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TILLAGE AND ROW SPACING EFFECTS ON THE DEVELOPMENT AND GROWTH OF DRY BEAN (<u>PHASEOLIS</u> <u>VULGARIS</u> L.) AND SUGAR BEET (<u>BETA</u> <u>VULGARIS</u> L.) ON A PARKHILL LOAM SOIL

By

Chuanguo Xu

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ABSTRACT

TILLAGE AND ROW SPACING EFFECTS ON THE DEVELOPMENT AND GROWTH OF DRY BEAN (PHASEOLIS VULGARIS L.) AND SUGAR BEET (BETA VULGARIS L.) ON A PARKHILL LOAM SOIL

by

Chuanguo Xu

The objective of this study was to examine the effects of tillage systems and row spacing on the development, growth, and yield of dry bean (Phaseolis vulgaris L., var. Mayflower) and sugar beet (Beta vulgaris L., var. Mono-Hy E-4). This study was conducted in 1989 and 1990 on a Parkhill loam soil of Saginaw County, Michigan. The tillage treatments were moldboard plow, moldboard plow without secondary tillage (nst), chisel plow, ridge tillage, no till, and no till plus cultivation. The row spacings were 56 cm and 71 cm. Rates of dry bean development and growth appeared to be altered in the time flowering and seed development. Dry bean growth and development was retarded and final yields were reduced under the no till systems due to wet soil conditions in 1990. Dry bean yields in the 56 cm row spacing were higher than in the 71 cm row spacing in 1989 and 1990. Sugar beet growth was more rapid and yields were higher under moldboard plow (nst) as compared to the no-tillage treatments. Sugar beet yields were higher in the 71 cm row spacing than in the 56 cm spacing in 1989 and 1990.

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INTRODUCTION

Any mechanical manipulation that changes a soil condition may be considered tillage (Schafer and Johnson, 1982). Lal (1977) defined tillage as physical, chemical or biological soil manipulation to optimize conditions for seed germination, emergence and seedling establishment. Soil manipulation can induce profound changes in fertility status and these changes may be manifested in good or poor performance of crop growth. Since tillage operations loosen, granulate, crush or even compact soil particles, soil factors that influence plant growth such as bulk density, pore size distribution and, hence, the composition of the soil atmosphere may be affected (Ohiri and Ezumash, 1990). In brief, tillage effects on soil conditions are multifaceted, reflected in some combination of soil physical properties including texture, structure, permeability, and consistency, and are modified by chemical and biological processes depending on how the soils are managed.

Due to the energy crisis and continued excessive erosion on some soils, farmers are showing increasing interest in alternative tillage methods to enhance soil conservation. Conservation tillage is broadly defined as any tillage or plant systems that reduces soil erosion by maintaining surface residue that covers at least 30% of the soil at planting (Conservation Tillage Information Center, 1988). Any tillage systems that does not meet the minimum residue-cover requirement is consider a form of conventional tillage.

Conventional tillage and conservation tillage may have different effects on soil physical properties. Both systems are intended to provide optimum seed-zone conditions for crop germination, emergence, and root growth, but the soil matrix undergoes less disturbance with conservation tillage while conventional tillage systems use numerous tillage operations. However, reduced soil disturbance under conservation tillage systems may increase soil bulk density within soil surface layers resulting in conditions adverse to crop growth and yield (Voorthees and Lindstrom, 1983).

Results from continuous long-term tillage studies on soil physical properties are quite variable. Some researchers (Gantzer and Blake, 1978; Pidgeon and Soane, 1977) have observed significant differences in bulk density between soil under conventional and conservation tillage treatments. In other instances, no such differences were observed (Blevins et al., 1983; Shear and Moschler, 1969; Tollner et al., 1984; Van Doren et al., 1976).

Soil impedance is an important soil physical property influencing root growth. Soil impedance within the upper soil profile has usually been observed to be greater under conservation tillage as compared to conventional tillage in continuous, long-term studies (Bauder et al., 1981; Lindstrom et al., 1984; Pidgeon and Soane, 1977).

The importance of soil water in plant growth and crop development is widely recognized. Tillage can influence soil water content through its effect on infiltration, surface runoff, evaporation, and water availability to plants. Volumetric water content can be greater under no tillage systems as compared to conventional tillage systems (Limstron et al., 1984; Hammel, 1989; Tollner et al., 1984; Gantzer and Blake, 1978). Blevins et al. (1971) attributed increased soil moisture over a period of three growing seasons to reduced evaporation and a greater ability to store moisture under no-tillage. Gantzer and Blake (1978) attributed the increased capability to store soil water under no-tillage to rearrangement of the pore size distribution or to residue cover reducing evaporation.

No-tilled soil generally has reduced porosity when compared with moldboard plow soil. Van Ouwerkerk and Boone (1970) hypothesized that no-tillage not only reduces total pore space but also radically changes the pore size distribution with the large pores disappearing and the finer pores becoming more predominate. This hypothesis agrees with the observation that one effect of plowing is to increase the number of drainable pores (Tollner et al., 1984; Negi et al., 1981).

There is disagreement whether the increase in soil water retention occurring with no-tillage truly benefits plant growth. Tollner et al. (1984) stated that no-tilled soil had significantly less water available to the plant near the surface than did the soil under conventional tillage. Van Ouwerkerk and Boone (1970) found that the amount of plant available water was the same for no tillage and conventional tillage although soil water retention was greater for no-till. Overall, the influence of tillage on soil water characteristics and subsequent plant growth will probably depend on tillage method, climate, and soil properties.

Conservation tillage is generally accepted as the most successful technology currently available for reducing soil loss and runoff. However, adaptation of conservation tillage for crop production on poorly drained soils is limited because it often results in yields lower than under conventional tillage. Excess soil moisture early in the growing season is a major factor limiting the productivity of these soils. However, ridge tillage has been shown to accelerate drying and warming of the seed zone of moderately to well-drained soil (Potter et al. 1985; Al-Darby and Lowery 1987). It has been shown that ridge tillage systems can achieve yields equivalent to yields under the moldboard plow system.

Tillage management affects root growth, shoot growth and, ultimately, crop yields through its effect on soil physical properties. Van Doren et al. (1976) reported that long term yields of continuously grow corn on a silty clay loam in Ohio under no-tillage were lower than under conventional tillage. In contrast, yields of no-tilled corn grown on Coastal Plain soils in Maryland have consistently exceeded conventionally tilled corn yields on the same soils after an initial three to six year period (Bandel, 1984; Bandel, 1983).

Crop residues on the soil surface moderate soil temperature (Willis et al., 1957; Burrows and Larson, 1962; Moody et al., 1963) which can have significant effects on plant development and growth. Fortin and Pierce (1990) reported that retarded development in corn grown under full residue cover was accounted for by soil temperature differences between bare and residue covered soil.

In order to reveal how plant form and behavior adjust to different soil conditions created by tillage, crop residues cover, the optimum soil conditions for plant growth for different soil types, microclimate, cropping systems, and yield goals must be identified. Karlen et al. (1990) hypothesized that optimum tilth for sugar beets (<u>Beta vulgaris</u> L.) may not be identical to the optimum tilth for wheat. Most studies have dealt with tillage effects on sugar beets yields and sugar beet quality with little attention to growth and development. Johnson (1987) reported that deep fall tillage produced higher root yield than did normal fall tillage. Smith and Yonts (1986) found that sugar beet yields from under the moldboard plow system were higher than under reduced tillage. Specific studies relating dry edible bean (*Phaseolis vulgaris* L.) crop yield and tillage systems are limited (Smith and Yonts, 1986).

In order to understand how plants respond to tillage practices, quantitative relationships between soil tillage and plant growth and development need to be determined.

The objective of this study was to evaluate tillage and row spacing effects on the development and growth of sugar beets and dry beans to gain a better understanding of factors affecting yield differences among six tillage and two row spacing treatments.

REFERENCES

Al-Darby, A. M. and B. Lowery B. 1987. Seed zone soil temperature and early corn grown with three conservation systems. Soil Sci. Soc. Am. J. 51:768-774.

Blevins, R. L., G. W. Thomas, M. S. Smith, W. W. Frye, and P. L. Cornlius. 1983. Changes in soil properties after 10 years continue non-tilled and conventional tilled corn. Soil Tillage Res. 3:135-146.

Elkins, C. B. 1985. Plant roots as tillage tools. In Proc. office of Con. Educ., Auburn Univ. pp. 519-523.

Ellis, F. B., J. G. Ellott, F. Pollard, R. Q. Cannell, and B. T. Barnes. 1979. Comparison of direct drilling reduce cultivation and plowing on growth of cereals. 3. Winter wheat and spring barley on calcareous soils J. Agric. Sc. (Cambridge) 93:391-401.

Fortin M. C. and F. J. Pierce. 1990. Development and growth effects of crop residues on corn. Agron. J. 82:710-715.

Gontzer, C. J. and G. R. Blake. 1978. Physical characteristics of the Le Seur clay loam following no till and conventional tillage. Agron. J. 70:853-857.

Hammel, J. E. 1989. Long-term tillage and crop rotation effects on bulk density and soil impedance in Northern Idaho. Soil Sci. Soc. Am. J. 53:1515-1519.

Hill R. L. 1990. Long term conventional and no-tillage effects on selected soil physical properties. Soil Sci. Soc. Am. J. 54:161-166.

Johnson, B. S. 1987. Alleviation of compaction fine-textured Michigan soil. Ph. D. Diss. Michigan State University, MI.

Karlen, D. L., D. C. Erbach, T. C. Kaspar, T. S. Colvin, E. C. Berr, and D. R. Timmons. 1990. Soil Tilth: A review of past perceptions and future needs. Soil Sci. Soc. Am. J. 54:153-160.

Ohiri, A. C. and H. C. Ezumah. 1990. Tillage effectson cassava (Manihot esculenta) production and some soil properties. Soil and Tillage Research. 17:221-229.

Lal, R. 1977. Importance of tillage systems in soil water management in the tropics. In: R. Lal (Ed.), Soil Tillage and crop production. I. I. T. A., Ibadan, Nigeria, pp.25-32.

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

Pidgeon, J. D. and B. D. Soane. 1977. Effects of tillage and direct drilling on soil properties during the growing season in a long term barely mono-culture system. J. Agric. Sci. 88:431-442.

Potter, K. N., R. M. Cruse and R. Horton. 1985. Tillage effects on soil thermal properties. Soil Sci. Soc. Am. J. 49:968-973.

Schafer, R. L. and C. E. Johnson. 1982. Changing soil condition- The soil dynamics of tillage. In: Predicting tillage effects on soil physical properties and processes. ASA Spec. Publ. No. 44:13-27.

Shear, G. M., And W. W. Monscher. 1969. Continuous corn by no tillage and conventional tillage methods: A six years comparison. Agron. J. 61:524-526.

Tollner, E. W., W. L. Hargrove, and G. W. Largdale. 1984. Influence of conventional and no-till practices on soil physical properties in the southern Piedmont. J. Soil Water Conserv. 39:73-76.

Van Doren, D. M., Jr. G. B. Triplett, and J. E. Henry. 1976. Influence of long term tillage, crop rotation and soil type combinations on corn yield. Soil Sci. Soc. Am. J. 40:100-105.

Voorhees, W. B., and M. J. Lindstrom. 1983. Soil compaction constructs on conservation tillage in the Northern Corn Belt. J. Soil Water Consev. 38:948-953.

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

CHAPTER 1

TILLAGE AND ROW SPACING EFFECTS ON GROWTH AND DEVELOPMENT OF DRY BEAN (*Phaseolis vulgaris* L.)

ABSTRACT

Some forms of tillage and proper row spacing are considered essential for dry bean (*Phaseolis vulgaris* L.) growth and development and hence, grain yield. This study was conducted to examine the effects of tillage methods and row spacing on dry bean development and growth. The research goal was to gain a better understanding of the factors affecting yield differences between tillage treatments and row spacing on a Parkhill loam soil (Molli haplaquepts, fine-loamy, mixed, nonacid, mesic). The study was conducted in 1989 and 1990 in the Saginaw Valley of Michigan. The main plot factors included six tillage treatments: moldboard plow, moldboard plow without secondary tillage, chisel plow, ridge tillage, no-till and no-till plus cultivation. Sub-plots factors split from these tillage treatments were two row spacings, 56 cm and 71 cm. The development and growth of Mayflower dry bean were measured in three vegetative stages on the tillage treatment plots. To assess the affects of tillage and row spacing, weekly measurements in the border plots were conducted to

determine the statistical relationships among non-destructive plant measurement and plant biomass. The development and growth of Mayflower dry beans was significantly different for the years 1989 and 1990. Rates of development and growth appeared to be altered around flowering and seed development. In 1989, tillage and row spacing treatments did not significantly effect development and growth of dry beans. In 1990, under the no-till systems, dry bean growth and development was retarded and final yields were reduced due to wet soil conditions. Dry bean yields in the 56 cm row spacing treatment were significantly higher than in the 71 cm row spacing treatment across all tillage treatments in 1989 and 1990. The data from this study suggested that the no-till and ridge tillage systems decrease grain yields in wet years. Cultivation improved grain yields in the no-tillage system in a wet year. The data from this study indicated that narrow rows (56 cm) have considerable potential to improve dry bean productivity regardless of tillage.

INTRODUCTION

Dry bean (*Phaseolis vulgaris* L.) is a deep-rooted short season crop. Some forms of tillage are often considered essential for high yields (Robertson et al., 1982). Conservation tillage systems are desirable for the production of dry bean because they reduce soil erosion by wind and water, equipment costs, and conserve soil moisture. However, conservation tillage can pose problems that require increased management.

Smith and Yonts (1988) reported that dry bean yields under no-till or minimum till were lower than under plow and rotary till systems. However, dry bean yields were reduced only in the early years of their study due to early season soil moisture losses and weed growth.

Under no-till, crop residues on the soil surface produce colder, wetter soil conditions compared to moldboard plow systems (Webber et al., 1987). Moreover, dry beans are sensitive to low soil temperature throughout their life cycle (Hardwick 1988). Tillage systems such as no-tillage may not reduce overall yield but cold delays maturation so that uneven ripening results (Bruggen et al., 1986). On the other hand, the ridge till system has the potential to increase seed germination and seedling growth under cool and wet spring soil condition. Benjamin et al, (1990) stated that some benefits from ridge tillage include warmer and dryer seed-zone soil conditions in the spring, better control of wheel traffic patterns, and better crop residue management for erosion control.

Row spacing can have significant effects on dry bean yields. The yield response to row spacing was attributed by Hardwick (1988) to more even maturity in plants grown in narrow rows and at high plant population density. Grafton et al. (1988) attributed improved dry bean yield in narrow rows versus conventional row spacing (76 cm) to increased plant population.

The relative advantages of specific tillage systems depend upon soil type, microclimate, cropping systems, and yield goal. Specific studies relating dry edible bean crop yield and tillage systems are limited (Smith and Yonts 1986). Furthermore, studies addressing management effects on dry beans have focused primarily on yields with little attention to development, phenology and growth effects during the life cycle of dry beans. However, studying the development, phenology, and growth of dry bean can reveal how plant form and behavior vary according to soil conditions creating by tillage.

Thus, the objective of this study was to evaluate tillage and row spacing effects on the development, phenology, and growth of dry bean specifically to gain a better understanding of factors affecting yield differences among six tillage and two row spacing systems.

MATERIALS AND METHODS

Field experiments were conducted in 1989 and 1990 in the Saginaw Valley near Hemlock, Michigan, to evaluate tillage and row spacing effects on dry beans. The soil was a Parkhill loam (Mollic Haplaquepts, fine-loamy, mixed, nonacid, mesic), poorly and very poorly drained, formed in loamy glacial till on till plains and moraines. The soil was tile drained and was cropped to a corn-soybean rotation for more than 10 years prior to the study. The experimental design was randomized complete block split-plot, with tillage treatments arranged as the main plots and row spacing as the sub-plots with four replications.

The study consisted of six tillage treatments and two row spacings. The tillage treatments were: (1) Fall moldboard plowing followed by spring secondary tillage (consisting of a disking followed by a field cultivation); (2) Fall moldboard plowing with no spring secondary tillage; (3) Chisel plowing in fall followed by spring secondary tillage; (4) Ridge tillage; (5) No-tillage; and (6) No-tillage plus cultivation. Row spacings were 56 cm and 71 cm. Individual plots were 6 m wide and 18 m long.

Dry beans (var. Mayflower) followed corn in an oats-corn-dry bean-sugar beet rotation. Dry beans were planted at 2 cm depth on June 14, 1989, and June 4, 1990 at a seeding rate of 280,000 seeds per hectare. Starter fertilizer (28% nitrogen) was applied through the planter at a rate of 56 kg N ha^{-1}. A pre-emergence herbicide consisting of a tank mix of 2.5 L ha^{-1} Dual (metolachlor) and 10 L ha^{-1} Amiben (chloramben) was broadcasted to plots following planting.

To predict plant dry weight and leaf area in the treatment plots, eight plant samples were randomly selected from border plots on a weekly basis during the growing season. Leaf area (1990 only), plant dry weight, trifoliate leaf number, and the length and width of each single leaflet (blade) were measured on these samples. The trifoliate leaf number and the length of a single leaflet (blade) were compared with the leaf area and plant dry weight of leaflets from non-treatment border plot. The effect of tillage and row spacing on dry bean phenology was determined at three stages of plant development (Hiler and Bavel, 1972): (1) Vegetative stage (from germination to beginning flowering, up to 36th day after planting.); (2) Flowering and early pod formation stage (36th to 54th days after planting); (3) Pod development stage (54th day after planting to harvest). In 1989, six consecutive plants in each plot were marked after plant emergence. Trifoliate leaf number and plant height (distance from ground surface to top of extended vines) were measured on July 18, August 3, and August 30. Flowering rate was determined when 50% of plants had at least one flower. Flowering was measured on August 1, August 3, and August 7 (49, 51, and 55 days after planting). In 1990, three plant samples from each plot were collected on July 9, July 29, and August 28 in order to count trifoliate leaf number and to measure leaf area. All samples were oven dried at 65° C for 48 hours to determine dry weight. Canopy height (distance from surface of ground to average of top of plant) was measured in the field on the same day plant samples were collected. Flowering rate was determined by counting the number of flowers on 10 plants on each plot on July 24, 26 and 27. Six dry bean samples from each plot were collected on September 12 to determine the number of pods per plant, seeds per pod, and weight per 100 seeds. The number of pods per plant was measured in the field on August 9 and August 28 on five plants from each plot. Initial and final dry bean population were calculated from the number of plants in a two meters length in two rows in each plot for both 1989 and 1990.

The data for seed yield in 1989 were obtained on October 4th by direct cutting with a plot combine. The harvest area for each plot consisted of 1.42 m by 18 m. In 1990, dry beans were harvested by hand-pulling on September 2nd from all treatments except no-tillage and no-tillage plus cultivation (dry beans in these treatments were not mature at the time). The harvest area for each plot consisted of two row width by 6 meters length. The two no-till treatments were harvested on September 18th by hand pulling.

Permanent Time Domain Reflectometry (TDR) probes were installed to monitor soil volumetric moisture content under three tillage treatments (moldboard plow, ridge tillage and no-tillage) and two row spacings (56 cm and 71 cm). A total of nine TDR probes were installed in each of treatment three replications. Each probe consisted of two parallel steel rod (4.8 mm diameter) placed 50 mm apart. Probes were installed vertically by direct insertion from the soil surface. Three of the probes were installed in each of three depths (0-15 cm, 0-30 cm, 0-75 cm), with each probe placed in an adjacent row 10 cm from the next probe. TDR readings were taken weekly in each treatment plot for calculating volumetric soil moisture content (Topp, Davis and Annan, 1980). A weather station (Campbell Scientific, Inc; Model CR 10) was established in July of 1989 at the research site to collect hourly data on rainfall, air temperature, soil temperature, and wind speed. Growing Degree Days were calculated from maximum and minimum air temperature using a base temperature of 10° C, as follows:

$$GDD = \Sigma\{(T_{Max} + T_{Min}) / 2 - 10\} \quad [1]$$

Intact soil cores were taken for determination of soil bulk density, total porosity, air fill porosity and macro porosity (pore diameter > 48 um) on September 11, 1989 and September 27, 1990. Undisturbed soil cores 7.6 cm diam and 7.6 cm long were obtained with a Uhland double-cylinder, hammer driven sampler (Blake, 1986). Three cores were sampled from each tillage treatment (in 71 row spacing) at each of two depths (0 cm to 7.5 cm and 7.5 cm to 15 cm) for all tillage treatments. Three additional cores were sampled for ridge tillage at 15 cm to 22.5 cm depth as measured from the top of ridge. Soil cores were saturated by wetting from the bottom for at least 48 hours. Soil water retention at 1 and 6 kpa was determined on a tension table. Cores were oven dried at 105° C for 48 hours and weighed for bulk density determination. Water loss between saturation and oven dry was taken to represent total soil porosity. Macroporosity (pores >48 um diam) was determined by subtracting the measured volumetric water at 6 kpa from the total porosity. Saturated hydraulic conductivity of these samples was determined using the constant head method (Klute and Dirksen, 1986).

Tillage and row spacing effects on soil moisture content, development, phenology and growth of dry bean were evaluated by using analysis of variance for split-plot. Least significant differences (LSD) at level of $p=0.05$ were calculated when the F-statistic between treatments was significant.

RESULTS AND DISCUSSION

EVALUATION OF NON-DESTRUCTIVE PLANT MEASUREMENTS

Plant development, phenology and growth were measured over time in the border plot in order to develop statistical relationships among non-destructive plant measurements and plant biomass. These relationships were used to assess the effects of tillage and row spacing on dry beans.

The development of Mayflower dry beans, expressed in

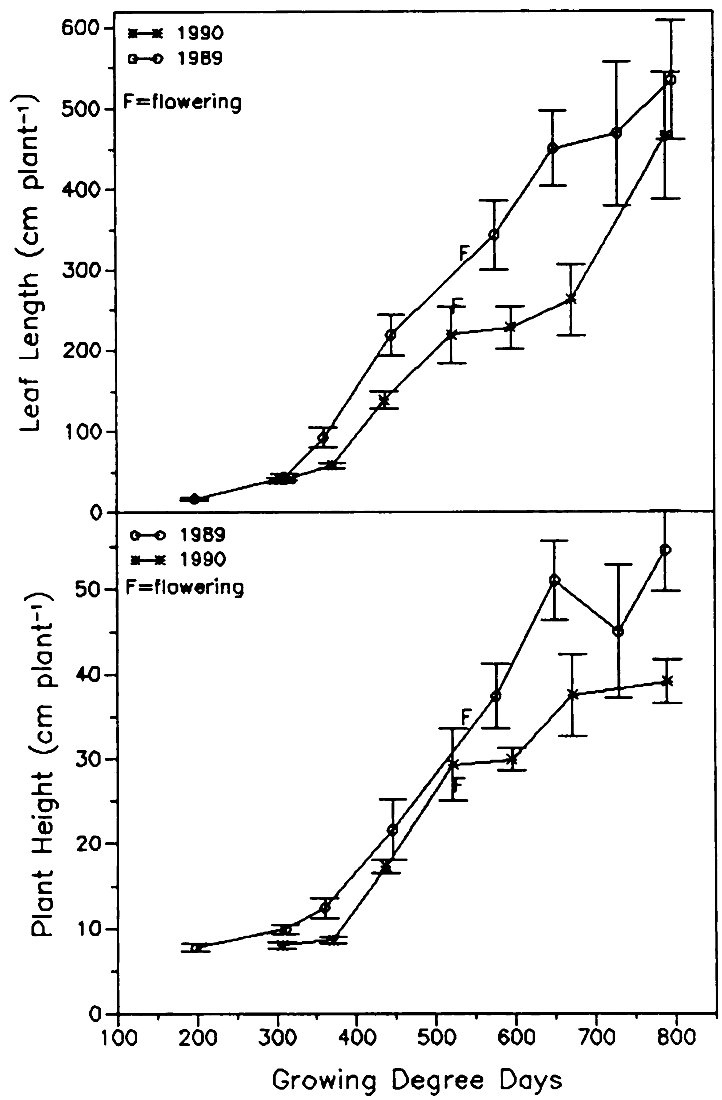

Figure 1.1. Development and growth of Mayflower navy beans on a Parkhill loam soil in 1989 and 1990 expressed as plant height and leaf length vs. growing degree days.

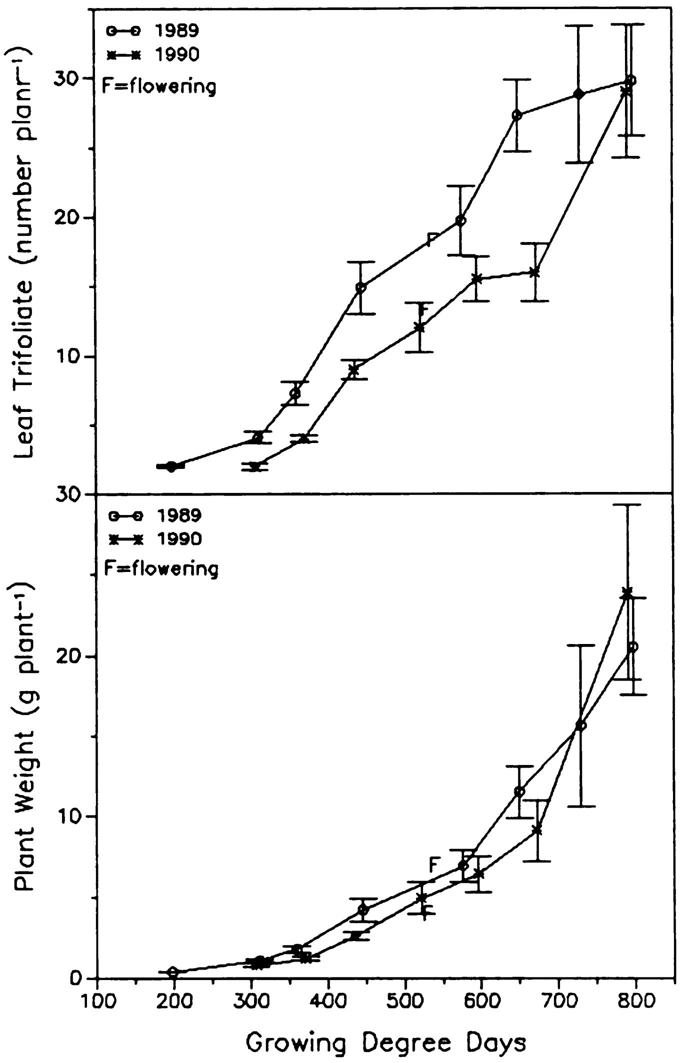

Figure 1.2. Development and growth of Mayflower navy beans on a Parkhill loam soil in 1989 and 1990 expressed as plant weight and leaf number vs. growing degree days.

growing degree days, is given in Figure 1.1 and Figure 1.2. Although growing degree days was similar or slightly higher in 1990 versus 1989 (Figure 1.3), leaf number, leaf length, and plant biomass were higher and accumulated faster in 1989 than 1990. Rainfall was considerable higher in 1990 than 1989 (Figure 1.4) and soil water contents were adequate to high throughout the 1990 growing season (Figure 1.5 and Figure 1.6). High soil water contents in 1990 were evidenced by the lack of water extraction in the 30 to 75 cm soil depth when compared to the water extraction pattern in that zone in 1989 (Figure 1.6). The occurrence of root diseases, often associated with high soil moisture and low soil temperature (Bruggen, 1986) offers a possible explanation for slower development and reduced growth in 1990. However, root diseases were not monitored in either year of the study.

The rate of leaf trifoliate appearance in growing degree days differed between years and was variable in growing degree days (Figure 1.1, Figure 1.2, and Table 1.1). Leaf appearance rates increased in both years until flowering and then declined for a short period after flowering with a corresponding decline in the accumulation of associated leaf length and plant biomass. Leaf area accumulation in growing degree days 1990 clearly shows a rapid rate of increase prior to flowering followed by a sharp decline (Figure 1.7) It would appear that the dry

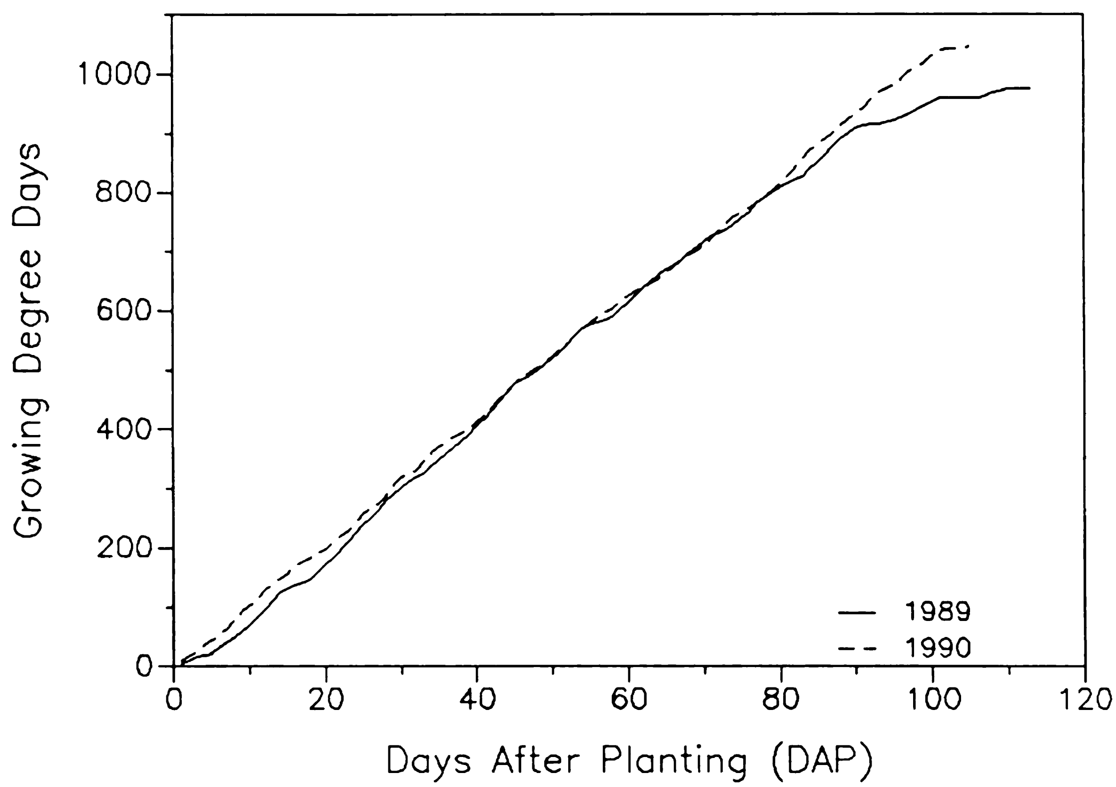

Figure 1.3. Growing degree days verses days after planting in 1989 and 1990.

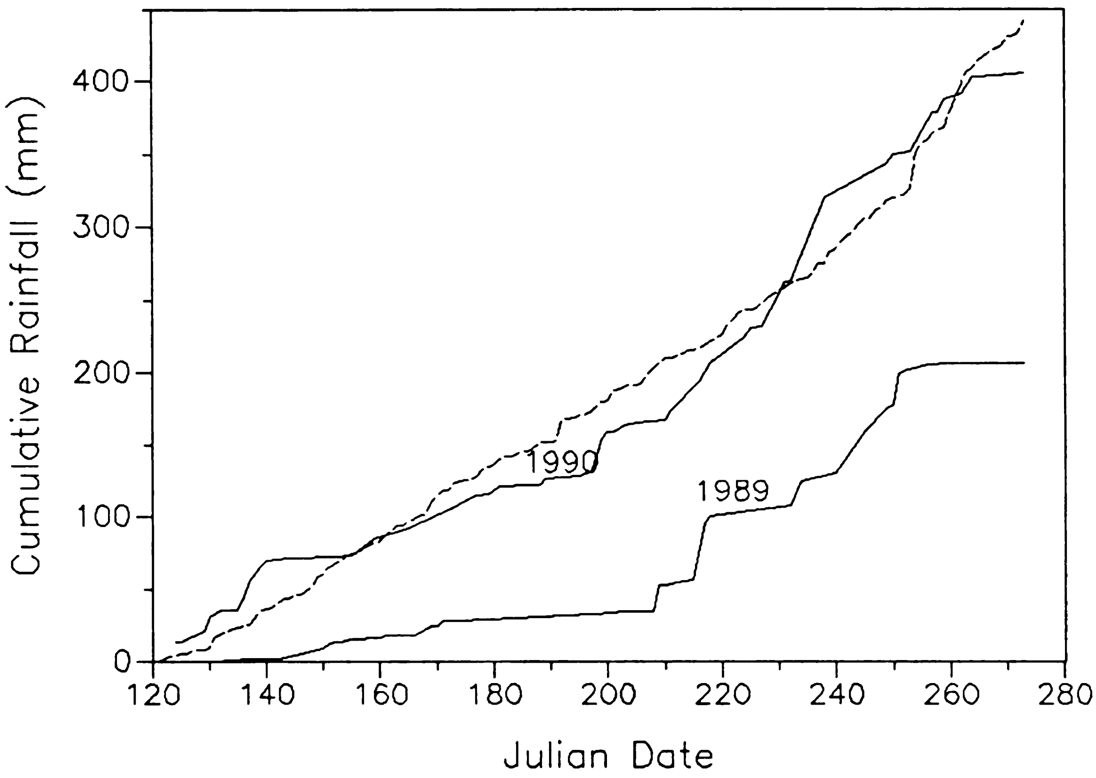

Figure 1.4. Cumulative rainfall from May 1 to September 30 in 1989 and 1990 (Dash line is the average rainfall from 1977-1988 at the beet and bean farm,10 Kilometers east of research farm).

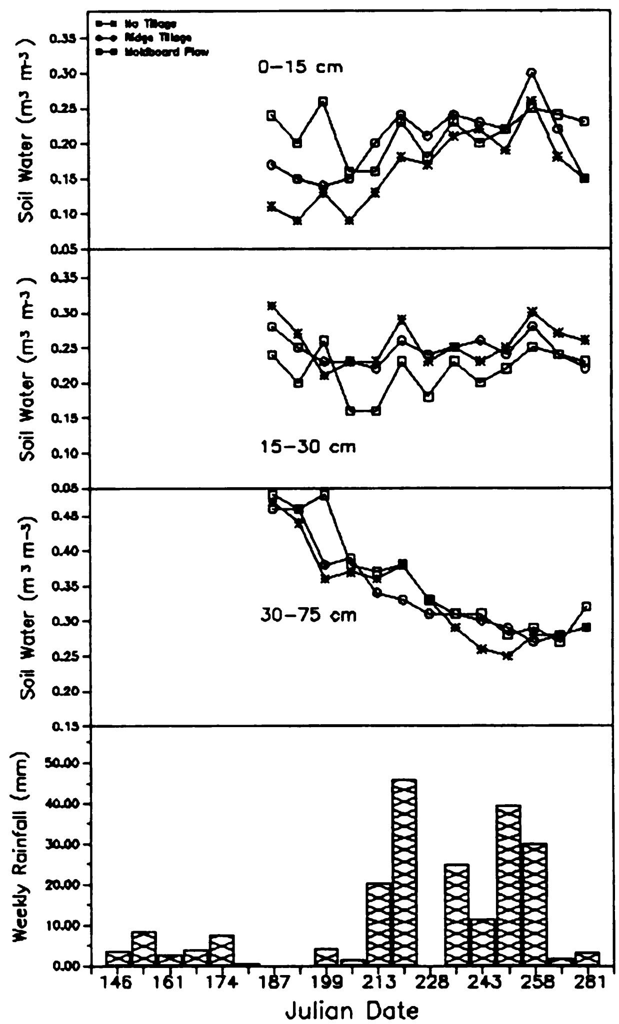

Figure 1.5. Weekly rainfall and soil water content for three tillage systems at three soil depths (0-15, 15-30, and 30-75 cm) under the 71 cm row spacing in 1989.

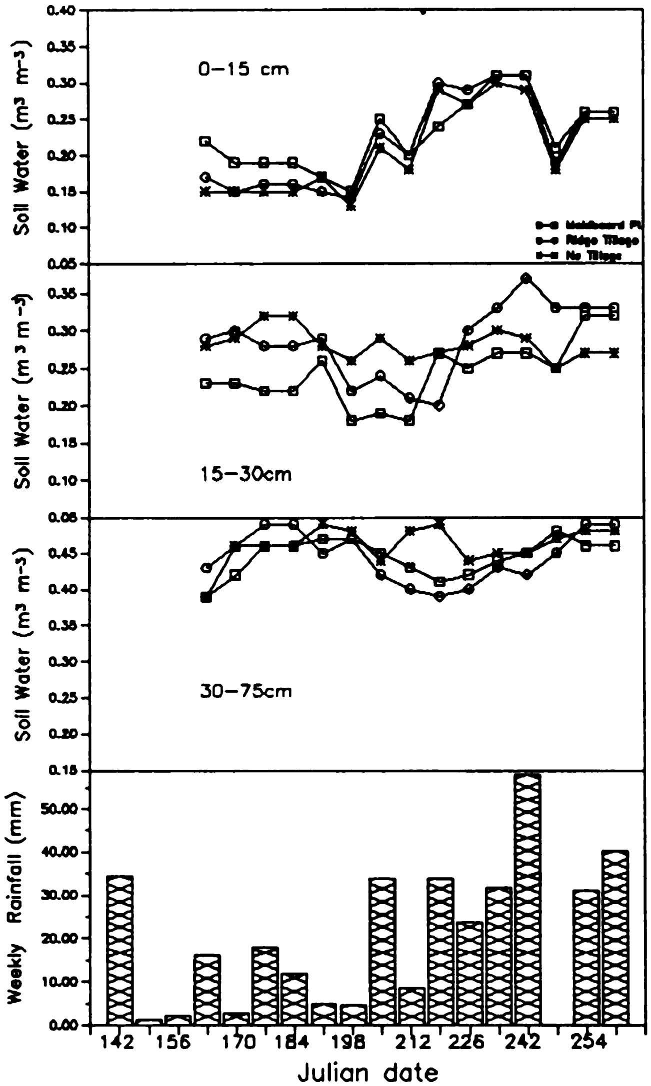

Figure 1.6. Weekly rainfall and soil water content for three tillage systems at three soil depths (0-15, 15-30, and 30-75 cm) under the 71 cm row spacing treatment in 1990.

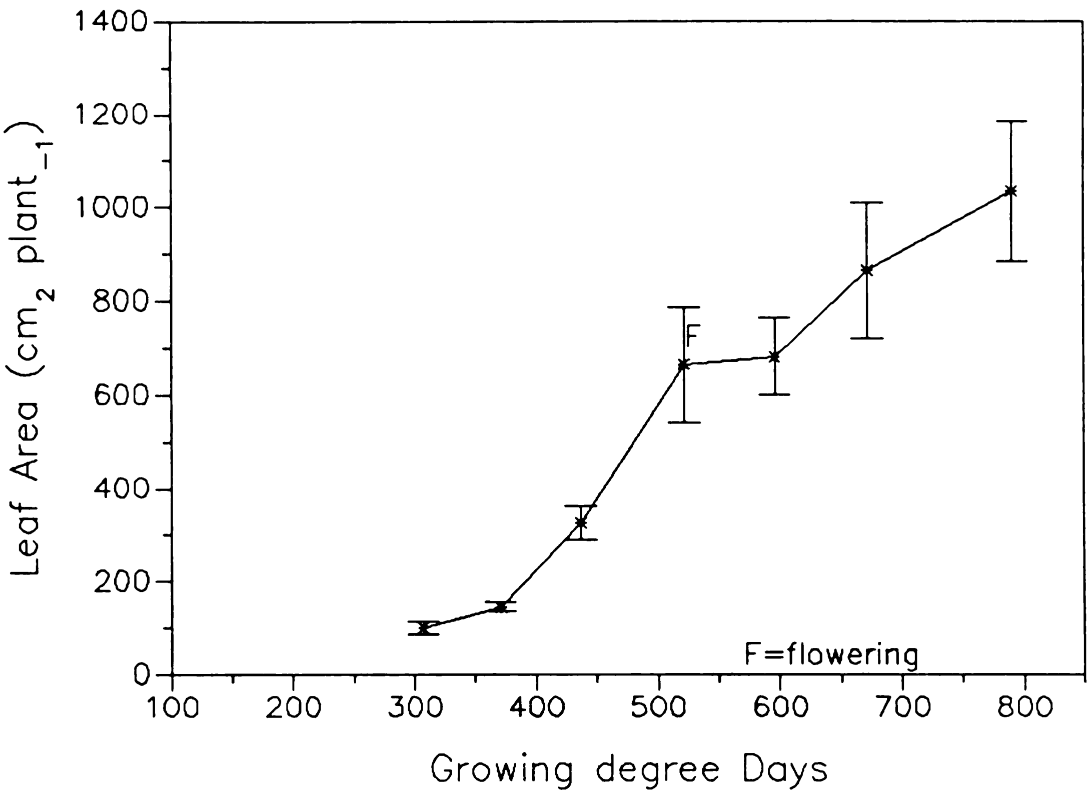

Figure 1.7. Relationship between leaf area and growing degree days in 1990.

Table 1.1. Rates of growth and development of Mayflower navy bean for sampling periods in 1989 and 1990.

DAP	GDD	Leaf Length (cm GDD^{-1})	Plant Height (cm GDD^{-1})	Biomass (g GDD^{-1})	Leaf Trifoliate (number GDD^{-1})	Leaf Area (cm-2 GDD^{-1})
			1989			
1-21	198	0.09	0.04	0.00	0.01	
22-30	113	0.23	0.02	0.01	0.02	
31-35	49	1.00	0.05	0.01	0.07	
36-42	86	1.46	0.11	0.03	0.09	
43-54	130	0.95	0.12	0.02	0.04	
55-62	74	1.45	0.18	0.06	0.10	
63-71	80	0.23	-0.08	0.05	0.02	
72-78	68	0.97	0.14	0.07	0.01	
			1990			
1-29	307	0.13	0.03	0.00	0.01	0.33
30-35	64	0.28	0.01	0.01	0.03	0.72
36-42	66	1.23	0.13	0.02	0.08	2.71
43-50	85	0.94	0.14	0.03	0.04	3.98
51-57	74	0.12	0.01	0.02	0.03	0.21
58-66	76	1.37	0.10	0.04	0.03	2.40
67-78	119	1.13	0.02	0.12	0.11	1.43

DAP: Days After Planting
GDD: Growing Degree Days

bean was partitioning photosynthate away from leaf production in favor of flower and pod development. A similar shift is apparent at the time of seed formation. These shifts in plant development appear in data reported by Hoogenboom et al (1988) for dry beans grown in Gainsville, Florida and at Columbia although the shift was not identified by the authors.

Leaf area measured in 1990 was linearly related (r^2=0.94) to leaf number (Figure 1.8). Leaf number was also linearly related to plant biomass prior to flowering but the relationship was different for 1989 and 1990 (Figure 1.9). The weight of the trifoliate in 1989 was less than those produced in 1990, but that would be expected due to the greater leaf numbers produced in 1989. Since the leaf size appeared to be different in 1990 and 1989, the regression between leaf area and leaf number measured for 1990 (Figure 1.8) could not be used to predict leaf area in 1989.

TILLAGE AND ROW SPACING EFFECTS ON DRY BEAN DEVELOPMENT

The differences in plant development and growth between 1989 and 1990 were also apparent in the experimental treatments. There were no effects of tillage or row spacing on development or growth of Mayflower dry beans in 1989 (Table 1.2). The yield of dry beans in 198 averaged 0.3 Mg ha-1 more in 56 rows, but there were no differences in dry bean yield in 1989 due to tillage. In 1990, there were

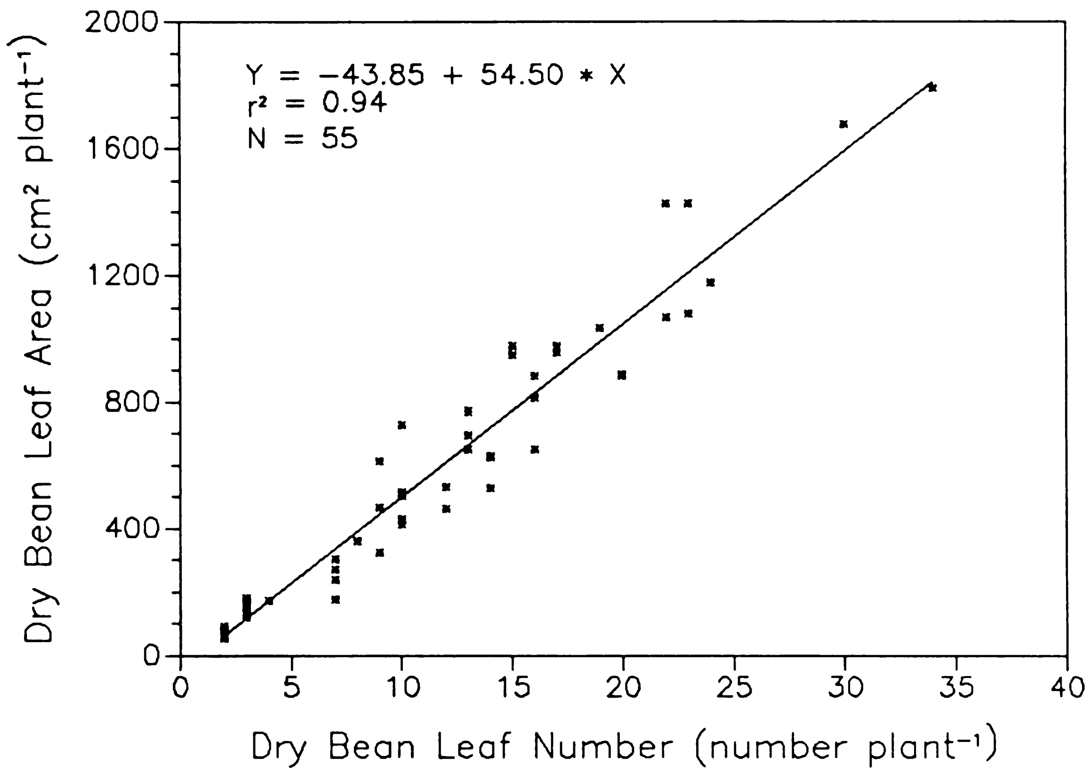

Figure 1.8. Relationship between leaf area and leaf number for Mayflower navy beans measured in 1990.

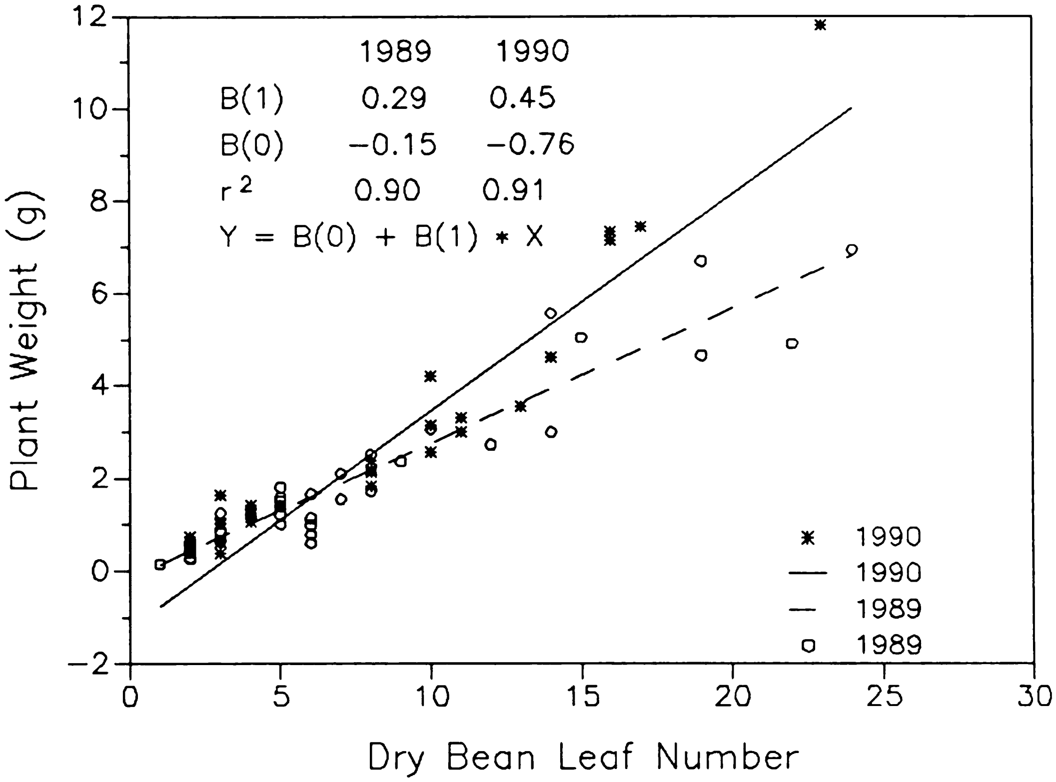

Figure 1.9. Relationship between plant biomass and leaf number in 1989 and 1990.

Table 1.2. Summary of the development, and growth of Mayflower navy bean averaged across all treatments in 1989.

Measurement Date	7/18	8/03	8/30
Growing Degree Days(GDD)	348	531	789
Plant height(cm)	11	44	75
Leaf Trifoliate (Number Plant^{-1})	7	17	24

	Row Spacing (cm)		LSD
	56	71	
Growing Degree Days of 50% Flowering	531	531	NS
100 Seed weight (g)	18.4	18.4	NS
Seed moisture (%)	14.3	14.2	NS
Harvest population (1000 Plant ha^{-1})	268	252	NS
Grain yield (Mg ha^{-1})	2.6	2.3	0.3

considerable differences in development, growth and yield in Mayflower dry beans due to both tillage and row spacing. However, there was no significant interaction between tillage and row spacing for any measurements. Therefore, the main effects of tillage and row spacing for 1990 will be discussed separately.

The main tillage effects were primarily due to the no-tillage treatments (Table 1.3). The dry beans in the no-tillage treatments, with or without cultivation, developed much slower than those in the other tillage treatments. Canopy height, number of leaf trifoliate, leaf area, and plant biomass were all lower on the July 9 and July 27 sampling dates than the other tillage systems. The effect of cultivation of no-tillage was to increase canopy height on those sampling dates. By the August 28th sampling date, the canopy height, number of trifoliate and leaf area of the no-tillage plots were similar to the other tillage treatments but plant biomass was still significantly lower on that date. The cultivated no-tillage treatment resulted in higher leaf numbers and leaf area by August 28th but similar plant biomass to other tillage treatments. As indicated earlier, wet conditions in 1990 resulted in quite different development and growth patterns in the dry beans than in 1989. As discussed later, the no-till soil had wetter soil conditions than the other tillage treatments and this may have contributed significantly to the retarded

Table 1.3. Tillage effects on development, growth and yield component of Mayflower navy bean in 1990.

TILLAGE TREATMENT	7/09 (360)	7/27 (544)	8/28 (870)
	Canopy Height (cm)		
Moldboard Plow	9.6	30.0	31.5
Moldboard Plow (nst)	8.9	28.6	35.8
Chisel Plow	10.5	30.8	34.2
Ridge Till	9.9	27.1	35.3
No-tillage	6.7	14.2	33.9
No-tillage+cultivation	8.4	19.6	32.6
LSD (0.05)	1.4	2.9	3.6
	Leaf Trifoliate (number plant^{-1})		
Moldboard Plow	5.7	16.8	14.8
Moldboard Plow (nst)	5.5	18.1	20.8
Chisel Plow	5.6	16.3	19.0
Ridge Till	5.0	16.1	21.0
No-tillage	2.6	7.9	24.3
No-tillage+cultivation	3.0	10.1	34.0
LSD (0.05)	0.8	3.3	7.3
	Leaf Area (cm^2 plant^{-1})		
Moldboard Plow	182	831	971
Moldboard Plow (nst)	177	1107	1297
Chisel Plow	192	838	1220
Ridge Till	170	763	1214
No-tillage	53	309	1295
No-tillage+cultivation	73	389	2341
LSD (0.05)	44	292	434
	Plant Biomass (g plant^{-1})		
Moldboard Plow	6.7	16.2	26.4
Moldboard Plow (nst)	6.6	19.0	30.5
Chisel Plow	7.0	18.1	29.7
Ridge Till	6.2	16.4	28.6
No-tillage	1.8	5.9	18.1
No-tillage+cultivation	2.6	8.6	31.6
LSD (0.05)	1.7	5.0	8.7

nst: no Secondary tillage
Growing Degree days in parentheses

Table 1.3. Continued.

TILLAGE TREATMENT	Grain Yield ($Mg\ ha^{-1}$)	Population (1000 Plants ha^{-1})
Moldboard Plow	3.35	203
Moldboard Plow (nst)	3.29	152
Chisel Plow	3.26	190
Ridge Till	2.91	175
No-tillage	2.72	153
No-tillage+cultivation	3.04	151
LSD (0.05)	0.22	36

	Number of Pods (Pods $plant^{-1}$)	Seed Moisture (%)	Number of Seeds (seeds $plant^{-1}$)	100 Seed weight (g)
Moldboard Plow	17	19.2	77	17.9
Moldboard Plow (nst)	21	19.8	88	18.5
Chisel Plow	15	19.8	71	17.8
Ridge Till	16	20.5	77	17.8
No-tillage	17	23.7	75	16.7
No-tillage+cultivation	15	24.0	66	18.4
LSD (0.05)	5	1.0	NS	1.5

nst: no secondary tillage

development in the dry beans in the no-tillage systems.

For the August 28, 1990 sampling, the moldboard plow treatment had significantly lower canopy height than the moldboard plow (nst) and the ridge tillage treatments and showed a decline in trifoliate leaf number from the July 27th sampling. This may have resulted from the fact that the plants were sensitive at this time and the moldboard plow treatment was more advanced in that stage of development. Harvest of these plots took place just five days after this plant sampling.

Dry bean grain yields were higher in the two moldboard plow treatments and the chisel plow treatment than the ridge tillage and the two no-tillage treatments (Table 1.3). The cultivated no-tillage had significantly higher yields than no-tillage but was similar to the ridge tillage. Plant populations were lower in the two no-tillage and the moldboard plow (nst) treatment than the chisel plow and moldboard plow treatments. The moldboard plow (nst) treatment compensated for reduced populations with significantly higher number of pods per plant that the chisel plow, ridge tillage and no-tillage with cultivation treatments. Seed moisture was higher in the two no-tillage treatments, indicative of the delayed development. Additionally, the ridge tillage treatment had slightly higher seed moisture than the moldboard plow treatment. No-tillage without cultivation had significantly lower seed

Table 1.4. Row spacing effects on development in Mayflower navy bean in 1990.

	Row Spacing (cm)		
	56	71	LSD
Canopy Height (cm)			
7/09 (360)	8.8	9.2	NS
7/27 (544)	23.9	26.2	1.3
8/28 (870)	34.1	33.6	0.8
Leaf Trifoliate (number Plant^{-1})			
7/09 (360)	13	13	NS
7/27 (544)	15	13	1.3
8/28 (870)	26	19	6.2
Leaf Area (cm^2 plant^{-1})			
7/09 (360)	140	142	NS
7/27 (544)	783	643	69
8/28 (870)	1616	1164	NS
Biomass (g plant^{-1})			
7/09 (360)	5.2	5.1	0.8
7/27 (544)	16.6	12.4	2.9
8/28 (870)	30.9	24.1	6.2
Yield Component			
Yield (Mg ha^{-1})	3.4	2.8	0.2
Population (1000plant ha^{-1})	161	180	14
Pod number (pod plant^{-1})	20	14	2.6
Seed moisture (%)	21.8	20.6	0.6
Seed number	89	62	12
100 Seeds weight (g)	18.4	17.2	0.9

Growing Degree days in parentheses

weights than all other treatments.

There were no differences in plant measurements for the two row spacings at the July 9, 1990 sampling (Table 1.4). Canopy height was higher in the 71 cm row spacing for the July 27th sampling date only. Trifoliate leaf numbers and plant biomass were significantly higher in the 56 cm than the 71 cm row spacing on the July 27 and August 28 samplings. Leaf area was higher for the 56 cm row spacing on the July 27 sampling as well. Normally, one would expect the narrow row spacing to produce small plants in part due to higher plant populations than in wider rows. The larger plants in the narrow row spacing in 1990 seems reasonable since harvest plant populations were significantly lower in the 56 than 71 cm row spacing. These differences resulted in greater pods and seed number per plant and higher seed weight, all of which contributed to significantly higher grain yields in the 56 than the 71 cm row spacing. The increase was independent of tillage system and averaged 0.6 Mg ha-1.

TILLAGE AND ROW SPACING EFFECTS ON SOIL PHYSICAL PROPERTIES

A summary of the soil properties of the Parkhill soil averaged over all treatments in both years is given in Table 1.5. Soil physical properties of the Parkhill clay loam soil were significantly affected by tillage in only a few selected cases. In 1989, the no-tillage treatment had a

Table 1.5. Soil physical properties of the Parkhill Clay Loam soil averaged across treatments in 1989 and 1990.

Soil Depth (cm)	Bulk Density ($Mg\ cm^{-3}$)	Total Porosity ($m^3\ m^{-3}$)	Macro Porosity ($m^3\ m^{-3}$)	Conductivity ($cm\ h^{-1}$)
		1989		
0-7.5	1.44	0.44	0.06	8.3
7.5-15	1.58	0.40	0.04	4.3
		1990		
0-7.5	1.29	0.48	0.05	12.4
7.5-15	1.53	0.41	0.06	7.7

higher bulk density in the 0 to 7.5 cm soil depth than the moldboard plow, chisel plow and ridge tillage treatments (1.52 versus 1.39, 1.39, and 1.37 Mg m^{-3}, respectively. In 1990, the moldboard plow (nst) treatment had a higher macroporosity (pores > 48 micron diameter) in the 7.5 to 15 cm soil depth that the other tillage treatments.

Volumetric soil water contents in the 0 to 15 cm soil depth were driest in the no-tillage treatment and intermediate in the ridge tillage treatment compared to the moldboard plow treatment in the first two sampling dates on July 6 and July 12, 1989 (Table 1.6). After July 12, there were no differences at any other sampling time for any sampled depth in the 1989 growing season due to the significant weekly rainfall (Figure 1.6). Water extraction patterns in the 30 to 75 cm soil depth were similar for the three tillage systems.

In 1990, soil water contents in the 0 to 15 cm soil depth were drier on June 12 (soon after planting) in the no-tillage and ridge tillage treatments than the moldboard plowed treatment (Table 1.6 and Figure 1.6). Soil water contents in the 0 to 15 cm soil depth were frequently higher in the no-tillage and ridge tillage treatments than the moldboard plow treatment throughout June and July and again on August 21. In the 30 to 75 cm soil depth, soil water contents remained high all season. Frequent rains beginning in late July caused the no-tillage to become quite wet and

Table 1.6. Selected soil moisture content ($m^3\ m^{-3}$) as affected significantly by tillage treatments in 1989 and 1990.

Measurement Date	TILLAGE TREATMENT NT	RT	MP	LSD
	0-15 cm			
1989	----------- $m^3\ m^{-3}$		--------------	
July 6 (187)	0.13	0.16	0.19	0.05
July 12 (193)	0.11	0.14	0.16	0.05
	0-15 cm			
1990	----------- $m^3\ m^{-3}$		--------------	
June 12 (163)	0.16	0.17	0.22	0.05
	15-30 cm			
	----------- $m^3\ m^{-3}$		--------------	
June 19 (170)	0.29	0.30	0.24	0.05
June 26 (177)	0.29	0.30	0.26	0.00
July 3 (184)	0.30	0.30	0.25	0.05
July 17 (198)	0.29	0.24	0.20	0.07
July 24 (205)	0.30	0.26	0.21	0.07
Aug. 21 (233)	0.35	0.32	0.28	0.07
	30-75 cm			
	----------- $m^3\ m^{-3}$		--------------	
July 24 (205)	0.44	0.42	0.44	0.00
July 31 (212)	0.46	0.41	0.42	0.05
Aug. 8 (220)	0.49	0.40	0.41	0.00

NT: No Tillage
RT: Ridge Tillage
MP: Moldboard PLow
Julian Date in Parentheses

have significantly higher soil water contents during late July and early August.

SUMMARY

The development and growth of Mayflower dry beans was significantly different for the years 1989 and 1990. Rates of development and growth appeared to be altered around flowering and seed development and may be indicative of a change in the partitioning of photosynthate from leaf development and growth to flower development and pod and seed initiation. Tillage and row spacing did not effect development and growth in dry beans in 1989 but the 56 cm row spacing did increase yields by 0.3 Mg ha- 1. In 1990, a wet year, development was retarded when compared to 1989. The no-tillage soil was significantly wetter than other tillage systems and this appeared to contribute to retarded development and a reduction in final grain yields. Ridge tillage did not appear to effect development and growth of dry beans during the season but did reduce yields compared to moldboard and chisel plow treatments. The 56 cm row spacing increased plant size and productivity of dry beans resulting in 0.6 Mg ha-1 average increase in grain yields over all tillage treatments. Narrow row spacings appeared to increase yields regardless of tillage system. However, stand density appeared to play an important role in plant productivity since the narrower row spacing had lower populations in 1990. No-tillage and ridge tillage systems decreased grain yields in wet years. Cultivation improved grain yields in the no-tillage system in a wet year.

REFERENCES

Adams, M. W. 1967. Basis of yield component compensation in crop plants with special reference to the field bean, Phaseolus vulgaris. Crop Sci. 7:505-510.

Bennett, J. P., M. W. Adams, and C. Burga. 1977. Pod yield component variation and intercorrelation in Phaseolis vulgaris L. as affected by plant density. Crop Sci. 17:73-75.

Blake, G. R. 1965. Bulk density. In C. A. Black et al. (ed.) Methods of soil analysis, Part 1. Agronomy 9:374-380.

Bruggen, A. H. C., C. H. Whalen, and P. Arneson. 1986. Emergence, growth,and development of dry bean seedlings in response to temperature, soil moisture, and Rhizoctonia solani. Phytopathology 76:568-572.

Doss, B. D., R. W. Pearson, and Howard T. Rogers. 1974. Effect of soil water stress at various growth stages on soybean yield. Agon. J. 66:297-299.

Dubetz, S. and P. S. Mathalle. 1969. Effect of soil water stress on bush beans Phaseolus vulgaris L. at three stages of growth. J. Am. Soc. Hortic. Sci. 94:479-481.

Grafton, K. F., A. Schneiter, and B. J. Nagle. 1988. Row spacing, plant population, and genotype * row spacing interaction effects on yield and yield components of dry bean. Agron. J. 80:631-634.

Hardwick, R. C. 1988. Review of recent research on navy beans (Phaseolus vulgaris) in the United Kingdon. Ann. Appl. Biol. 113:205-227.

Hiler, E. A., C. H. M. V. Bavel, M. M. Hossain, and W. R. Jordan. 1972. Sensitivity of southern peas to plant water deficit at three growth sates. Agron. J. 64:60-63.

Hoogenboom, G., C. M. Peterson, and M. G. Huck. 1987. Shoot growth rate of soybean as affected by drought stress. Agron. J. 79:598-607.

Hoogenboom, G., J. W. Jones, J. E. White, And K. J. Boote. 1988. Predicting growth, development, and yield of dry bean at different location. Vol. 31 p. 172-173. In Annual Report of Bean Improvement Cooperative. Bean Improvement Cooperative.

Klute, A. 1985. Laboratory measurement of hydraulic conductivity of saturated soil. In C. A. Black et al. (ed.) Methods of soil analysis, Part 1. Agronomy 9:374-380.

Montojos, J. C., and A. C. Magalhaes. 1971. Growth analysis of dry beans (Phaseolus vulgaris L. var. pintado) under varying conditions of solar radiation and nitrogen application. Plant and Soil. 35:217-223.

Muramoto, H., J. Hesketh, and M. El-Sharkawy. 1965. Relationships among rate of leaf area development, photosynthetic rate, and rate of dry matter production among American cultivated cottons and other species. Crop Sci. 51:163-166.

Jorge, A. Acosta Gallegos and Josue Kohashi Shibata. 1989. Effect of water stress on growth and yield of indeterminate dry-bean (Phaseolus vulgaris) cultivars. Field Crops Research. 20:81-93.

Radford, P. J. 1967. Growth analysis formulae - their use and abuse. Crop Sci. 7:171-175.

Robertson, L. S., D. R. Christenson, A. J. M. Smucker and D. L. Mokma. 1982. Tillage systems. In L. S. Robertson and R. D. Frazier (ed.) Dry bean production-principles and practice. Mich. State. Univ. Coop. Ext. Serv. Bul. E-1251. pp.78-93.

Smith, J. A., C. D. Yonts. 1988. Crop yields from reduced tillage systems of corn, edible beans, and sugarbeets. Am. Soc. Eng. Microfiche Collect. St. Joseph, Mich. The Society. (fiche No. 88-2011) 14p.

Robins, J. S. and C. E. Domingo. 1956. Moisture deficits in relation to the growth and development of dry beans. Agon J. 48:67-70.

Smucker, A. J. M. and A. K. Strivastava. 1983. Soybean and dry bean production with no secondary tillage soil compaction. Am. Soc. Agric. Eng. Microfiche collect. St. Joseph, Mich. The Society. (fich No. 83-1041) 1 microfiche: ill.

Topp, G. C., J. L. Davis and A. P. Annan. 1980. Electromagnetic determination of soil water content: Measurements in coaxial transmission lines. Water Resour. Res. 16:574-582.

VanBruggen, A. H. C., C. H. Whalen, and P. A. Arneson. 1986. Emergence, growth, and development of dry bean seedling in response to temperature, soil moisture, and rhizoctonia solani. Vol. 76 p. 568-572. In Phypotopathology. American Phytopathological Society. St. Paul, Minn.

Wagger, M. G. 1989. Tillage effects on grain yields in wheat, double crop soybean, and corn rotation. Agron. J. 81:493-498.

Webber, C. L. III, M. R. Gebhardt, and H. D. Kerr. 1987. Effect of tillage on soybean growth and production. Agron. J. 79:952-956.

Westermann, D. T. and S. E. Crothers. 1987. Plant population effects on the seed yield components of beans. Crop Sci. 17:493-496.

Whisler, F. D., J. R. Lambert, and J. A. Landivar. 1982. Predicting tillage effects on cotton growth and yield. p. 179-198. In D. M. Van Doren et al. Predicting Tillage Effects on Soil Physical Properties and Processes. ASA Spec. Pub. 44 ASA, CASSA, and SSSA, Madison, WI.

CHAPTER 2

TILLAGE AND ROW SPACING EFFECTS ON GROWTH AND DEVELOPMENT OF SUGAR BEETS (Beta vulgaris L.)

ABSTRACT

Tillage methods affect soil physical properties which, in turn, affect crop growth. The objective of this study was to evaluate the effects of various tillage systems and row spacing on sugar beet (Beta vulgares L., var. Mono-Hy E-4) growth, development, yield and quality. This study was conducted in 1989 and 1990 on Parkhill loam soil (Molli haplaquepts, fine-loamy, mixed, nonacid, mesic) on Saginaw County of Michigan. Tillage treatments consisted of (1) moldboard plow with secondary tillage; (2) moldboard plow without secondary tillage; (3) chisel plow; (4) ridge till; (5) no till plus cultivation; and (6) no till without cultivation. Row spacing evaluated were 56 and 71 cm. Adjacent plants within a treatment row were marked to measure plant leaf length and leaf number on selected dates in order to calculate growth rate by a multiple linear formula. Sugar beet leaf growth under the moldboard plow without secondary tillage systems was more rapid than under

the no till and no till plus cultivation systems. Sugar beet yields were higher for moldboard plow without secondary tillage and lower for no-tillage treatments. Sugar beet yield was higher for 71 cm row spacing than 56 cm spacing in 1989 and 1990. Sugar beet quality was lower for 71 cm row spacing. Time Domain Reflectometry (TDR) measurement for soil moisture content showed lower levels of soil moisture at a 0-15 cm depth and higher level soil moisture at 15-30 cm depth under no till as compared to moldboard plow treatment during lower rainfall period.

INTRODUCTION

Sugar beet production is often limited by seedling emergence (Yonts, et al., 1983). Seedling emergence is affected by the soil temperature, soil moisture, aeration, and physical impedance (Bowen, 1966). Radekee and Bauer (1965) found the root temperature for emergence of sugar beets to be in the range from 25 to 35^{o} C. Hunter and Erickson (1952) found that sugar beet seed must attain a moisture content of approximately 31 percent to germinate. Yonts et. al. (1983) indicated as soil moisture tension increases, the emergence rate of sugar beets decreases. Sugar beets are a small seeded and shallowly planted crop and thus, seed bed preparation is considered a critical operation for sugar beet production. However, repeated seed bed tillage may dissipate needed soil moisture, which is often considered more beneficial than the tillage because a good crop stand is the first requisite for acceptable yields.

Sugar beets have a deep tap root. Therefore, the root zone should receive serious consideration in soil preparation. Deep chisel or subsoiling help to break up compacted soil layers. Johnson (1987) reported that deep tillage produced higher root yields than normal fall tillage.

Conservation tillage practices have been adapted to sugar beet production (Simmons and Dotzenko, 1975). Lamb (1985) stated that the no till treatment had the highest root yields as compared to disk and plow treatments. Brutlag et al. (1989) reported that the ridge tillage system demonstrated a significant increase in yield compared with conventional tillage system. Glenn and Dotzenke (1978) and Sojka et al. (1980) examined several reduced tillage systems for sugar beets and found comparable yield between reduced tillage and conventional tillage systems. In some areas where wind erosion is a major problem in sugar beet production, standing grain stubble from reduced tillage systems (such as strip tillage) and no tillage systems are used to protect young sugar beet seedlings in the spring. Halvorson and Hartman (1984) indicated that sucrose yield of sugar beets seeded under no tillage conditions in standing grain stubble was 103% of the yield under conventional tillage conditions in 1977 and 1978.

Row spacing effects on sugar beet production have been reported. Christenson (1978) observed that sugar beet yield in 49 cm row spacing was higher than in 76 cm row spacing treatment. Sugar beet quality tended to be better in the narrower rows as compared to 71 cm rows. Results of 31 research studies complied by Cattanach and Schroeder (1980) indicated sugar beet yield averaged 0.66 Mg/ha greater for 56 cm row spacing than for 76 row spacing. Other studies have also indicated higher yields for sugar beets grown in 56 cm rows than for those grown in 76 cm rows (Fornstrom and Jackson, 1983; Hills, 1973).

In order to reveal how plant form and behavior adjust to different soil conditions created by tillage and row spacing, measurements of sugar beet weight, leaf area, or some other factors are employed to analyze plant growth and development. These methods are simple in principle but provide valid measures of the effects of treatment on the growth patterns (Follett et al., 1970). Snyder (1975) found that sugar beet yield correlates positively with leaf area for the individual plant. He also observed that the relationship between shoot parameters and root weight is established very early in the life of the plant.

Sugar beet production in the Lake States Region typically utilizes intensive tillage and wider row spacings. Commonly, tillage includes fall moldboard plowing with multiple spring tillage operations to create a smooth, level seedbed. Deep tillage operations, primarily subsoiling, are also common. Row spacing are normally 71 to 76 cm.

The objective of this study was to evaluate tillage and row spacing effects on sugar beet growth, development, yield and quality. Nondestructive measurement methods developed to evaluate growth and development, are also presented and discussed.

MATERIALS AND METHODS

Field experiments were initiated in the spring of 1988 to examine the effects of tillage and row spacing on crop performance in an oat-corn-dry bean-sugar beet rotation. The experiment was located in the Saginaw Valley in east central Michigan on a Parkhill clay loam. The Parkhill soil series consists of poorly and very poorly drained soil formed in loamy glacial till on till plain moraines. The study site is adequately tile drained and had been cropped to a corn-soybeans (Glycine max L.) rotation for more than 10 years with fall chisel plowing as the primary tillage operation.

Six tillage treatments and two row spacings were evaluated in a randomized complete block split plot design with four replications. Tillage formed the main blocks and row spacing the subplots within each tillage treatment. Tillage treatments were: (1) Fall moldboard plowing followed by spring secondary tillage; (2) Fall moldboard plowing with no secondary tillage; (3) Fall chisel plowing followed by spring secondary tillage; (4) Ridge till; (5) No tillage and (6) No tillage plus cultivation. Secondary tillage consisted of two passes with a field cultivator prior to planting. Row spacing of 56 and 71 cm were established in subplots 6.1 m wide by 18 m long within each tillage treatment.

Sugar beets were planted approximately 2 cm deep on April 23 in 1989 and April 24 in 1990 using a John Deere 7300 plate planter with attachments for no-tillage and ridge tillage. Two similarly equipped planters were used and set for 56 cm or 71 cm row spacings respectively.

Non-destructive plant measurements were developed to predict sugar beet above ground biomass and leaf area in the treatment plots. Sugar beet leaves (above ground) were sampled on eight plants each week on the non-treatment border plots from June 21 to August 30 in both 1989 and in 1990. Leaf number and leaf length were measured on each leaf sample and above ground biomass was determined on oven dried at 65° C for 48 hours. Leaf area was measured with an electrical leaf area meter on each sample taken in 1990 but not in 1989. Regression analysis was used to develop predictive relationships among plant growth and the development components: above ground biomass, leaf length, leaf number, and leaf area.

Three adjacent plants in one row within each tillage treatment plot were marked early in the growing season. Plant leaf number and leaf length were measured on these plants on June 21, July 5, and July 24 in 1989 and June 21, August 9,and September 11 in 1990. These three plants were harvested on September 21 in 1989 to determine sugar beet above ground biomass and sugar beet leaf number, and October 7 in 1990 to determine above ground biomass and sugar beet dry weight by oven drying at 65° C for 48 hours. Leaf Area (LA), Leaf Area Index (LAI), and Leaf Growth Rate (GR) were calculated by regression formulas generated from data obtained from the measurements on border plots.

Sugar beets were harvested from two 18 meter rows in the center of the plots on September 26, 1989 and October 23 1990. In 1989, plant populations at harvest were taken in the two harvest rows after the beets were topped. In 1990 the entire treatment (4 rows) was evaluated for population at harvest.

Permanent Time Domain Reflectometry (TDR) probes were established in the sugar beet plots to monitor soil volumetric moisture content under three tillage treatments (moldboard plow, ridge tillage and no tillage) and two row spacings (56 cm and 71 cm). A total of nine TDR probes (18 rods) were installed in each treatment, with three replications per treatment plot. Each probe consisted of two parallel steel rods (4.8 mm diam) placed 50 mm apart installed vertically by direct insertion from the soil surface. Three of the probes were installed in each of three depths (0-15 cm, 0-30 cm, and 0-75 cm), with each probe placed in an adjacent row 5 cm from the next probe. TDR readings were taken weekly in each treatment plot to calculate volumetric soil moisture content according to formula developed by Topp et al. (1980). A weather station (Campbell Scientific, Inc; Model CR 10) was established in July of 1989 at the research site to collect hourly data on rainfall, air temperature, soil temperature, and wind speed. Growing Degree Days (GDD) were calculated from maximum and minimum air temperatures using a base temperature of 3° C (Milford et al., 1985), as follow:

$$GDD = \Sigma\{(T_{Max} + T_{Min}) / 2 - 3\} \qquad [1]$$

where T_{Max} is daily maximum air temperature, T_{min} is daily minimum air temperature.

Undisturbed soil cores were taken for determination of soil bulk density, total porosity, and macroporosity (pore diameter > 48 um) on September 14, 1989 and September 19, 1990. Undisturbed soil cores 7.6 cm diameter and 7.6 cm long were obtained with a Uhland double-cylinder, hammer driver sampler (Blake, 1986). Three core samples were taken from each tillage treatment in the 71 cm row spacing at two depths (0 cm-7.5 cm and 7.5 cm-15 cm). Three additional co

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core samples were taken for ridge tillage at a 15-22.5 cm depth as measured from the top of the ridge. Soil cores were saturated by wetting from the bottom for at least 48 hours. Soil water retention at 1 and 6 kpa was determined on the tension table. Cores were oven dried at 105° C for 48 hours and weighed for bulk density determination. Water loss between saturation and oven dried was taken to represent total soil porosity. Macroporosity (pores > 48 um diameter) was determined by subtracting the measured volumetric water at 6 kpa from the total porosity. Saturated hydraulic conductivity of these samples was determined using the constant head method (Klute and Dirksen, 1986).

Tillage and row spacing effects on development and growth of sugar beets and soil physical properties were evaluated using analysis of variance for a split-plot design. A least significant difference (LSD) at the $p = 0.05$ level was calculated when the F-statistic between treatments was significant.

RESULTS

EVALUATION OF NON-DESTRUCTIVE PLANT MEASUREMENTS

Sugar beet development and growth were measured over time in the border plots in order to develop statistical relationships between non-destructive plant measurements and plant biomass. These relationships were determined in order to assess the effects of tillage and row spacing on sugar beet growth and development.

There were considerable differences in the weather and weed pressures between 1989 and 1990. Growing degree days were similar in both years but slightly higher in 1990 than 1989 (Figure 2.1). Growing season precipitation was substantially higher in 1990 than 1989 (Figure 2.1). As a result, soil water content was higher in 1990 than 1989 (Figures 2.2 and 2.3). Weed control was very good in 1989 and poor in 1990 and resulted in reduced plant populations in 1990. These differences contributed to differences in plant development between the two years.

Leaf numbers (Figure 2.4) were higher in the latter part of the growing season in 1990 than 1989, however numbers were reduced due to leaf necrosis when heavy rainfall produced saturated soil conditions. Leaf length was similar between two years (Figure 2.4) but leaf weight was generally higher in 1990 than 1989 (Figure 2.4 and Figure 2.5). The exception occurred at about 1600 GDD where a large increase in leaf weight was observed in 1989 followed by a sharp decline. This was associated with rainfall from August 3 to 6 followed by drought conditions. The relationship between above ground biomass and leaf length (cm) was similar in both years (Figure 2.6) approximately 0.13 g cm^{-1} plant $^{-1}$. However, leaf length

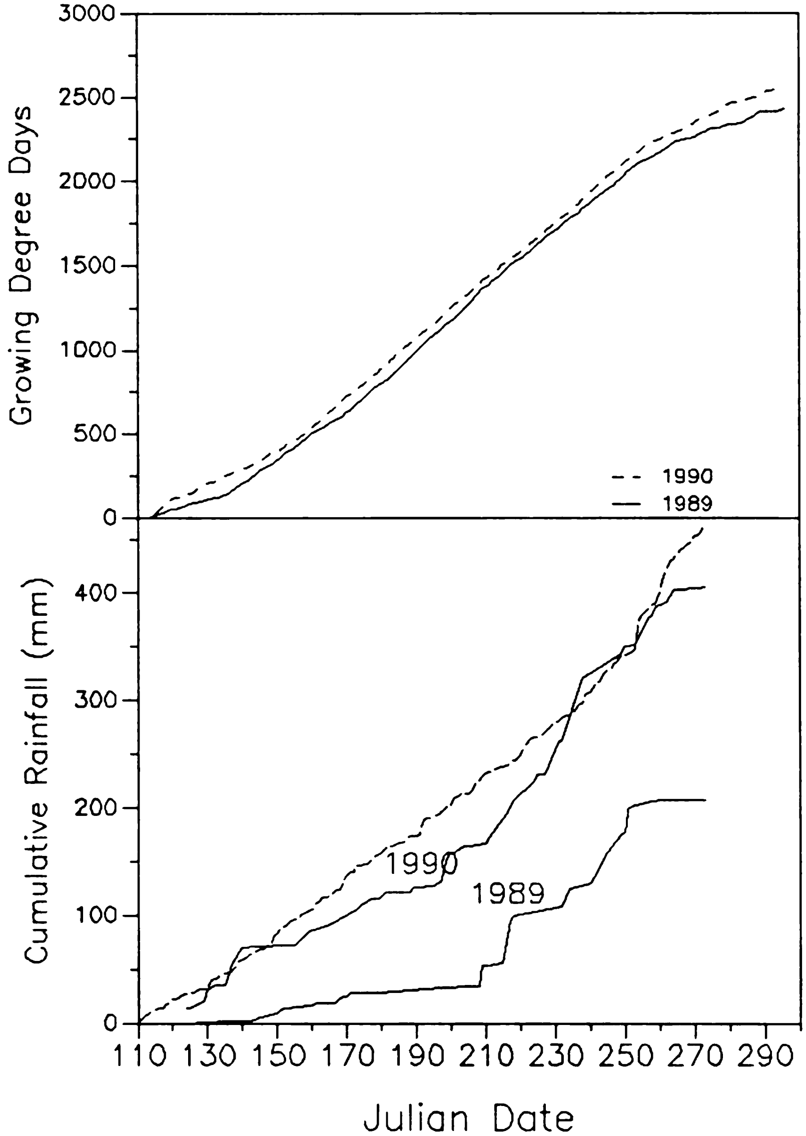

Figure 2.1. Growing degree days and cumulative rainfall from April 20 to October 27 1989 and 1990 (dash line is the average rainfall from 1977-1988 at the beet and bean farm).

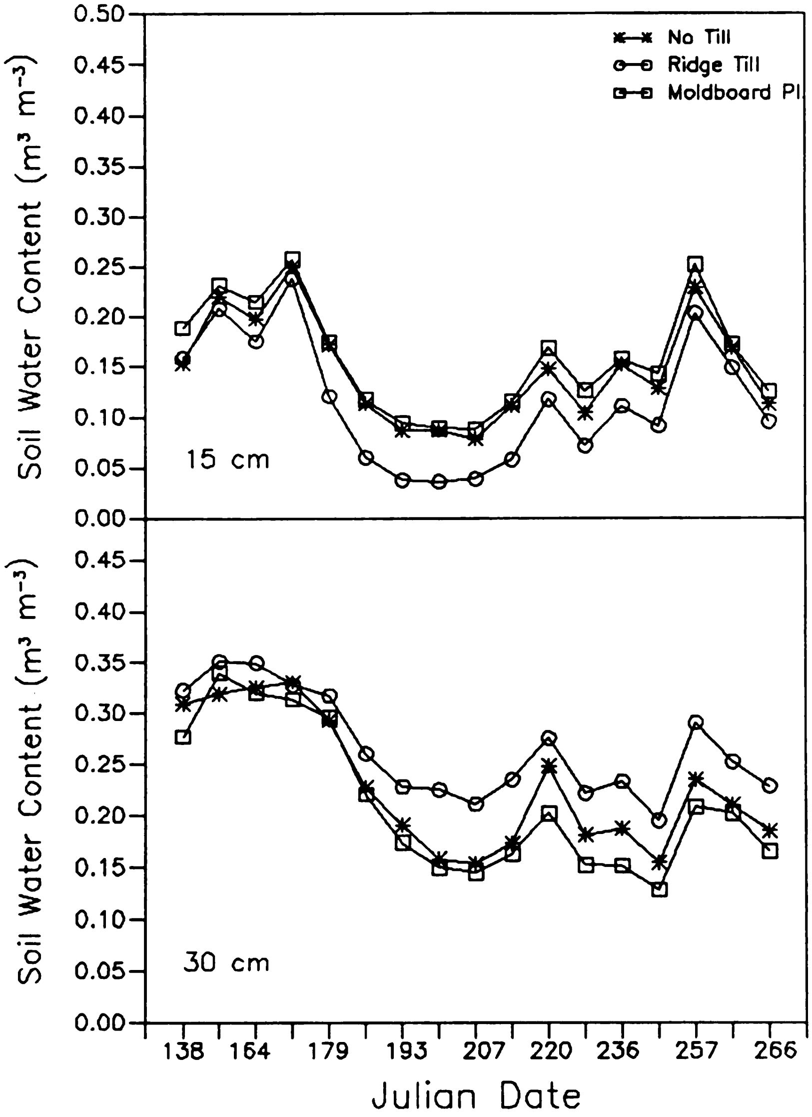

Figure 2.2. Soil water content for three tillage treatments at two soil depths (0-15 and 10-30 cm) under 71 cm row spacing.

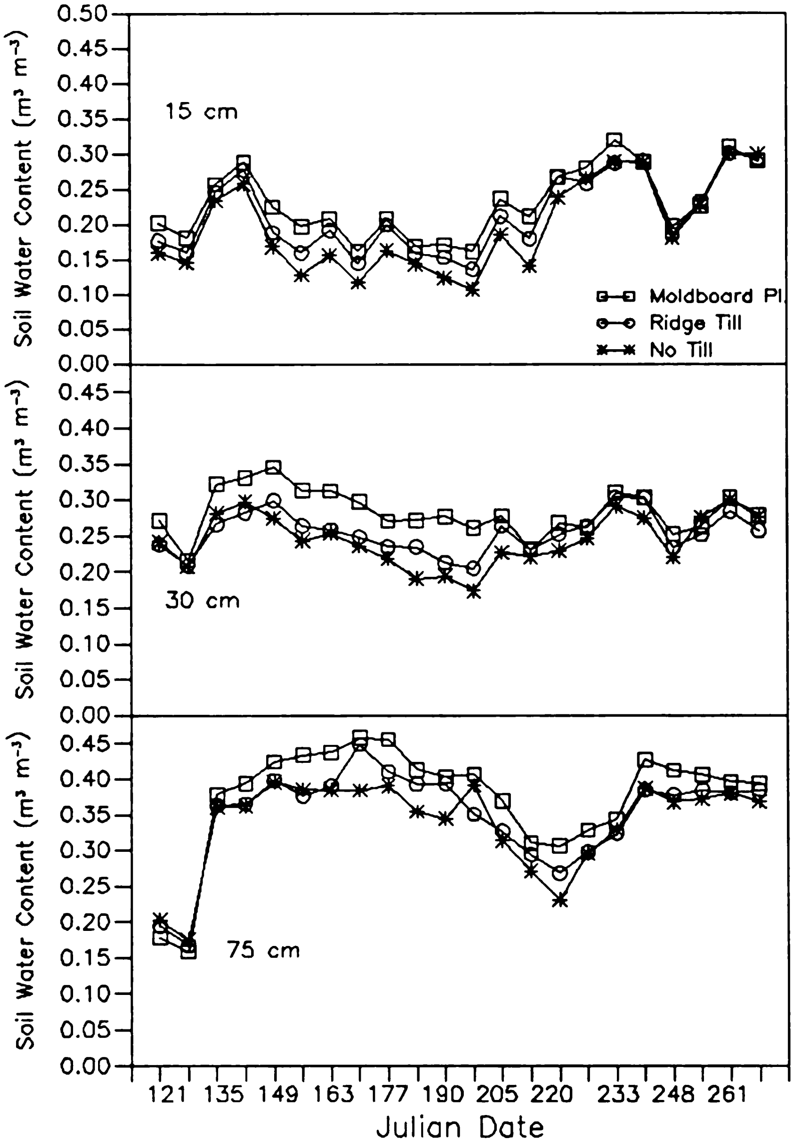

Figure 2.3. Soil water content for three tillage treatments at three soil depths (0-15, 15-30 and 30 -75 cm) under the 71 cm row spacing.

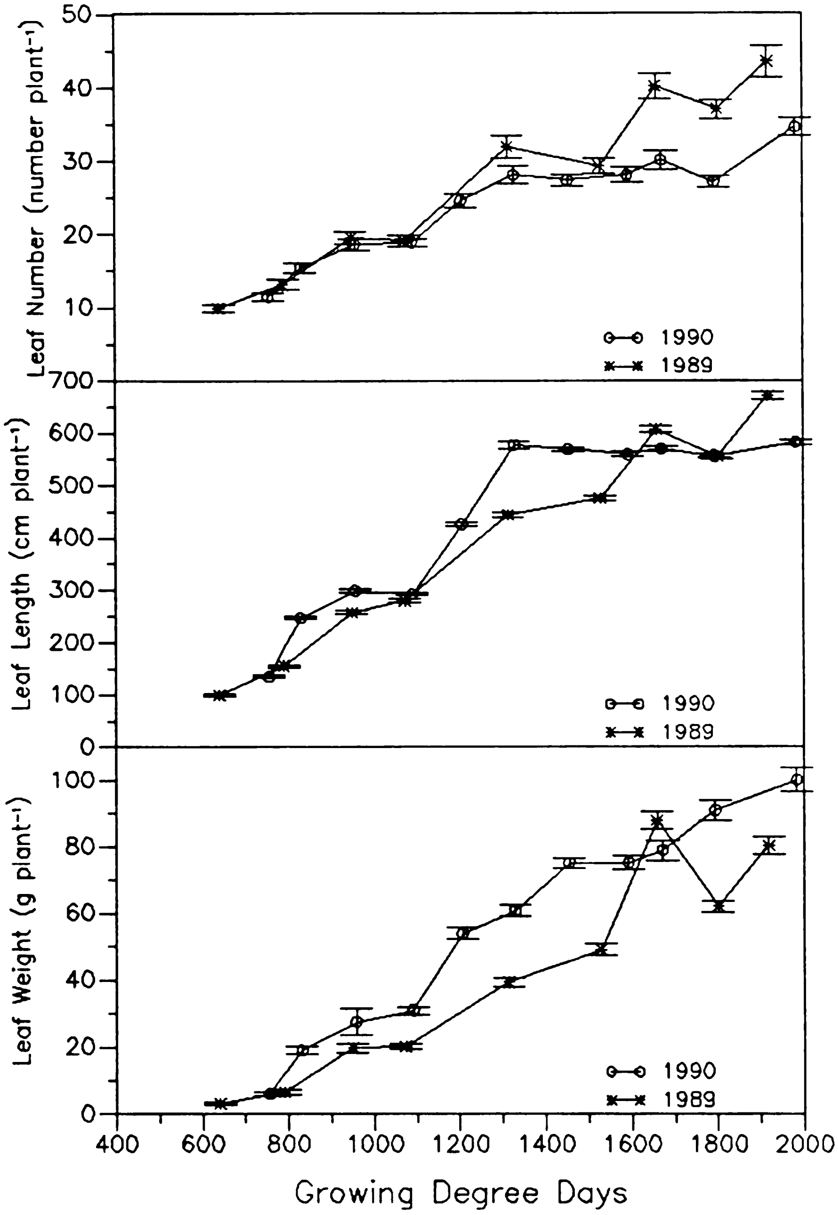

Figure 2.4. Development and growth of sugar beet on a Parkhill Loam soil in 1989 annd 1990 expressed as leaf number, leaf length and leaf weight vs. growing degree days.

per plant was slightly higher in 1990 than 1989 (Figure 2.7). Leaf area, only measured in 1990, showed a strong relationship (r^2=0.94) to leaf length (cm) (Figure 2.8). These data indicate the leaf length per plant is a good predictor of above ground biomass in sugar beets and that this is independent of variable weather condition.

TILLAGE AND ROW SPACING EFFECTS ON SUGAR BEETS

With the exception of sugar beet yields in 1990, only the main effects of tillage and row spacings were significant for measured parameters. Therefore, the main effects of tillage and row spacing will be discussed separately.

In order to evaluate effects of tillage and row spacing on development and growth, two parameters were calculated from the measured data and relationships developed above.

Sugar beet Leaf Area Index (LAI) was calculated as the product of plant population and mean leaf area per plant. Leaf area per plant (cm^2 $plant^{-1}$) was calculated from the equation given in Figure 2.8. LAI (m^2 $m-^2$) was calculated as the ratio of leaf area (A) to ground area (m^2) as described by Follett (1970).

The concept of growth rate, as described by Radford (1967) for a unit area of canopy cover, at any instant in time (t), is "the increase of plant material per unit of

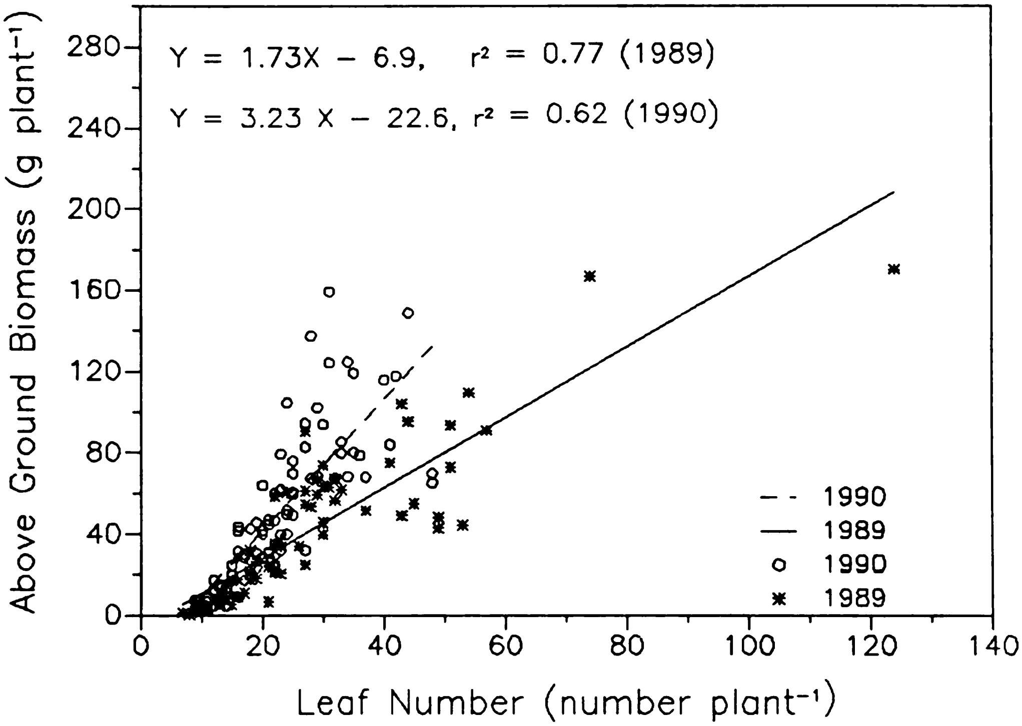

Figure 2.5. Relationship between sugar beet above ground biomass and leaf number in 1989 and 1990.

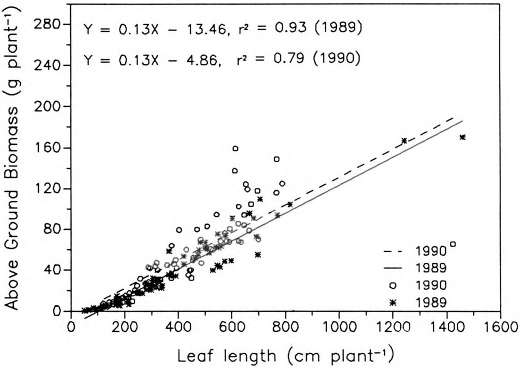

Figure 2.6 Relationship between sugar beet above ground biomass and leaf lenngth in 1989 and 1990.

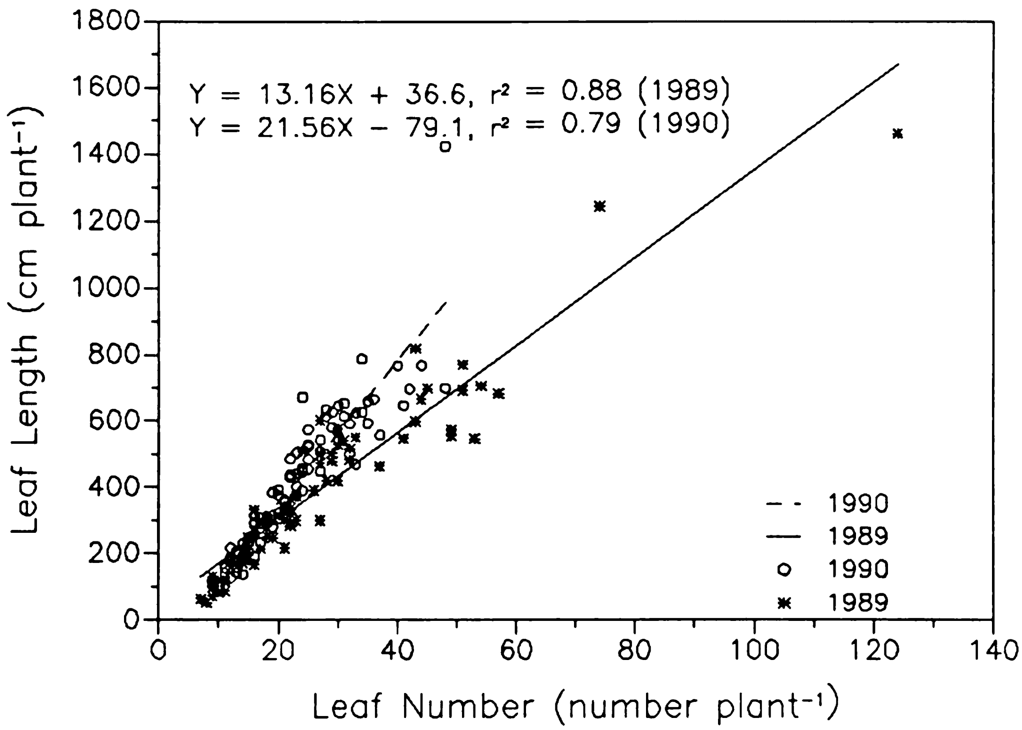

Figure 2.7. Relationship between leaf length and leaf number in 1989 and 1990.

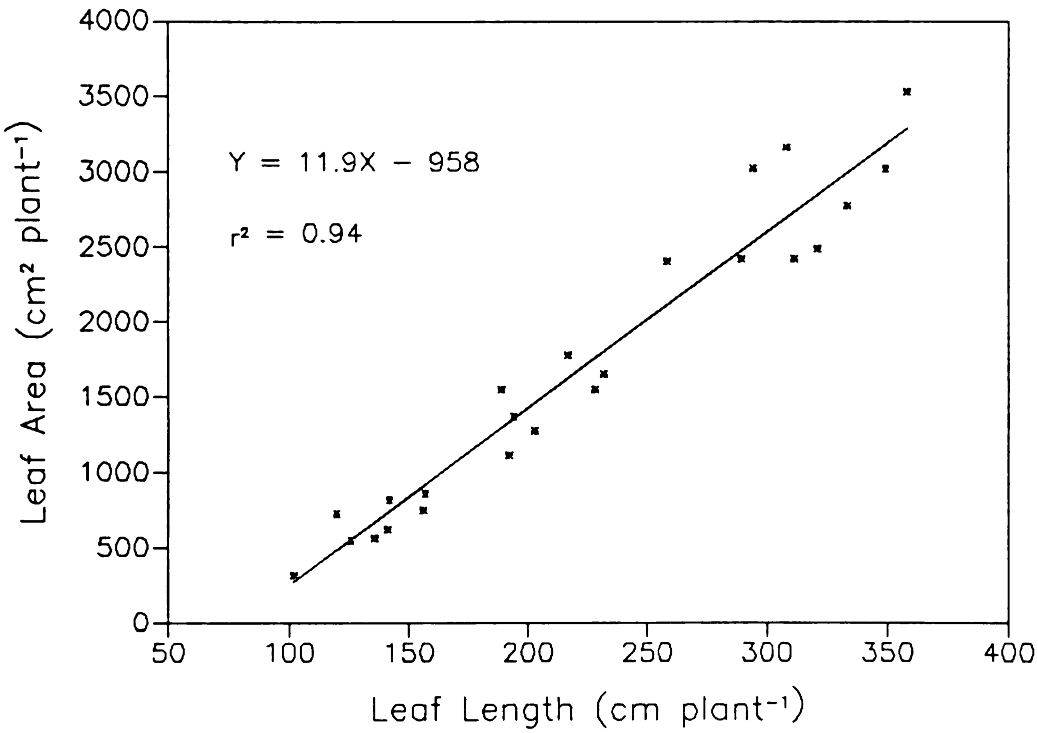

Figure 2.8. Relationship between leaf area and leaf length in 1990.

time" (expressed as a gm/day. m^{-2}). For this study, Radford's general concept was used to evaluate treatment effects on sugar beet leaf growth rate. Sugar beet leaf length was converted to sugar beet above ground biomass (Wt) by equation [1]. For the September 21, 1989 and October 7, 1990 sampled dates, above ground biomass was determined by oven drying 3 samples for each plot.

$$Wt = 0.169 * LL - 0.52 * LN - 11.45 \qquad [1]$$

where LL is leaf length and LN is leaf number. The increase in leaf dry weight as grams per plant (WtD) for a given time period was calculated as:

$$WtD = (Wt2 - Wt1) / (t2 - t1) \qquad [2]$$

where Wt1 and Wt2 are the initial and final dry weights, and t2-t1 is the length of the time period. The increase in sugar beet above ground biomass accumulation rates as grams per week per square meter (gm $week^{-1}$ m^{-2}) was calculated from WtD for a population of plants (plant ha^{-1}) and then divided by total area in which the population was located.

Tillage Effects

Tillage significantly affected sugar beet development and growth in both 1989 and 1990. In 1989, the no-tillage, no-tillage plus cultivation, and the chisel plow treatments retarded development and reduced growth in sugar beets (Table 2.1). Leaf number, leaf length, leaf area index and biomass accumulation rates were all reduced in these tillage treatments relative to the two moldboard plow and ridge tillage treatments. The moldboard plow with no secondary tillage generally produced the fastest growing and largest sugar beet plants in 1989 with the ridge tillage treatment very similar. Lack of spring secondary tillage following fall moldboard plowing enhanced growth in 1989 as evidenced by significantly higher leaf numbers and associated leaf lengths for the July and September plant sampling dates. Sugar beet yields were significantly higher in the chisel plow (59.3 Mg ha^{-1}) and ridge tillage (58.0 Mg ha^{-1}) treatments than the moldboard plow (52.4 Mg ha^{-1}) and the two no tillage (47.9 Mg ha^{-1}) treatments (Table 2.3). There was no differences between the chisel plow and ridge tillage treatments and the moldboard plow (nst) or between the two moldboard plow treatments. Yield differences were not due to stand differences since there were no differences in plant populations in 1989. Sugar beet quality was not affected by tillage in 1989.

In 1990, development and growth of sugar beets was confounded by weeds and associated poor plant stands. Compared to 1989, leaf numbers were reduced, leaf length and leaf areas indices were increased and biomass accumulation

Table 2.1. Tillage effects on the development and growth of sugar beet in 1989.

TILLAGE TREATMENT	Jun 21	July 5	July 24	Sept.21
	------- Leaf Number			----------------
Moldboard Plow	10.0	15.0	22.0	40.0
Moldboard Plow (nst)	10.0	17.0	26.0	55.0
Chisel Plow	9.0	15.0	25.0	49.0
Ridge Till	11.0	16.0	24.0	44.0
No-tillage	10.0	15.0	25.0	47.0
No-tillage+cultivation	10.0	15.0	22.0	41.0
LSD (0.05)	1.0	2.0	4.0	12.0
	-------Leaf length (cm)------------			
Moldboard Plow	115	236	364	
Moldboard Plow (nst)	137	280	428	
Chisel Plow	111	232	397	
Ridge Till	130	250	382	
No-tillage	94	214	372	
No-tillage+cultivation	99	225	354	
LSD (0.05)	21	30	61	
	----Leaf Area Index (m^2 m^{-2})-----			
Moldboard Plow	0.25	1.12	2.04	
Moldboard Plow (nst)	0.36	1.25	2.16	
Chisel Plow	0.21	1.00	2.05	
Ridge Till	0.37	1.25	2.23	
No-tillage	0.13	1.00	2.12	
No-tillage+cultivation	0.13	1.00	1.87	
LSD (0.05)	0.15	0.27	NS	
	Above Ground Biomass Accumulation Rates (g m^{-2} $week^{-1}$)			
Moldboard Plow	18.4	62.9	57.5	7.9
Moldboard Plow (nst)	21.2	64.3	58.6	15.9
Chisel Plow	13.8	61.7	65.7	11.6
Ridge Till	23.5	63.4	62.9	11.1
No-tillage	14.1	63.9	71.1	6.6
No-tillage+cultivation	13.5	62.6	54.7	10.0
LSD (0.05)	6.3	NS	NS	NS

Leaf area is predicted from formula in Figure 2.8. Leaf area index is calculated as the ratio of leaf area to the ground area.

rates were reduced by nearly one-half for all tillage treatments (compare Tables 2.1 and 2.2). Sugar beets in the no-tillage treatments developed slower and produced smaller plants than those in the other tillage treatments in 1990 (Table 2.2). Cultivation of no-tillage appeared to have a more detrimental effect as evidenced by the lowest leaf number (24), leaf length (452 cm), and biomass accumulation rates (4.3 g m^{-2} $week^{-1}$) on the September 11th sampling date. Leaf number and leaf length were lower in the no-tillage without cultivation on June 21 but recovered by September 11th to levels of the other tillage systems. Plant populations were lowest for the no-tillage treatments when compared to the full width tillage treatments of moldboard plowing and chisel plowing. Ridge tillage was intermediate in plant population and differed significantly only from the chisel plow treatment. Beet dry weights at harvest were significantly lower for the no-tillage treatments (229 to 144 g $beet^{-1}$) when compared to the four other treatments (307 to 402 g $beet^{-1}$). In 1990, there was a significant interaction between tillage and row spacing for sugar beet yield (Table 2.3). Yields were higher in the 71 cm than the 56 cm row spacing for the moldboard plow (nst) and the ridge tillage treatments but there were no differences due to row spacing in the other tillage treatments. Within the 71 cm row spacing, the moldboard plow (nst) produced significantly higher yields (63.5 Mg

Table 2.2. Tillage effects on the development and growth of Sugar beet in 1990.

TILLAGE TREATMENT	June 21	Aug.9	Sept. 11	Oct. 7
	------- **Leaf Number** ----------------			
Moldboard Plow	10.0	24.0	33.0	
Moldboard Plow (nst)	10.0	24.0	32.0	
Chisel Plow	12.0	25.0	28.0	
Ridge Till	11.0	26.0	32.0	
No-tillage	9.0	21.0	28.0	
No-tillage+cultivation	9.0	20.0	24.0	
LSD (0.05)	2.0	5.0	6.0	
	------- **Leaf Length (cm)** -----------			
Moldboard Plow	130	542	720	
Moldboard Plow (nst)	160	530	759	
Chisel Plow	150	523	575	
Ridge Till	129	481	548	
No-tillage	87	432	764	
No-tillage+cultivation	98	390	452	
LSD (0.05)	42	NS	141	
	--- **Leaf Area Index (m^2 m^{-2})** ----			
Moldboard Plow	0.21	2.13	2.84	
Moldboard Plow (nst)	0.36	2.15	3.26	
Chisel Plow	0.42	2.28	2.56	
Ridge Till	0.20	1.81	2.60	
No-tillage	0.04	0.99	1.46	
No-tillage+cultivation	0.09	1.13	1.33	
LSD (0.05)	0.21	0.93	0.87	
	Above Ground Biomass Accumulation Rates (g m^{-2} $week^{-1}$)			
Moldboard Plow	3.9	33.6	16.9	40.9
Moldboard Plow (nst)	8.0	31.4	28.6	49.4
Chisel Plow	9.6	32.1	6.5	51.1
Ridge Till	3.2	28.3	20.7	24.2
No-tillage	0.3	15.8	6.4	12.9
No-tillage+cultivation	1.3	17.7	4.3	20.9
LSD (0.05)	5.6	17.3	19	NS

Leaf area is predicted from formula in Figure 2.8. Leaf area index is calculated as the ratio of leaf area to the ground area.

Table 2.3. Yield, plant population at harvest, and beet weight as affected by tillage and row spacing in 1989 and 1990.

TILLAGE TREATMENT	1989 Yield (Mg ha^{-1})	1989 Population (1000s plant ha^{-1})	1990 Yield (Mg ha^{-1})		1990 Population (1000s Plant ha^{-1})	1990 Beet Dry Weight (g $Beet^{-1}$)
			ROW SPACING (cm)			
			56	71		
Moldboard Plow	52.4	60.7	48.9	43.2	38.1	326
Moldboard Plow (nst)*	56.6	52.7	45.2	63.5	40.7	402
Chisel Plow	59.3	55.2	39.0	37.5	43.4	280
Ridge Till	58.0	62.1	27.7	43.0	31.7	307
No-tillage	47.9	60.8	11.9	14.3	23.7	229
No-tillage+cultivation	47.9	57.4	20.0	26.7	29.1	144
LSD (0.05)	4.8	NS	*	*	11.1	126

* Tillage and row spacing interaction:
LSD (0.05) to compare row spacing mean for the same tillage = 11.8
LSD (0.05) to compare tillage mean for the same Or for different row spacing = 12.8

ha^{-1}) than all other tillage treatments. The no-tillage treatments yielded significantly less than the moldboard plow and the ridge tillage treatments with the chisel plow intermediate. Within the 56 cm row spacing, there were no differences in yield between the full width tillage treatments. The ridge tillage treatment was lower than the moldboard plow treatments, but was not different from the chisel plow treatment or the no-tillage treatments. As was true in 1989, tillage had no effect on sugar beet quality and sugar beet quality was similar between two years.

Row Spacing

The effects of row spacing on development and growth of sugar beets was significant but varied with year and sampling date (Tables 2.4 and 2.5). In 1989, there were slightly but significantly fewer leaves for 56 cm spacing on the June 21 sampling date but no difference at later sampling dates. Leaf numbers were not affected by row spacing in 1990. Leaf lengths were not affected by row spacing in 1989, but were significantly higher on the September 11th sampling date for the 56 cm row spacing (677 cm plant^{-1}) than the 71 cm row spacing (596 cm plant^{-1}). Leaf area indices were higher for the 56 cm row spacing for the July, 1989 sampling but not different in 1990. This corresponds to a significant increase in biomass accumulation rates in July, 1989, for the 56 cm row spacing.

Table 2.4. Row spacing effects on development and growth of sugar beet in 1989.

ROW SPACING	Jun 21	July 5	July 24	Sept.21
	Leaf Number			
56 cm	9.7	15.5	24.5	45.0
71 cm	10.0	15.5	23.8	46.7
LSD (0.05)	0.3	NS	NS	NS
	Leaf length (cm)			
56 cm	111	236	381	
71 cm	118	243	385	
LSD (0.05)	NS	NS	NS	
	Leaf Area Index (m^2 m^{-2})			
56 cm	0.24	1.21	2.32	
71 cm	0.24	0.99	1.83	
LSD (0.05)	NS	0.16	0.27	
	Above Ground Biomass Accumulation Rates (g m^{-2} $week^{-1}$)			
56 cm	18.2	72.1	70.4	8.8
71 cm	16.6	54.1	53.1	12.3
LSD (0.05)	NS	9.0	9.0	NS

Leaf area is predicted from formula in Figure 2.8. Leaf area index is calculated as the ratio of leaf area to ground area.

Table 2.5. Row spacing effects on development and growth of sugar beet in 1990.

ROW SPACING	June 21	Aug.9	Sep. 11	Oct. 7
	------- Leaf Number ----------------			
56 cm	10.0	24.0	31.0	
71 cm	10.0	24.0	29.0	
LSD (0.05)	NS	NS	NS	
	-------Leaf length (cm)------------			
56 cm	123	495	677	
71 cm	129	471	596	
LSD (0.05)	NS	NS	64	
	----Leaf Area Index (m^2 m^{-2})----			
56 cm	0.19	1.76	2.42	
71 cm	0.25	1.74	2.25	
LSD (0.05)	NS	NS	NS	
	Above Ground Biomass Accumulation Rates (g m^{-2} $week^{-1}$)			
56 cm	4.0	27.0	16.9	44.0
71 cm	5.0	26.0	12.8	25.0
LSD (0.05)	NS	NS	NS	17.0

Leaf area is predicted from formula in Figure 2.8. Leaf area index is calculated as the ratio of leaf area to ground area.

The relative lack of row spacing effect on development and growth of sugar beets in 1990 may be related to poor stands and weed pressures.

Yields were higher in 1989 for sugar beets in the 71 cm row spacing than the 56 cm row spacing regardless of tillage system (Table 2.5). There was no effect of row spacing on sugar quality. In 1990, there was a significant tillage by row spacing interaction. Yields were higher in the 71 cm row spacing for the moldboard plow (nst) and the ridge tillage treatments but no effect of row spacing in the other tillage treatments (Table 2.3). Sugar beet quality, however, was reduced in the 56 cm row spacing across all tillage treatments (Table 2.6). Sugar beets in the 56 cm row spacing average 0.9 % less sugar and clear juice purity (CJP) was lower by 0.9 %. Recoverable white sugar (RWS) was reduced by 16 kg Mg^{-1} and NH2-N was increased by 5.7 cmol Kg^{-1} sugar. Plant populations were not significantly different between row spacings but plant populations were considerably lower than 1989. The reduction in quality may be related to weed pressure difference between the two row spacings.

TILLAGE EFFECTS ON SOIL MOISTURE AND SELECTED SOIL PHYSICAL PROPERTIES

Volumetric soil moisture content depended upon the weekly amount of rainfall (figure 2.2 and Figure 2.3). Soil

Table 2.6. Effects of row spacing on sugar beet yield plant population and quality in 1989 and 1990.

ROW SPACING	Yield ($Mg\ ha^{-1}$)	Population (1000s plant ha^{-1})	Sugar (%)	CJP	RWS ($kg\ Mg^{-1}$)	NH2-N ($cmol\ Kg^{-1}$ sugar)
1989						
56 cm	52.4	65.7	16.0	94.9	124	7.1
71 cm	55.1	50.6	16.0	94.8	123	7.1
LSD (0.05)	2.3	NS	NS	NS	NS	NS
1990						
56 cm	*	33.1	15.7	93.6	102	16.2
71 cm	*	35.8	16.6	94.5	107	10.5
LSD (0.05)	*	NS	0.4	0.3	3.6	0.9

* Tillage /row spacing effects on sugar beet yield in 1990, see Table 2.3.

moisture content at the 0-15 cm depth measured in 1989 (Table 2.7) under the moldboard plow treatment was significantly greater than under the ridge till system at the beginning of the growing season (from June 13 to August 1). In contrast, the soil moisture content at 15-30 cm depth was significantly higher under the ridge tillage treatment as compared with the moldboard plow treatment from July 12 to August 1. After August 6, soil moisture content was not significantly different between tillage treatments at any depth. As observed from the curve of cumulative rainfall for the period from May 1 to end of July was lower than after August 1. Soil moisture content at 30-75 cm depth was not obtained due to TDR probe installation problems.

In 1990, soil moisture contents were greater under the moldboard plow than the no till treatment during the beginning of growing season (from May 1 to late July) and on August 21 were observed at the 0-15 cm depth. Soil moisture content at 0-15 cm depth during sugar beet emergence and seedling periods, shown in Table 2.7, suggests that low soil moisture content (0.1 to 0.15 m^3 m^{-3}) under the no till treatment from May 1 to July 17 may have reduced sugar beet emergence and reduced growth rate in the seedling period. These reductions in emergence and growth rate have potential to decreased the yield. Because sugar beet seed is small and must be planted at a shallow depth (2 cm), adequate soil

Table 2.7. Selected Sugar Beets Soil Moisture Content (m^3 cm^{-3}) as Affected Significantly by Tillage Treatments in 1989 and 1990.

Measurement Date	TILLAGE TREATMENT NT	RT	MP	LSD (0.05)
1989				
		0-15 cm		
June 13 (164)	0.20	0.18	0.20	0.00
June 28 (179)	0.17	0.12	0.17	0.00
July 12 (193)	0.08	0.05	0.09	0.00
July 19 (200)	0.08	0.05	0.08	0.00
July 26 (207)	0.07	0.05	0.08	0.00
Aug. 1 (213)	0.11	0.08	0.11	0.00
		15-30 cm		
July 12 (193)	0.19	0.23	0.17	0.05
July 19 (200)	0.18	0.21	0.16	0.05
July 26 (207)	0.17	0.19	0.16	0.00
Aug. 1 (213)	0.18	0.20	0.16	0.00
1990				
		0-15 cm		
May 1 (121)	0.16	0.17	0.19	0.00
May 29 (149)	0.15	0.18	0.20	0.05
June 5 (156)	0.12	0.15	0.18	0.05
June 12 (163)	0.15	0.18	0.20	0.05
July 7 (188)	0.11	0.14	0.16	0.05
July 17 (198)	0.18	0.19	0.23	0.00
July 24 (205)	0.18	0.19	0.23	0.00
July 31 (211)	0.13	0.16	0.19	0.00
Aug. 21 (233)	0.28	0.29	0.31	0.00

NT = No Tillage
RT = Ridge Tillage
MP = Moldboard Plow
Julian Date in Parentheses

Table 2.8. Soil physical properties of the Parkhill Loam soil averaged across tillage treatments in 1989 and 1990.

Soil Depth (cm)	Bulk Density ($g\ cm^{-3}$)	Total Porosity ($m^3\ m^{-3}$)	Macro Porosity ($m^3\ m^{-3}$)	Conductivity ($cm\ h^{-1}$)
		1989		
0-7.5	1.50	0.41	0.05	6.8
7.5-15	1.61	0.39	0.04	3.2
		1990		
0-7.5	1.43	0.43	0.06	7.3
7.5-15	1.57	0.39	0.04	4.1

moisture is essential for plant emergence.
Statistical differences in soil moisture content between three tillage treatments at 15-30 cm and 30-75 cm depth were not observed over the entire growing season in 1990.

Soil physical properties as measured across treatments in 1989 and 1990 are presented in Table 2.8. These results indicate that soil physical properties were not significantly affected by tillage treatments in 1989 and 1990.

DISCUSSION

Tillage method effects on sugar beet growth and development, sugar beet yields, sugar beet quality and soil physical properties were observed in the this study. In 1989 and 1990, sugar beet growth rate was significantly lower for no till and no till plus cultivation treatments than for the moldboard plow without secondary tillage treatments.

Numerous investigators have demonstrated that plant responses to actions that alter the soil physical environment vary dramatically with climate. Sugar beet yields under moldboard plow without secondary tillage were significantly higher than any other tillage treatments in 1989 and 1990. This result suggest that the moldboard plow without secondary tillage holds significant production potential under climatic conditions such as those occurring in 1989 and 1990. However, the yields under the moldboard plow, chisel plow and ridge tillage vary between 1989 and 1990, The no tillage systems, with and without cultivation, however, do not appear to be viable for sugar beet production in either 56 cm or 71 cm row spacings based upon 1989 and 1990 data.

Comparison of sugar beet yields to sugar beet growth and development as affected by tillage treatment are associated with sugar beet growth rate during the first two months of the growing seasons. Lower sugar beet yields under the no till system were a likely result of lower growing rates during the first two months of the growing season.

Narrow row spacing (56 cm) produced lower yield in both years and reduced quality in 1990. These data do not support other data benefit of narrow row spacing on sugar beet production (Christenson, 1978; Cattanach and Schroeder, 1980; Fornstrom and Jackson, 1983; and Hills, 1973).

Significantly lower soil water contents under the ridge tillage system in 1989 and under no till treatment in 1990 as compared to the moldboard plow system at 0-15 cm depth were observed in beginning of growing season. On the other hand, at 15-30 cm depth soil moisture content was significantly high for ridge till in 1989 and significantly high for no till in 1990.

In conclusion, this study indicated that the measurement of sugar beet leaf length is an indirect way to examine plant growth rate, but it is simple, quick, and accurate, and because it does not interrupt or disrupt plant growth. The data from this study also showed that sugar beet growth rate and sugar beet yield were lower for the no till treatment and high for moldboard plow without secondary tillage treatment. Sugar beet yield under the 71 cm row spacing was higher than under the 56 cm row spacing.

REFERENCES

Blake, G. R. and K. H. Hartge. 1986. Bulk density. p. 363-375 In A.Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Bowen, H. D. 1966. Measurement of Edaphic factors for determining planter specifications. TRANSACTIONS OF THE ASAE. 9:725- 735.

Brutlag, A., G. H. Smith, J. F. Giles, and A. W. Cattanach. 1989. Modified ridge till system for sustainable sugarbeet production. Sugarbeet Research and Extension Reports. pp. 165-170.

Cattanach, A. and G. Schroeder. 1980. A comparison of 22 versus 30-inch row spacings at equal plant populations in 1967-77. 1979 North Dakota-Minnesota sugarbeet research and extension reports. PP. 198-203.

Christenson, D. R. 1978. Effect of row width and fertilizer application on sugar beets. Agr. Expt. Sta. Res. Rep. No. 351.

Follett, R. F., W. R. Schmehl and F. G. Viets. 1970. Seasonal leaf area, dry weight, and sucrose accumulation by sugarbeets. J. Am. Soc. Sugar Beet Technol. 16:235-252.

Fornstrom, K. J. and G. Jackson. 1983. Sugarbeets planted to stand in 56 and 76-centimeter rows. J. Am. Soc. Sugar Beet Technol. 22:108-118.

Glenn, D. C. and A. D. Dotzenke. 1978. Minimum vs. conventional tillage in commercial sugar beet production. Agon. J. 70:341- 344.

Halvorson, A. D. and G. P. Hartman. 1984. Reduced seedbed tillage effects on irrigated sugarbeet yield and quality. Agron. J. 76:603-606.

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

Johnson, B. S. 1987. Alleviation of compaction fine-textured Michigan soil. Ph.D. Diss. Michigan State University, MI.

Klute A. and C. Dirksen. 1986. hydraulic conductivity and diffusivity: Laboratory methods. pp. 687-734. In A. Klute (ed.) Methods of soil analysis. Part 1. 2nd ed. Agron. Monogr. 9. ASA and SSSA, Madison, WI.

Lamb, J. A. 1985. Tillage rotation study. Sugarbeet Research and Extension reports. pp. 103-104.

Milford, F. J., T. O. Pocock and Janet Riley. 1985. Analysis of leaf growth in sugar beet. II. Leaf appearance in field crop. Ann. appl. Biol. 106:173-185.

Radekee, J. K. and R. E. Bauer. 1965. Growth of sugarbeets as affected by root temperatures Part I: Greenhouse studies. Agron. J. 61:860-863.

Radford P. J. 1967. Growth analysis formulae - their use and abuse. Crop Sci. 7:171-175.

Simmons, S. R. and A. D. Dotzenko. 1975. Evaluation of conservation tillage effectiveness on sugarbeet fields in Northeastern Colorado. J. Am. Soc. Sugar Beet Technol. 18:307-311.

Snyder, F. W. 1975. Leaf and root accretion by sugar beet seedlings in relation to yield. J. Am. Soc. Sugar Beet Technol. 18:205- 213.

Sojka, R. E., E. J. Deibert, F. B. Arnold, and J. Enz. 1980. Sugarbeet production under reduced tillage - prospects and problems. North Dakota Farm Research. 38:14-18.

Topp, G. C., J. L. Davis and A. P. Annan. 1980. Electromagnetic determination of soil water content: Measurements in coaxial transmission line. Water Resour. Res. 16:574-582.

Yonts, C. D., K. J. Fornstrom and R. J. Edling. 1983. Sugarbeet emergence affected by soil moisture and temperature. J. Am. Soc. Sugar Beet Technol. 22:119-134.