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Title: Effects of Differential Irrigation and Tillage-Induced Soil Compaction on Bush Green Beans and Sweet Corn.

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Five experiments were conducted in 1986, 1987, and 1988 on Chehalis silty clay loam, in two locations at the Oregon State University Vegetable Research Farm, Corvallis. 'Jubilee' sweet corn and 'Oregon 91G' bush green beans were grown in location 1, on rototilled, conventional moldboard plowed, and wet plowed treatments for the three years of study. In 1987 and 1988, location 2 was added and a fall subsoil with spring conventional tillage treatment included. A water gradient was established using the line source irrigation system that was installed perpendicularly to the soil treatments with crop rows parallel to the line source. Six water levels were used to determine if applied water would overcome the effects of tillage-induced soil compaction. A penetrometer was used to evaluate tillage-induced soil compaction. In L1Y3 (location 1, year 3) and in L2Y2 penetrometer readings were significantly higher for the rototill treatment compared to other treatments.

Pod yields of beans from the rototill and wet plow treatments in L1Y2 were significantly lower than from the

conventional treatment. Yield from the wet plow treatment exceeded all other treatments in L2Y1 and L2Y2. The rototill treatment reduced husked ear yield and ear length of sweet corn in L1Y2 and in L1Y3, yield and ear number were were significantly lower than for other treatments. Husked ear yield and ear number were lowest for the rototill treatment in L2Y2 while yield and ear number were higher for the wet plow treatment than other treatments.

As total applied water was reduced yield and biomass were significantly lower for beans and corn than at the highest levels of applied water. Detrimental effects of tillage-induced soil compaction were overcome in the two highest water levels for sweet corn and green beans except for wet plow and rototill treatment bean yields in L1Y3 compared to the conventional tillage treatment yields.

EFFECTS OF DIFFERENTIAL IRRIGATION AND TILLAGE-INDUCED SOIL COMPACTION ON BUSH GREEN BEANS AND SWEET CORN

by

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EFFECTS OF DIFFERENTIAL IRRIGATION AND TILLAGE-INDUCED SOIL COMPACTION ON BUSH GREEN BEANS AND SWEET CORN

CHAPTER 1

INTRODUCTION

Soil compaction can be beneficial or detrimental, depending on the degree of compaction. Soil is compacted over most crop seed after planting to provide good seed-soil contact for optimum germination conditions. Compaction of soils under certain conditions has been reported to benefit corn production (Boone et al. 1987). As soil strength is increased through compaction, resistance to root penetration increases and can reduce bean yields (Tu and Tan, 1988). Plant roots exert forces to penetrate the soil profile in the range of 900 to 1300 kilopascals (Barley, 1968). Zimmerman and Kardos (1961) reported that roots of most plant species do not penetrate soils with strengths greater than 3000 kilopascals except through low strength cracks.

Tilled agricultural lands are compacted by various means. Wheel pressure and/or tillage in conjunction with high soil water content are considered to be the primary causes of soil compaction (Davies et al. 1973). The use of various tillage systems and implements result in characteristic environments for root growth and water retention and subsequently affect the growth and yield of vegetable crops. Significantly higher yields of husked sweet corn were produced with moldboard plowing than with strip tillage and yields of strip tillage were significantly higher than no till (Peterson, Mack, and Cuenca, 1985).

Sufficient applied water is critical for maximum green bean and sweet corn yield and quality. Water deficit adversely affect green bean crop growth, yield, and pod quality (Carolus and Schleusener, 1950). Reduced numbers of good ears and ear length in sweet corn often result from insufficient applied water (Braunworth and Mack, 1987).

These studies were conducted to investigate the effects of tillage treatments and total applied water on various yield components of bush green beans and sweet corn. Tillage treatments included rototill, wet plow, conventional (moldboard plowed and disked; the rotara was used to prepare the final seedbed), and fall subsoiling followed by spring conventional tillage. The line source irrigation method was used to provide six levels of applied water. Bush green bean pod yield, sieve size distribution, and in most cases, total above ground biomass production were evaluated. Yield components evaluated for sweet corn were good husked ear yield, ear length, ear number, and, in some cases plant height and total above ground biomass.

CHAPTER 2

LITERATURE REVIEW

I. Introduction

Conventional methods of vegetable crop production include soil tillage to provide a suitable seed bed and favorable environment for root growth, and an adequate water supply. Tillage disrupts structural components of the soil so that root penetration, aeration, moisture retention, and nutrient availability are altered. Depending on the tillage methods and water content of the soil during tillage, effects can be advantageous or detrimental to soil tilth. Excessive tillage or tillage with wet soil conditions will cause the soil to become compacted. Thus tillage practices can affect the growth and subsequent yield of vegetable crops.

Adequate water will not overcome all of the effects of soil compaction but will help crops achieve maximum productivity. Water deficits can reduce plant vigor, root and shoot growth, yield and or product quality. Excess water in poorly drained soils can result in stunting or death of crop plants.

Topics covered in this literature review include; 1) tillage effects on soil compaction; 2) soil water availability as affected by tillage and soil compaction; 3) root growth responses to soil compaction; 4) response of green beans and sweet corn to soil compaction and irrigation; and 5) techniques for overcoming or modifying soil compaction.

II. Tillage Effects on Soil Compaction.

When soils are tilled, soil aggregation normally declines, soils become more compact, and the total volume of pore space decreases. There is a shift in the pore size distribution as number of larger pore sizes diminish and number of smaller pore sizes increase (Hillel 1982). A decrease in pore size could be desirable for sandy soils because the soil water retention would increase. But an increase in small pore spaces in fine textured soils is generally detrimental. Any change in structure of the soil is likely to alter the amount of pore space and likewise the weight per unit volume or the soil density. Soil density can be an indicator of potential root penetration, water infiltration and movement, and land use management.

A. Causes of soil compaction.

Agricultural lands are compacted by various means. Wheel pressure and/or tillage in conjunction with high soil moisture content is considered to be the primary source of soil compaction (Davies et al., 1973; Flocker et al., 1966; Hillel, 1982; Swain, 1975; and Voorhees et al., 1986). The general consensus is that with increased axle load or increased soil water, compaction will be more severe (Voorhees, 1986; Stone, 1987). Others are convinced that soil compaction is also affected by tillage. Moldboard plowing followed by seedbed preparation with a power harrow, strip tillage, and no-till tillage treatments affected the yield of Jubilee sweet corn (Peterson, et al. 1985). Moldboard plowing produced significantly higher yields of husked sweet corn than did strip tillage, and strip tillage yields were significantly higher than no-till yields. Squash yields were reduced from tillage induced compaction (Smittle and Williamson, 1977; Smittle and Threadgill, 1982). Yield reductions resulting from soil compaction were reported by Stone (1988) for broad beans, cabbage, leeks, and red beets. Douglas and McKyes (1983) conducted experiments using moldboard plow, chissel plow, and subsoil techniques to evaluate tillage system effects on traffic induced soil compaction. Chissel and moldboard plowing were more effective in loosening the plow layer of the soil and yields were higher than for the subsoil treatment. Subsoiling loosened the soil to a greater depth and yields were increased but the top 10 cm of soil remained more compact than for the other treatments. When irrigation or rain water impact compacted soil the resulting surface layer becomes even more dense and crusting occurs. Crusting of the soil surface after planting restricts seedling emergence (Hegarty and Royle, 1978; Heydecker, 1962).

B. Measuring soil density.

Historically, the accepted procedure for estimating soil density and soil compaction involved bulk density estimates. Bulk density estimates are obtained by carefully collecting known volumes of "undisturbed" soil, oven drying the sample, and dividing the oven dry sample weight by the volume (Blake. 1965.). The resulting information is expressed in grams per cubic centimeter and can be used to estimate porosity. Undisturbed samples are difficult to extract because a container must be forced into the soil to retrieve the sample. The procedure is very time consuming, and many samples are required to reliably estimate the true bulk density. Bulk density sampling methods can also be disruptive to plot conditions.

The penetrometer is becoming a more popular tool for measuring soil strength. Penetrometers vary from simple hand held versions to sophisticated hydraulic machines equipped with electronic pressure sensors and computers for data storage. The principle remains the same since all employ the use of a rod that is forced through the soil profile and the amount of resistance encountered is measured. Force per unit area required to press the cone through the soil, expressed in pascals, is an index of soil strength called the "cone index" (ASAE standard: ASAE S313.2, 1986). The penetrometer is a useful tool for determining the force required to penetrate the soil profile and can be an indicator of pressures encountered by growing roots although roots grow through areas of least resistance rather than in a constant direction. Advantages to the penetrometer method are that measurements can be taken rapidly, the data are readily available, and measurements are taken under field conditions encountered by the crop. Soil water, structure, porosity, and mineralogy are determining factors when measuring resistance.

III. Soil Water Availability as Related to Tillage and Soil Compaction.

A. Soil water supply and crop demand.

Plant response to available soil water depends primarily on the evaporative demand which is affected by leaf surface area, temperature, humidity, and wind speed. The plant remains turgid if the water uptake from the roots balances the water requirements of the plant. If the rate of water uptake falls below the transpiration rate the plant begins to loose water and eventually wilts. Mid-day wilting may occur regardless of available soil water because the roots can not extract soil water fast enough to meet the high plant demand. In addition to the evaporative demand, the plant water uptake is governed by the root-soil interaction, soil aeration, and available soil water. Movement of water through the soil depends on pore size distribution (structure) and soil texture. As suction is applied to the soil either by artificial means or by the demands of a plant the pattern of water release is called the soil-moisture release curve. The amount of water that is held by the soil at low levels of suction is primarily due to the capillary effect and the pore size distribution, so is highly dependent on the soil structure. The amount of water retained at higher levels of suction is less influenced by capillarity and pore size but is due to adsorption. These adsorptive forces that resist the removal of soil water are influenced by the soil texture and the specific surface of the soil material. Basically, during drier soil conditions more plant energy is required to extract water from the soil. Larger pores retain more water than small pores and that water is released more readily. The smaller the pore size the more suction is required to remove the stored water. Compacted soils have smaller pores than noncompacted soils, thus the available water storing capacity is reduced and more suction is required to remove the retained water (Hillel, 1982).

B. Monitoring soil water.

The neutron scattering technique of monitoring soil water was developed in the 1950's and is an efficient and reliable method (Holmes, 1956; van Bavel, 1963). Aluminum access tubes are installed into bored holes in the soil.

The tubes allow access for the neutron emitting probe. Neutrons are randomly emitted and bounce about through the soil but are slowed by impacting water molecules. A scaler or rate meter detects the slow moving neutrons and stores the count of slow moving neutrons returning to the probe. The concentration of water molecules in the soil determines the deflection frequency and when the slowed neutrons are counted the soil moisture can be calculated.

IV. Response of Green Beans and Sweet Corn to Soil Compaction and Irrigation.

Proper irrigation scheduling enables growers to apply adequate water to the soil and avoid overwatering with loss of water to deep percolation. The amount of available water and uptake influences yield and quality of vegetable crops.

Accurate irrigation scheduling reduces irrigation costs and insures meeting sweet corn yield goals (Braunworth and Mack, 1987b). During water stress corn leaves will curl and bean leaves become darker green (Andrew and Weis, 1974; and Keller and Carlson, 1967). Reduced numbers of good sweet corn ears and ear length result from insufficient applied water (Braunworth and Mack, 1987a). Green bean crop growth, yield, and quality are adversely affected by inadequate water (Carlos and Schleusener, 1950; Kramer, 1963; and MacKay and Eaves, 1962). Reduced bush green bean pod length, percentage of set pods, and number of seeds per pod, and increased fiber content of pods and weight per seed result from low irrigation levels (Bonanno and Mack, 1983a). The growth stage of crop plants is critical when avoiding crop water stress. Begg and Turner (1976) emphasize crop growth and yield reduction when water stress occurs during flowering and fruit development. For corn, yields are reduced if insufficient water is available at tassel emergence, silking and pollination completion (Dale and Shaw, 1965; Denmead and Shaw, 1960; Downey, 1971; Herrero and Johnson, 1981; Robins and Domingo, 1953; Stanberry et al., 1963; and Stewart et al., 1975).

Impeded plant root growth can reduce nutrient and water uptake. Smittle et al. (1981) reported that sweet corn yields were higher for moldboard plowed treatments than for subsoiling and even less for the disked treatment. Differences in plant growth resulting from tillage treatment were attributed to variations in nutrient uptake. Water deficits usually cause marked reductions in total leaf area (Begg and Turner, 1976). Gates (1964) reported premature senescence of older leaves and reduced total plant leaf area under water stress conditions. Bonanno and Mack (1983b) showed that total plant dry weight, total leaf dry weight, total leaf area, average area per leaf, and number of leaves per plant were reduced by water deficits in two green bean cultivars.

V. Soil Compaction Effects on Root Growth.

Increasing soil compaction causes an increase in the percentage of small pore spaces, soil strength increases, resulting in more resistance to root growth. Barley (1962) examined the ability of corn roots to overcome resistance due to soil strength. When cells differentiated and elongated while the root apex was compressed, root length increased continuously, but at a declining rate with increased mechanical stress. Taylor and Ratliff (1969) showed that the rate of peanut root elongation decreased as the soil strength around the root increased. As roots grow into the soil they occupy space that was previously occupied by soil pore space and soil particles. Soil particles are displaced and the soil directly around the root is compacted resulting in increased density. Greacen et al. (1968) showed increases in soil bulk density next to the root of 1.6 and 1.7 g/cm3 compared to an initial level of 1.5 g/cm3. As roots grow and the pressures increase, the interaction between soil resistance and root force can become critical and restrict growth. The maximum force exerted by growing roots usually ranges from 9 to 13 bars (900 and 1300 kiloPascals) (Barley, 1968; Taylor and Ratliff, 1969a; Eavis et al. , 1969). Roots of most species do not penetrate soils with strengths greater than 30 bars (3000 kiloPascals) except by following low strength cracks or fissures (Taylor and Burnett. 1964., Zimmerman and Kardos. 1961.). Water content of the soil has a direct effect on soil strength. Taylor and Gardner (1963) found that at a specific bulk density root penetration decreased as water content decreased. They indicated that soil strength, and not bulk density or any other physical factor of soil, controlled the penetration of cotton tap roots through soil cores. As the water content decreased the soil strength increased reducing root penetration. Tu and Tan (1987) in a greenhouse study, reported reduced root growth and biomass production by white beans due to compacted soil. Tillage experiments were conducted by Hilfiker and Lowery (1988) on silt loam and sandy loam soils to determine the effects of tillage systems on sweet corn root growth. By summing corn root lengths, they determined that the root density from 0-50 cm was greatest for the moldboard plowed treatment and equal for ridge tillage, chisel plow, and no-till treatments. Taylor et al. (1966) found that penetrometer resistance of four soils was changed by varying the water content and root penetration was inversely related to penetrometer resistance. If root growth is restricted, the volume of soil utilized for uptake of water and nutrients is reduced and crop growth can be adversely affected.

Soil compaction may also reduce the rate of gas exchange. Eavis et al. (1969) reduced soil oxygen content from 21% to 3% and found the root pressure of cotton was reduced from 11 bars to 5 bars, respectively. Huck (1970) reported an abrupt stop in root elongation when the soil oxygen supply was reduced. In severe cases of soil compaction where pore size and water content restricts or curtails gas exchange, the anaerobic condition of the soil would prohibit root growth. Boone et al. (1987) concluded that yield reductions resulting from severe compaction were caused by insufficient soil aeration.

VI. Overcoming or Modifying Soil Compaction.

A. Water availability and tillage.

The old saying "An ounce of prevention is worth a pound of cure" holds true in the battle with soil compaction. As American agriculture shifted to larger farms the equipment also became larger and more powerful and the potential for compaction from wheel traffic increased. For certain tillage treatments it may be advantageous to use dual or flotation-wheeled tractors to reduce the force applied per unit area. Smaller tractors may be more profitable than larger ones over time. Performing tillage operations at a reasonable level of soil water is an important preventative practice. Subsoiling may help break up compacted layers of soil and improve aeration and soil water utilization. Vapraskas and Minor (1986) found that subsoiling increased root penetration below a dense soil layer that had been compacted by plow tillage. Busscher et al. (1988) also reported that subsoiling effectively reduced subsoil compaction and allowed better root penetration although yields were not significantly affected. Weatherly and Dane (1979) found that subsoiling permitted greater corn root penetration and roots extracted more water from the 50-110 cm depth. Russet Burbank potatoes were deeper rooted and subsequently more drought tolerant when sandy soil was subsoiled, while subsoiling of the loam soil was of little benefit (Miller and Martin, 1986). Flocker et al. (1966) reported that in terms of plant responses, fall plowing reduced the harmful effects of compaction more than other methods tested including spring plowing. They suggest that fall plowing a compacted soil when it is very dry might increase the exposure of the soil to effective wet-dry cycling, in addition to mixing the normally horizontal orientation of the platy fragments. The use of herbicides can reduce trips over the soil for cultivation (Hillel, 1982). The reincorporation of organic materials including crop residues and cover crops stimulated microbial activity and aided in the preservation of soil structure (Rosenberg, 1964). Free et al. (1947) reported that soils with higher organic contents do not compact as much as soils with lower organic percentages. Four soils with varying organic matter were used. A Honeoye silt loam with 4.1 percent organic matter and the same soil with 2.8 percent were compacted to 1.47 and 1.60 grams per cubic centimeter respectively. If good soil tilth can be maintained or improved power imput for tillage will be reduced.

B. Fertilizer use.

The use of fertilizer may partially overcome the effects of compacted soil. Smittle and Williamson (1977) reported that the detrimental effects of soil compaction could be partially overcome in cucumber production by increasing the rate of nitrogen fertilizer. However the effects of compaction on cucumber yield could not be completely alleviated even with a 3-fold increase in N fertilization. Timm and Flocker (1966) found that the adverse effects of compaction on potato yield and quality could not be overcome by additional fertilizer or water. Sufficient applied water can reduce the soil strength and allow more root penetration.

CHAPTER 3

EFFECTS OF DIFFERENTIAL IRRIGATION AND TILLAGE-INDUCED SOIL COMPACTION ON BUSH GREEN BEANS

Abstract

Bush green beans, 'Oregon 91G', were grown at the Oregon State University Vegetable Research Farm, in location 1, with three soil tillage treatments: rototill, conventional moldboard plow, and wet plow treatments in 1986, 1987, and 1988. In 1987 and 1988 a fall subsoiling treatment followed by spring conventional tillage was included in location 2 in addition to the above three tillage treatments. The line source method of irrigation was used to provide six differential irrigation levels to the tillage treatments. Total pod yield and pod sieve size distribution were compared among tillage treatments and levels of total applied water in the five experiments. In all cases except location 1 year 1 (L1Y1), the effects of tillage treatment and total applied water on total above ground biomass were also evaluated.

Yields of pods did not differ significantly among tillage treatments in L1Y1 or in L1Y3. Pod yield from the rototill and wet plow treatments in L1Y2 were significantly lower than the conventional treatment. Yield of the wet plow treatment was significantly higher than other treatments for all water levels in L2Y1, but conventional

and rototill treatment yields did not differ. Yield of pods from the wet plow treatment was higher than the other three tillage treatments in L2Y2.

Total above ground biomass production in L1Y1, L1Y2, L1Y3, and L2Y1 was similar among the soil tillage treatments. Biomass production was higher for the wet plow treatment than for the other three tillage treatments in L2Y2.

Total applied water was highly significant in determining pod yield and total above ground biomass. Pod yield, pod number per plant, and above ground biomass diminished with declining applied water.

Cone index values (CIV) in soil from the conventional and rototill treatments were significantly lower than the wet plow treatment in L1Y1. Cone index values were similar for all tillage treatments in L1Y2. Significantly higher CIV were recorded from the rototill treatment in L1Y3 compared to the other tillage treatments. There were no significant differences in CIV between treatments in L2Y1. The CIV for the rototill treatment were significantly higher than for the other three tillage treatments in L2Y2.

Introduction

Planting schedules for commercial vegetable production can force producers to till when soil conditions are wetter than desired. Wheel pressure and/or tillage in conjunction with high soil moisture content are considered the primary causes of soil compaction (Davies et al., 1973; Flocker et al., 1966; Hillel, 1982; Swain, 1975; and Voorhees et al., 1986). Soil compaction is normally considered to be detrimental to vegetable production, but may be benificial under certain conditions (Boone et al., 1987). Various tillage systems and implements result in characteristic environments for root growth and water retention and affect the growth and yield of vegetable crops accordingly.

Very little soil tillage or soil compaction research has been conducted with green beans. Tu and Tan (1987) grew two white bean cultivars in pots with compacted and non-compacted soil of densities 1.3 and 1.6 g cm^{-3}, respectively. Compaction significantly reduced total biomass production, plant height, and total leaf area. The two bean cultivars appeared to differ in susceptibility to soil compaction independent of root rot symptoms. Smittle et al. (1981) reported that sweet corn yields were higher for moldboard plowed treatments than for subsoiled and even greater for disked treatments.

Adequate water is critical for maximum green bean yield and quality; water stress adversely affects crop growth, yield, and quality (Carolus and Schleusener, 1950). Gates

(1964) reported premature senescence of older bean leaves and reduced total plant leaf area under water stress conditions. Bonanno and Mack (1983) showed that total plant dry weight, total leaf dry weight, total leaf area, average area per leaf, and numbers of leaves per plant were reduced by water deficits in two green bean cultivars. Insufficient soil water can impede root growth. Soil strength increases as soil water content declines (Taylor and Gardner, 1963).

The studies reported here were conducted to: (1) evaluate the effects of various soil tillage treatments on soil compaction and resultant effects on growth and yield of bush green beans and (2) determine if various amounts of applied water differentially affect crop responses to tillage treatments.

Materials and Methods

Five experiments were conducted in three consecutive years (1986, 1987, 1988) on Chehalis silty clay loam soil (Mesic Cumulic Ultic Haploxeroll) at the Oregon State University Vegetable Research Farm, Corvallis. Tillage treatments were randomly assigned in three blocks, in two locations, and tillage treatment blocks were bisected perpendicularly with a line source irrigation system to provide a water gradient. In location 1, 11.6 by 42.4 meter plots received the same three tillage treatments for three consecutive years. These consisted of conventional tillage, wet plowing, and rototilling. Conventional and wet plowed plots were moldboard plowed, disked, and finished with a rotara that stirs the soil with vertical rotating 25 cm spikes. Two blocks in location 2 with 12.2 by 41.9 meter plots received the above three tillage treatments for two consecutive years (1987, 1988) plus an additional treatment of conventional tillage in the spring after fall subsoiling. Tillage penetration for rototilling, plowing, and subsoiling was 15, 33, and 43 cm respectively. Field soil water was closely monitored and tillage was performed when tillage profile volumetric soil water was near 22% for rototilling, 25% for conventional treatments, and 29% for wet plowing. Soil water percent (volumetric basis) was approximately 40% at field capacity. During seedbed preparation there was no variation of tractor size or number of passes over the plots regardless of treatment.

In each experiment soil resistance was measured by penetrometer to document the severity of soil compaction within ten days after crop emergence. The only exception to this occurred during the first year of location one (L1Y1) when penetrometer measurements were taken on September 4, 1986. The 2.54 cm diameter penetrometer cone with 45 degree angle tip was hydraulically forced into the soil at six locations per soil tillage treatment. Eighteen force measurements were recorded at each 2.54 cm depth to a depth of 45.7 cm.

Fonofos was pre-plant incorporated into the seedbed for garden symphylan control. Plots were planted with a four row planter with 90 cm between rows 'Oregon 91G', the standard commercial bush green bean cultivar, was used. Eptc was pre-plant incorporated in 1986 and plots were oversprayed post-plant, pre-emergence with dinoseb for weed control. For the two following years eptc and trifluralin were incorporated pre-plant followed by a post-plant, pre-emergence application of metolachlor was made. After planting and herbicide applications were complete all plots were uniformly watered to promote even germination and emergence. Final stands averaged 271,948 plants/per hectare. Planting dates for location 1 were June 17, 1986, May 28, 1987, and June 22, 1988. Location 2 planting dates were May 14, 1987, and June 21, 1988. Fertilizer was banded at planting at a rate of 56, 74, and 47 kilograms of N, P, and K per hectare, respectively.

Bean pod maturity was determined from rows with maximum water and all plots were harvested when the average percentages of pod sieve size grades 1-4 were 66, 50, and 73 in 1986, 1987, and 1988 respectively. Harvest dates for location 1 were August 19, 1986, August 7, 1987, and August 29, 1988. Location 2 plots were harvested on July 22, 1987 and August 31, 1988. Harvest area for all years was 7.24 meters of row at six applied water levels for each replication and treatment (Table 1). Total above ground biomass was determined from ten-plant samples on the above harvest dates except for location 1 in 1986 when data were not collected.

Irrigation water was applied weekly, consistent with the line source experimental design. Tillage treatment plots were arranged perpendicularly to, and were bisected by the irrigation line while bean rows were parallel to the irrigation line. Bisected tillage treatments provided two replications in the single block in location 1 and four replications in the two blocks in location 2. Irrigating during windless conditions combined with the nozzle type and spacing of the line source, provided a water distribution profile resembling a bell-shaped curve. A water gradient was formed as applied water diminished with distance from the irrigation source. Hanks et al. 1976, and Cuenca et al. 1978, explained the line source experimental design in greater detail. At each irrigation application the amounts of applied water were measured by catch cans at various distances from the line source and resulted in six established irrigation levels or treatments (Table 1). Neutron probe access tubes were placed in rows throughout the water gradient. A neutron meter (Model 503DR Hydroprobe Moisture Depth Gauge, Campbell Pacific Nuclear Corp., Panchico, CA.) was used to measure soil water content at 30, 60, and 90 cm. Measurements were taken weekly the day before and the day after an irrigation application.

The linear multiple regression technique was used to fit models for soil water, pod yield, total above ground biomass, and penetrometer resistance. Tillage treatments were represented in models as indicator variable numbers. The conventional plot was used as the model constant when all other tillage treatments and total applied water levels were compared. Simple and interactive models were analyzed, then the extra sum of squares f test determined the most effective model.

Results

Total green bean pod yield and pod sieve size distribution were compared among tillage and irrigation treatments in the five experiments. In all cases except location 1 year 1 (L1Y1), the effects of tillage treatments and total applied water on total above ground biomass were also evaluated. Yields were not significantly different among tillage treatments in L1Y1 and L1Y3 (Table 2; Fig. 1,3). Yields from the rototill and wet plow treatments were significantly lower than from the conventional treatment in L1Y2 (Table 2; Fig. 2). Yield of the wet plow treatment in L2Y1 was significantly higher than other tillage treatments for all water levels, but yields from the conventional tilled and rototilled treatments were similar (Table 2; Fig. 4). Yield of pods from the wet plow treatment in L2Y2 were higher than for the other three soil tillage treatments (Table 2; Fig. 5). In most cases, the yields from the rototill treatment declined in comparison to conventional tillage when the same tillage treatment was applied to the same plots for more than one season.

Total biomass production for the rototill, wet plow, and conventional tillage treatments did not significantly differ for any of the treatments in location 1 for the three years of study although total pod yields from the tillage treatments varied significantly (Table 3). Biomass was significantly higher in the wet plow treatment than in conventional tillage in L2Y2 and this treatment also produced the highest pod yield. Total applied water significantly influenced total above ground biomass production. Biomass production decreased as applied water declined in all tillage treatments (Table 3). The number of pods per plant decreased more rapidly than did the average weight per plant indicating increased stress.

Cone index values (CIV) from penetrometer readings of soil in the wet plow treatment in L1Y1 were significantly higher than for the conventional and rototill treatments at 12.7 cm and the conventional treatment CIV was lower than other treatments at 25.4 cm. (Fig. 7). The higher CIV in the wet plow treatment were depth dependent and the plow layer to a depth of 25 centimeters was most affected by the tillage. In L1Y2 there were no significant differences in CIV among tillage treatments (Fig. 8). CIV for the rototill treatment were significantly higher than other soil treatments in L1Y3 (Fig. 9). No significant differences in CIV among treatments were evident in L2Y1 (Fig. 10). Large CIV in L2Y2 were highly significant for the rototill treatment compared to conventional tillage, other treatments did not vary significantly except the wet plow treatment CIV was higher than conventional and subsoil/conventional CIV at 12.7 cm and lower than the rototill treatment CIV (Fig. 11).

Total applied water significantly affected yields in all years and locations (Table 4; Fig. 6). Yields at the lowest levels of applied water (1-5 cm) ranged from about 1 to 4 mt/ha while at the highest levels of applied water (17-

24 cm) yields were 9 to 11 mt/ha. Yields decreased rapidly when applied water was below the 15-16 cm range. Total applied water affected the pod sieve size distribution. The percentage of pods of sieve sizes 1-4 usually increased as the total applied water decreased (Table 4).

Soil water data were not taken in L1Y1. Conventional tilled plots in L1Y2 retained significantly less soil water than did the wet plow treatment (Table 5). In areas where 14.8, 10.5, and 3.2 cm of water were applied, L1Y3 conventional tilled plots maintained a significantly higher average percent water content than did other treatments at the 60 and 90 cm depths (Table 6). In L2Y1, the average soil water for the subsoil treatment was significantly (01) lower throughout the sample profile than all other treatments (Table 7). There were no significant differences in soil water for the various treatments in L2Y2 (Table 8).

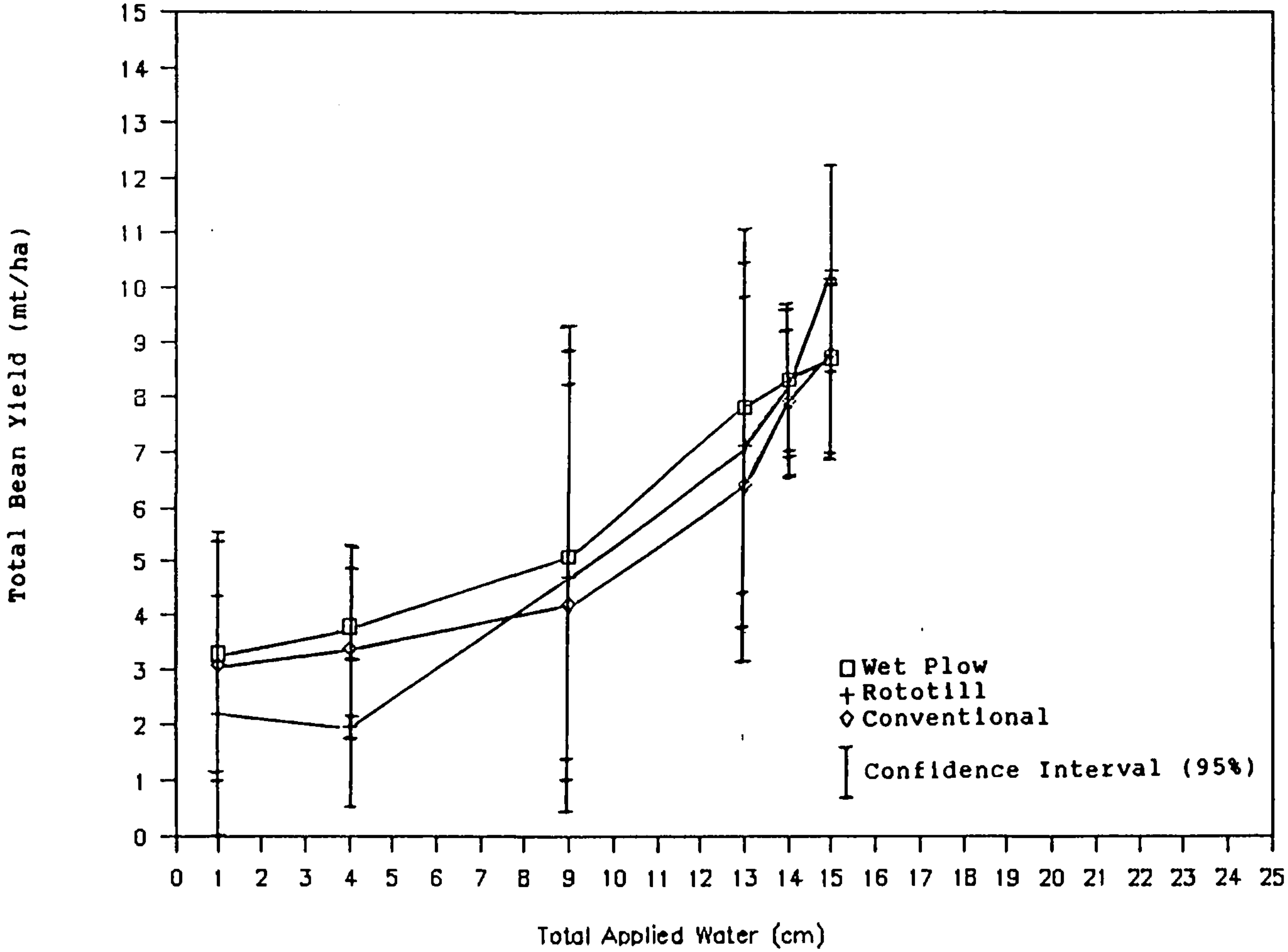

Figure 1. Effects of tillage treatments and applied water on pod yield of bush green beans, L1Y1 (1986).

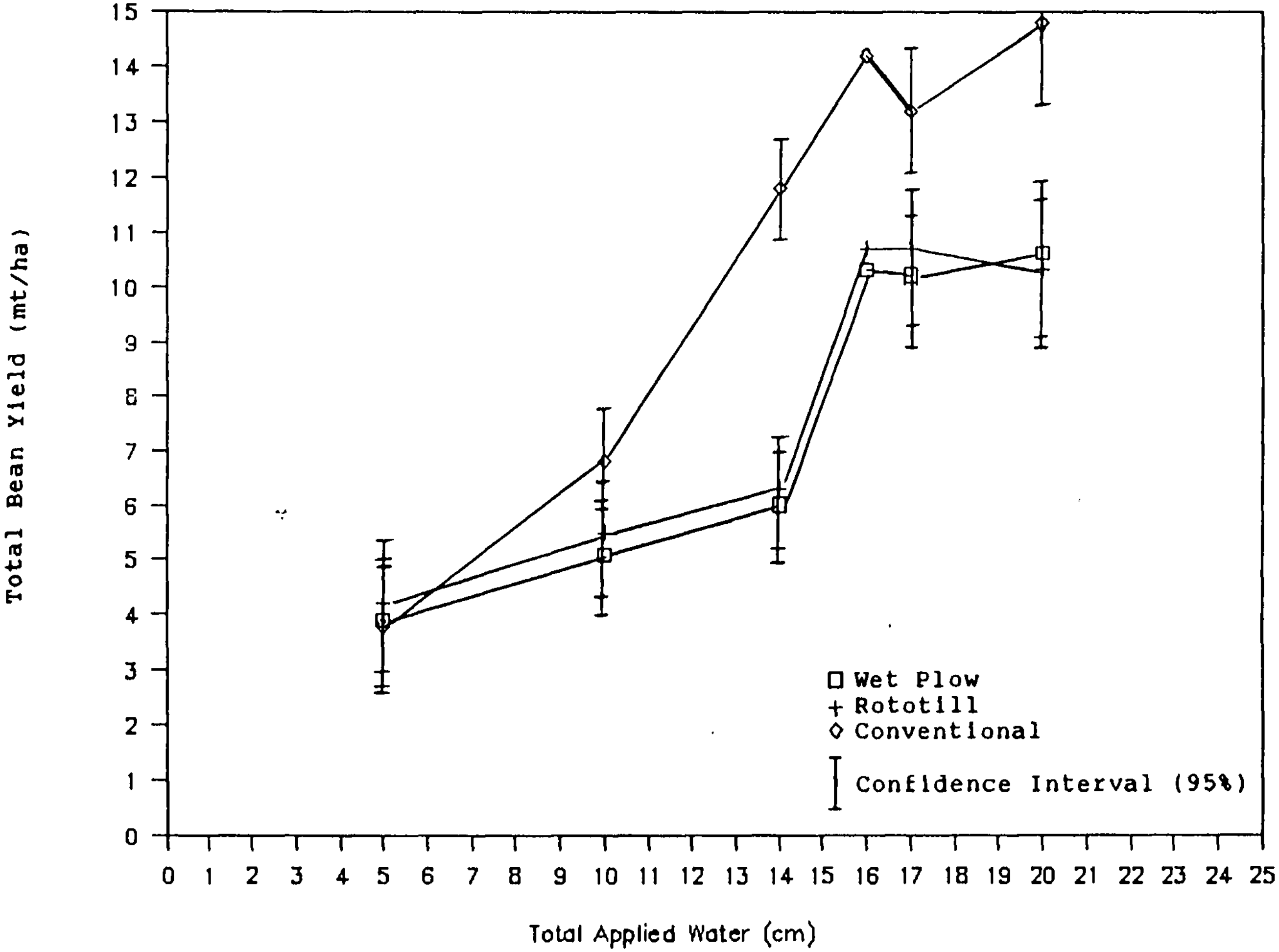

Figure 2. Effects of tillage treatments and applied water on pod yield of bush green beans, L1Y2 (1987)

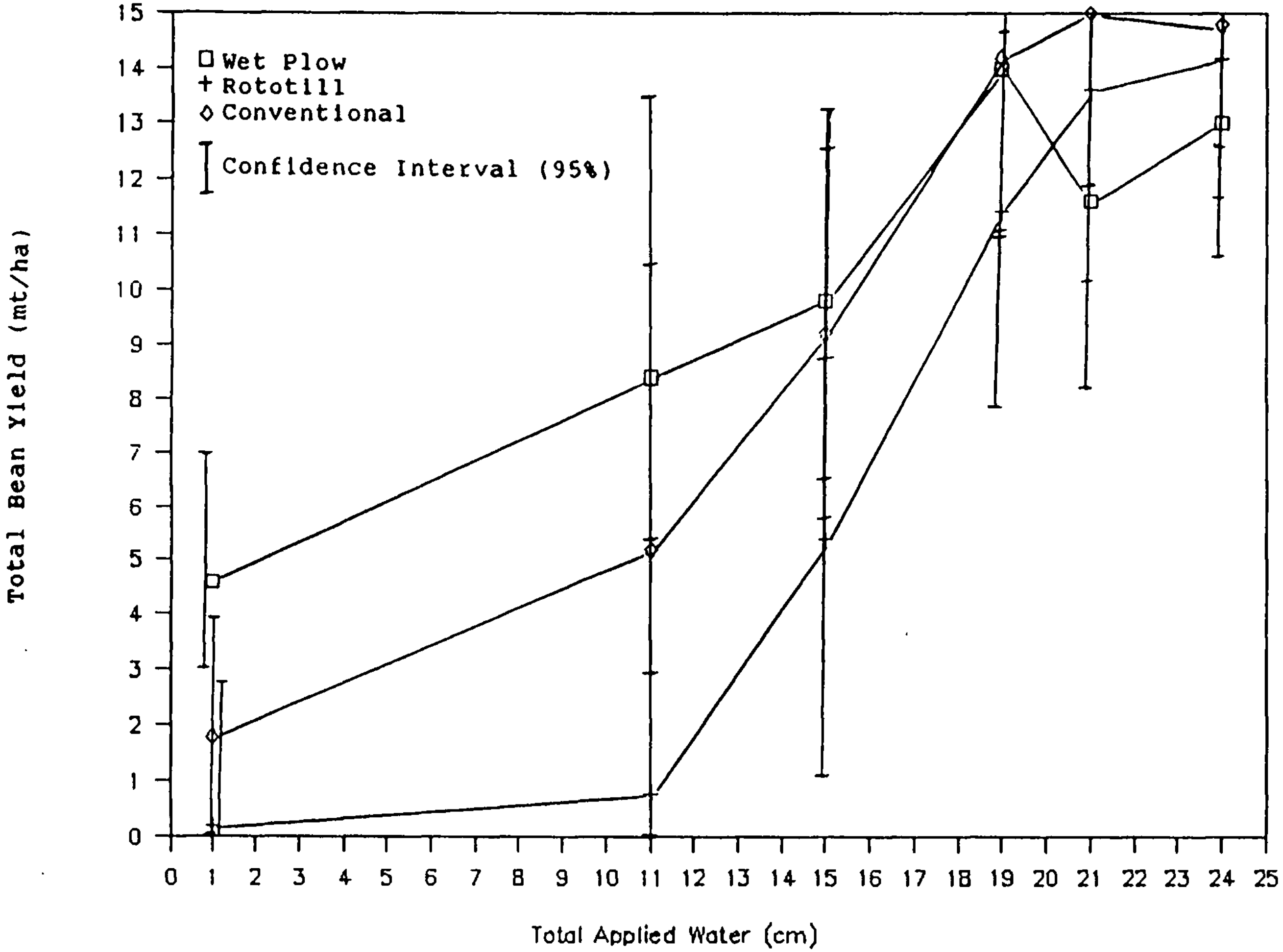

Figure 3. Effects of tillage treatments and applied water on pod yield of bush green beans, L1Y3 (1988)

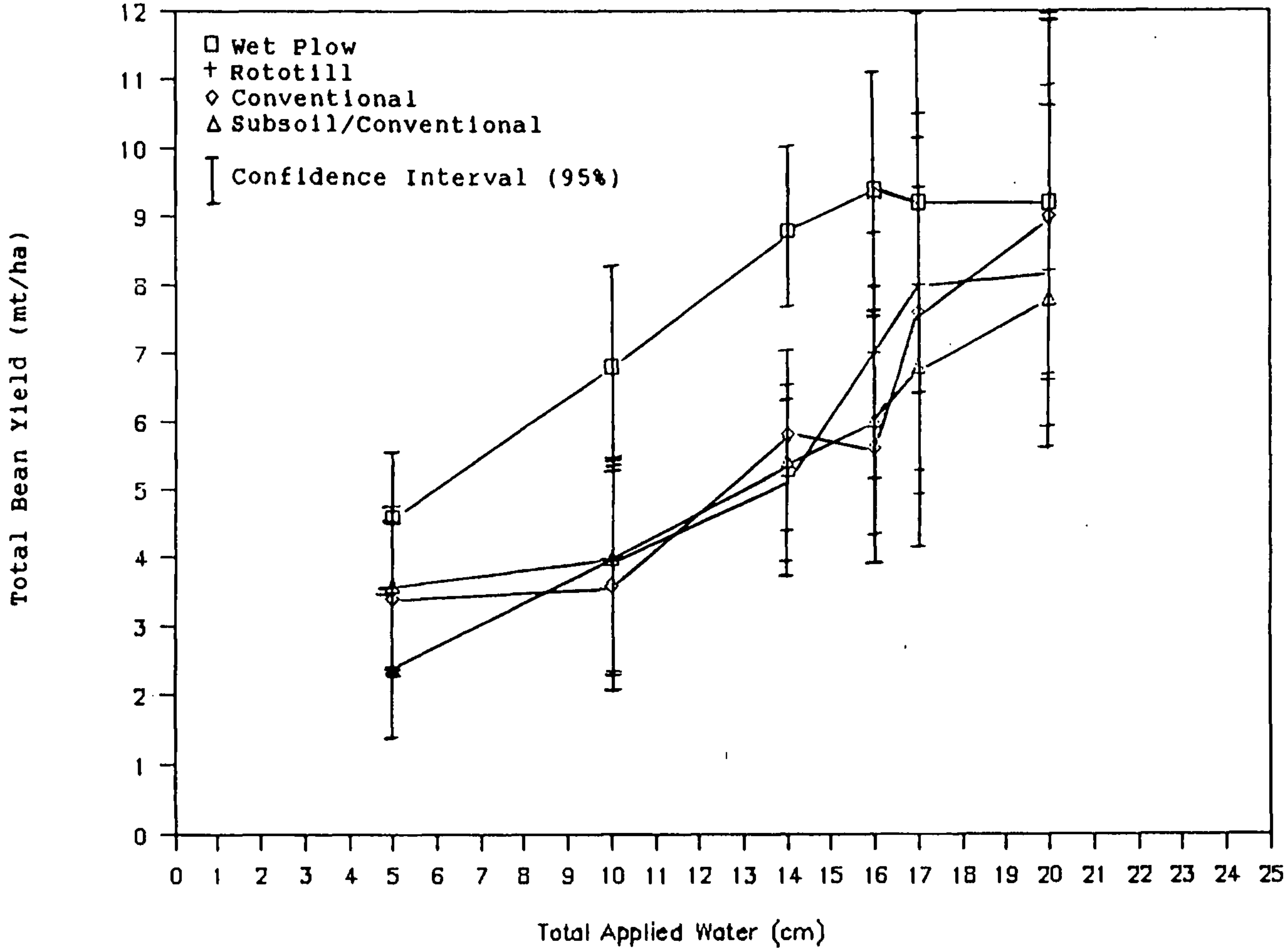

Figure 4. Effects of tillage treatments and applied water on pod yield of bush green beans, L2Y1 (1987)

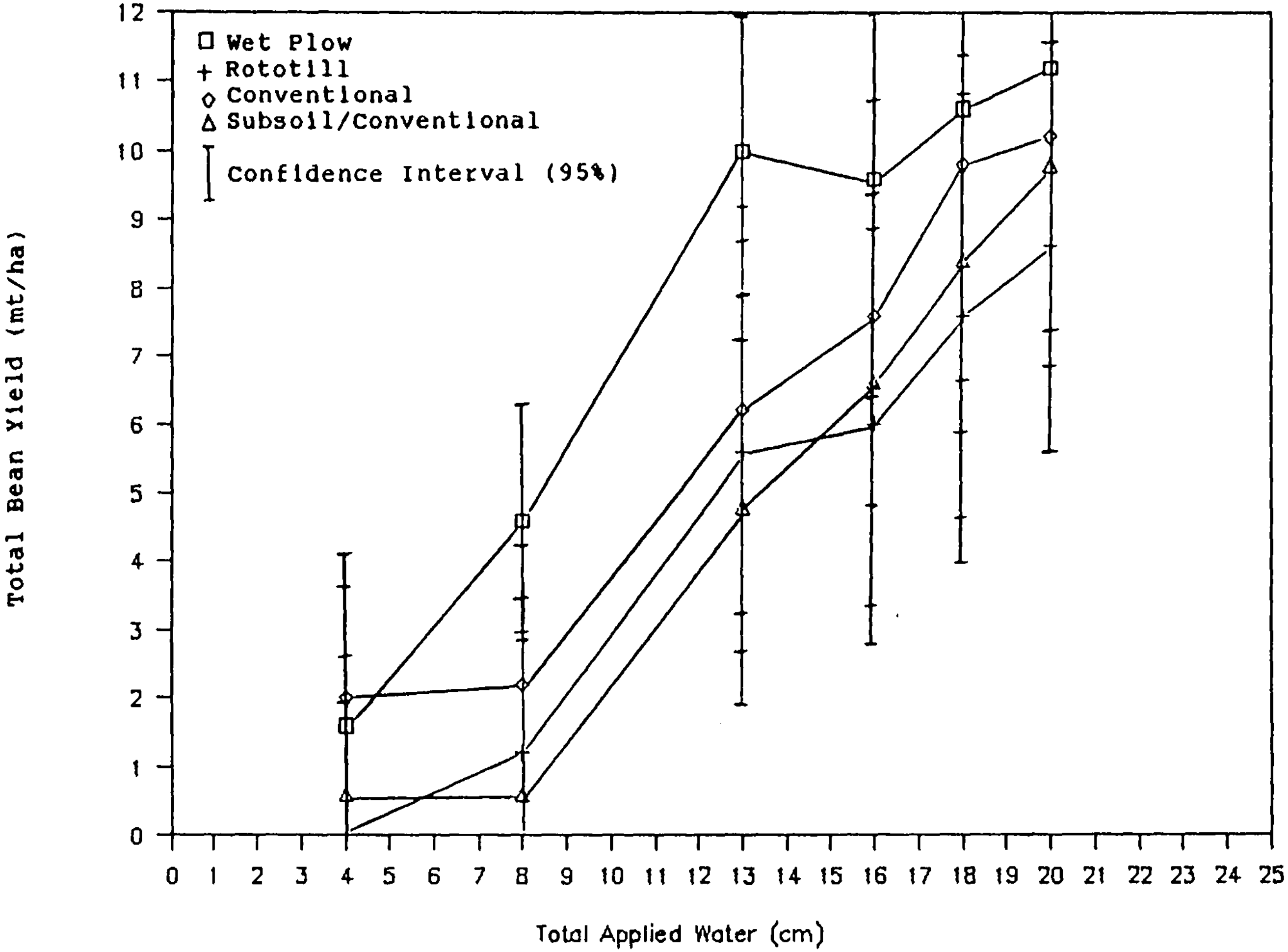

Figure 5. Effects of tillage treatments and applied water on pod yield of bush green beans, L2Y2 (1988)

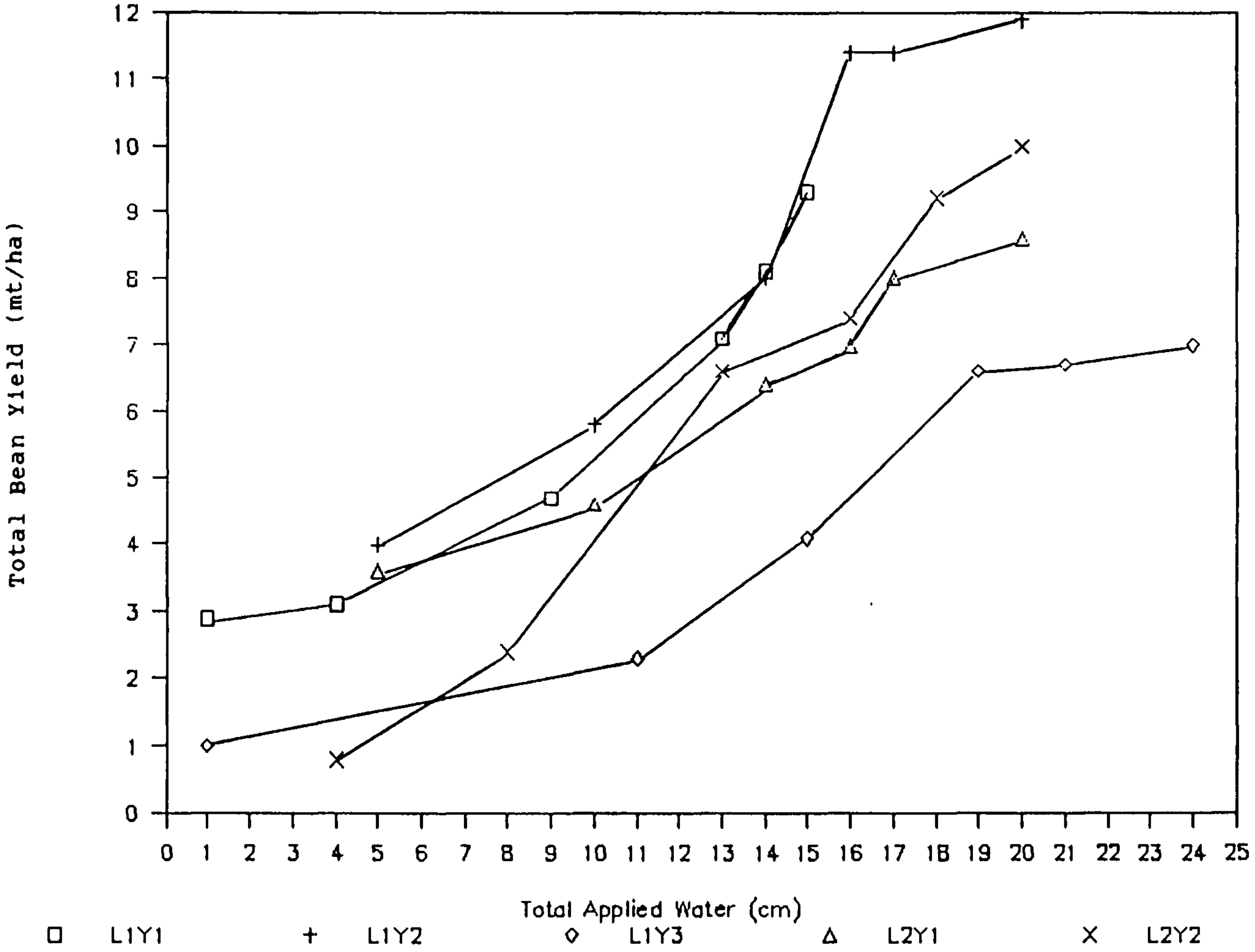

Figure 6. Effect of applied water on pod yield of bush green beans in five experiments

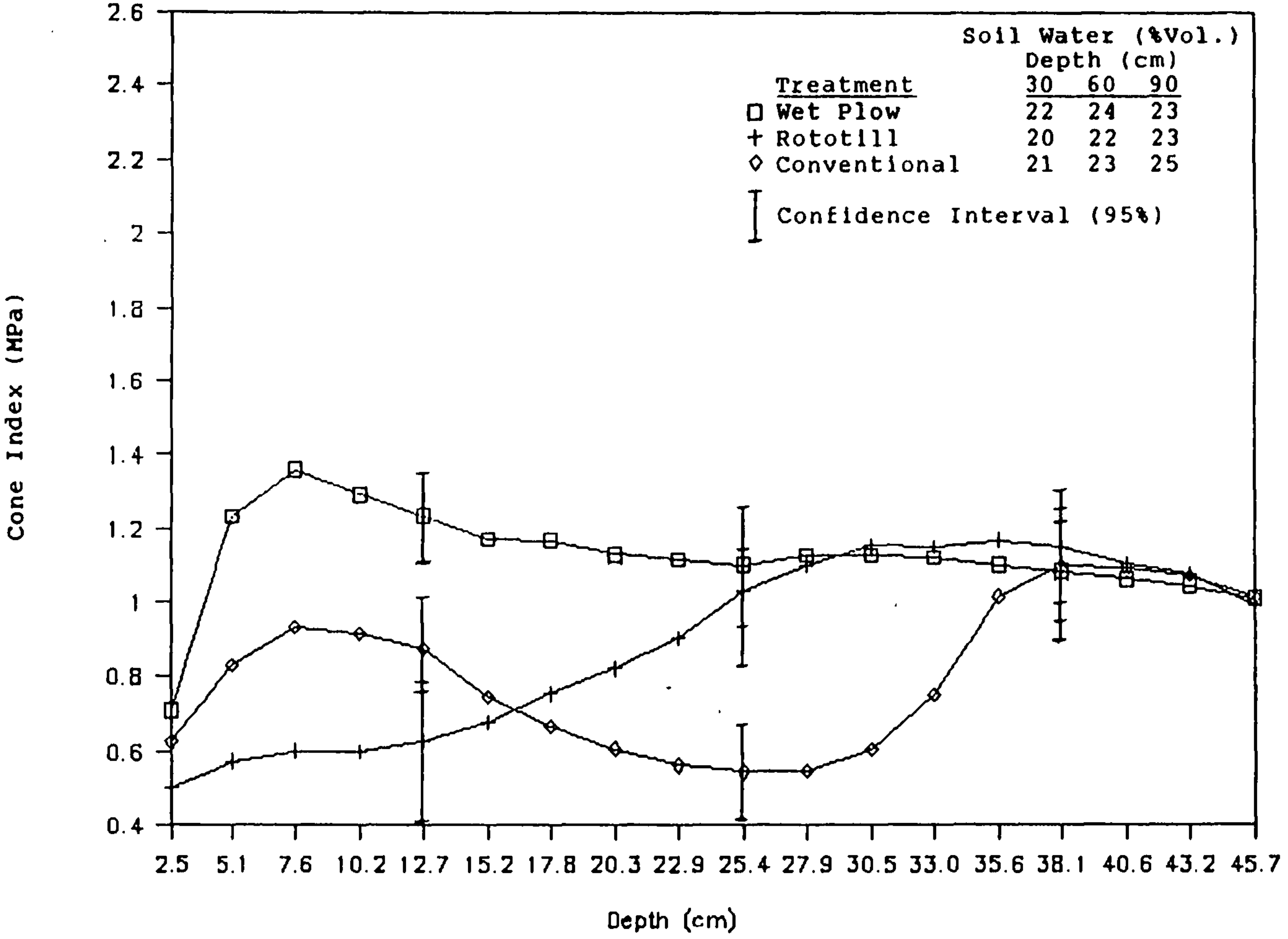

Figure 7. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y1 (1986)

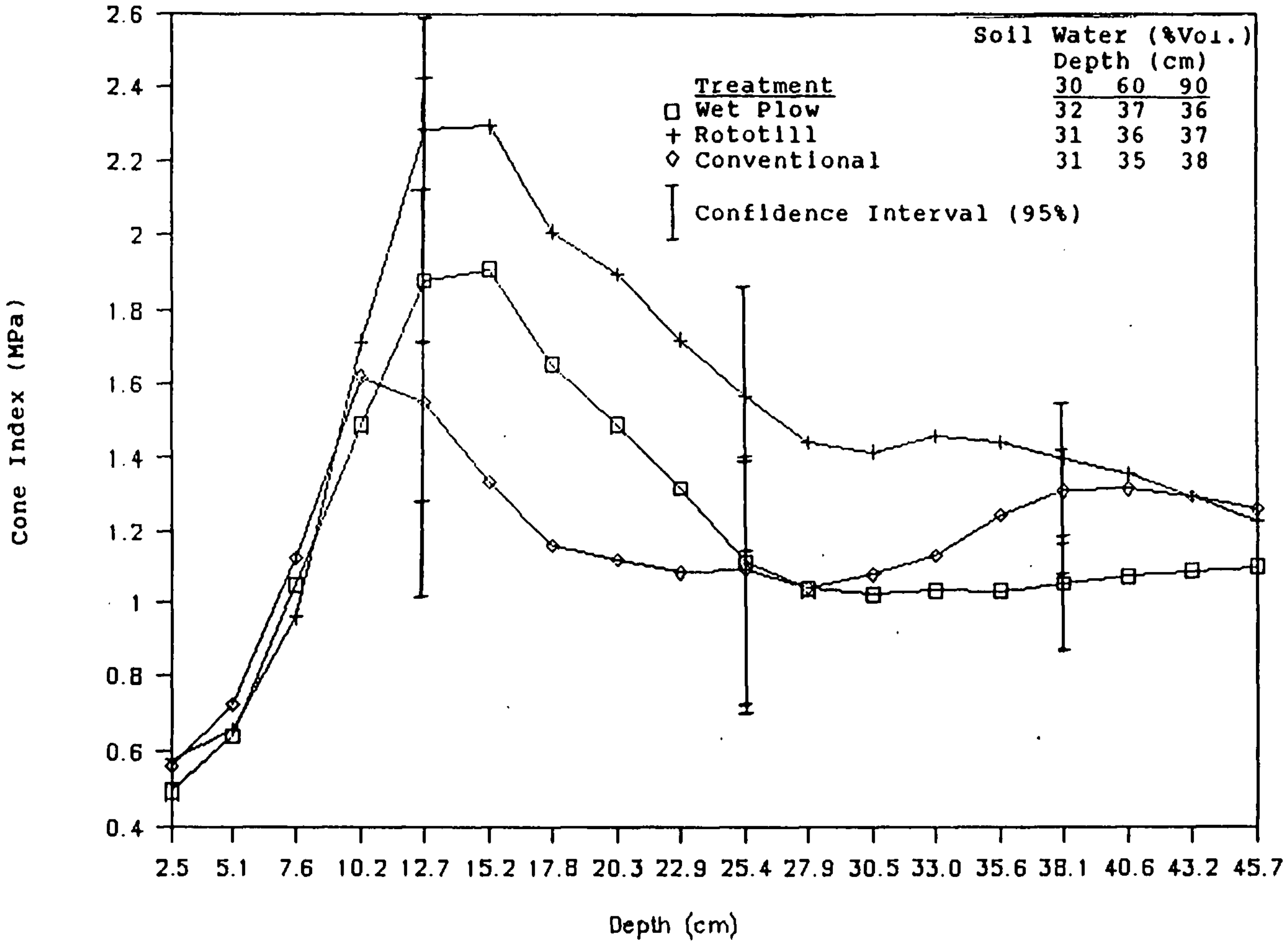

Figure 8. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y2 (1987)

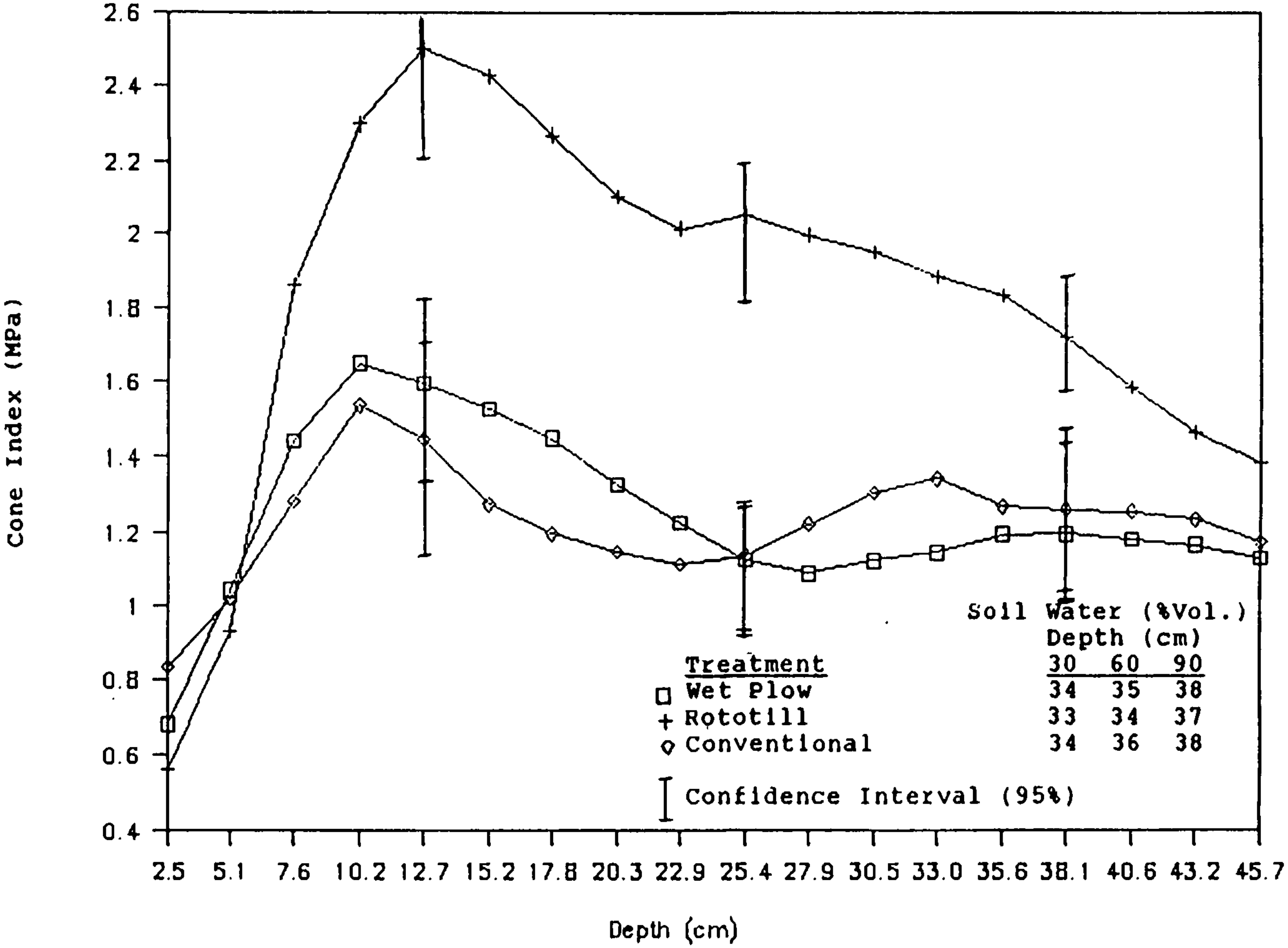

Figure 9. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y3 (1988)

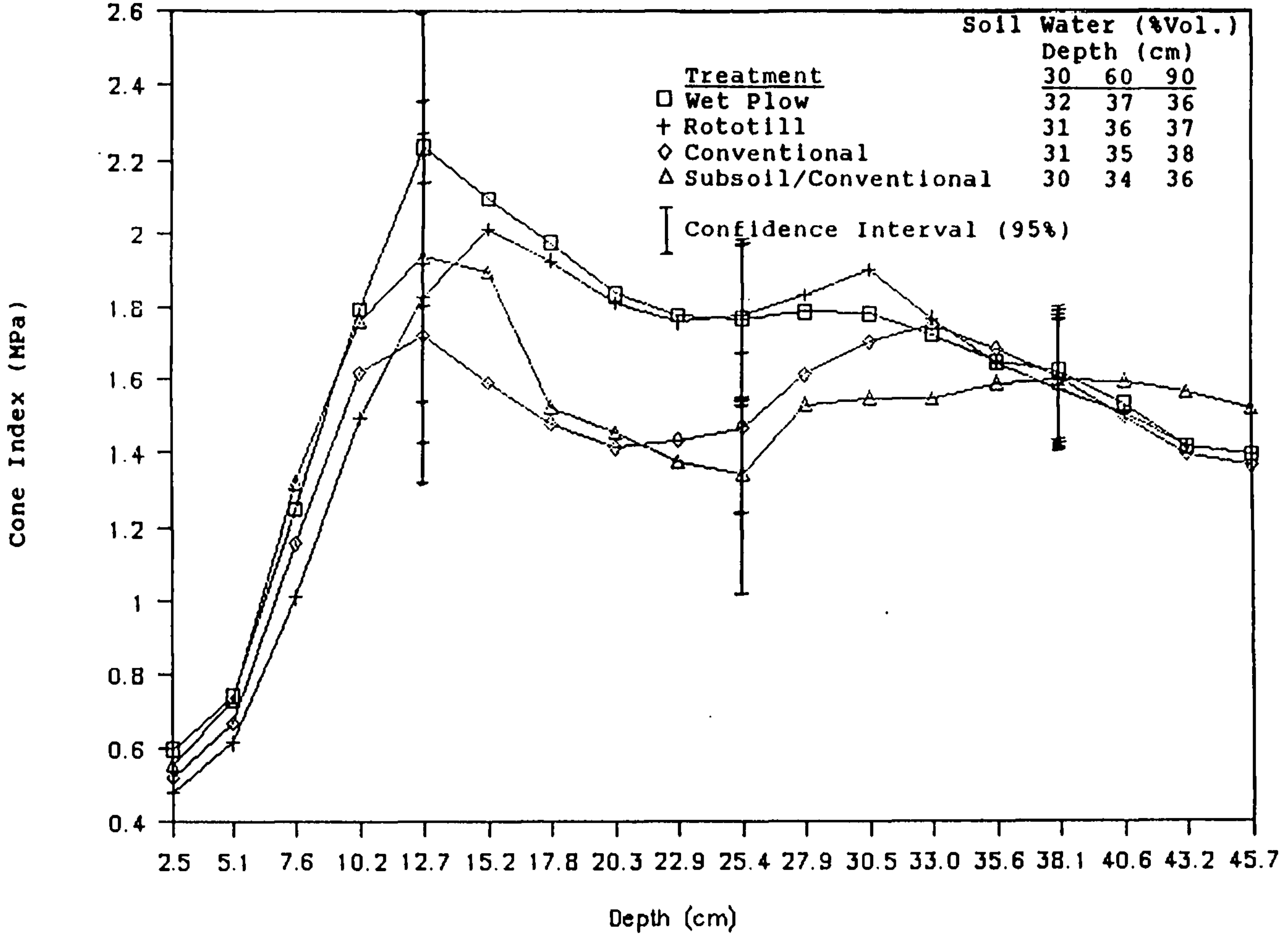

Figure 10. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L2Y1 (1987)

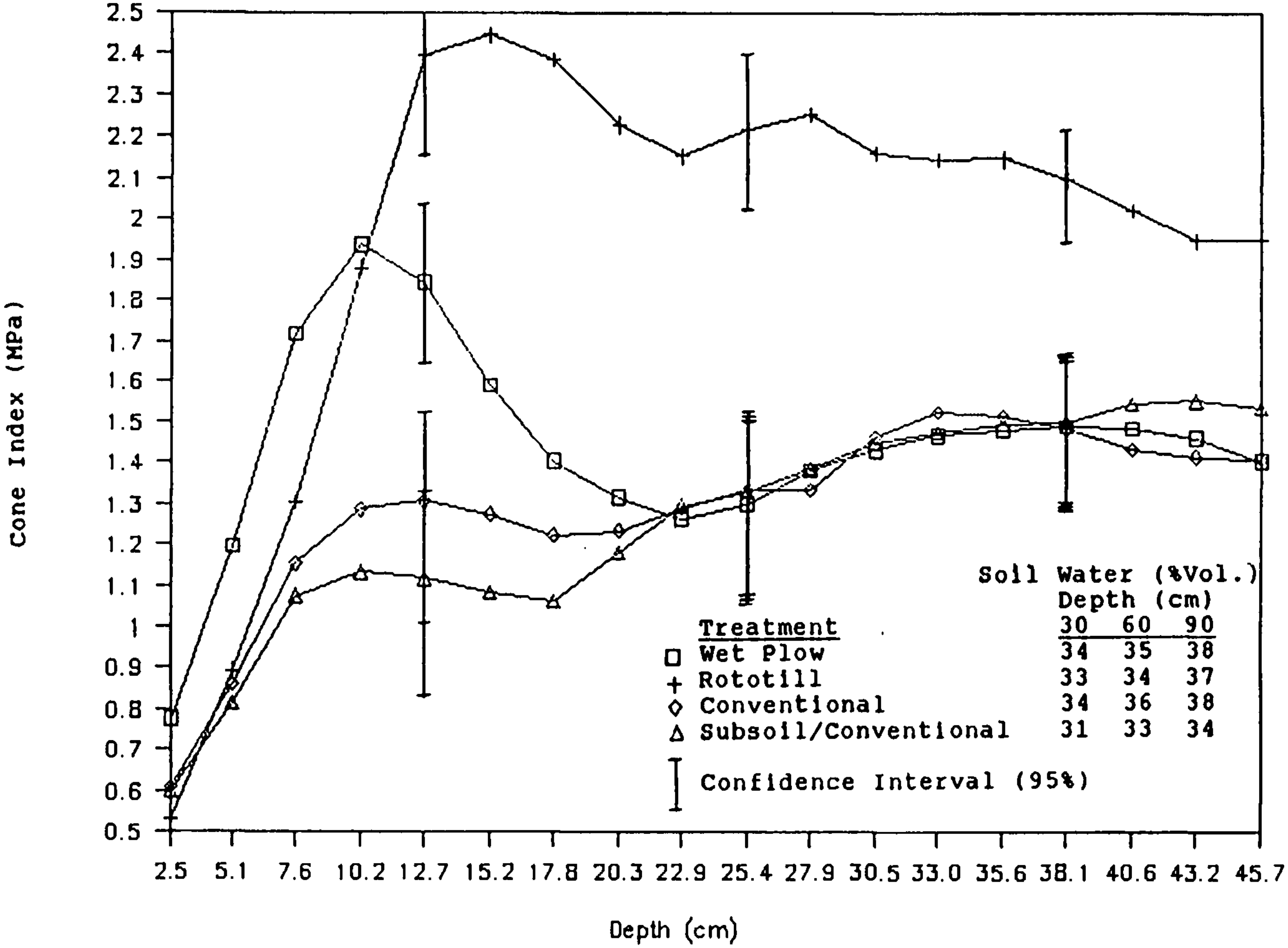

Figure 11. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L2Y2 (1988)

Table 1. Total applied water from the line source in five experiments on bush green beans.

		Centimeters of water applied[z]					
		Meters from line source					
Year	No. of applications	3.2	5.0	6.9	8.7	10.5	12.3
Loc. 1							
1986	5	14.5	14.0	12.6	8.7	4.1	1.1
1987	4	20.3	16.5	15.9	13.7	10.2	5.4
1988	7	24.0	20.8	19.0	14.8	10.5	1.2
Loc. 2							
1987	4	20.3	16.5	15.9	13.7	10.2	5.4
1988	7	20.3	17.8	15.8	13.3	7.5	3.5

[z] Applied water amounts above do not include rainfall which was as follows; 1986 = 3.7 cm, 1987 = 6.1 cm, 1988 = 3.2 cm.

Table 2. Effect of tillage treatment on yield and percent sieve sizes 1-4 of bush green beans.

Loc.	Year	Tillage Treatment[z]	Yield (mt/ha)	Sieve Size %1-4[y]
1	1	1	6.2	50
		2	5.8	58
		3	5.6	53
1	2	1	7.7	57
		2	7.8	60
		3	10.8	55
1	3	1	10.3	65
		2	7.6	78
		3	10.0	65
2	1	1	8.0	41
		2	5.8	40
		3	5.8	62
		4	5.6	62
2	2	1	7.9	75
		2	4.8	79
		3	6.3	82
		4	5.3	74

[z] Treatments: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

[y] Percent of pod yield in sieve sizes 1-4.

Table 3. Effects of applied water and tillage treatments on total biomass production of bush green beans.

			Average wt/plant(g)					No. pods/plant			
		Applied Water	Treatment^z					Treatment			
Loc.	Year	(cm)	1	2	3	4	Avg.	1	2	3	4
1	2	20.3	360	340	380	-	360	26	25	27	-
		16.5	350	330	400	-	360	27	23	27	-
		15.9	220	280	370	-	290	12	15	20	-
		13.7	230	290	310	-	277	14	16	17	-
		10.2	250	210	200	-	220	15	10	11	-
		5.4	170	100	140	-	137	8	4	8	-
Avg.			226	258	300						
1	3	24.0	180	210	180	-	190	16	18	15	-
		20.8	240	180	180	-	200	21	12	16	-
		19.0	150	200	120	-	157	14	13	11	-
		14.8	160	150	160	-	157	12	9	12	-
		10.5	110	90	80	-	93	8	8	5	-
		1.2	70	20	30	-	40	5	1	2	-
Avg.			152	142	125						
2	1	20.3	160	150	140	130	145	11	10	10	11
		16.5	220	210	160	160	188	18	16	11	10
		15.9	170	150	150	130	150	13	10	9	8
		13.7	200	180	180	130	172	14	13	12	11
		10.2	140	110	110	110	118	13	7	7	7
		5.4	110	100	110	100	105	9	6	6	6
Avg.			167	150	142	127					
2	2	20.3	140*	150	130	150	142	14	14	10	12
		17.8	170	130	140	120	140	15	10	10	8
		15.8	140	130	120	130	130	12	9	9	8
		13.3	160	110	100	110	120	13	8	6	8
		7.5	120	90	70	80	90	9	5	2	4
		3.5	50	20	40	40	38	3	1	2	2
Avg.			130	105	100	105					

^{z} Treatments: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

* Linear regression of biomass throughout the water gradient was significantly (.01) higher for the wet plow treatment compared to the conventional treatment.

Table 4. Effects of applied water on yield and sieve size grade of bush green beans, five experiments.

Loc.	Year	Applied water (cm)	Yield mean (mt/ha)	Percent sieve sizes 1 - 4
1	1	14.5	9.3a[z]	48
		14.0	8.1a	41
		12.6	7.1b	48
		8.7	4.7c	51
		4.1	3.1c	67
		1.1	2.9c	67
1	2	20.3	11.9a	59
		16.5	11.4a	54
		15.9	11.4a	55
		13.7	8.0b	57
		10.2	5.8c	57
		5.4	4.0d	62
1	3	24.0	14.0a	66
		20.8	13.4a	64
		19.0	13.2b	67
		14.8	8.1b	69
		10.5	4.8c	75
		1.2	2.2d	75
2	1	20.3	8.5a	47
		16.5	7.9a	44
		15.9	7.0b	50
		13.7	6.3b	49
		10.2	4.6c	54
		5.4	3.5d	65
2	2	20.3	9.9a	77
		17.8	9.1b	76
		15.8	7.5b	79
		13.3	6.7b	80
		7.5	2.4c	82
		3.5	1.0c	70

[z] The letters following yield means categorize them into least significant difference ranges (.05) in regard to applied water.

Table 5. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L1Y2 - 1987).

		Soil water percentage[y]			Soil water % (avg)[x]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[z]	water(cm)	30	60	90	30	60	90
1	20.3	29.3	34.7	37.4	29.6	34.9	37.1
1	15.9	29.1	34.5	38.2	28.7	34.0	36.4
1	10.2	28.0	32.9	36.5	27.0	33.3	35.7
Avg.		28.8	34.0	37.4			
2	20.3	29.5	34.4	36.6			
2	15.9	30.0	34.0	37.0			
2	10.2	26.8	33.7	35.4			
Avg.		28.8	34.0	36.3			
3	20.3	29.9	35.7	37.4			
3	15.9	27.1	33.6	34.0			
3	10.2	26.2	33.2	35.1			
Avg.		27.7	34.2	35.5			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional

[y] Each soil water value is the mean of five biweekly measurements.

[x] Average percent soil water content at levels of total applied water.

Table 6. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L1Y3 - 1988).

Treatment[z]	Applied water(cm)	Soil water percentage[y]			Soil water % (avg)[x]		
		Depth (cm)			Depth (cm)		
		30	60	90	30	60	90
1	24.0	33.7	35.6	39.6	33.3	35.0	38.2
1	20.8	34.0	36.4	40.5	33.8	36.0	40.6
1	19.0	33.3	35.6	38.0	33.1	35.1	36.7
1	14.8	32.6	33.7	37.2	32.4	34.1	38.9
1	10.5	30.4	31.5	37.0	30.2	32.5	36.6
1	1.2	29.3	31.2	35.6	30.1	32.9	36.8
Avg.		32.2	34.0	38.0			
2	24.0	32.6	35.0	37.7			
2	20.8	33.3	36.4	41.1			
2	19.0	32.5	34.7	36.6			
2	14.8	32.0	34.3	39.9			
2	10.5	30.3	32.3	35.9			
2	1.2	30.5	33.3	35.9			
Avg.		31.9	34.3	37.9			
3	24.0	33.6	34.5	37.3			
3	20.8	34.1	35.2	40.2			
3	19.0	33.6	35.0	35.4			
3	14.8	32.5	34.4	39.5			
3	10.5	30.0	33.7	36.8			
3	1.2	30.4	34.3	39.0			
Avg.		32.4	34.5	38.0			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional

[y] Each mean is the average of twelve biweekly measurements taken throughout the season.

[x] Average percent soil water content at levels of total applied water.

Table 7. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L2Y1 -1987).

		Soil water percentage[y]			Soil water % (avg)[x]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[z]	Water(cm)	30	60	90	30	60	90
1	20.3	28.4	32.5	38.1	28.2	32.2	34.3
1	15.9	27.3	34.3	36.4	28.0	32.7	30.7
1	10.2	25.6	31.3	33.8	25.6	32.0	31.3
Avg.		27.1	32.1	36.1			
2	20.3	27.8	33.5	36.0			
2	15.9	28.5	34.6	36.3			
2	10.2	25.5	31.4	35.7			
Avg.		27.3	33.2	36.0			
3	20.3	28.2	32.7	36.9			
3	15.9	29.1	34.7	34.7			
3	10.2	26.0	33.7	34.5			
Avg.		27.8	33.7	35.4			
4	20.3	28.5	30.2	26.0			
4	15.9	26.9	27.0	15.5			
4	10.2	25.4	31.7	21.3			
Avg.		26.9	29.6	20.9			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

[y] Each mean is the average of three observations.

[x] Average percent soil water content at levels of total applied water.

Table 8. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L2Y2 - 1988).

		Soil water percentage[y]			Soil water % (avg)[x]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[z]	water(cm)	30	60	90	30	60	90
1	20.3	32.4	37.4	38.5	33.3	37.5	39.8
1	17.5	34.1	36.8	39.8	33.6	36.6	39.8
1	15.8	32.7	36.8	38.6	33.0	35.5	38.8
1	13.3	32.7	37.0	38.0	32.9	36.1	38.8
1	8.5	31.5	35.2	36.1	31.5	34.3	37.6
1	3.5	29.7	33.2	37.1	30.3	33.1	37.3
Avg.		32.2	36.1	38.0			
2	20.3	33.5	36.2	39.8			
2	17.5	33.6	36.9	38.5			
2	15.8	33.7	35.7	37.7			
2	13.3	34.4	37.8	41.6			
2	8.5	32.1	33.5	37.0			
2	3.5	31.1	34.1	36.0			
Avg.		33.1	35.7	38.4			
3	20.3	34.4	38.4	42.0			
3	17.5	32.8	37.4	40.9			
3	15.8	32.1	34.9	42.5			
3	13.3	31.4	34.8	39.9			
3	8.5	30.1	33.7	39.4			
3	3.5	30.3	33.1	41.3			
Avg.		31.8	35.4	41.0			
4	20.3	33.9	37.8	38.9			
4	17.5	33.7	35.3	40.0			
4	15.8	33.8	34.7	36.5			
4	13.3	33.2	34.7	35.5			
4	8.5	32.1	34.7	37.7			
4	3.5	29.9	31.9	34.8			
Avg.		32.8	34.9	37.3			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

[y] Each mean is the average of twelve biweekly measurements taken throughout the season.

[x] Average percent soil water content at levels of total applied water.

Discussion

The reduced yields in the wet plow and rototill treatments in L1Y2 may be related to tillage induced compaction. Penetrometer data (CIV) from years 2 and 3 in both locations showed significant variation among tillage treatments, indicating that specific annually repeated tillage treatments were increasing soil strength. The greatest reduction in yield from tillage induced compaction was from the rototill treatment. A lack of large soil aggregates was visually observed after tillage in the rototill treatment compared to the other tillage treatments. The reduction in large soil aggregates resulted in more resistance to the penetrometer cone within the tillage zone. Rosenberg (1964) reported that the major cause of soil compaction was due to manipulation of large soil aggregates by traction, tillage implements, and compression of soils by vehicular traffic. Higher CIV in the rototill treatment at greater depths could be due to the lack of deep tillage, wheel traffic from tillage passes, or to vibration from the action of the tiller. Even when adequate soil water was provided by irrigation, the soil strength for the rototilled treatment probably restricted root growth and as the crop matured the stunted root system might have been unable to provide sufficient water to meet the evaporative demand. Begg and Turner (1976) emphasize crop growth and yield reduction when water stress occurs during flowering and fruit development. Root growth is hampered by severe soil compaction (Greacen et al., 1968) and roots of most plant species do not penetrate soils with strengths greater than 3 MPa except by following low strength cracks and fissures (Taylor and Burnett, 1964; Zimmerman and Kardos, 1961). CIV in the present study were usually higher than 2.0 MPa at depths of 10 - 25 cm for the rototill treatments in the second and third years.

Significantly higher pod yields from the wet plow tillage treatment were realized in L2Y1 and L2Y2 compared to conventional tillage plot yields.. Higher green bean yields from the wet plowed plots may have been due to increased soil water availability. However neutron meter measurements of soil water did not show consistent results in these two years. In L2Y1, soil water was slightly lower in the wet plow treatment compared to conventional tillage, while in L2Y2 soil water for the wet plow treatment was slightly higher than for the conventional tillage treatment. The higher water availability of a soil can result from an increased percentage of small pore spaces (Hillel, 1982). Boone et al. (1987) conducted corn growth experiments on fine sand and loamy fine sand with plot CIV of 1.6, 1.1, 0.7, and 0.8 MPa at a depth of 15 cm. Despite smaller corn root systems caused by soil compaction, three out of five experiments were favored by soil compaction. The positive relation between crop growth and soil compaction was attributed to better water availability, probably due to improved soil water transport and root-soil contact. Slight yield reductions in corn silage were reported from the loose treatments and large yield reductions caused by insufficient soil aeration from the severely compacted treatment.

Above ground biomass production for rototill, wet plow, and conventional treatments was not significantly different for any of the three years in location 1. Total biomass production did not reflect yield responses from tillage treatment with the exception of the wet plow treatment in L2Y2 that produced significantly more biomass than the other three tillage treatments.

Applied water was a major determining factor for yield and biomass production and effects were consistent for all treatments and years. Green bean crop growth, yield, and quality are adversely affected by water deficits (Carolus and Schleusener, 1950; Kramer, 1963; and MacKay and Eaves, 1962). The above ground biomass and pod number were adversely affected as total applied water declined for all locations and years of this study. Field observations of plant vigor revealed plant stunting and a darker green leaf color for plants under water stress conditions in this study and agree with other studies (Andrew and Weis, 1974; and Keller and Carlson, 1967). Although the percentage of sieve sizes 1-4 increased as the total applied water decreased the quality of the stunted pods declined from water stress. Bonanno and Mack, 1983, concluded that in green bean pods reduced length and an increased fiber content were results of low level irrigation.

Soil strength increases as soil water decreases. Taylor and Gardner (1963) reported that as soil water decreased, soil strength increased reducing penetration of plant roots. In this study soil water was also significantly affected by total applied water. However, differences in soil water throughout the applied water gradient do not appear to be as dramatic and consistent as expected. Available soil water must exceed the evaporative demand of the crop for the crop to maximize growth and yield (Cuenca 1989). As plants became more stunted with the decline in applied water, the evaporative demand probably declined and the soil water was not depleted. Begg and Turner, 1976, reported that water deficits usually caused marked reductions in total leaf area. Reductions in total leaf area would reduce the evapotranspiration from the plants. Visual observations indicated that there were smaller and fewer leaves on plants as levels of applied water were decreased in the present study but no measurements were made of leaf area.

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CHAPTER 4

EFFECTS OF DIFFERENTIAL IRRIGATION AND TILLAGE-INDUCED SOIL COMPACTION ON SWEET CORN

Abstract

'Jubilee' sweet corn was grown in location 1 in 1986, 1987, and 1988 with three tillage treatments: rototill, conventional moldboard plow, and wet plow. In 1987 and 1988, location 2 was added and a fall subsoiling treatment followed by conventional tillage in the spring was included in addition to the above three tillage treatments. The line source method of irrigation was used to provide a water gradient resulting in six irrigation levels. Measured crop components included good husked ear yield, ear number, ear length, plant height, and total above ground biomass.

Yields of husked ears were significantly lower for the rototill treatment than for other treatments in location 1 for the second (L1Y2) and third years (L1Y3) of tillage treatment. In the first year there were no differences in yield from the three tillage treatments. Ear length was shorter for the rototill treatment the second year and ear number was lower in the third year compared to conventional tillage. Plant height was not recorded for L1Y1. For all other years and locations, plant height was shorter for the rototill treatment than for other tillage treatments. In L2Y2 plant heights in the subsoil/conventional treatment were significantly shorter than for conventional tillage.

Yield of husked ears of the wet plow treatment as well as ear number were significantly higher than for all other tillage treatments in L2Y2, while the rototill treatment produced a significantly lower yield and number of husked ears than other tillage treatments.

Total above ground biomass, including ears, was measured for L1Y3 and L2Y2. Biomass in the wet plow treatment was significantly higher than for other treatments in L1Y3. There were no significant differences among treatments for biomass production in L2Y2.

Total applied water significantly influenced yield, biomass production, and plant height. As total applied water declined, all of the above ground crop components diminished. There were no significant interaction effects among tillage treatments and amounts of applied water on good husked yield except for L1Y3. In L1Y3, yields of good husked ears for the rototill treatment were significantly lower than for the conventional tillage treatment at all water levels except the two highest.

Cone index values (CIV) in soil from the conventional and rototill treatments were significantly lower than in the wet plow treatment in L1Y1. In L1Y2, there were no significant differences in CIV among treatments. Significantly higher CIV were recorded from the rototill treatment in L1Y3. In L2Y2, the CIV for the rototill treatment were significantly higher than for all other tillage treatments.

Introduction

Tilled agricultural lands are compacted by various means. Wheel pressure and/or tillage in conjunction with high soil moisture content are considered to be the primary causes of soil compaction (Davies et al., 1973; Flocker et al., 1966; Hillel, 1982; Swain, 1975; and Voorhees et al., 1986). The use of various tillage systems and implements result in characteristic environments for root growth and water retention and subsequently affect the growth and yield of vegetable crops. Significantly higher yields of husked sweet corn were produced with moldboard plowing than with strip tillage, and yields from strip tillage were significantly higher than for no-till (Petersen, Mack, and Cuenca, 1985). Lower yield with no-till practices is often attributed to poor soil conditions for root growth (Hilfiker and Lowery, 1988). Douglas and McKyes (1983) conducted experiments using moldboard plow, chisel plow, and subsoil techniques to evaluate tillage system effects on traffic-induced soil compaction. Chisel and moldboard plowing was more effective in loosening the plow layer of the soil profile and corn yields were higher than for the subsoiled treatment. Yield increases were observed but root growth was restricted in all plots. Boone et al. (1987) conducted experiments on fine sand and loamy fine sand. Despite smaller corn root systems caused by soil compaction early crop growth in three out of five experiments was favored by soil compaction. The positive relation between crop growth and soil compaction was attributed to better water availability, probably due to improved soil water transport and root-soil contact. Soil compaction benefits are limited when air and water infiltration is reduced or root growth is severely restricted. Growing roots of most species do not penetrate soils with strengths greater than 3000 kiloPascals except by following low strength cracks and fissures (Taylor and Burnett. 1964; Zimmerman and Kardos. 1961).

The amount of available soil water influences the yield and quality of sweet corn. Reduced numbers of good ears and ear lengths in sweet corn result from insufficient applied water (Braunworth and Mack, 1987). Insufficient applied water can impede root growth. Soil strength increases as soil water declines (Taylor and Gardener, 1963). Stunted root systems can not supply the evapotranspirative demands of a maturing sweet corn crop and the crop may become stunted. The stage of crop maturity is a critical time for an adequate water supply and Begg and Turner (1976) emphasize crop growth and yield reduction when water stress occurs during flowering and fruit development. For corn, yields are reduced if insufficient water is available at tassel emergence, silking, and pollination completion (Dale and Shaw, 1965; Denmead and Shaw, 1960; Downey, 1971; Herrero and Johnson, 1981; Robins ans Domingo, 1953; Stanberry et al., 1963; and Stewart et al., 1975).

Five experiments were conducted to evaluate the effects of three or four soil tillage methods on sweet corn growth and yields under six irrigation levels.

Materials and Methods

Five experiments were conducted in three consecutive years (1986, 1987, and 1988) on Chehalis silty clay loam soil (Mesic Cumulic Ultic Haploxeroll) at the Oregon State University Vegetable Research Farm, Corvalis. Tillage treatments were randomly assigned in three blocks, in two locations, and tillage treatment blocks were bisected perpendicularly with a line source irrigation system to provide a water gradient. In location 1 , 11.6 by 42.4 meter plots received the same three tillage treatments for three consecutive years. These consisted of conventional tillage, wet plowing, and rototilling. Conventional and wet-plowed plots were moldboard plowed, disked, and finished with a rotara that stirs the soil with vertical rotating 25 cm spikes. In location 2, two blocks with 12.2 by 41.9 meter plots received the above three tillage treatments for two consecutive years (1987, 1988) plus a forth treatment of conventional tillage in the spring after fall subsoiling. Tillage penetration for rototilling, plowing, and subsoiling was 15, 33, and 43 cm respectively. Field conditions were closely monitored and tillage was performed when tillage profile volumetric soil water was near 22% for rototilling, 25% for conventional treatments, and 29% for wet plowing. Soil water percent (volumetric basis) was approximately 40% at field capacity. During seedbed preparation there was no variation of tractor size and number of passes over the plots were held consistent regardless of treatment.

In each experiment soil resistance measurements (cone index values) were taken by penetrometer to determine the severity of soil compaction within ten days of crop emergence. The only exception occurred during the first year of location one when penetrometer measurements were taken on September 4, 1986. The 2.54 cm diameter penetrometer cone with 45 degree angle tip was hydraulically forced into the soil at 6 locations per soil tillage treatment. Force measurements were recorded at each 2.54 cm depth to a depth of 45.7 cm. Three representative depths of 10, 20, and 30 cm were used for statistical analyses.

Fonofos was pre-plant incorporated into all seedbeds for garden symphylan control. Plots were planted by using a four row planter with 90 cm row spacing. The standard commercial sweet corn cultivar 'Jubilee' was planted, oversprayed with alachlor and atrazine, and watered uniformly to enhance uniform germination and emergence. Resulting stands were very similar for all years and averaged 97,222 plants/per hectare. Planting dates for location 1 were June 17, 1986, May 28, 1987, and June 22, 1988. Location 2 planting dates were May 14, 1987, and June 21, 1988. Fertilizer was banded at planting at a rate of 56, 74,and 47 kilograms of N, P, and K per hectare, respectively. When well watered plants were 60-65 cm high all rows were sidedressed with 180 kilograms nitrogen (urea) per hectare.

Plots were harvested at processing maturity of about 72% kernel moisture to determine total husked ear weight and total above ground biomass including ear weight. Harvest dates for location 1 were September 26, 1986, September 10, 1987 and October 11, 1988. Location 2 harvest dates were September 8, 1987 and October 8, 1988. For all locations and treatment years 7.24 meters of row were harvested at 6 irrigation levels for each replication and tillage treatment (Table 1.). Average ear length was derived from measurements of five ear samples. Plant height measurements were taken at crop maturity at all recorded applied water levels. Measurements were taken from ground level to the base of the tassel and an average height was calculated from ten plant samples.

Water was applied weekly consistent with the line source experimental design. Tillage treatment plots were arranged perpendicularly to, and were bisected by the irrigation line while corn rows were parallel to the irrigation line. Bisected tillage treatments provided two replications in the single block in location 1 and four replications in the two blocks in location 2. Irrigating during windless conditions, combined with the nozzle type and spacing of the line source, provided a water distribution profile resembling a bell shaped curve. A water gradient is formed as applied water diminishes with distance from the irrigation source. Hanks et al. 1976, and Cuenca et al. 1978, explain in greater detail the line source experimental design. At each irrigation application the amount of applied water was measured by catch cans at various distances from the line source and resulted in six irrigation levels or treatments (Table 1). Neutron probe access tubes were placed in rows throughout the water gradient. A neutron meter (Model 503DR Hydroprobe Moisture Depth Gauge, Campbell Pacific Nuclear Corp., Panchico, CA.) was used to measure soil water content at 30, 60, and 90 cm. Measurements were taken weekly the day before, and the day after irrigation.

The linear multiple regression technique was used to fit models for soil water, yield components, total biomass, and penetrometer resistance (cone index values). Numbered tillage treatments were represented in models as indicator variables. The conventional tillage treatment was used as the model constant when all other tillage treatments and applied water levels were compared. Simple and interactive models were analyzed then the extra sum of squares f test determined the most effective model.

Results

Total husked ear yield, ear number, and ear length were usually compared among tillage treatments and water levels. In some cases, effects of treatments on total above ground biomass (including ears) were evaluated. Effects of treatment on plant height were also measured.

Yields of husked ears and other yield components in L1Y1 (Location 1, Year 1) were not significantly different for the three tillage treatments (Table 2, Fig. 1). Husked ear yield (Fig. 2) and ear length (Table 2) for the rototill treatment were significantly lower than for the wet plow or conventional treatments in L1Y2. In the rototill treatment in L1Y3, husked ear yield (Fig. 3) and ear number (Table 2) were significantly lower than for other tillage treatments. The decline in yield of husked ears for the rototill treatment (L1Y3) appears to be more rapid than for other treatments with respect to decreasing amounts of applied water (Figures 1,2,3). Yield means for the rototill treatment in location 1 were lower in comparison to wet plow and conventional tillage in the second and third years than in the first year (Table 2). In L2Y1 ears were significantly shorter in the rototill and wet plow treatments than in conventional or subsoil/conventional tillage treatments (Table 2); however there were no significant yield differences (Fig. 4). In L2Y2 husked ear yield (Fig. 5) and ear number in the wet plow treatment (Table 2) were significantly higher than for all other treatments while the rototill treatment produced significantly lower yields and fewer husked ears than other tillage treatments.

Significant reductions in yield of good husked ears occurred as water levels were reduced from the highest to the lowest in the five experiments as illustrated in figures 1 - 5 and summarized in figure 6. Although yields varied among tillage treatments, no significant interaction effects occurred among tillage treatments and amounts of applied water on good husked yield except for L1Y3. In L1Y3, yields of husked ears for the rototill treatment were signifcantly lower than for the conventional tillage treatment at all water levels except for the two highest. Yield means of the six applied water treatments (tillage treatments combined) in Table 3 indicate that reductions in yield were 68%, 32%, 61%, 31%, and 82%, respectively, for the five experiments, when the lowest amounts of applied water are compared to the highest amounts. Similar trends were evident for ear numbers, while effects on ear length from water levels were not significant in some cases.

Measurements of total above ground biomass, including ears, were taken for three water levels in L1Y3 and for L2Y2. Biomass production for the wet plow tillage treatment (L1Y3) was significantly higher (.05) than for other treatments (Table 4), but this trend was not reflected by the yield data (Table 2). There were no differences in biomass production among tillage treatments (Table 4) in

L2Y2. Applied water significantly affected the total biomass production. Average plant weight declined between 23 and 55 percent and ear numbers from 13 to 72 percent as total applied water decreased from the highest to the lowest levels shown in Table 4.

Plant heights were not recorded for L1Y1. For all other years and locations, plants were shorter for the rototill treatment than for all other tillage treatments (Table 2). In L2Y2 plant height in the subsoil/conventional treatment was significantly shorter than for conventional tillage. Plant height consistently declined with diminishing applied water for all tillage treatments (Table 3). Height reductions, though less marked, were of a similar trend to husked yield reductions (Table 2). A representative graph showing both effects of tillage treatments and levels of applied water on plant height is presented in Figure 7.

Cone index values (CIV) from penetrometer readings of soil in the conventional and rototill tillage treatments in L1Y1 were significantly lower than for the wet plow treatment at 12.7 cm and the conventional treatment CIV was lower than other treatments at 25.4 cm (Fig. 8). The difference was depth dependent and the plow layer to a depth of 25 cm was influenced by tillage. In L1Y2, there were no significant differences in CIV among tillage treatments (Fig. 9). CIV for the rototill treatment were significantly higher than for other tillage treatments in L1Y3 (Fig. 10).

No significant differences in CIV among treatments occurred in L2Y1 (Fig. 11). Large CIV for L2Y2 were highly significant for the rototill treatment compared to conventional tillage, other treatments did not vary significantly except the wet plow CIV was higher than conventional and subsoil/conventional CIV at 12.7 cm and lower than the rototill treatment CIV (Fig. 12).

Differences in soil water content (percent volume) were significant in two locations and years of the study (Tables 6,7) and in two locations and years there were no significant differences (Tables 5,8). There was significantly less water in the three depths observed in the soil profiles of the conventional and subsoil treatments for L2Y1 (Table 7) compared to the wet plow treatment. Soil water in L1Y3 rototill and conventional treatments was significantly higher than for the wet plow treatment (Table 6).

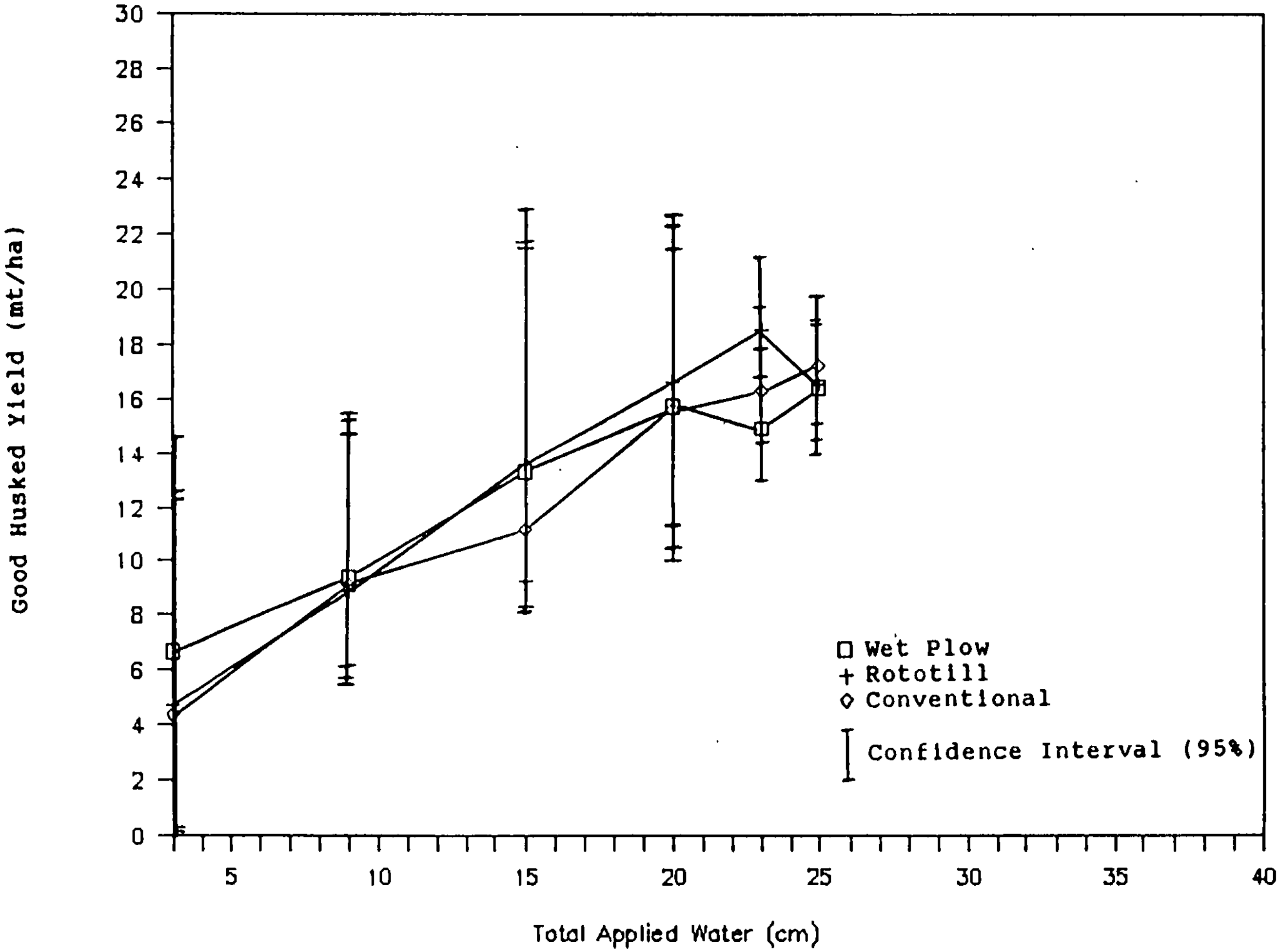

Figure 12. Effects of tillage treatments and applied water on good husked yield of sweet corn, L1Y1 (1986)

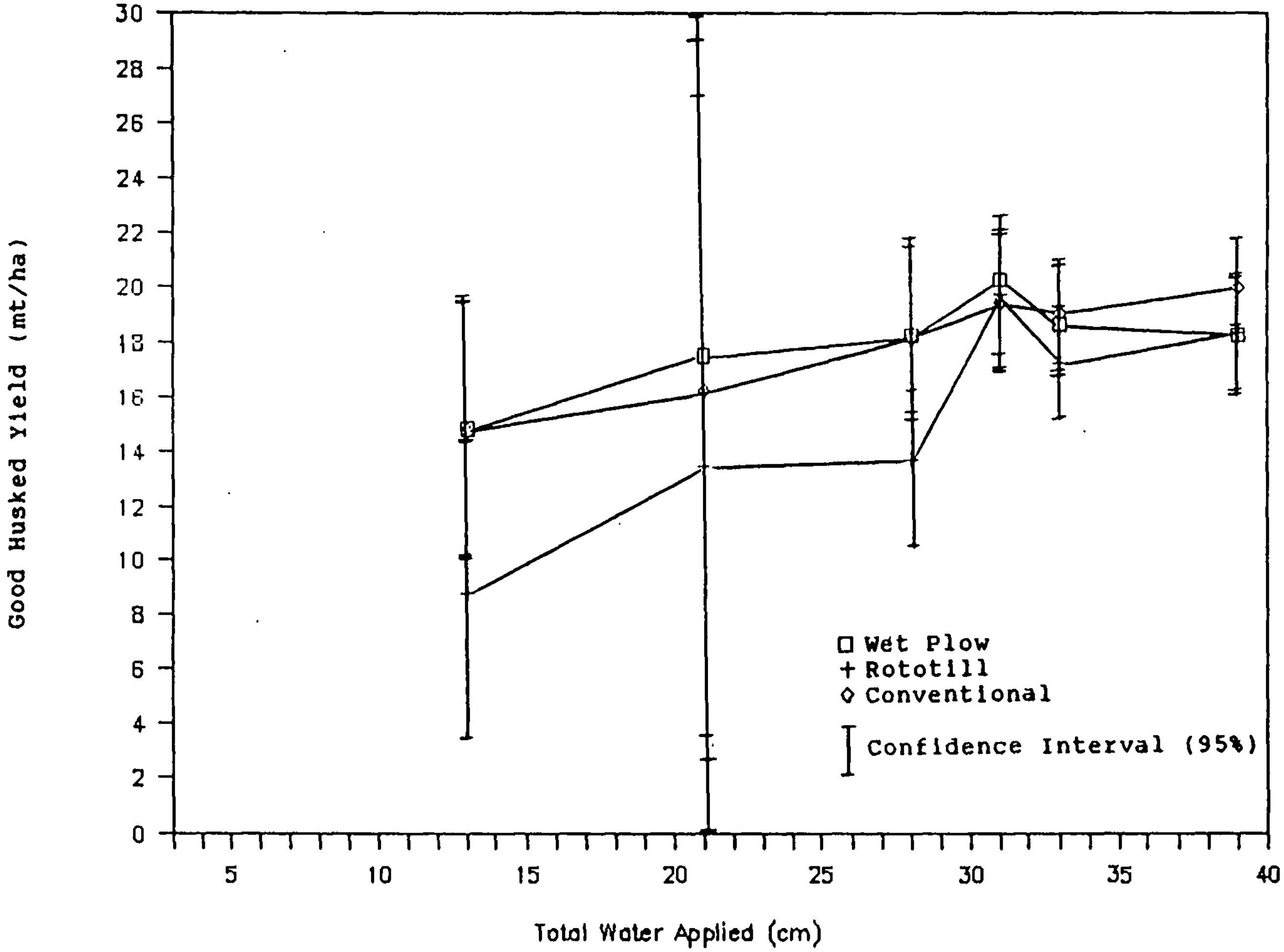

Figure 13. Effects of tillage treatments and applied water on good husked yield of sweet corn, L1Y2 (1987)

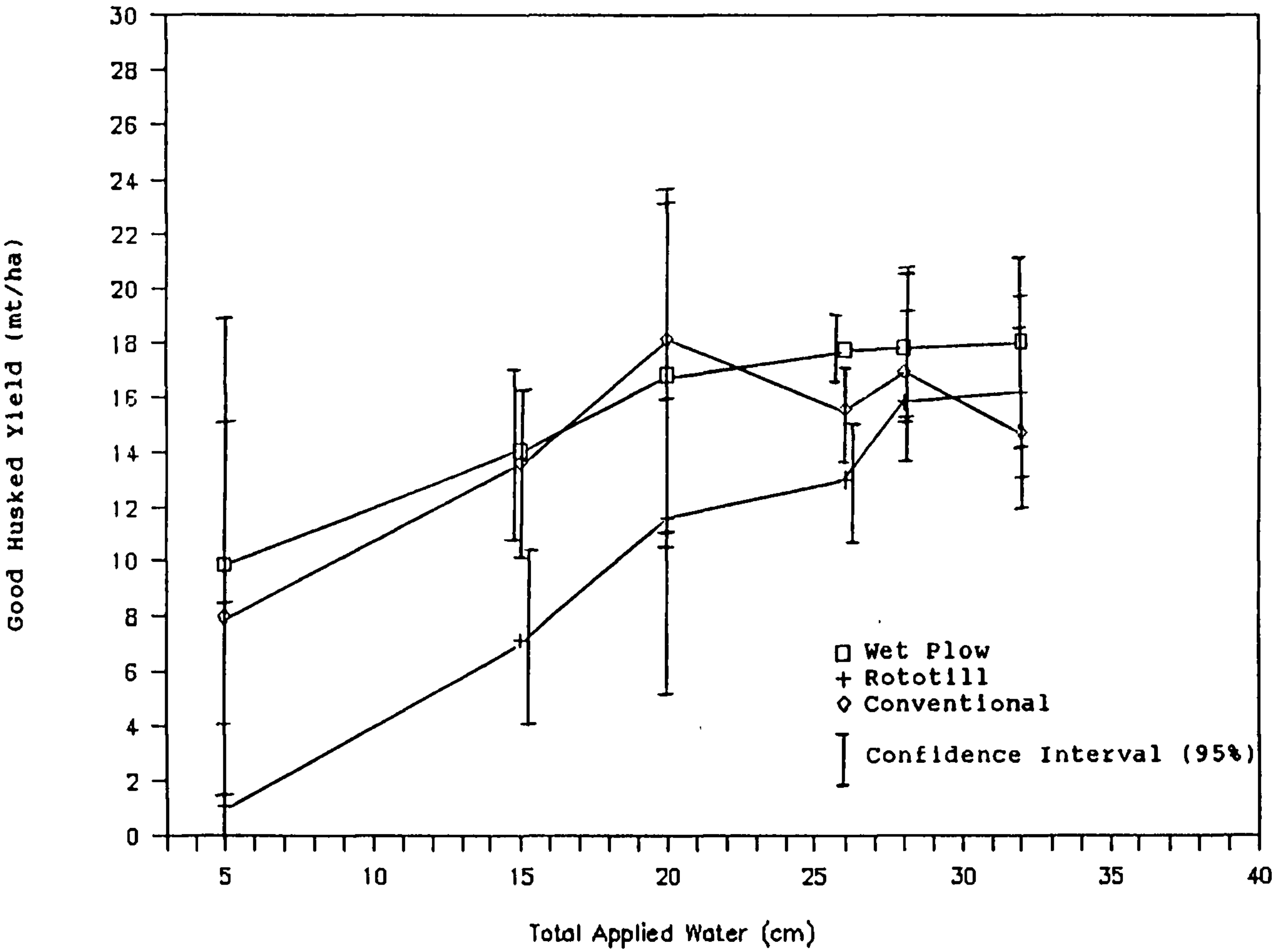

Figure 14. Effects of tillage treatments and applied water on good husked yield on sweet corn, L1Y3 (1988)

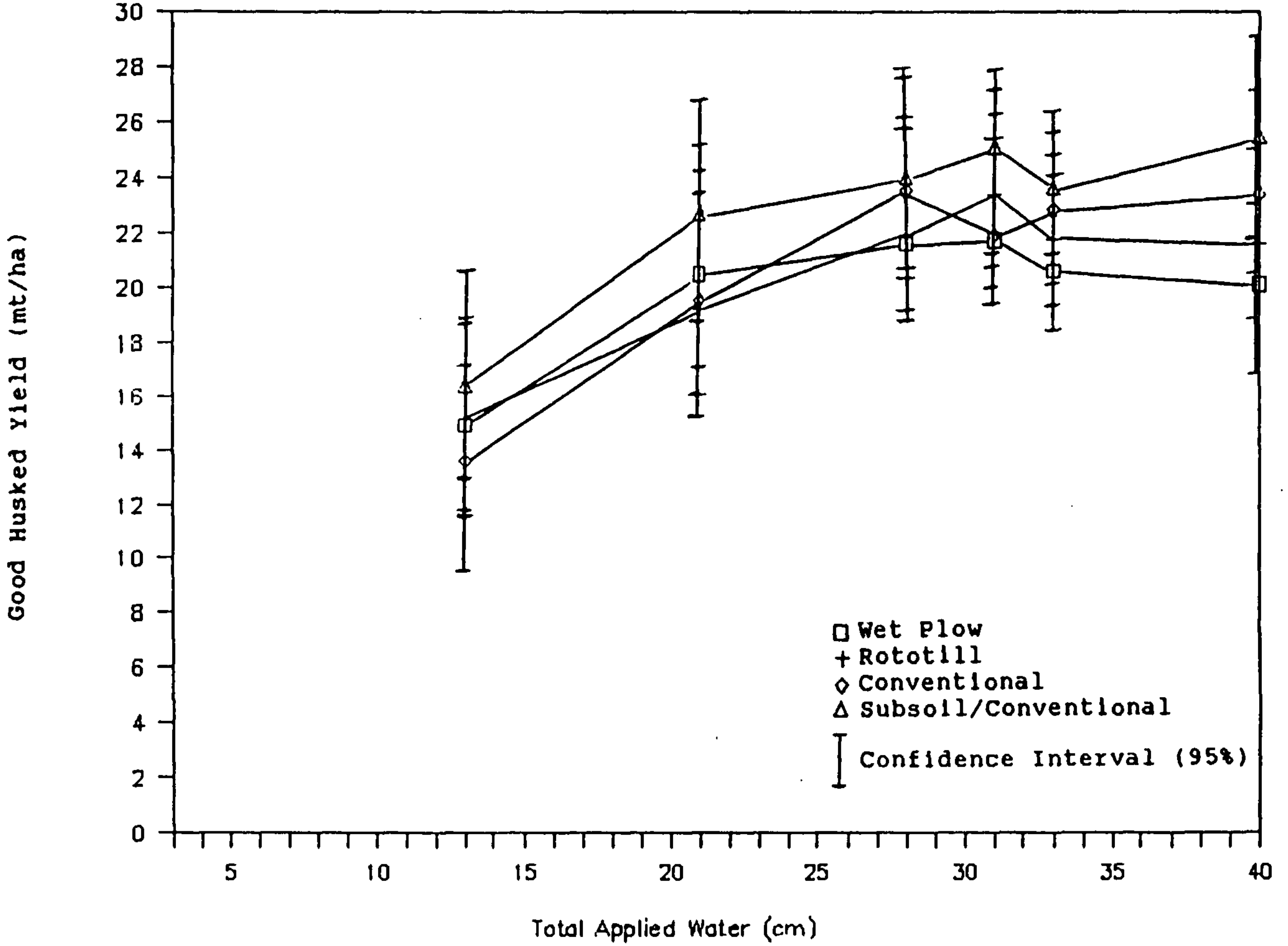

Figure 15. Effects of tillage treatments and applied water on good husked yield of sweet corn, L2Y1 (1987)

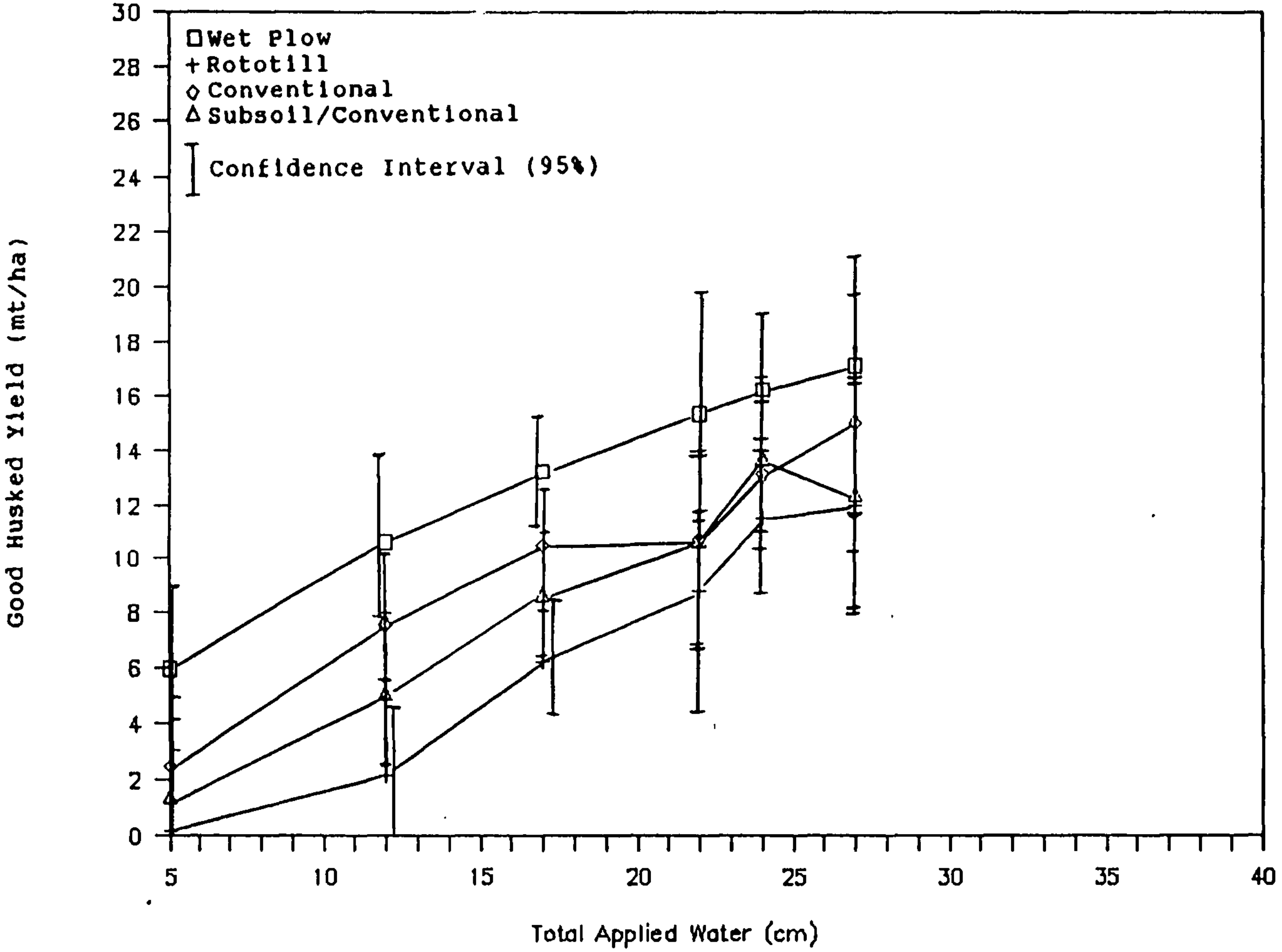

Figure 16. Effects of tillage treatments and applied water on good husked yield of sweet corn, L2Y2 (1988)

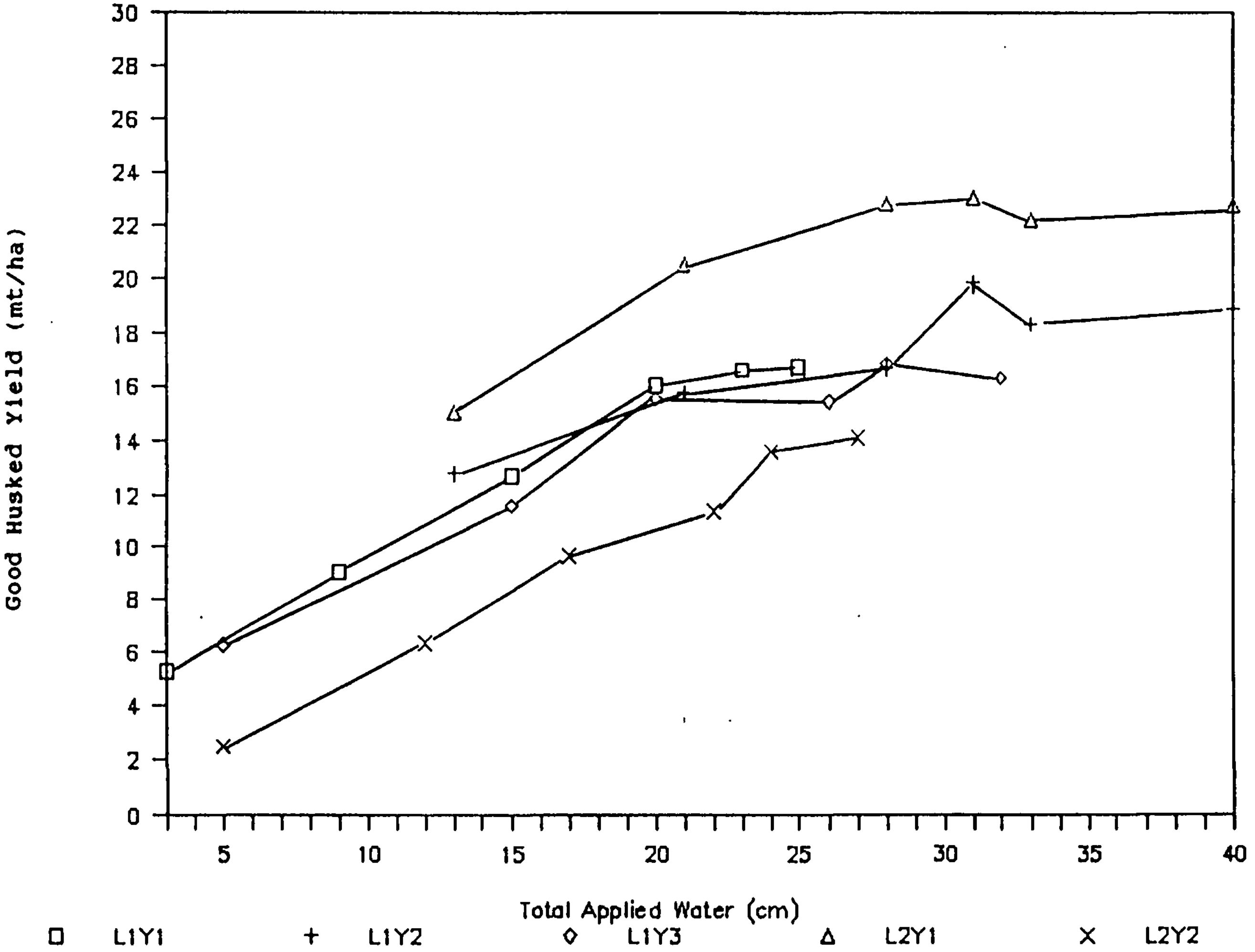

Figure 17. Effects of applied water on good husked yield of sweet corn in five experiments

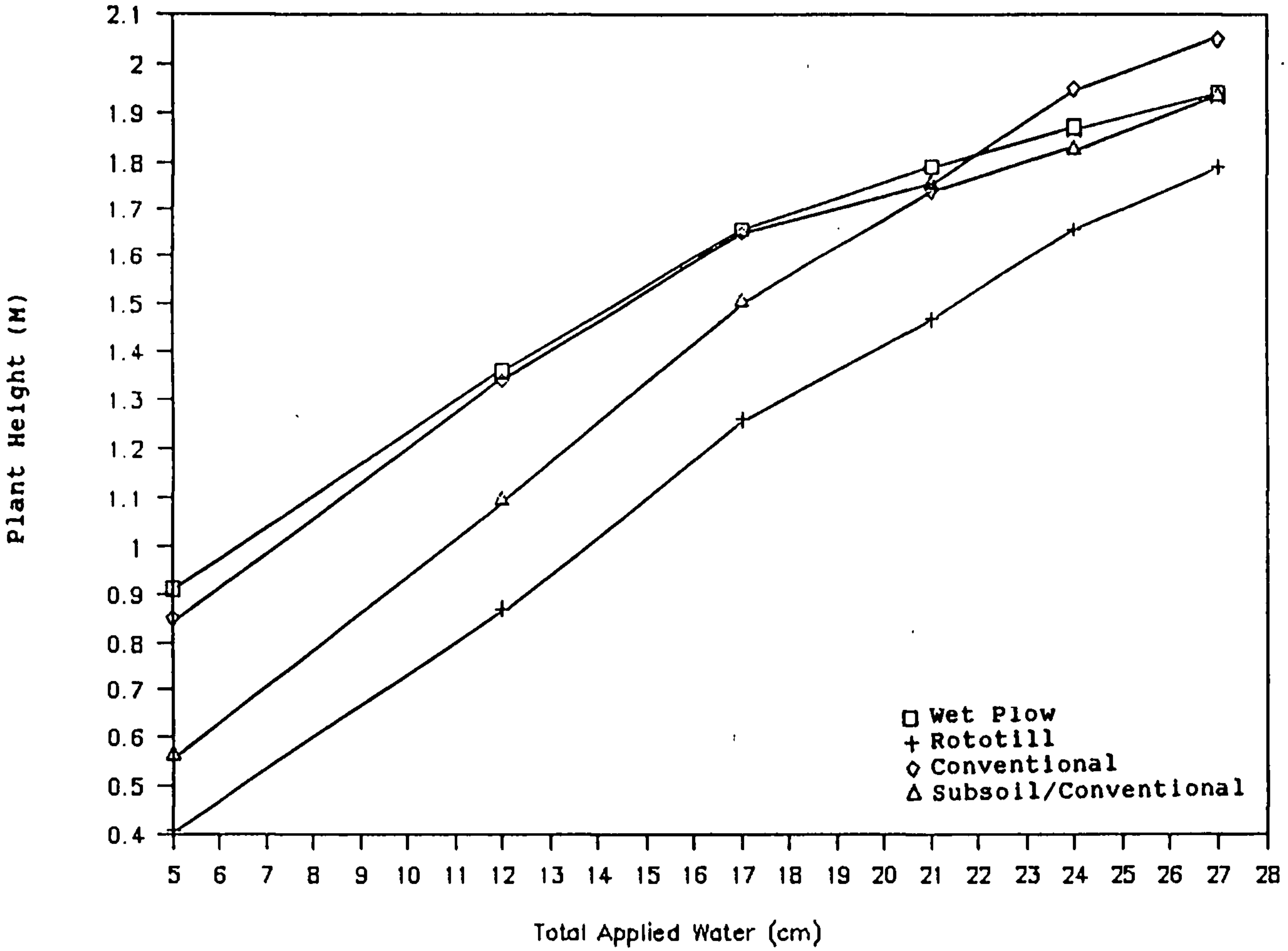

Figure 18. Effects of applied water on plant height of sweet corn L2Y2 (1988)

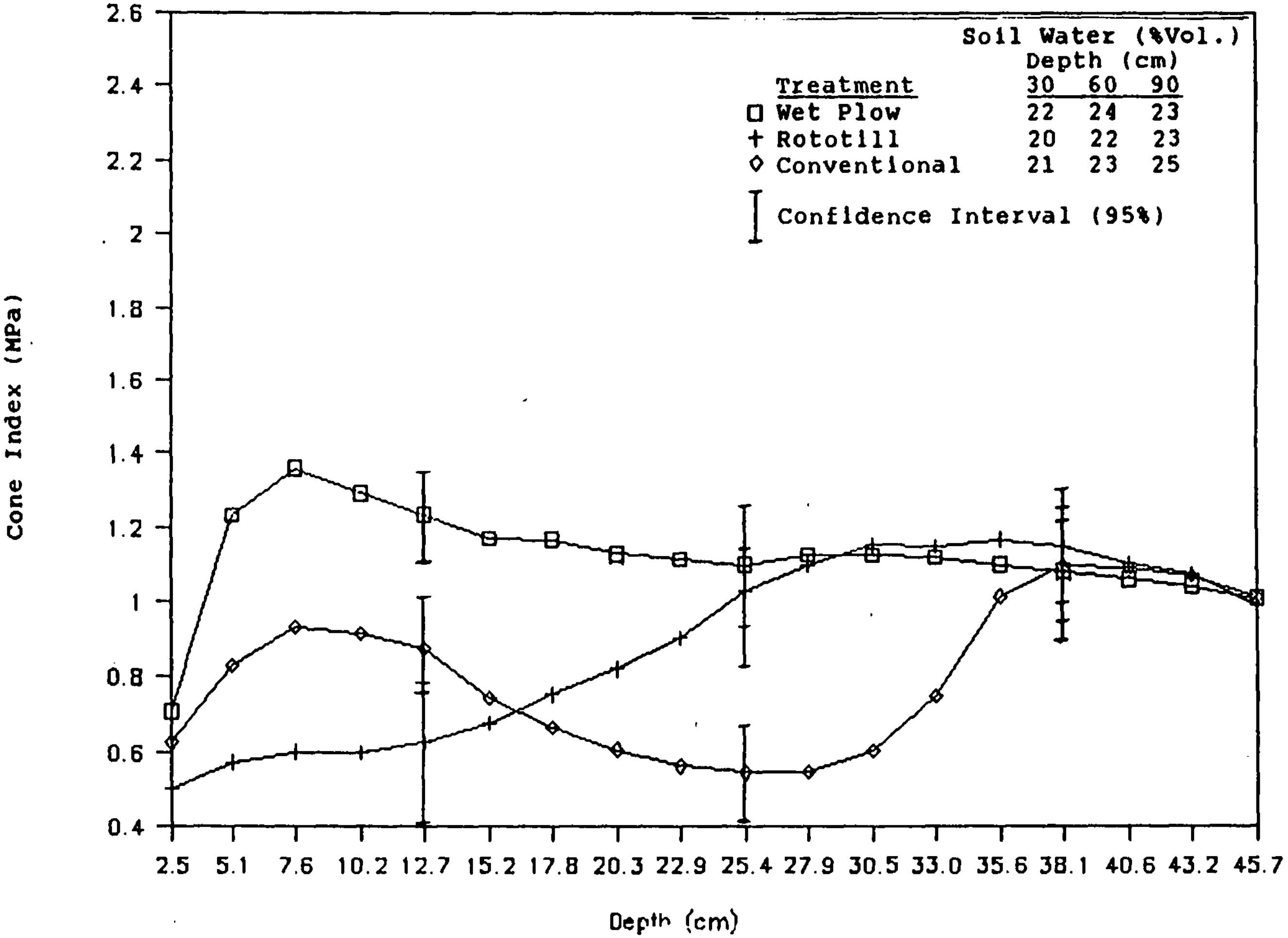

Figure 19. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y1 (1986)

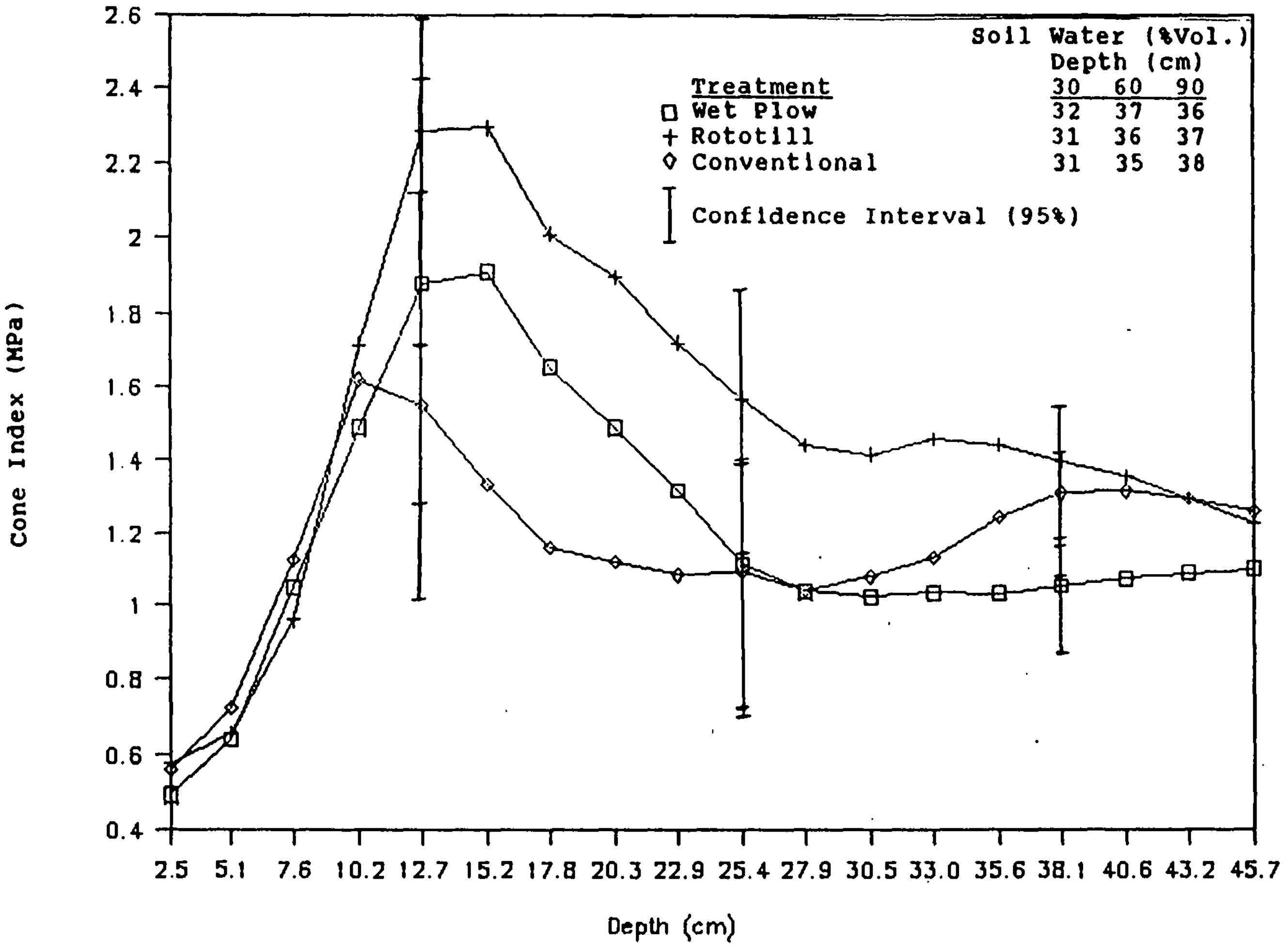

Figure 20. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y2 (1987)

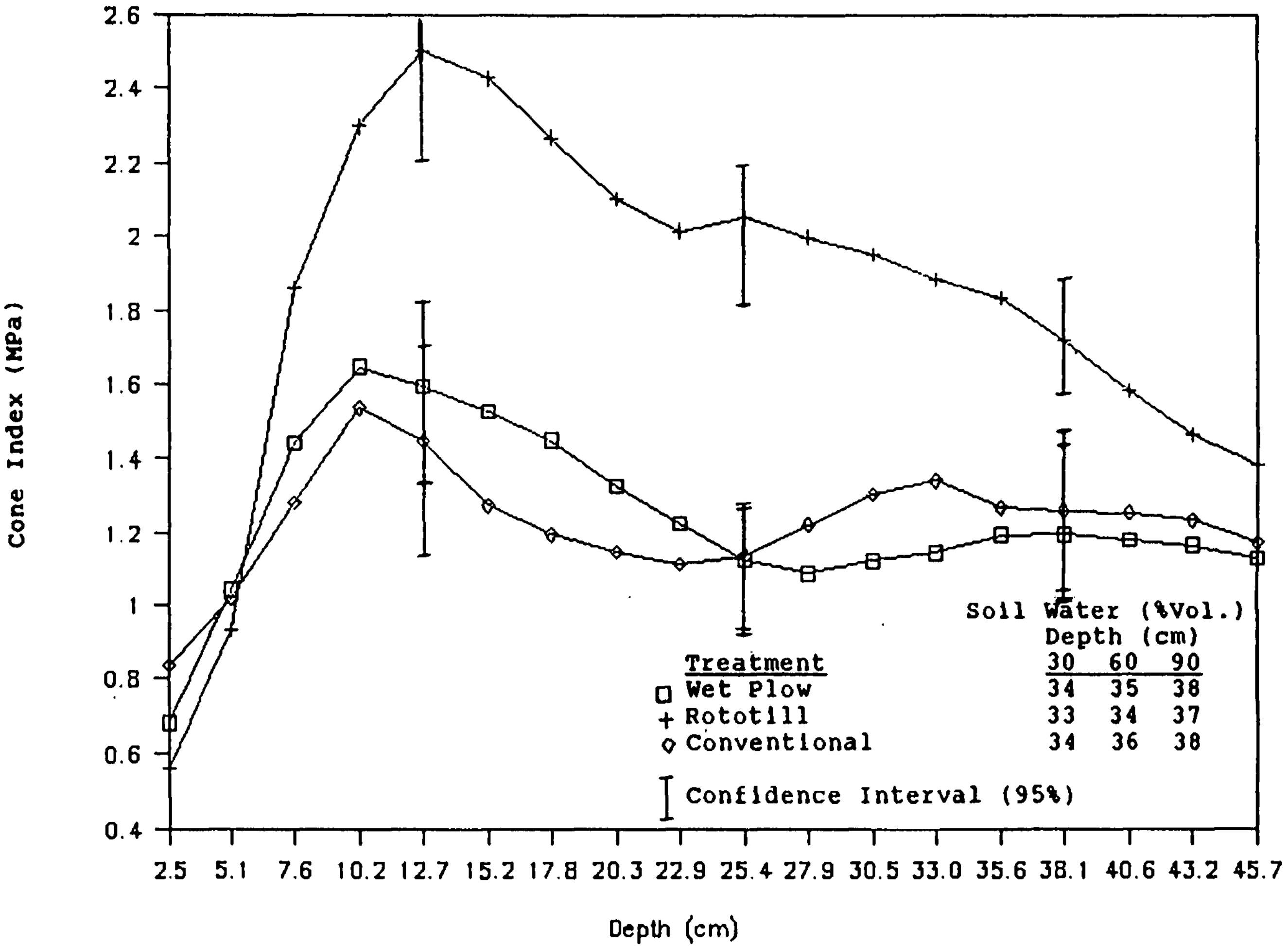

Figure 21. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L1Y3 (1988)

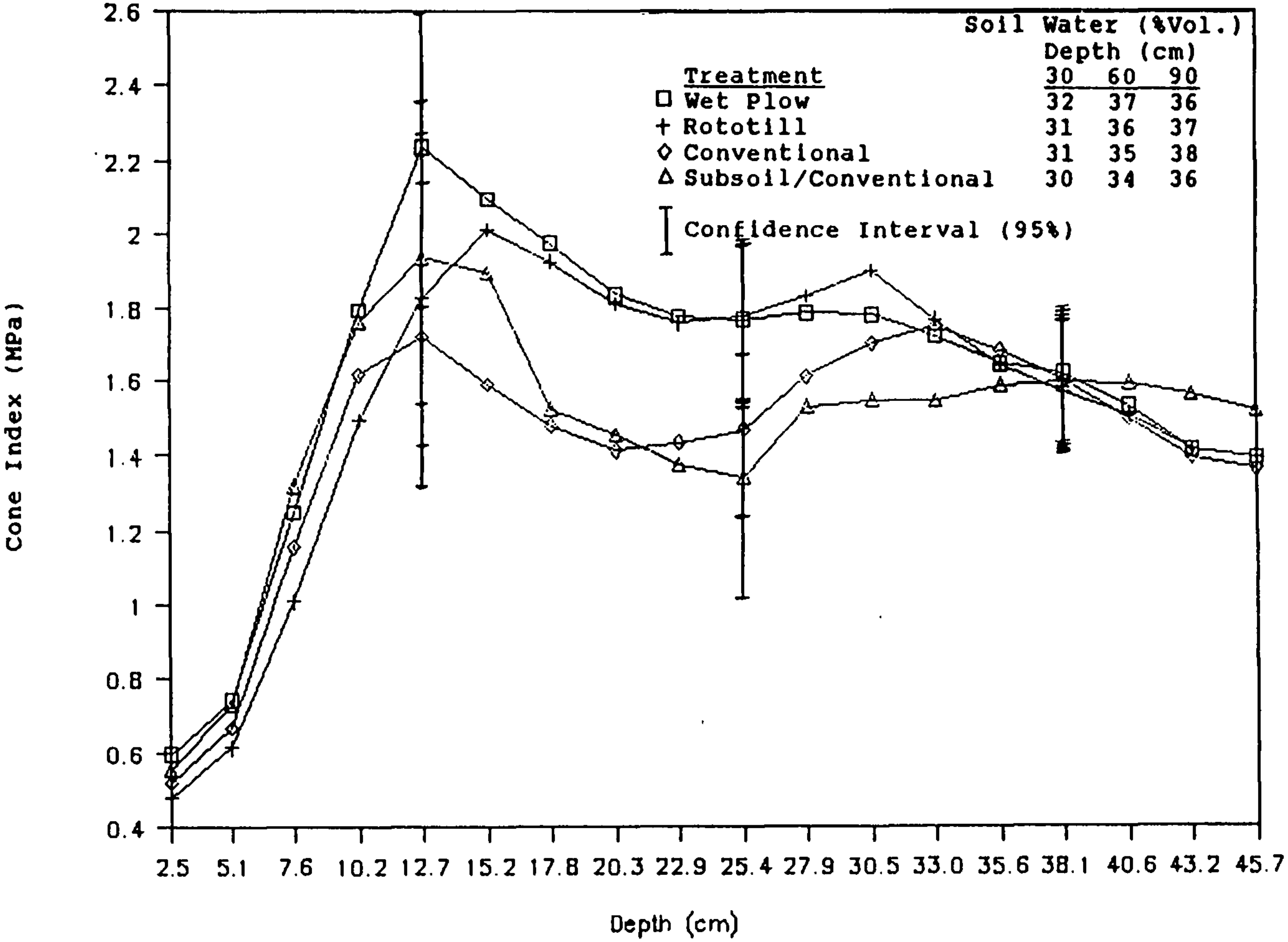

Figure 22. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L2Y1 (1987)

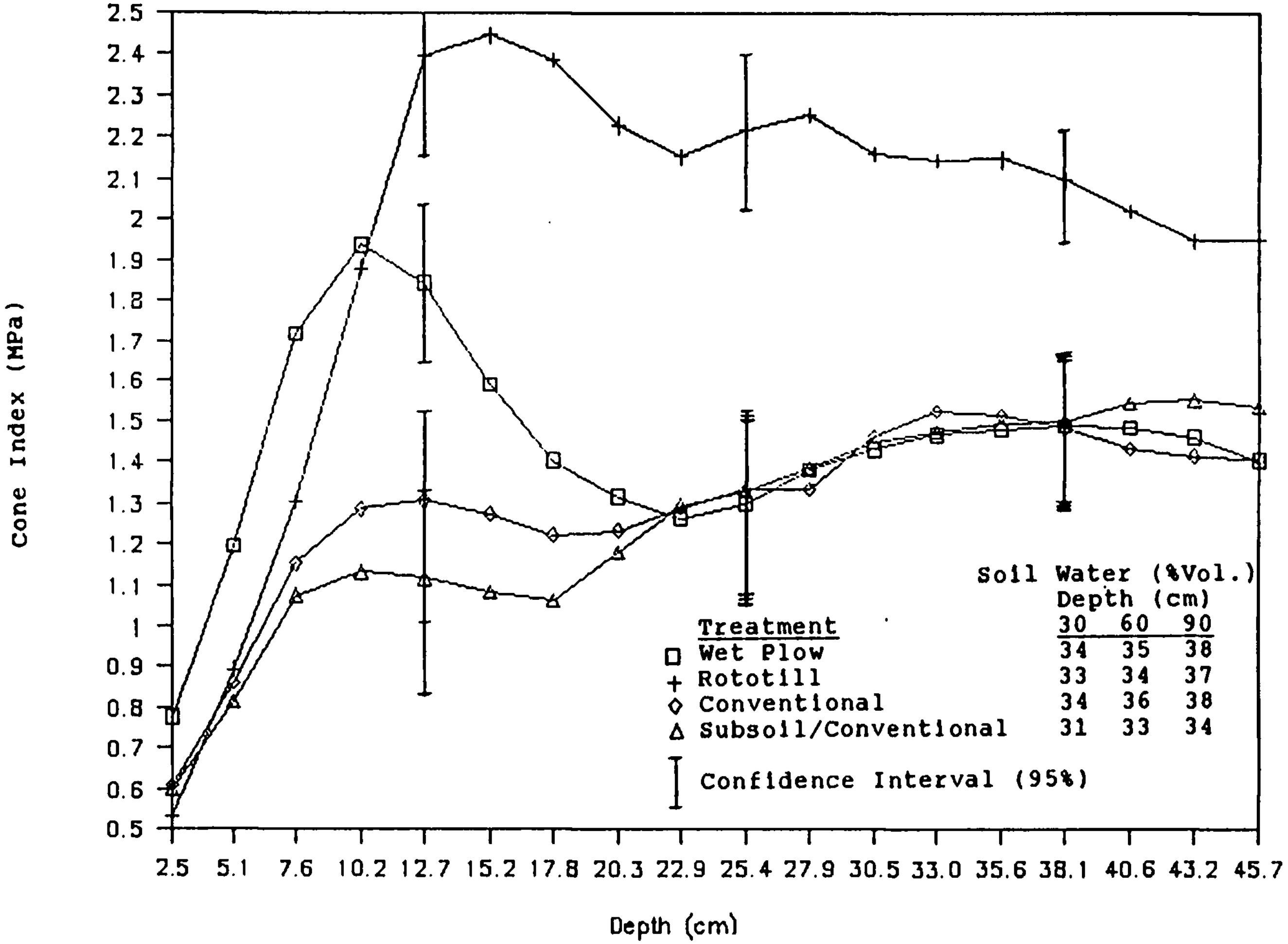

Figure 23. Effects of tillage treatments on cone index values (penetrometer readings) at various soil depths, L2Y2 (1988)

Table 9. Total applied water from the line source in five experiments on sweet corn.

		Centimeters of water applied[z]					
	No. of	Meters from line source					
Year	applications	3.2	5.0	6.9	8.7	10.5	12.3
Loc. 1							
1986	7	25.3	23.4	20.0	15.2	9.2	2.9
1987	7	39.4	33.0	31.1	27.6	21.3	12.7
1988	9	31.5	27.8	25.5	19.8	15.0	5.1
Loc. 2							
1987	7	39.4	33.0	31.1	27.6	21.3	12.7
1988	9	27.3	24.3	21.8	17.3	11.5	4.8

[z] Applied water amounts above do not include rainfall which was as follows: 1986 = 7.3 cm, 1987 = 6.8 cm, and 1988 = 5.7 cm.

Table10. Effect of tillage treatment on sweet corn husked ear yield, ear number, ear length, and plant height for each location and year.

Loc.	Year	Tillage treatment^z	Yield (mt/ha)	Ear number	Ear length (cm)	Plant height (m)
1	1	1	12.7	26	19.7	1.77
		2	13.1	29	19.4	1.63
		3	12.3	25	19.7	1.68
1	2	1	17.9	51	18.3	2.27
		2	15.2	47	17.6	2.02
		3	17.9	49	18.2	2.19
1	3	1	15.7	35	18.3	1.85
		2	10.8	26	18.8	1.57
		3	14.5	33	19.1	1.87
2	1	1	19.9	51	17.9	2.16
		2	20.5	53	17.9	2.08
		3	21.3	54	18.3	2.19
		4	22.9	57	18.4	2.19
2	2	1	13.1	28	18.5	1.59
		2	6.8	17	16.5	1.25
		3	9.9	22	19.0	1.60
		4	8.7	20	17.8	1.43

^{z} Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

Table 11, Effect of applied water levels on sweet corn yield of husked ears, ear number, ear length, and plant height for each location and year.

Loc.	Year	Applied Water (cm)	Yield^z (mt/ha)	Ear Number	Ear Length (cm)	Plant Height (m)
1	1	25.3	16.7a	35a	19.5b	2.07a
		23.4	16.6a	33a	19.7b	1.92b
		20.1	16.0b	31a	20.4a	1.79c
		15.2	12.7c	27b	19.3b	1.61d
		9.2	9.1d	19c	19.6b	1.43e
		2.9	5.3e	14d	19.0c	1.33f
1	2	39.4	18.8a	50a	18.5a	2.33a
		33.0	18.3a	52a	18.2a	2.28a
		31.1	19.8a	56a	17.8b	2.28a
		27.6	16.7b	51a	17.8b	2.19b
		21.3	15.7b	45b	18.1a	2.03c
		12.7	12.8c	38b	17.9b	1.85d
1	3	31.5	16.3a	36a	19.1a	2.15a
		27.8	16.8a	36a	19.2a	2.14a
		25.5	15.4b	35a	19.1a	2.00a
		19.8	15.5b	34a	19.0a	1.84b
		15.0	11.6c	29b	17.5c	1.45c
		5.1	6.3d	17c	18.4b	1.01d
2	1	39.4	22.7a	57a	18.5a	2.29a
		33.0	22.2a	55b	18.3b	2.26a
		31.1	23.0a	58a	18.0c	2.21b
		27.6	22.8a	56a	18.1b	2.16c
		21.3	20.6b	55b	18.2b	2.07d
		12.7	15.7c	42c	17.8c	1.93e
2	2	27.3	14.1a	30a	19.3a	1.93a
		24.3	13.6a	30a	19.4a	1.83b
		21.8	11.4b	27b	19.3a	1.69b
		17.3	9.7c	23b	19.3a	1.52c
		11.5	6.4d	16c	19.0b	1.17d
		4.8	2.5e	7d	11.2c	0.66e

[z] The letters following means categorize them into least significant difference ranges (.05) in regard to applied water.

Table12. Effects of applied water and tillage treatments on total above ground biomass of sweet corn for L1Y3 and L2Y2.

			Average wt/plant				No good ears/10 plants			
		Applied water[z]	Treatment[y]				Treatment			
Loc.	Year	(cm)	1	2	3	4	1	2	3	4
1	3	31.5	930	820	710	-	10	8	8	-
		25.5	850	840	700	-	7	7	8	-
		15.0	600	610	580	-	5	5	7	-
Avg.			793	757	663					
2	2	27.3	880	800	810	1030	10	9	8	11
		21.8	600	680	770	820	8	8	10	9
		11.5	680	360	560	510	7	4	6	3
Avg.			720	613	713	787				

[z] Applied water was a signifcant factor, L1Y3 (.05) and L2Y2 (.01), for determining total biomass production.

[y] Treatments: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

Table 13. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L1Y2 - 1987).

		Soil water percentage[y]			Soil water % (avg)[x]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[z]	water(cm)	30	60	90	30	60	90
1	39.4	25.0	31.6	32.2	26.0	32.5	33.8
1	31.1	30.1	34.0	36.9	29.2	34.2	36.3
1	21.3	29.9	34.6	37.1	29.7	34.8	37.2
Avg.		28.4	33.4	35.4			
2	39.4	26.4	33.8	34.3			
2	31.1	28.4	34.1	36.4			
2	21.3	29.3	35.4	37.1			
Avg.		28.0	33.7	36.0			
3	39.4	26.6	32.2	34.9			
3	31.1	29.1	34.5	35.7			
3	21.3	29.8	34.4	37.4			
Avg.		28.4	33.4	35.4			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional

[y] Each mean is the average of fifteen biweekly measurements taken throughout the season.

[x] Average percent soil water content at levels of total applied water.

Table 14. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L1Y3 - 1988).

		Soil water percentage[y]			Soil water % (avg)[x]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[z]	water(cm)	30	60	90	30	60	90
1	31.5	32.1	34.8	39.5	32.9	35.2	38.5
1	27.8	32.4	34.1	36.0	33.1	35.0	37.6
1	25.5	32.0	33.9	37.4	32.7	34.8	38.5
1	19.8	30.6	32.1	36.5	31.9	33.9	37.2
1	15.0	30.1	30.8	36.6	30.8	32.7	38.0
1	5.1	29.3	29.7	34.1	30.0	31.4	35.5
Avg.		31.1	32.6	36.7			
2	31.5	32.8	34.9	36.1			
2	27.8	32.9	35.4	38.1			
2	25.5	32.4	34.5	38.2			
2	19.8	32.1	33.2	37.1			
2	15.0	31.4	33.7	37.5			
2	5.1	30.2	33.4	36.0			
Avg.		32.0	34.2	37.2			
3	31.5	33.7	35.8	39.8			
3	27.8	34.0	35.5	38.6			
3	25.5	33.6	35.9	40.0			
3	19.8	32.9	36.4	38.1			
3	15.0	31.0	33.5	39.9			
3	5.1	30.5	31.2	36.4			
Avg.		32.6	34.7	38.8			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional

[y] Each mean is the average of sixteen biweekly measurements taken throughout the season.

[x] Average percent soil water content at levels of total applied water.

Table 15. Effects of soil tillage and applied water on soil water content (% volumetric) at three depths (L2Y1 - 1987).

		Soil water percentage[Y]			Soil water % (avg)[X]		
	Applied	Depth (cm)			Depth (cm)		
Treatment[Z]	water(cm)	30	60	90	30	60	90
1	39.4	29.0	35.6	37.5	28.3	34.3	36.5
1	31.1	30.6	37.2	36.6	29.8	36.0	37.6
1	21.3	30.8	36.1	38.2	29.6	35.7	38.9
Avg.		30.1	36.3	37.5			
2	39.4	29.4	34.3	35.5			
2	31.1	29.8	35.5	37.5			
2	21.3	30.0	35.9	37.7			
Avg.		29.7	35.2	36.9			
3	39.4	27.3	34.1	37.5			
3	31.1	29.5	35.6	38.9			
3	21.3	29.0	35.1	39.8			
Avg.		28.6	34.9	38.7			
4	39.4	27.4	33.2	35.4			
4	31.1	29.2	35.7	37.6			
4	21.3	28.8	35.6	39.8			
Avg.		32.6	34.7	38.8			

[Z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

[Y] Each mean is an average of thirteen biweekly measurements taken throughout the season.

[X] Average percent soil water content at levels of total applied water.

Table 16. Effects of soil tillage and applied water on soil water content (% volumetric), at three depths (L2Y2 - 1988).

Treatment[z]	Applied water(cm)	Soil water percentage[y]			Soil water % (avg)[x]		
		Depth (cm)			Depth (cm)		
		30	60	90	30	60	90
1	27.3	32.6	34.5	38.4	31.7	32.7	33.1
1	24.3	32.6	34.4	36.7	32.1	32.6	31.9
1	21.8	31.0	31.6	34.5	31.2	30.7	30.4
1	17.3	31.7	33.7	35.7	29.6	30.5	29.4
1	11.5	30.6	32.2	34.8	31.1	29.9	31.0
1	4.8	28.1	30.2	34.0	29.3	29.9	31.1
Avg.		31.1	32.8	35.7			
2	27.3	30.7	29.4	29.8			
2	24.3	32.1	35.3	35.1			
2	21.8	31.7	34.8	35.2			
2	17.3	30.3	33.4	35.9			
2	11.5	32.0	34.0	35.5			
2	4.8	29.5	33.6	38.3			
Avg.		31.1	33.4	35.0			
3	27.3	30.3	32.5	32.8			
3	24.3	32.1	33.2	34.1			
3	21.8	31.2	34.2	34.9			
3	17.3	29.3	32.7	34.8			
3	11.5	31.2	32.6	37.1			
3	4.8	29.4	31.0	36.1			
Avg.		30.6	32.7	35.0			
4	27.3	33.1	34.3	31.2			
4	24.3	31.5	27.3	21.6			
4	21.8	30.7	22.3	17.1			
4	17.3	27.1	22.3	11.1			
4	11.5	30.4	20.9	16.7			
4	4.8	30.2	24.7	16.1			
Avg.		30.5	25.3	19.0			

[z] Treatment: 1)Wet Plow; 2)Rototill; 3)Conventional; 4)Subsoil/Conventional

[y] Each mean is the average of sixteen biweekly measurements taken throughout the season.

[x] Average percent soil water content at levels of total applied water.

Discussion

Significant differential responses in sweet corn yield did not occur during the first year that the tillage treatments were imposed, but were apparent during the second and third years. These yield responses were related, at least in part, to the effects of tillage treatments on soil compaction. This conclusion is supported by data showing that in L2Y1 the CIV from the four tillage treatments were not significantly different and for L1Y1 all CIV were relatively low, though values from the tillage treatments were significantly different. Most of the soil macrostructure was probably still intact during the year of initial tillage treatments, which maintained a lower resistance to the penetrometer cone, indicating less soil strength in comparison to the second and third years of imposed tillage treatments. In the second or third years, CIV showed significant differences among tillage treatments and indicated that specific annually repeated tillage treatments were increasing soil strength or soil compaction. When CIV for the rototill treatment exceeded 2.0 MPa (10-20 cm depth), as was the case for L1Y2, L1Y3, and L2Y2, this was a good indication that yields would be low compared to the other tillage treatments.

A lack of large soil aggregates was visually observed after tillage with the rototiller compared to other tillage treatments. Rosenberg (1964) reported that the major cause of soil compaction was due to the manipulation of large soil aggregates by traction tillage implements, and compaction of soils by vehicular traffic. Higher CIV in the rototill treatment at greater depths could be due to lack of deep tillage, wheel traffic from tillage passes, or from the vibrating action of the tiller. Soil strength for the rototilled treatment probably restricted root growth and as the crop matured the stunted root system was unable to provide sufficient water to meet the evaporative demand. Root growth is hampered by severe soil compaction (Greacen et al., 1968) and roots of most plant species do not penetrate soils with strengths greater than 3 MPa except by following low strength cracks and fissures (Taylor and Burnett, 1964; Zimmerman and Kardos, 1961).

Higher yields in some tillage treatments could have resulted due to increased soil water availability. The higher water availability of a soil can be a result of an increased percentage of small pore spaces (Hillel, 1982). Boone et al. (1987) conducted corn growth experiments on fine sand and loamy fine sand with plot CIV of 1.6, 1.1, 0.7, and 0.8 MPa at a depth of 15 cm. Despite smaller corn root systems caused by soil compaction, three out of five experiments were favored by soil compaction. The positive relation between crop growth and soil compaction was attributed to better water availability, probably due to improved soil water transport and root-soil contact. Slight corn silage yield reductions were reported from the loose treatments and large yield reductions caused by insufficient soil aeration from the severely compacted treatment.

Total applied water consistently affected sweet corn yield, ear number, and ear length was significantly affected in some cases. Braunworth and Mack (1987) reported that reduced number of good ears and ear length in sweet corn yields were a result of insufficient applied water. Water deficits during tassel emergence, silking, and pollination completion reduce corn yields (Dale and Shaw, 1965; Stanberry et al., 1963; and Stewart et al., 1975).

Total above ground biomass data were not extensive enough to be reliable for soil tillage treatment effects in relation to yields of husked ears. Biomass production for the wet plow tillage treatment in L1Y3 was significantly higher but this difference was not reflected by the husked ear yield. Total above ground biomass and ear number were adversely affected as total applied water declined. Total applied water was a highly significant factor in determining biomass production for all treatments. When observing the mature crop from the end of the plots perpendicular to the line source, the contour of the crop (plant height) resembled a bell shaped curve that reflected the diminishing applied water with distance from the line source. Part of the decline in plant height and total biomass production was probably caused by increased soil strength and restricted root penetration due to diminishing water. Taylor and Gardner (1963) reported that as soil water decreased, soil strength increased reducing penetration of plant roots. Crop appearance was best for corn in the wet plowed treatment with deep green foliage and sturdy stalks throughout the water gradient and worst for corn in the rototilled treatment that was stunted and somewhat chlorotic in areas of water stress. Field observations of plant vigor revealed plant stunting and curled leaves for plants under water stress conditions (Andrew and Weis, 1974; and Keller and Carlson, 1967).

In L2Y1, average soil water content for conventional and subsoil/conventional treatments was significantly lower throughout the sample profile compared to the wet plow and rototill treatments. The slightly higher CIV from the wet plow and rototill treatments indicate a slightly more compact soil compared to the conventional tillage treatment that could have a more favorable pore size distribution thus increasing the water holding capacity. Average soil water in L1Y3 for the wet plow tillage treatment was lower than for other treatments; however, total biomass was greater than the conventional treatment and yield was greater than the rototill treatment. The evapotranspiration demand from increased biomass and yield could account for the depletion of soil water. Differences in soil water throughout the applied water gradient did not appear to be as dramatic or consistent as expected. Available soil water must exceed the evaporative demand of the crop for the crop to maximize growth and yield. As plants became more stunted with the decline in applied water, the evaporative demand probably declined and the soil water was not depleted (Cuenca 1989). However soil water data in the present study do not always appear to be reliable in relating to yield responses obtained or to the level of applied water from the line source system. Begg and Turner, 1976, reported that water deficits usually caused marked reductions in total leaf area. Reductions in total leaf area would reduce the evapotranspiration from the plants. However leaf area measurements were not taken in this study.

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CHAPTER 5

SUMMARY AND CONCLUSIONS

Five experiments were conducted in two locations at the Oregon State University Vegetable Research Farm, Corvallis, to evaluate the effects of soil tillage treatments and levels of applied water on bush green beans and sweet corn.

Responses to soil tillage treatments varied between 'Jubilee' sweet corn and 'Oregon 91G' bush green beans. Generally, green beans responded more favorably to the wet plow soil treatment (L2Y1&2) than did the sweet corn with higher yield of good husked ears in only L2Y2. Cone index values (CIV) indicate a slight increase in soil strength, that may have favored the green beans. Pod yield tended to decline in response to the rototill tillage treatment; however, corn ear yields declined significantly after the second year of rototill treatment (L1Y2&3, L2Y2). Corn plant height was adversely affected by the rototill tillage treatment in all locations and years except L1Y1 when no data were taken. Rototilling produced the most severely compacted soil profile after repeated seasonal treatments (L1Y3, L2Y2). It appears as though sweet corn is more susceptible to severe soil compaction than are green beans.

Total applied water was a highly significant factor in determining yield and total above ground biomass production for green beans and sweet corn. As total applied water (including rainfall) ranged from 23 to 27 cm, highest yields of beans were produced. When levels of applied water declined below these amounts, pod yield and total above ground biomass diminished. Highest yields of sweet corn usually occured when 30 to 36 cm of water was applied (including rainfall). Sweet corn consistently responded to declining applied water with reductions in good husked ear yield, ear number, and plant height. Ear length was significantly affected in some cases. There were no significant interaction effects between tillage treatments and amounts of applied water except husked ear yield of sweet corn in L1Y3. In regard to these results it appears as though tillage induced soil compaction is not alleviated by increasing amounts of applied water.

Soil moisture data were not consistent enough to make clear determinations. It would have been useful to have evapotranspiration data to determine crop water use between tillage treatments and over the water gradient. Evaluation of the root zone could have revealed from where the water was being extracted and possible restrictions due to soil compaction.

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APPENDIX

Table 17. Analysis of variance for green bean pod yields by treatment at each water level.

Loc.	Yr	Water level	Source of variation	Sum of squares	d.f.	Mean square	F	Sig. level
1	86	14.5	Between gps[z]	3.435	2	1.717	5.34	.1028
			Within gps[y]	.966	3	.322		
1	86	14.0	Between gps	.155	2	.077	.21	.8231
			Within gps	1.115	3	.372		
1	86	12.6	Between gps	2.038	2	1.019	.46	.6676
			Within gps	6.593	3	2.198		
1	86	8.7	Between gps	.879	2	.440	.15	.8664
			Within gps	8.767	3	2.922		
1	86	4.1	Between gps	3.712	2	1.856	9.63	.0495
			Within gps	.578	3	.193		
1	86	1.1	Between gps	1.412	2	.706	.69	.5685
			Within gps	3.088	3	1.029		
1	87	20.3	Between gps	6.252	2	3.126	18.93	.0199
			Within gps	.495	3	.165		
1	87	16.5	Between gps	2.622	2	1.311	31.13	.0099
			Within gps	.126	3	.042		
1	87	15.9	Between gps	5.201	2	2.601	55.88	.0042
			Within gps	.140	3	.047		
1	87	13.7	Between gps	10.886	2	5.443	181.93	.0007
			Within gps	.090	3	.030		
1	87	10.2	Between gps	.747	2	.373	8.22	.0606
			Within gps	.136	3	.045		
1	87	5.4	Between gps	.029	2	.014	.72	.5546
			Within gps	.060	3	.020		
1	88	24.0	Between gps	3.360	2	1.680	.80	.5268
			Within gps	6.303	3	2.101		
1	88	20.8	Between gps	11.870	2	5.935	2.44	.2350
			Within gps	7.300	3	2.433		
1	88	19.0	Between gps	9.104	2	4.552	1.04	.4531
			Within gps	13.098	3	4.366		
1	88	14.8	Between gps	24.050	2	12.025	4.57	.1229
			Within gps	7.899	3	2.633		
1	88	10.5	Between gps	57.878	2	28.939	1.72	.3178
			Within gps	50.449	3	16.816		
1	88	1.2	Between gps	20.486	2	10.243	11.22	.0405
			Within gps	2.739	3	.913		
2	87	20.3	Between gps	1.100	3	.367	.16	.9229
			Within gps	27.961	12	2.330		
2	87	16.5	Between gps	3.126	3	1.042	.59	.6312
			Within gps	21.074	12	1.756		
2	87	15.9	Between gps	8.442	3	2.814	3.83	.0390
			Within gps	8.814	12	.735		
2	87	13.7	Between gps	8.984	3	2.995	7.94	.0035
			Within gps	4.524	12	.377		
2	87	10.2	Between gps	6.903	3	2.301	3.96	.0355
			Within gps	6.969	12	.581		
2	87	5.4	Between gps	2.292	3	.764	3.05	.0702
			Within gps	3.010	12	.251	3.05	

2	88	20.3	Between gps	3.514	3	1.171	.52	.6740
			Within gps	26.824	12	2.235		
2	88	17.8	Between gps	5.674	3	1.891	.72	.5568
			Within gps	31.344	12	2.612		
2	88	15.8	Between gps	7.561	3	2.520	.92	.4619
			Within gps	32.980	12	2.748		
2	88	13.3	Between gps	15.323	3	5.108	1.53	.2571
			Within gps	40.044	12	3.337		
2	88	7.5	Between gps	6.587	3	2.196	3.12	.0664
			Within gps	8.450	12	.704		
2	88	3.5	Between gps	2.457	3	.819	.91	.4654
			Within gps	10.807	12	.901		

[z] Source of variation between treatment groups

[y] Source of variation among treatment groups, treatment groups and replications in d.f.

Table 18. Analysis of variance table for sweet corn good husked ear yields by treatment at each water level.

Loc.	Yr	Water level	Source of variation	Sum of squares	d.f.	Mean square	F	Sig. level
1	86	25.3	Between gps[z]	.773	2	.387	.29	.7655
			Within gps[y]	3.966	3	1.322		
1	86	23.4	Between gps	13.051	2	6.526	6.53	.0808
			Within gps	2.999	3	1.000		
1	86	20.0	Between gps	1.137	2	.568	.08	.9286
			Within gps	22.452	3	7.484		
1	86	15.2	Between gps	1.137	2	.569	.08	.9286
			Within gps	22.452	3	7.484		
1	86	9.2	Between gps	.259	2	.130	.04	.9583
			Within gps	8.996	3	2.999		
1	86	2.9	Between gps	6.243	2	3.122	.24	.7993
			Within gps	38.751	3	12.917		
1	87	39.4	Between gps	3.573	2	1.786	2.00	.2812
			Within gps	2.686	3	.895		
1	87	33.0	Between gps	3.836	2	1.918	5.58	.0974
			Within gps	1.031	3	.344		
1	87	31.1	Between gps	.667	2	.334	.25	.7966
			Within gps	4.076	3	1.359		
1	87	27.6	Between gps	26.105	2	13.052	2.17	.2619
			Within gps	18.087	3	6.029		
1	87	21.3	Between gps	18.011	2	9.006	.28	.7771
			Within gps	98.349	3	32.783		
1	87	12.7	Between gps	47.247	2	23.624	5.02	.1104
			Within gps	14.128	3	4.709		
1	88	31.5	Between gps	10.999	2	5.499	2.79	.2070
			Within gps	5.921	3	1.974		
1	88	27.8	Between gps	3.850	2	1.925	1.28	.3963
			Within gps	4.511	3	1.504		
1	88	25.5	Between gps	22.009	2	11.005	15.40	.0265
			Within gps	2.144	3	.715		
1	88	19.8	Between gps	47.021	2	23.511	4.62	.1215
			Within gps	15.282	3	5.094		
1	88	15.0	Between gps	57.938	2	28.969	13.52	.0316
			Within gps	6.429	3	2.143		
1	88	5.1	Between gps	86.068	2	43.034	4.52	.1244
			Within gps	28.572	3	9.524		
2	87	39.4	Between gps	63.329	3	21.110	1.86	.1908
			Within gps	136.459	12	11.372		
2	87	33.0	Between gps	19.349	3	6.450	1.28	.3251
			Within gps	60.379	12	5.032		
2	87	31.1	Between gps	29.856	3	9.952	1.19	.3536
			Within gps	100.038	12	8.336		
2	87	27.6	Between gps	16.274	3	5.425	.43	.7325
			Within gps	149.934	12	12.494		
2	87	21.3	Between gps	27.392	3	9.131	.67	.5897
			Within gps	164.885	12	13.740		
2	87	12.7	Between gps	7.890	3	2.630	.13	.9396
			Within gps	240.281	12	20.024		

2	88	27.3	Between gps	66.968	3	22.323	1.59	.2438
			Within gps	168.691	12	14.058		
2	88	24.3	Between gps	45.767	3	15.256	2.46	.1132
			Within gps	74.522	12	6.210		
2	88	21.8	Between gps	91.273	3	30.424	3.27	.0590
			Within gps	111.601	12	9.300		
2	88	17.3	Between gps	102.775	3	34.258	4.99	.0178
			Within gps	82.291	12	6.858		
2	88	11.5	Between gps	153.499	3	51.166	4.05	.0334
			Within gps	151.677	12	12.640		
2	88	4.8	Between gps	76.408	3	25.469	3.11	.0669
			Within gps	98.385	12	8.199		

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[z] Source of variation between treatment groups

[y] Source of variation among treatment groups, treatment groups and replications in d.f.

Table 19. Analysis of variance table for penetrometer readings by treatment for three depths.

Loc.	Yr	Depth	Source of variation	Sum of squares	d.f.	Mean square	F	Sig. level
1	86	12.7	Between gps[z]	14373.6	2	7186.79	22.64	.0000
			Within gps[y]	4762.2	15	317.48		
1	86	25.4	Between gps	14014.2	2	7007.11	10.49	.0014
			Within gps	10017.6	15	667.84		
1	86	38.1	Between gps	188.9	2	94.47	.57	.5779
			Within gps	2490.9	15	166.06		
1	87	12.7	Between gps	21073.5	2	10536.76	2.05	.1633
			Within gps	77115.2	15	5141.01		
1	87	25.4	Between gps	11246.2	2	5623.11	2.91	.0858
			Within gps	29037.3	15	1935.82		
1	87	38.1	Between gps	5003.8	2	2501.92	4.21	.0353
			Within gps	8910.5	15	594.03		
1	88	12.7	Between gps	50571.2	2	25285.61	17.28	.0001
			Within gps	21948.9	15	1463.26		
1	88	25.4	Between gps	43689.2	2	21844.62	26.36	.0000
			Within gps	12429.8	15	828.65		
1	88	38.1	Between gps	12468.4	2	6234.19	9.53	.0021
			Within gps	9811.0	15	654.07		
2	87	12.7	Between gps	23364.6	3	7788.21	1.34	.2731
			Within gps	255443.7	44	5805.54		
2	87	25.4	Between gps	22137.1	3	7379.05	3.76	.0172
			Within gps	86261.3	44	1060.48		
2	87	38.1	Between gps	210.5	3	70.16	.08	.9711
			Within gps	39144.3	44	889.64		
2	88	12.7	Between gps	154492.6	3	51497.55	21.58	.0000
			Within gps	104980.4	44	2385.92		
2	88	25.4	Between gps	93767.0	3	31255.67	17.68	.0000
			Within gps	77776.4	44	1767.65		
2	88	38.1	Between gps	43092.5	3	14364.15	10.31	.0000
			Within gps	61287.8	44	1392.90		

[z] Source of variation between treatment groups

[y] Source of variation among treatment groups, treatment groups and replications in d.f.