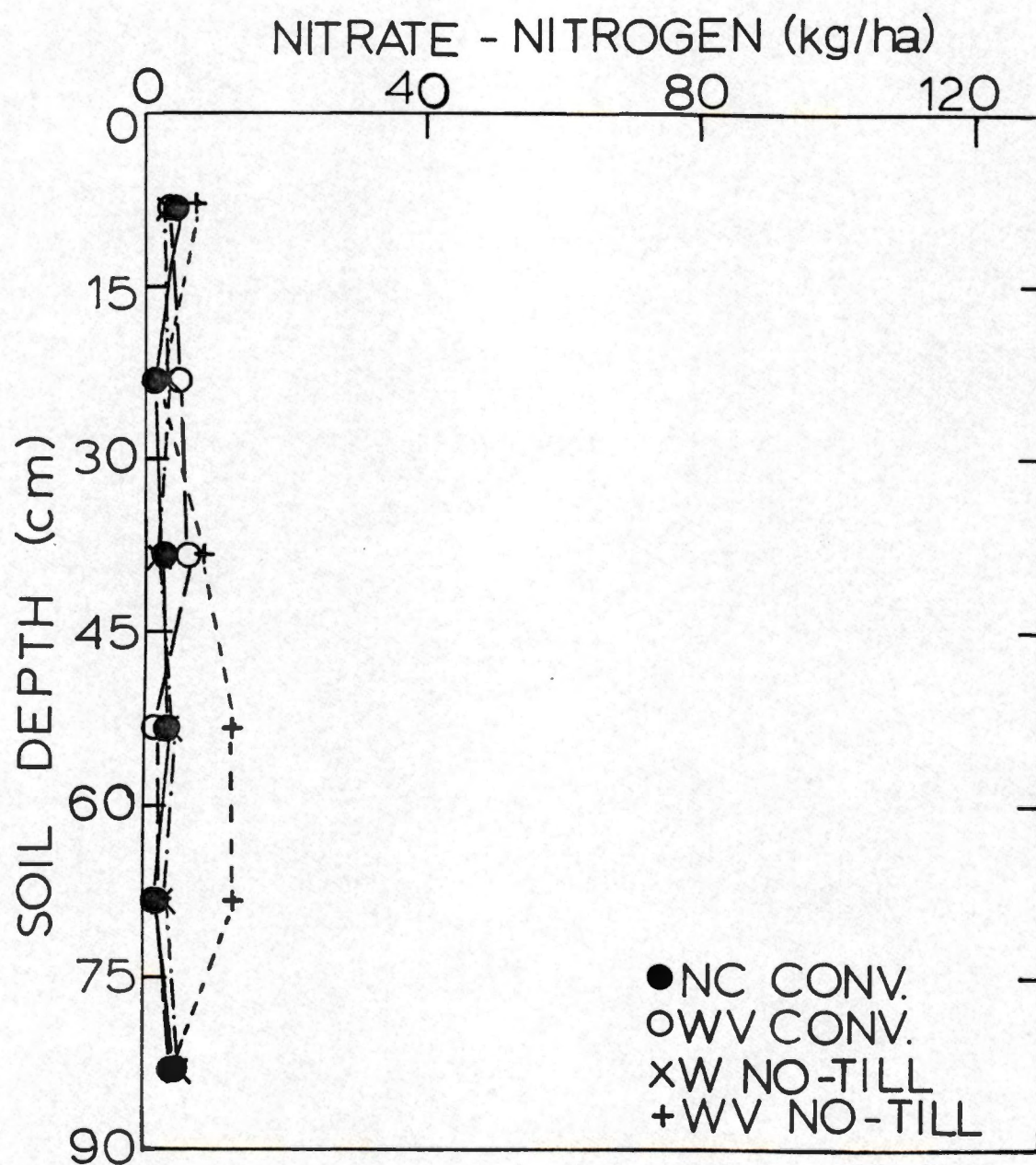


Figure 43. Soil nitrate-nitrogen distributions at the 112 kg N/ha rate on August 5, 1981.

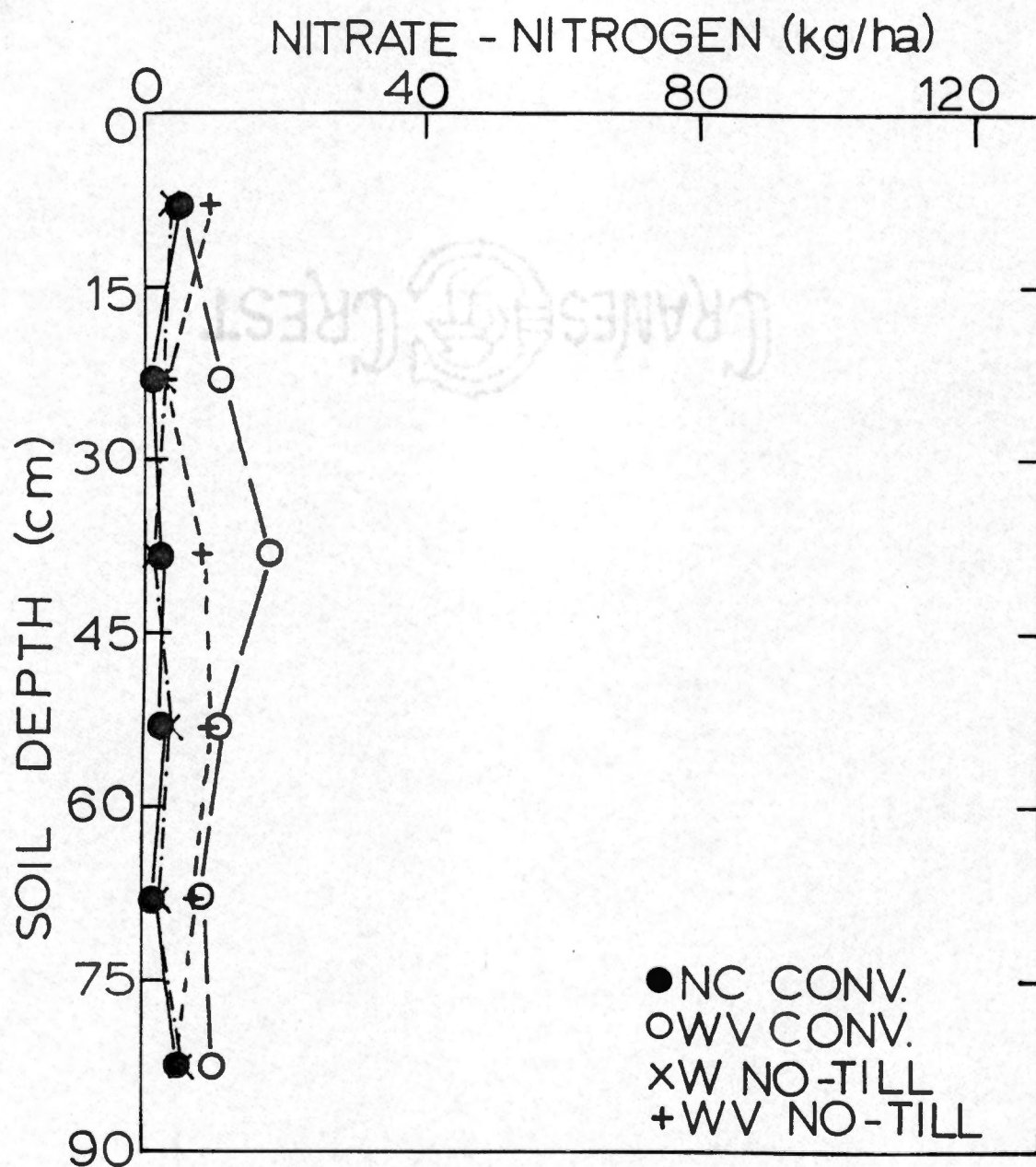


Figure 44. Soil nitrate-nitrogen distributions at the 168 kg N/ha rate on August 5, 1981.

Soil pH

Measurements of soil pH in the treatments indicated that differences were minor. Soil pH values from samples collected in the top 0-2 cm soil layer ranged from 6.00 to 6.89 (Appendix B). Since the test had been conducted only one year at the sampling date the cumulative amount of nitrogen fertilizer applied was still too small to cause a noticeable lowering of soil pH in the plots receiving high nitrogen rates.

Soil Organic Matter

The percent soil organic matter in the surface soil layers were not significantly different in the four cover crop-tillage treatments (Table 4). The results reported by Blevins et al. (1977), Lal (1976), and Moschler et al. (1971) indicated that the surface soil layer in no-tillage systems have higher levels of organic matter than the surface layer in conventionally tilled systems. The results from this research project indicate that after one growing season the percent of soil organic matter in the surface soil layers was not significantly different in no-tillage systems as compared to conventionally tilled systems.

Corn Grain Yields

As shown in Table 5, in 1980 corn grain yields did not respond significantly to more nitrogen fertilizer than 112 kg N/ha. Lack of soil water, not soil nitrogen, prevented the corn from attaining higher yields at the 112 kg N/ha rate. Across the test the conventional tillage plots yielded higher than the no-tillage plots. The analysis

Table 4. Mean Percent Soil Organic Matter Under All Treatments When the Experiment was Initiated and the Mean Percent Soil Organic Matter from Three Replications at the Beginning of the Second Growing Season.

Treatment	Nitrogen rate kg N/ha	Soil Depth (cm)			
		0-5	5-10	10-15	15-30
Background ¹		1.28	1.19	0.77	0.41
nc conv	0	1.12	0.84	0.60	0.43
wv conv	0	1.21	0.91	0.79	0.40
wv no-till	0	1.27	0.90	0.72	0.41
w no-till	0	1.08	0.91	0.80	0.42
nc conv	56	1.33	1.09	0.84	0.51
wv conv	56	1.18	1.09	0.64	0.33
wv no-till	56	1.30	0.98	0.85	0.42
w no-till	56	1.44	0.98	0.71	0.48
nc conv	112	1.20	0.88	0.59	0.39
wv conv	112	1.46	0.99	0.65	0.55
wv no-till	112	1.40	0.98	0.54	0.42
w no-till	112	1.21	0.86	0.62	0.48
nc conv	168	1.21	1.04	0.75	0.38
wv conv	168	0.98	1.07	0.71	0.44
wv no-till	168	1.58	0.76	0.70	0.39
w no-till	168	1.32	0.95	0.68	0.44

¹The mean percent soil organic matter from all the treatments when the test was first initiated.

Table 5. Corn Grain Yields in 1980 and 1981 from the Cover Crop-Tillage Treatments at the Milan Experiment Station, Milan, Tennessee.

Treatment	1980			1981		
	0	56	112	0	56	112
	kg N/ha			kg N/ha		
	-----kg/ha-----			-----kg/ha-----		
no conv	941f	3574c	4389ab	2006k	4514h	6897bc
wv conv	1818de	4264abc	4577ab	3511i	5768ef	6897bc
wv no-till	815e	2508d	3574c	2947ij	5079gh	6082de
w no-till	627f	1756f	4076bc	1254l	2633j	5204fg
			3887bc			6270cde
						7148ab
						7587a
						6521bcd
						6270cde

of variance is shown in Appendix C. Nitrogen rates, cover crop-tillage, and the interaction of the two factors were all highly significant. This agrees with the water content differences between tillage treatments observed 1980. This also agrees with the differences in dry matter accumulation between the tillage systems observed by John Lyle (personal communication). The corn grain yields as a whole were not significantly increased when the nitrogen rate was increased from 112 kg N/ha to 168 kg N/ha. The nitrogen mineralized during the decomposition of the vetch residues in plots with wheat-vetch cover crops had an important impact on corn grain yields at the 0 and 56 kg N/ha rates (Table 5). The higher yields in the wv conv plots as compared to wv no-till plots suggests that incorporation of residues helps nitrogen mineralization. The wv conv tillage treatments had higher yields than the nc conv treatments at the 0 and 56 kg N/ha rate. The wheat-vetch no-tillage treatments had higher yields than the w no-till treatments at the 0 and 56 kg N/ha rate. These relationships were not present at the 112 and 168 kg N/ha rates, but at those rates, soil water, not nitrogen, was the most limiting factor. Wheat no-tillage was consistently lower in yield at the 0 and 56 kg N/ha rate suggesting that nitrogen was being immobilized during the decomposition of the wheat residue.

Corn grain yields in 1981 were consistently higher than the 1980 corn yields (Table 5). The higher rainfall in 1981 resulted in a significant increase in corn grain yield when the nitrogen rate was increased from 112 kg N/ha to 168 kg N/ha. Wheat-vetch with conventional tillage yielded highest as compared to the other treatments.

This indicates that nitrogen released during the decomposition of the vetch residue had a positive impact on yield. Since the wv conv treatment was significantly higher in yield than the wv no-till treatment at all nitrogen rates except the 0 kg N/ha rate, incorporation of residues must effect their rates of decomposition. The yield results agree with the water content differences observed in August 5, 1981 samples (Figures 9-12, pages 37-40). The higher nitrate-nitrogen levels found in the wv conv treatments on June 11 and August 5, 1981 (Figs. 37-44, pp. 67-70 and 72-75) indicate that the higher grain yields resulted from higher nitrogen availability in the wv conv plots which resulted from the decomposition of the vetch residue. Across the nitrogen rates there was no significant difference in yield between the nc conv treatments and the wv no-till treatment. The analysis of variance table (Appendix D) indicates that there was an interaction between nitrogen rates and cover crop-tillage treatments. The wv no-till plots yielded higher than the nc conv treatments at the 0 and 56 kg N/ha rates, but the results were reversed at the 112 and 168 kg N/ha rates. This suggests that the 0 and 56 kg N/ha rates nitrogen released during the decomposition of the vetch in the wv no-till plots was more critical than the other factors related to tillage which came into play at the 112 and 168 kg N/ha rates. In 1981, the wheat no-tillage treatments yielded consistently lower as compared to the other treatments indicating that the immobilization of nitrogen which occurred during the decomposition of the wheat residue had a negative impact on the treatment yields. The nitrogen immobilization was observed in the lower nitrate-nitrogen levels as compared to the other treatments in samples

collected on June 11 and August 5, 1981 (Figures 37-44, pages 67-70 and 72-75).



CHAPTER V

CONCLUSION

Conclusive statements concerning the effects that different cover crops, tillage systems and nitrogen rates have on corn are difficult to make from the 1980 growing season. Soil water became limiting late in the season causing corn yields to be unresponsive to nitrogen fertilizer application rates above 112 kg N/ha. Lower soil water contents were observed in conventional tillage treatments as compared to no-tillage treatments at the 112 kg N/ha and 168 N/ha rates. At these nitrogen rates soil water differences were not attributed to higher transpiration rates in conventional planted plots but rather to the presence of mulches in the no-tillage treatments which would have reduced the loss of rainfall water to runoff and surface soil water to evaporation.

In 1980 at the 0 and 56 kg N/ha fertilizer applications the wv conv plots outyielded the other treatments. The differences in yield that were observed between the wv conv and nc conv plots were due to nitrogen mineralized during the decomposition of the wheat-vetch residue in the wheat-vetch plots. The higher growth rates in the wv conv plots resulted in higher transpiration rates which were evidents in the lower soil water contents present for this treatment. The nitrogen mineralized during the decomposition of the wheat-vetch residues was evident in the higher soil nitrate-nitrogen levels found under wv conv plots. Nitrogen mineralization was not high enough in

wv no-till plots to cause the corn yields in those plots to equal the yields from the wheat-vetch or no cover conventional tillage plots. This suggests that incorporation of vetch residues into the soil is necessary to get maximum N mineralization. Lower yields, and lower nitrogen levels in the wheat no-tillage plots as compared to the other treatments, indicated that nitrogen was being lost and probably immobilized during the decomposition of the wheat residues.

In 1981 increases in nitrogen fertilization up to 168 kg N/ha resulted in higher corn grain yield over the 112 kg N/ha rate. Plots with wv conv yielded higher within all nitrogen rates except nc conv at 112 kg N/ha where yields were equal between wv conv and nc conv. Higher nitrate-nitrogen levels in soil samples from wv conv plots as compared to nitrate-nitrogen levels under other treatments indicate that the higher yields in the wheat-vetch conventional tillage plots resulted from nitrogen mineralized during the decomposition of the wheat-vetch residue. Corn yields were higher in wv no-till plots at the 0 and 56 kg N/ha rates as compared to no cover conventional tillage at same rate. Results from nitrate-nitrogen levels in the plots indicate that more nitrogen was present under the wv no-till plots. This was attributed to greater nitrogen mineralization in the wv no-till plots resulting from the decomposition of the vetch residue. The nc conv plots outyielded the wv no-till plots at the 112 and 168 kg N/ha rates indicating that the additional nitrogen provided by the vetch was not as important at high nitrogen rates as other factors related to tillage. Immobilization of nitrogen during the decomposition of the wheat in the w no-till was evident in the lower nitrate nitrogen levels

in the soil samples and lower yields as compared to the other treatments. Wheat-vetch plots receiving conventional tillage had higher grain yield and nitrate-nitrogen levels in their soil samples than the wheat-vetch plots receiving no-tillage. This indicates that tillage aids in the decomposition of leguminous cover crop residues resulting in greater nitrogen mineralization. At the 168 kg N/ha rate yields were not equal between no-tilled and conventionally tilled plots. Results indicated that soil water was not the limiting factor in no-tillage plots. This research indicates that more nitrogen is needed for no-tillage corn to reach yields attainable with conventional tillage.

Differences in soil pH between the treatments after the second year of the test were minor. Soil organic matter levels were higher in the 0-5 cm soil layer in no-tillage plots as compared to the conventional tillage plots.



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LITERATURE CITED

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APPENDICES

APPENDIX A

Table 6. Soil Water Distributions Expressed as Percent by Soil Volume from Various Sampling Dates in 1980 and 1981 at Milan, Tennessee.

Sampling Date	kg N/ha Rate	Cover Crop/ Tillage	Soil Depth (cm)					
			0-15	15-30	30-45	45-60	60-75	75-90
May 21, 1980	0	wv conv	34	37	38	39	36	37
	0	wv no-till	34	37	38	38	38	39
	0	w no-till	33	36	39	39	38	38
	0	nc conv	32	37	37	37	37	38
	56	wv conv	33	37	38	38	38	38
	56	wv no-till	34	37	37	37	36	36
	56	w no-till	31	38	40	38	38	37
	56	nc conv	33	38	38	38	38	38
	112	wv conv	31	36	36	38	36	37
	112	wv no-till	33	34	35	36	36	38
	112	w no-till	34	36	37	38	38	38
	112	nc conv	31	36	37	38	39	38
	168	wv conv	33	35	36	36	37	38
	168	wv no-till	34	35	36	36	37	37
	168	w no-till	34	39	40	41	40	40
	168	nc conv	31	36	38	38	38	37
June 3, 1980	0	wv conv	28	37	38	38	38	38
	0	wv no-till	29	33	38	38	40	40
	0	w no-till	28	35	40	40	40	40
	0	nc conv	28	35	38	37	39	39
	56	wv conv	29	35	37	37	38	37
	56	wv no-till	29	34	38	39	38	40
	56	w no-till	29	35	38	39	40	40
	56	nc conv	26	33	37	38	38	39
	112	wv conv	28	36	36	39	39	39
	112	wv no-till	26	35	37	38	39	40
	112	w no-till	26	37	38	39	38	38
	112	nc conv	28	35	37	36	36	40
	168	wv conv	27	36	37	39	39	40
	168	wv no-till	27	35	38	39	38	40
	168	w no-till	28	36	38	38	39	38
	168	nc conv	27	34	37	38	39	40
June 11, 1981	0	wv conv	32	33	38	40	39	40
	0	wv no-till	37	36	38	40	40	40
	0	w no-till	35	38	38	40	39	39
	0	nc conv	34	36	39	40	41	42
	56	wv conv	35	31	38	39	39	40
	56	wv no-till	34	35	38	39	39	39
	56	w no-till	35	34	38	39	39	38
	56	nc conv	33	33	37	38	39	38
	112	wv conv	29	31	37	39	38	39
	112	wv no-till	33	32	36	39	39	39
	112	w no-till	35	34	38	38	40	37
	112	nc conv	36	34	38	39	39	40
	168	wv conv	40	39	39	39	39	40
	168	wv no-till	36	38	39	39	39	38
	168	w no-till	37	37	38	38	39	36
	168	nc conv	37	39	39	38	39	39

APPENDIX B

Table 7. The Mean pH Values Under All the Treatments When the Experiment Was Initiated and Mean pH Values Under the Various Treatments Prior to the Second Growing Season.

Sampling Date	kg N/ha Rate	Cover Crop/ Tillage	Soil Depth (cm)			
			0-2	2-4	4-6	6-12
April 2, 1981	0	wv conv	6.63	6.52	6.09	5.33
	0	wv no-till	6.74	6.54	6.04	5.10
	0	w no-till	6.84	6.57	5.87	5.27
	0	nc conv	6.85	5.08	5.89	5.16
	56	wv conv	6.63	6.36	5.68	5.45
	56	wv no-till	6.52	6.13	5.71	5.05
	56	w no-till	6.84	6.66	5.83	5.39
	56	nc conv	6.84	6.29	5.74	4.99
	112	wv conv	6.76	6.58	5.96	5.42
	112	wv no-till	6.76	6.50	5.90	6.40
	112	w no-till	6.89	6.34	5.90	5.18
	112	nc conv	6.57	6.09	5.68	5.28
	168	wv conv	5.00	6.46	6.00	5.01
	168	wv no-till	5.78	6.45	5.60	5.25
	168	w no-till	5.33	6.54	5.97	5.14
	168	nc corn	6.83	6.25	5.92	5.15
Background ¹			6.44	6.23	5.72	5.07

¹The mean pH values from all the treatments when the test was first initiated.

APPENDIX C

Table 8. Analysis of Variance Summaries for 1980 Corn Grain Yields.

	D.F.	S.S.	M.S.	F
Total	63	36529.5		
Replications	3	177.2	59.1	1.3
Nitrogen rate	3	27414.1	9139.0	206.5**
Cover crop	3	4354.6	1451.5	22.6**
Error a	9	398.3	44.3	0.8
Replication by cover crop	9	822.9	91.4	1.7
Nitrogen by cover	9	1932.6	214.7	3.3**
Replication by nitrogen by cover crop	35	2249.7	64.3	

**Significant at 1% level of probability.

Cover crop tillage across nitrogen rates	Nitrogen rates across tillage kg N/ha	
41.2 b wheat no-till	17.0 c	0
42.8 b wheat-vetch no-till	48.2 b	56
55.7 a no-cover conventional	66.1 a	112
60.6 a wheat-vetch conventional	69.0 a	168

Values followed by the same letter are not significantly different at the 5% level of probability according to Duncans New Multiple Range Test.

APPENDIX D

Table 9. Analysis of Variance Summaries for 1981 Corn Grain Yields.

Source	D.F.	S.S.	M.S.	F
Total	63	63177.7		
Replications	3	67.7	22.6	0.3
Nitrogen rate	3	49329.3	16442.1	195.3**
Cover crop	3	9162.7	3054.2	76.0**
Error a	9	757.8	84.2	2.5
Replication by cover crop	9	545.1	60.6	1.8
Nitrogen by cover crop	27	2413.7	268.2	6.7**
Replication by nitrogen by cover crop	27	901.4	33.4	1.0
Error b	36	1446.5	40.2	

**Significant at 1% level of probability

Cover crop tillage across nitrogen rates	Nitrogen rates across tillage kg N/ha	
61.3 c wheat no-till	38.5 d	0
82.1 b no cover conventional	71.7 c	56
82.1 b wheat vetch no-till	100.2 b	112
94.7 a wheat vetch conventional	109.8 a	168

Values followed by the same letter are not significantly different at the 5% level of probability according to Duncan's New Multiple Range Test.

VITA

William E. Stevens was born in Memphis, Tennessee on November 26, 1957. He was reared on a farm near Oakland, Tennessee. Following his graduation from Fayette Academy in June 1975, he enrolled at Union University in September. He became interested in soil science through a part-time job at the West Tennessee Agricultural Experiment Station and decided to pursue that field in graduate school after completing a Bachelor of Science degree in Biology at Union University in June 1979. In September 1979, he enrolled in a Master's degree program in Plant and Soil Science at The University of Tennessee, Knoxville.

Mr. Stevens is a member of Alpha Tau Omega. He has accepted an offer to farm with his father, Ralph P. Stevens, after he graduates.

He is married to the former Leeta J. Thomason of Jackson, Tennessee.