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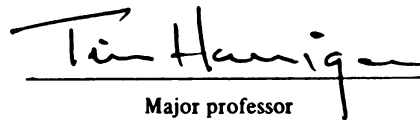
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of the requirements for

M.S. degree in **Agricultural Technology
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PLANT-TO-STAND FIELD PERFORMANCE OF SUGAR BEET PLANTERS

By

Andreas Ch. Smyrillis

A THESIS

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ABSTRACT

PLANT-TO-STAND FIELD PERFORMANCE OF SUGAR BEET PLANTERS

By

Andreas Ch. Smyrillis

An evaluation of the plant-to-stand field performance of two general purpose planters (Monosem and John Deere) and two specialized sugar beet planters (Accord and Stanhay) was conducted in two locations in 2000 and one location in 2001 at the Saginaw Valley Bean and Beet Research Farm. A pelleted and a fasonated seed treatment were evaluated at two planting speeds of 4.8 and 7.3 km/h (3.0 and 4.5 mph). Key measures of planter performance were rate of seedling emergence, final plant population, seed spacing uniformity, beet size uniformity and the standard measures of sugar beet yield and quality. The rate of emergence varied among trials with soil moisture. When soil moisture was adequate there was little difference among planters. In dry soil the Deere and Monosem tended to provide more rapid emergence, likely due to improved seed-to-soil contact. The Accord planter provided the best plant spacing uniformity while the Deere and Monosem tended to provide the highest final plant stand. The 4.8 km/h forward travel speed generally provided a more uniform plant spacing than when traveling at 7.3 km/h. The three centimeter mode range measurement of plant spacing uniformity was not a reliable predictor of beet size uniformity.

To my parents

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CHAPTER 1

1. INTRODUCTION

Agriculture plays an important role in Michigan's economy. In 1999 the total cash receipts from crops, livestock and livestock products was \$3.47 billion (MASS, 1999). Michigan's sugar beet industry was valued at \$129.7 million and was ranked fourth nationally with 10.6% of the U.S production. In 1999, 194,000 acres were planted and 190,000 acres were harvested. Yields averaged 18.6 tons per acre. Continued improvement in the productivity of the sugar beet industry is required in order to stay competitive in the world market.

Currently there are two types of planters used: specialized and general purpose planters. Both types of planters have either a mechanical or pneumatic seed delivery system. The functions of the planter are the same for each type of planter: 1) open a seed furrow, 2) meter the seed, 3) place the seed, 4) close the furrow, and 5) firm the soil over the seed. Seed spacing is important because it helps provide a uniform root size which in turn reduces harvest loss and leads to a potential increase in sugar yield (Lan et al.,1999). Seed spacing may be influenced by the type of seed, planter speed, and seedbed preparation.

Until the 1970's nearly all sugar beet crops were planted in a high plant population and thinned to a final stand (Panning et al.,1997). This technique, plant-and-thin, was used to manage seed spacing since the planters which were used were not precise in terms of seed spacing uniformity. The idea was to plant excess seed and thin the plants to a desired plant spacing. This technique was inefficient in terms of cost and

time. The cost increased because of the unnecessary seeds sown, the purchase of thinning equipment, and the extra labor for thinning.

An alternative to plant-and-thin is plant-to-stand. Plant-to-stand is a method which places seed at the targeted spacing. In general, plant-to-stand has not been as rapidly accepted in the United States as in Europe. In certain geographic regions of the United States it is estimated that plant-to-stand is used on as much as 90% of the crop, while in other regions as little as 20% of the crop is planted-to-stand. However, plant-to-stand is increasing and is expected to eventually become the predominate practice (Smith et al., 1991b).

A possible contribution of plant-to-stand establishment is better seed quality and seed treatment. Today, pelleted and coated seed are both used to improve plantability. Both types of seed contain fungicides which are used to prevent seed and soil diseases and increase the chance for better germination. However, when comparing pelleted versus coated seed, it is not clear which is handled better by precision planters and which gives the most uniform spacing, and if improved spacing justifies the higher cost. Pelleted seed is an improvement from the standpoint of planting due to its spherical shape. This allows the round seed to slide with little friction through the internal surface of the planter's parts and improve uniformity of spacing.

The forward travel speed of the planter also affects seed placement. The delivery of the seed from the metering mechanism to the furrow follows a trajectory which is affected by a combination of the horizontal forward speed of the planter and the vertical gravitational force that is exerted on the seed while dropping. Hence, the seed hits the ground with a certain speed which causes the seed to bounce in the furrow and change its

location. The drop distance from the metering mechanism to the furrow varies from planter to planter. The higher the point from which the seed is released, the higher the vertical speed of the seed and bounce due to acceleration. Moreover, since the seed follows a certain trajectory during delivery, the path it follows in the drop tube may not be straight downward due to seed bounce on the walls of the drop tube. Seed bounce in the drop tube may delay seed drop to the furrow. A delayed seed drop will alter the seed spacing.

The question of whether to buy a specialized planter for sowing sugarbeets is being asked by many growers. General purpose planters can sow corn and beans as well as sugar beet. On the other hand, some specialized planters can only sow sugar beet seed (Smith et al., 1991b). There is a need to evaluate the performance of planters, seed treatments, and planter forward travel speed in order to improve stands and sugar recovery.

1.1 OBJECTIVES

The purpose of this study was to compare the field performance of general purpose and precision seeders in non-irrigated plant-to-stand establishment of sugar beet.

Specific objectives were to:

1. Compare the rate of emergence, uniformity of plant spacing and final plant stand for a pelleted and fasonated seed treatment using general purpose and precision seeders.
2. Evaluate the effect of forward travel speed on the uniformity of seed spacing.
3. Evaluate the effect of plant stand uniformity on beet size uniformity.
4. Compare the effects of planter performance on beet yield, percent sugar, percent clear juice purity (CJP), recoverable white sugar per ton (RWST), and recoverable white sugar per acre (RWSA).

CHAPTER 2

2. LITERATURE REVIEW

2.1 PLANTER DEVELOPMENT

The history of sowing and planter development dates back to 1300B.C. One of the first methods of sowing, broadcast-by-hand, was first performed by the people of ancient Babylon (McClelland, 1997). This method was inefficient because the seeds were not distributed evenly and many were not covered by soil. Emergence and yields were often low. The need to mechanize for better seed distribution was recognized from the time of ancient Egyptians but mechanizing the sowing operation was very difficult.

In 1733, Jethro Tull published Horse-Hoeing Husbandry in England, where he described his revolutionary drill (McClelland, 1997). His drill was based on a device used to open furrows that was originally used by the Babylonians. Behind a furrow-creating device Tull added a funnel to transfer the seed from the hopper to the furrow. The seed covering device was a harrow which had wooden tines.

Americans employed a different planter development strategy in 1815. Rather than trying to develop a complex planter, they developed a simple mechanical broadcast seeder. A long, triangular-shaped seed box was mounted on a one-wheel chassis. Known as Bennett's sowing machine, the seed box contained a set of revolving brushes that threw seed against openings at the back of the box. The machine was inexpensive to build and easy to maintain. The Bennett sowing machine led to the replacement of hand labor with horse power (McClelland, 1997).

In 1860, a two row planter in which the operator tripped the seed drop mechanism by hand when passing a specific mark was developed. In 1875, the first automatic check-

row planter using a knotted cord to trip the seed drop mechanism was introduced. By 1890 planter development had moved to the introduction of a single kernel, cumulative-drop planter, and in 1900, fertilizer attachments were added. In 1923 the tractor mounted planters were introduced (Deere and Company, 1992).

From 1923 until today, planter development has focused on three types of planters; the broadcast seeder, the drill seeder, and the precision planter (Srivastava et. al., 1994). Broadcast seeders were used for small grains such as oats, wheat, barley and grass or legume seed. The seeds were metered from a hopper through a variable orifice (Srivastava et. al., 1994). An agitator was used on top of the orifice to prevent bridging of the seed over the gate and to assure continuous feeding. The metered seed dropped onto a spinning disk which accelerated and threw it, usually horizontally. The width of coverage depended upon the size, shape, and density of the seeds. The seeding rate was controlled by the size of the gate opening, the speed of travel and the width of coverage. After broadcast seeding, a secondary tillage operation was used to cover the seed with soil.

The drill seeder used a fluted wheel to meter the seed as it passed through an adjustable gate (Srivastava et. al., 1994). The seed then passed through a tube to a furrow which had been opened by a disk. A common method for covering the seeds was to pull a small drag chain behind each furrow opener.

The evolution of the precision planters began with the conventional horse-drawn, horizontal plate planter (Shearer et. al., 1991). Cells, located around the plate, were directed through a seed mass. These cells were filled by seeds which were forced to the cavities by the help of the weight of the seed mass. As the cells left the mass, a small metal edge prevented additional seeds from exiting the metering device. These horizontal

plate planters remained popular until the mid 1960's when the finger pickup, vertical plate planters were introduced (Kepner, 1978; Srivastava et. al., 1994). The finger-pickup metering mechanism was developed to eliminate the need to change plates every time the seed size changed. The system had 12 spring-loaded fingers that were opened and closed by a cam as they rotated. The seed was fed into the reservoir by gravity. As the fingers rotated in the reservoir, they closed and trapped the seed between the finger and the stationary plate (Srivastava et. al., 1994). This method was not particularly sensitive to seed shape and size, but at high rotational speeds over-planting occurred (Shearer et al., 1991).

In the late 1960's, the first successful pneumatic metering device was produced (Kepner, 1978). Dimples with holes in the center were located in rows around the periphery of a drum. As the drum rotated, the seeds tumbled into the dimples and were held in place by a pressure differential created by pressurizing the inside of the drum (Shearer et al., 1991). In the early 1970's, several equipment manufacturers incorporated the pressure differential concept into vertical plate planters.

2.2 MECHANICAL SYSTEMS

The five main functions of modern planters are to: 1) open a furrow, 2) meter the seed, 3) deliver the seed to the furrow, 4) cover the seed, and 5) firm the soil around the seed (Panning et. al., 1997).

2.2.1 Furrow Openers

The major function of the furrow opener is to open a groove in the soil where the seed can be placed at the proper depth. There are five types of furrow openers: 1) V-trench opener, 2) disk opener, 3) runner opener, 4) combination runner and disk opener

(Deere and Company, 1992). The V-trench furrow opener is effective in moist soil conditions, and is popular because it can be used for conventional or conservation tillage systems. The two angled disks and close hugging gauge wheels are used to make a v-shaped planting trench. The wheels not only gauge the depth but they also firm the soil around the trench.

Disk openers are popular in minimum tillage systems. These furrow openers have the ability to cut through corn stalks and grain stubble and maintain a uniform planting depth. The double or single disk openers are placed in such an angle as to cut through the soil and push it aside.

Runner openers are used when planting crops such as corn and soybeans in ground that has been conventionally tilled. The runner type opener tends to push residue ahead and then ride over it causing irregular planting depths. A combination of the runner and double-disk opener, provide the advantage of both types of openers. The disk cuts through the trash while the runner holds the soil apart long enough to allow the seed to come to the seed groove before the loose soil can fall onto the seed. This method provides for better seed to soil contact and a more uniform depth of planting (Deere and Company, 1992).

2.2.2 Seed Metering

Seed metering systems select the seed from the hopper either individually for crops such as corn or sugar beet, or randomly for crops such as soybeans, or cotton, and deliver the seed to the seed placing mechanism at a selected rate (Deere and Company, 1992). There are three types of seed metering systems: 1) seed plate, 2) air devices and 3) volume devices.

The seed plate metering system has openings or cells at the edge of the plate and rotates at the bottom of the seed hopper. As the seed plate turns, each of the plate cells collect one seed on each rotation. A spring loaded cutoff pawl keeps seed other than the one in the seed plate cell from dropping from the hopper into the discharge tube. When a cell containing a seed passes over the discharge hole in the hopper bottom, a spring loaded knockout pawl ejects the seed through this opening to the seed placement device.

Air-type seed metering consist of a pressurized metering disk or a vacuum metering disk. This system can be used to meter various kinds of seed. To go from one type of seed to another there is a need to match the size openings of the wheel or drum to the seed and to adjust the pressure differential accordingly.

Volume seed metering can handle a number of crops such as soybeans, peanuts, cotton, wheat and oats. These devices are used on row-crop planters, grain drills and broadcast seeders. The four most common volume devices used on row-crop planters are: the feed cup, the picker wheel, the adjustable hole and the adjustable cutoff plate (Deere and Company, 1992).

2.2.3 Seed Placement

Seed placement mechanisms can be classified either as a gravity or as a power drop mechanism (Deere and Company, 1992). The function of the seed placement mechanism is to accept seed from the metering device and deliver it to the furrow so that the seeds are properly spaced.

Gravity drop seed placement is the simplest and least expensive. The most common gravity drop seed placement device is the drop tube. It has the disadvantage though, of not placing small seed (sugar beet seed and vegetable seed) uniformly in the

row (Deere and Company, 1992). A seed dropped to the soil has momentum due to the forward travel planter.

The four most common power systems are: a) seed conveyor belt drop, b) rotary-valve drop, c) chain drop and d) air drop. Since the gravity drop devices were not accurate in terms of plant spacing within the row, the power drop devices were built to improve the accuracy of seed placement in the row (Deere and Company, 1992). The seed conveyor belt is used with the finger pickup metering devices. It allows the seed to eject into the seed belt and be carried down to the furrow. This method eliminates seed bounce in the furrow (Deere and Company, 1992). The rotary valve seed drop is used with plate type metering systems. The seeds are carried down by the rotor. The valve which is located at the bottom of the planter unit, insures that the seed is in contact with the rotor lug before is ejected. The chain seed drop picks up the seed at the bottom of the seed metering mechanism and carries it to a point above the soil. The air seed drop transports the seeds from the meter to the soil by air velocity (Deere and Company, 1992).

2.2.4 Seed Covering

Once the seed is in the furrow it has to be covered by soil. Four common seed covering devices are: 1) shovel, 2) knife, 3) disk and 4) chain. The shovel is used in sticky soil conditions. The knife coverer is the least expensive and works well in conventional tilled soils. However, it tends to plug in trashy conditions. The disk coverer will either cut through surface residue or ride over it. Reduced and no-tillage systems require the use of disk coverers to obtain enough loose soil to cover the seed. The chain coverer is the simplest of all. It is attached at the very end of the furrow opener and

dragged over the top of the furrow which pushes the soil into the furrow and covers the seed (Deere and Company, 1992).

2.2.5 Press-Wheels

Good seed-to-soil contact is necessary for emergence and germination of the seed. Press wheels firm the soil around the seed. There are three types of press wheels: 1) seed firming wheel, 2) press wheel and 3) seed packer wheel. The seed-firming wheels close the seed furrow and firm the seedbed. The surface of the soil directly over the covered seed is not packed to prevent crusting and aid in seeding emergence. Press wheels are used in soil conditions where good seed-to-soil contact is not a problem. The press wheel firms the soil after the seed has been covered. In addition, the same wheel serves as a gauge wheel for depth control. The seed packer presses the seed into the bottom of the groove by the firming wheel before the seed is covered. This operation ensures that the seed will stay in place (Deere and Company, 1992).

2.2.6 Gauge-Wheels

Gauge wheels are used to control the depth at which seed is placed. Gauge wheels can be found in several different locations on the planting unit. Gauge wheels may be mounted in the front or the rear of the furrow opener, or in both front and rear. When the gauge wheels are located in front of the furrow opener they may also be used to prepare the seedbed for reduced tillage systems (Deere and Company, 1992).

2.3 PLANTER PERFORMANCE

Vacuum and air planters have the advantage of reduced seed damage and improved accuracy. However, many of these pneumatic systems give multiple seed drops, show decreased drop rates with increased planting rates, and are susceptible to

orifice clogging with dirt and seed treatment residues (Shafii and Holmes, 1990). Sugar beet plant populations are often determined by the placement of the seed during planting (Giles et al., 1990). By evaluating seed spacing, the performance of the planters can be studied. Factors which affect planter performance are divided into internal and external effects. Internal effects are dependent on planter adjustments and their components (Smith et al., 1991b). Depending on the planter that is used, components such as seed metering mechanisms, drop tubes and furrow openers can affect the planter's performance. External factors that directly affect the performance of planters are seed treatment, the seedbed cultivation and planting date.

2.3.1 Seed Spacing

Seed spacing uniformity has been shown to be a significant factor in production cost and yield (Lan et. al., 1999). Uniform seed spacing ensures a uniform root size which reduces harvest loss, leading to a potential increased sugar yield (Jaggard, 1990; Lan et al., 1999). In England, the sugar beet industry gives a lot of attention to uniform plant spacing because it is believed to give higher yields and reduce weed and insect problems (Jaggard, 1990). Fornstrom and Miller (1989) suggested that sugar beet yield was not affected by small variations in plant spacing if the plant population was maintained.

Plant-to-stand is a practice that eliminates planting excess seed and thinning (Smith et. al., 1991a). Adopting the plant-to-stand practice provides reduced costs from thinning the population and from using less seed (Smith et. al., 1991a).

2.4 PLANT SPACING COMPARISONS

Planter performance has been evaluated in many ways. Hofman (1988) and Jasa and Dickey (1982), developed a seed spacing index for the comparison of planter seed spacing uniformity for sunflower and corn seeds respectively. Brooks and Church (1987), Hollewell (1982), and Thomson (1986) examined the variability in plant spacing with the use of histograms of distance between plants. Kachman and Smith (1995) compared alternative measures such as mean, standard deviation, and the 1984 ISO-7256/1 standards (quality of feed index, multiples index, miss index, and precision). They concluded that the measures based on theoretical spacing appeared to do well in summarizing distributions of plant spacing for single seed planters, while the sample mean and sample standard deviation were not appropriate. The mean is the average of all the spacing. This average may include not only the targeted spacing, but also wide and narrow spacing. The mean may look artificially good, but in reality is not good because there are wide and narrow spacing, which are undesirable.

Smith et. al. (1991b) proposed a parameter for plant spacing comparisons based on the percentage of seed spacing that occurred within a 3cm range centered about the mode. Higher values for the 3cm mode range represent higher uniformity of seed spacing near the mode. The 3cm mode range is a representation of the ability of a planter to space seeds near the true planter spacing setting. Centering the range on the mode (target spacing) rather than selecting an arbitrary range helps remove the bias of operator adjustment or available planter components or settings (Smith et al., 1991b). An example of the 3cm mode range is as follows: the targeted spacing for planting a study is 15 cm. Hence the 3cm mode range is from 13.5cm to 16.5cm. 10 of the spacing collected from a

treatment consisted of 5cm, 13.5cm, 11cm, 18.5cm, 24cm, 8cm, 12.5cm, 16.5cm, 15cm, 14cm. As a result the amount of numbers that are included in the 3cm mode range is 4 (13.5, 16.5, 15, 14). 4, is the frequency of occurrence in the 3cm mode range and is divided by the total number of spacing collected (in this case is 10), and then is multiplied by 100 to get a percentage. Consequently, the 3cm mode range for this treatment is 40%.

2.5 THEORETICAL CONSIDERATIONS

2.5.1 Seed Metering

The seed metering mechanism for row-crop planters meters one seed at a time. The theoretical seeding rate for the row-crop planters is the ideal number of seeds per hectare. The theoretical seeding rate can be calculated as (Srivastava et. al., 1994):

$$R_{st} = \frac{10,000}{W * X_s} \quad (1)$$

Where:

R_{st} is theoretical seeding rate (seeds/ha)

W is row width (m)

X_s is seed spacing along the row (m).

The actual seeding rate will equal the theoretical seeding rate if the row-crop planter works perfectly and meters one seed at a time, all the time. The seed spacing can be calculated as (Srivastava et al., 1994):

$$X_s = \frac{60 * V}{\lambda_c * n} \quad (2)$$

where:

X_s is seed spacing

V is travel speed of planter (m/s)

λ_c is number of seeds delivered per revolution of the metering device

n is the rotational speed of the metering device (rev/min).

Kocher et al. (1998) reported that seed spacing was affected by the seed drop, variability in planter metering, seed trajectory, and seed bounce in the furrow. Based on variations from the uniformity of seed spacing, the International Organization for Standardization (1984), defined a number of indices based on the theoretical spacing for the planter. These measures include the occurrence of multiples, misses, quality of feed, and precision.

A theoretical spacing is the distance between seedlings assuming there are no skips, multiples or variability and is based on the manufacturer's specifications. The theoretical spacing, x_{ref} , forms the basis for obtaining the multiples index, miss index, quality of feed index, and precision. It is used to divide the observed spacing into regions. These regions are:

$n'_1 = \sum n_i (X_i \in (0 \text{ to } 0.5))$	multiple seed region
$n'_2 = \sum n_i (X_i \in (>0.5 \text{ to } <1.5))$	single seed region
$n'_3 = \sum n_i (X_i \in (>1.5 \text{ to } <2.5))$	single skip region
$n'_4 = \sum n_i (X_i \in (>2.5 \text{ to } <3.5))$	double skip region
$n'_5 = \sum n_i (X_i \in (>3.5 \text{ to } + \infty))$	triple skip region.

where:

$X_i = \frac{x_i}{x_{ref}}$ is variable allocated in the segment (divisions which equal to

0.1 * x_{ref} distributed on either side of x_{ref})

x_{ref} is theoretical seed spacing

x_i is median of the segment

n_i is number of times that each value of X_i has been plotted.

The multiples index, D, is the percentage of spacing that are less than or equal to half of the theoretical spacing. That is:

$$D = \frac{n_2}{N'} * 100 \quad (3)$$

where:

$n_2 = n'_1$ is number of multiples

$N = n'_1 + n'_2 + n'_3 + n'_4 + n'_5$ is number of seeds recorded during the test

$N' = n'_2 + 2n'_3 + 3n'_4 + 4n'_5$ is number of intervals.

The miss index, M, is the percentage of spacing greater than 1.5 times the theoretical spacing. That is:

$$M = \frac{n_0}{N'} * 100 \quad (4)$$

where:

$n_0 = n'_3 + 2n'_4 + 3n'_5$ is number of misses.

The quality of feed index, A, is the percentage of spacing that are more than 1.5 times the theoretical spacing. It is a measure of how often the spacing were close to the theoretical spacing. That is:

$$A = \frac{n_1}{N'} * 100 \quad (5)$$

where:

$n_1 = N - 2n_2$ is number of seed normally sown.

Possible causes for a low quality of feed index could be a large number of multiples or misses, and a large amount of variability around the drop site.

The precision, C, is a measure of the variability in spacing between plants after accounting for variability due to both multiples and skips. It is the coefficient of variation of the spacing that are classified as singles. That is:

$$\sigma = \sqrt{\frac{\sum n_i * X_i^2}{n'_2} - \bar{X}^2} \quad (6)$$

where:

σ is standard deviation

$\bar{X} = \frac{\sum n_i * X_i}{n'_2}$ is average spacing of normally sown seed at the region

$(X_i \in (>0.5 \text{ to } <1.5))$.

Hence, the coefficient of variation, C, is expressed as:

$$C = \sigma * 100 \quad (7)$$

2.5.2 Seed Transport

Since the metering mechanism is positioned above ground, there is a fixed height from which the seed is released. This height gives seed an acceleration due to gravity. Increasing drop distance increases transport time. Row-crop planters use drop tubes to transport the seed from the metering mechanism to the furrow. The path that the seed follows along the drop tube though varies since the seed bounces in the tube due to the

horizontal travel speed and the vertical acceleration. Seed bounce varies by the drop distance and time, hence affecting the seed spacing.

Giles et al. (1990) reported that the higher the ground speed of the planter, the more error in seed spacing. Increased travel speed increased percent skips and decreased seedling percentage. Seedling emergence, root yield, and recoverable sugar lbs/acre, (kg/ha) were all affected by planter speed (Giles et al., 1990). Recommendations for ground speed have not exceeded 7.3 km/h (4.5 mph) with any of the planter types (Giles and Cattanach, 1998). In England, growers maintain planter field speed below 6km/h (3.7 mph). Growers are encouraged to add more planter row units to their planter tool bar to increase field capacity without increasing field speed (Smith et al., 1991a). Increasing the travel speed from 3.2km/h to 8.0km/h, decreased the uniformity of seed spacing (Panning et al., 1997). Assuming the drop tubes are straight and there is no friction between the seed and the internal surface of the drop tube, the drop time and vertical velocity at the exit point can be calculated as (Goering et al., 1972; Pitt et al., 1982):

$$\ddot{z} = g - C_1 * \dot{z} * \sqrt{\dot{h}^2 + \dot{z}^2} \quad (8)$$

where:

z is vertical direction, m, positive downward

$\ddot{z}$ is vertical acceleration

$\dot{z}$ is vertical seed velocity in the drop tube

$\dot{h}$ is horizontal seed velocity in the drop tube

$C_1 = 0.5 * C_D * \rho_a * A_p / m$ is constant

C_D is drag coefficient

A_p is projected frontal area of particle (m)

m is mass of particle (kg)

ρ_a is mass density of air ($\text{kg/m}^3 = 29 \cdot P_b / (8.314 \Theta_a)$)

Θ_a is ambient air temperature ($^{\circ}K = ^{\circ}C + 273$)

P_b is barometric pressure (kPa)

g is acceleration of gravity (m/s^2).

The drag coefficient, C_D , varies with the Reynolds number.

$$C_D = \frac{24}{N_{re}} \quad \text{for } N_{re} \leq 1 \quad (9)$$

$$C_D = \left(26.38 \cdot N_{re}^{-0.845} + 0.49 \right) \quad \text{for } N_{re} \geq 1 \quad (10)$$

The equation for Reynolds number is given below:

$$N_{re} = \frac{\rho_a \cdot V_p \cdot d_p}{\mu_a} \quad (11)$$

where:

N_{re} is dimensionless Reynold's number

V_p is velocity of particle ($\text{m/s} = (\dot{h}^2 + \dot{z}^2)^{0.5}$)

d_p is effective diameter of particle (m)

μ_a is dynamic viscosity of air (N.s/m^2).

Over a wide range of barometric pressures, the air viscosity is a function only of air temperature, ie.:

$$\mu_a = 4.79 \cdot 10^{-6} \cdot e^{0.678 + 0.0027\alpha} \quad (12)$$

Another method for calculating the trajectory of a particle was reported by Pitt et al. (1982) who assumed that the initial vertical velocity of a particle is zero and the C_D is

constant. The approximate transit time in the tube can be calculated by the following equation:

$$t = \frac{\ln(Arg + \sqrt{Arg^2 - 1})}{2 * C_1 * C_2} \quad (13)$$

where:

t is time of particle to fall distance z.

$$Arg = 2 * e^{(2 * C_1 * z)} - 1$$

Z is length of the tube (m)

$$C_2 = (g/C_1)^{0.5} \text{ is constant.}$$

The horizontal distance traveled during that fall can be calculated by:

$$h = \frac{\ln(C_1 * \dot{h}_0 * t + 1)}{C_1} \quad (14)$$

where:

h is horizontal distance (m)

t is time for particle to fall distance z

$\dot{h}_0$ is initial velocity in the horizontal direction (m/s).

In addition, by solving 't', for 'z' and differentiating with respect to time, the following equation can be obtained for seed velocity in the drop tube:

$$\dot{z} = \frac{C_2 * \sinh(2 * C_1 * C_2 * t)}{1 + \cosh(2 * C_1 * C_2 * t)} \quad (15)$$

where:

$\dot{z}$ is seed velocity in the drop tube

t is transit time in the drop tube.

Upon hitting the ground, seed bounce may disrupt the uniformity of spacing. Panning et al. (1997) reported that planters which are used in the U.S today have the ability to reduce horizontal velocity of the seed. Drop tubes with a rearward curve lead the seed in the opposite direction of the planter. Directing the seed in the opposite direction will reduce the horizontal velocity of the seed. With reduced horizontal velocity there is less potential for the seed to roll in the furrow. If the exit velocity is at an angle θ_e from the vertical, then the x-component of velocity at the exit, relative to the planter is:

$$\dot{x}_r = \dot{z} * \tan \theta_e \quad (16)$$

where:

$\dot{x}_r$ is x-component of velocity at the exit of the drop tube

θ_e is angle of the seed from vertical during the exit velocity.

If the x-component of seed velocity relative to the planter is equal to the forward velocity of the planter, then the seed will drop with a zero horizontal velocity, hence the chance for seed bounce is eliminated.

In the case of the pneumatic planters, the seed attains a speed due to the air velocity in the hose. Consequently, the horizontal velocity of a seed at the exit of the planter is:

$$\dot{x}_r = V_a * \sin \theta_e \quad (17)$$

where:

V_a is velocity of the air in the hose

θ_e is the angle of the seed at the exit of the drop tube.

Giles and Cattnach (1999), reported that the use of an insert into any style of seed tube reduced the number of plants at the target spacing of five inches. An insert is a

tube which contains a sensor for monitoring the flow of seed. The insert is placed in the drop tube and for this reason the diameter of the tube from where the seed is dropped, is reduced. Based on planter test stand tests with a speed of 6.5 km/h (4 mph) and a medium size seed, they found that the most uniform plant spacing was achieved with a straight tube without an insert (of the 240 seeds on the belt, the 73 seeds/100 ft were spaced at exactly 5 inches apart from each other). Small beet tubes and curved tubes with an insert caused an erratic spacing (the straight tube with an insert gave 50 uniform seed spacing/100ft from the total of 240 seeds, and the small beet tube gave 64 uniform seed spacing/100ft from the total of 240 seeds found on the belt).

2.5.3 Seed-to-Soil Contact

Seed requires firm contact with moist soil to germinate. Early in the season soil moisture content increases with depth because drying occurs through moisture transfer to the surface (Srivastava et al., 1994). Even though deep planting provides good moisture, the choice for an optimum seed depth is a compromise because one should consider not only the soil moisture, but two other factors: 1) soil is warmer near the surface of the soil, and warm soil promotes seed germination, and 2) planting deep can stop emergence because the seed may not have the strength to reach the surface (sugar beet seed emerges in approximately 10 days). There is an optimum depth of planting which varies with type of crop and other factors (Morrison and Gerik, 1985).

2.6 COMPARISON OF LABORATORY AND FIELD TESTS

Precision planters should meter one seed at a time and place them in the furrow at the desired spacing (Srivastava, et al. 1994). Sometimes planter malfunctions occur due to component wear error and adjustments. It is recommended that growers should test

their planters prior to planting. This is made possible with the use of test stands that are available for most planters. “A well maintained drill could give full establishment of uniform crop. On the other hand though, poorly maintained drills can result in a loss of 2500 English pounds on a typical 850 tonne beet contract” (Ecclestone, 1995).

The test stand is useful to identify malfunctions of the planter from faulty or unadjusted components. The test stand allows field simulation with the only exaggerated issue of the seed bounce. The inability of the test stand to simulate a seed bounce during seed drop is a weakness that forces the method to be used only as an indicator of faulty planter components (Srivastava, et al., 1994; Panning et al., 1997). Even though test stand results are helpful in identifying faulty parts, they cannot be used to represent field tests. Seed spacing performance results from laboratory testing were generally higher than results from field-testing (Panning et al., 1997). In addition, the analysis of variance indicated that the interaction of test method, planter type and travel speed was significant. More specifically the analysis of variance showed that planter seed spacing performance from laboratory testing was generally higher than results from field testing. Having this interrelation between the three factors, test method, planter type, and travel speed, Panning et al. (1997) concluded that the laboratory test method cannot be used to predict field test method results. Laboratory testing methods could be used as identifiers (screening tests) of faulty components in the planters, and to determine which planters have poor seed spacing uniformity. Planters that give good seed spacing uniformity in laboratory testing must be tested in the field to determine which ones give the best seed spacing results when the effects of seed bounce and roll are included in the field (Panning et al., 1997).

Generally, planter vibrations in the field disrupt the seed drop by causing the seed to bounce inside the tube. It is more likely that the planter bounce will not be uniform, and each seed will vary causing variations in seed spacing (Panning et al., 1997). The inability of test stand to simulate seed bounce is attributed to the fact that the planter unit that is mounted on the test stand is propelled by an integrated electric motor. As a result, there are no vibrations on the planter unit. When the seed falls from the stationary drop tube it hits a moving grease belt where the seed sticks on the belt. When the seed sticks on the belt it does not roll, as it would normally do in the furrow.

The test stand operator can perform several adjustments on the planter units, and identify faulty parts based on how well the planter spaces the seeds on the greased belt (Harrigan, 1999b). The investment in drill testing pays handsome dividends towards achieving a profitable sugar beet crop (Ecclestone, 1994; Ecclestone, 1995). Giles, and Cattanaach (1998), supported the above idea, by identifying several recommendations which were derived from testing on a test stand John Deere plate type planters. The most important recommendations were: 1) seed cutoff replacement or adjustment, avoids profit losses 2) seed plate cells should be round and not oblong and of the proper size according to the seed size that is used 3) proper vacuum setting for specific sizes of seed are desired 4) seed plate should have little if any contact with the meter housing, while the seed ejection wheel should run smooth in the cell holes of the seed plate 5) the rubber seal in the meter door should not be cracked or grooved on the seed plate surface 6) the large straight seed tube without the insert is recommended.

A disadvantage of the test stand is that it is time consuming to obtain numerical representation of seed spacing uniformity (Seaborn and Hofman, 1999). Moreover, the

seed might still slide or bounce on high belt speeds (Kocher et al., 1998). In addition, the belt is limited to about ten feet of travel (Seaborn and Hofman, 1999). This limitation of the belt length restricts the consecutive seed spacing data that can be obtained (Seaborn and Hofman, 1999).

2.7 SEED TREATMENT

There are four seed treatment options: 1) untreated seed, 2) seed treatment for soil-borne pests, 3) seed treatment for insects, and 4) seed treatment for early emergence. (<http://www.britishsugar.co.uk>). The untreated seed does not contain any insecticide. It is intended for areas where no pest attacks are expected, or where granular insecticide is being used to control docking disorder.

The seed treatment for soil-borne pests is polymer coated. This seed treatment controls soil-borne pests which eat below-ground parts of seedlings e.g. springtails, millipedes, symphylids, pygmy beetles and wireworms.

The seed treatment for insecticides is polymer coat too. This synthetic pesticide will control most insect and insect-like pests of seedling roots and leaves, and will persist long enough to control an early migration of aphids. Lastly, the seed treatment for early emergence is a treatment where some of the germination process is completed before the seed is pelleted. This treatment is designed for early sowing opportunities (<http://www.britishsugar.co.uk>).

Seed placement and performance can be improved by altering the shape of the seed or by adding chemicals on the seed to get a better germination. There are two types of seed coatings in the market: pelleting (pelleted seed) and the coating (fasonated seed) (<http://www.britishsugar.co.uk>). Seed pelleting and coating technologies have been

developed to improve plantability of flat seeds and also to permit the addition of bioactive chemicals, nutrients and beneficial microbes (Halmer, 1988). The regular pelleted sugar beet seed ranges from 3.8 to 4.6mm. The medium coated (fasonated) sugar beet seed ranges from 3.2 to 3.6mm in diameter and 1.8 to 2.6mm in thickness (Lan et al., 1999).

At present, all sugar beet seed receives fungicides such as Tachigaren which insure against the damaging effects of diseases carried on seed and in the soil. Tachigaren, which is applied during pelleting in a discrete layer at a distance from the seed, controls soil-borne fungal pathogens, particularly *Aphanomyces*.

In addition, two insecticide seed treatments are available: the tefluthrin and imidacloprid. Both these treatments are applied by a thin-film coating process. This application technique uses specialist high precision equipment to spray, and simultaneously dry, chemical formulations mixed with binder and color pigment onto batches of pre-pelleted seed (Prince et al., 1997).

2.7.1 Seed Pelleting

Seed pelleting improves plantability and performance. The non spherical shapes of many vegetable seed including sugar beet seed prevent efficient precision planting. Seed processors apply coatings on the seed to get a heavier and rounder seed.

Pelleted seed is made up of fillers (clays, limestone, calcium carbonate, talc, vermiculite) and cementing additives (gum arabic, gelatin, methylcellulose, polyvinyl alcohol, polyoxyethylene glycol-based waxes) inoculants, and fungicides (Taylor and Harman, 1990). Pellets are believed to reduce anaerobic damage when calcium oxide and peroxides are added to the pelleting material. These compounds release oxygen to the

seed when there is a shortage of oxygen due to flooding or soil compaction (Ollerenshaw, 1985; Langan et al., 1986). Despite the processing problems and extra costs of pelleting, pelleted seeds are recognized as an important aspect of precision planters.

2.7.2 Seed Coating

Seed coating improves seed performance. The coating is a material that is applied to the seed but does not affect its shape. The purpose of seed coating is to avoid the stress of the planting environment by adding substances such as fungicides, insecticides, safeners, and micronutrients. Rushing (1988) reported that the ideal traits of a seed coating polymer are: 1) a water-based polymer, 2) a low viscosity range, 3) a high concentration of solids, 4) an adjustable hydrophilic-hydrophobic balance, and 5) form a hard film upon drying. These traits should lead to excellent plantability, contain no dust from additives, and provide for excellent germination. One of the major benefits of a seed coating is that it is placed directly on the seed and in the immediate vicinity of the germinating seedling. Less chemicals are required compared to broadcast or furrow applications with far less cost, avoiding environmental damage from excess pesticide use.

Pelleted and fasonated seed come in a variety of sizes and breeding techniques. There is a distinct visual difference between the two though. Pelleted sugar beet seed has a uniform spherical shape, size and mass, while the fasonated seed has an irregular shape, and less mass (Pahl, 1996).

Uniformly shaped pelleted sugar beet seed generally outperformed non-pelleted seed in Nebraska, by having a higher seeding percentage, with fewer doubles (two seeds at the same point) or skips (no seed at a desired point) (Smith et. al., 1991b). The physical characteristics (uniform shape, size and mass) of pelleted seed generally provided better

seed and plant spacing than medium sized non-pelleted seeds over the wide range of test parameters (Pahl, 1996). Pelleted seed improved the ability of the planter to perform better by having less skips and multiples.

2.8 SEEDBED CULTIVATION

Uniformity of planting depth and firming soil around the seed are important aspects for the performance of precision planters (Srivastava et al., 1994). Consistent planting depth and the firming of soil, can positively influence seed germination and emergence. “There is no trade-off between a seedbed that is good for the drill and one that is good for the seed” (Gummerson, 1986). Minimal spring cultivation has been shown to be beneficial. With no spring cultivation there is no compaction under the rows, spring work is reduced, and moisture is conserved (Harrigan, 1999a; Gummerson, 1989).

A desirable seedbed is the one with a firm soil below, and fine aggregates above (Harrigan, 1999a). An extension of Harrigan’s statement was made by Proctor (1994) who said that the soil particle should be fine enough to be in touch with the seed, keeping it moist. Smith et al. (1991a) suggested that the tillage should be shallow, 3-6cm deep. Shallow tillage conserves soil moisture and causes minimal disturbance. Deep tillage brings up big clods and moisture, hence drier soil below the surface (Smith et. al., 1991a). Gummerson (1989) concluded that a soil which was not leveled could affect the ability of the planter to place seed at a uniform depth. “The drill usually takes its depth control from wheels in front of the coulter so that on an undulating surface the coulter often rides out of the soil, leaving seeds uncovered” (Gummerson, 1989). The greatest range of seed depths was found in the seedbed without spring cultivation, due to the unevenness of the soil. Drilling into land leveled in autumn or winter with little or no cultivation in spring

proved generally successful. In 1983 and 1984 a light spiked roll was used to break the crust on the soil surface. This decreased final emergence in 1983 by 5% but increased it by 4% in 1984. In 1984 and 1985 autumn leveling was achieved using a furrow press attached to the plough. This resulted in about 5% less emergence than the best cultivated treatments.

2.9 PLANTING DATE

Selecting the most desirable planting date can enhance the growing season by taking advantage of the available soil moisture for germination and emergence and reduce the risk of frost damage (Yonts et al., 1999). So, is it better to plant early or late in the season? According to Yonts et al. (1999) when soil moisture and temperature are not favorable for germination, uneven stands due to low emergence rates result. On the other hand, when soil moisture and temperature are favorable, germination and emergence occur in a short period of time. But, even if the planting conditions are ideal and plants emerge early, there is no guarantee that the seedlings will survive due to the freezing conditions that may occur.

The primary reason for planting early is to increase the length of the growing season and increase total production. But there is always the chance of an additional costs from replanting due to stand loss and hence a reduction of the growing season. Planting later in the spring provides faster germination and decreases the potential for frost injury (Yonts et al., 1999). Similarly, Mayo and Dexter (1997), stated that an early planting date is critical to increase the yield, but it is always under the risk of frost damage.

CHAPTER 3

3. METHODS AND MATERIALS

The purpose of this study was to evaluate the field performance of four planters for sugar beet. The study was replicated twice in 2000 and once in 2001 at the Saginaw bean and beet research farm. A randomized complete block in combination with a factorial treatment design was applied to 6 blocks. Each block consisted of 14 treatments. The 14 treatments were based on 4 planters (Kverneland-Accord plate type planter, John Deere 7300 vacuum planter, Monosem vacuum planter, Stanhay-Ralley vacuum planter), 2 types of seed (variety E17 4m PAT pellet, fasonated #3) and 2 planter speeds, 4.8 km/h and 7.3 km/h (3.0 mph, 4.5 mph). Tables 1 and 2, provide an explanation on what components each treatment consists. Data for rate of emergence, plant spacing, pre-harvest stand, beet size, yield, percent sugar, percent clear juice purity (CJP), and recoverable white sugar per ton (RWST) were collected. An analysis of variance with mean separation by the least significant difference (LSD) procedure, the multiple linear regression, and principal component analysis (PCA) were used. Finally, a stepwise regression method was used to identify important independent variables.

Table 1. Treatments for trials one and two in 2000.

<u>Treatment</u>	<u>Planter</u>	<u>Seed</u>	<u>Speed, km/h (mph)</u>
1	Accord	Pellet	7.3 (4.5)
2	Accord	Pellet	4.8 (3.0)
3	John Deere	Pellet	7.3 (4.5)
4	John Deere	Pellet	4.8 (3.0)
5	John Deere	Fasonated	7.3 (4.5)
6	John Deere	Fasonated	4.8 (3.0)
7	Monosem	Pellet	7.3 (4.5)
8	Monosem	Pellet	4.8 (3.0)
9	Monosem	Fasonated	7.3 (4.5)
10	Monosem	Fasonated	4.8 (3.0)
11	Stanhay	Pellet	7.3 (4.5)
12	Stanhay	Pellet	4.8 (3.0)
13	Stanhay	Fasonated	7.3 (4.5)
14	Stanhay	Fasonated	4.8 (3.0)

Table 2. Treatments for trial three in 2001.

<u>Treatment</u>	<u>Planter</u>	<u>Seed</u>	<u>Speed, km/h (mph)</u>
1	Accord	Pellet	7.3 (4.5)
2	Accord	Pellet	4.8 (3.0)
3	John Deere	Pellet	7.3 (4.5)
4	John Deere	Pellet	4.8 (3.0)
5	John Deere	Fasonated	7.3 (4.5)
6	John Deere	Fasonated	4.8 (3.0)
7	Monosem ¹	Pellet	7.3 (4.5)
8	Monosem ¹	Pellet	4.8 (3.0)
9	Monosem ¹	Fasonated	7.3 (4.5)
10	Monosem ¹	Fasonated	4.8 (3.0)
11	Monosem ²	Pellet	7.3 (4.5)
12	Monosem ²	Pellet	4.8 (3.0)
13	Monosem ²	Fasonated	7.3 (4.5)
14	Monosem ²	Fasonated	4.8 (3.0)

Monosem¹: The press-wheels of the Monosem planter were set 1.25 in. apart

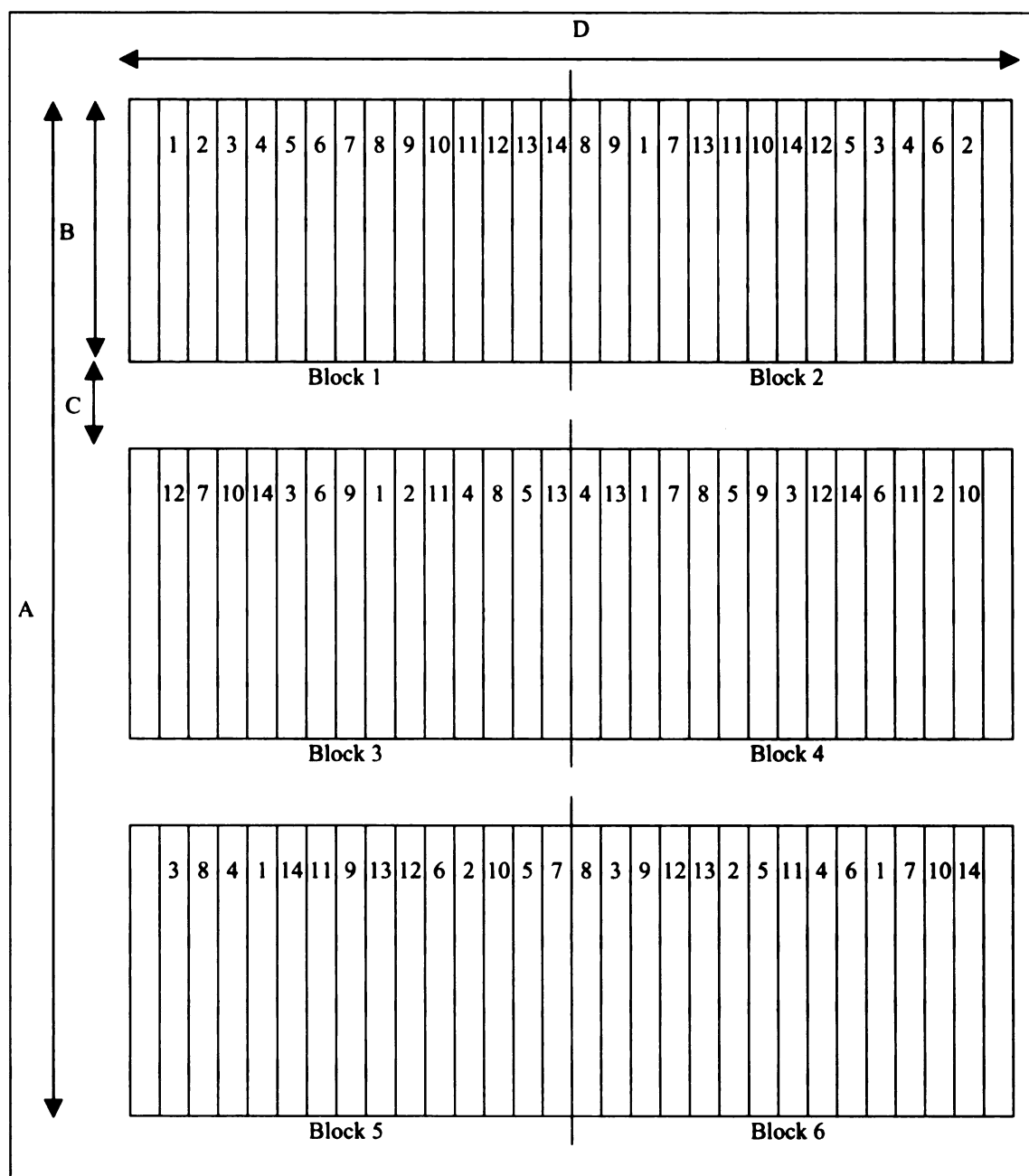
Monosem²: The press-wheels of the Monosem planter were set 2.25 in. apart

The fields were located at the Saginaw Bean and Beet farm. The soil was a Zilwaukee Silty Clay. For the first two replicated trials of the year 2000, the field length extended from north to south. Each plot was 100 feet long and 10 feet wide. The third replicated trial was performed the year 2001. The length of the field extended from east

to west and the plots were 70 feet long and 10 feet wide. The randomization for the 14 treatments was the same for all three studies. The Stanhay planter was unavailable during the last study and it was replaced by Monosem with its press-wheels at a wide setting (2.25 in.). A schematic drawing is provided in figure 1. All treatments were fall moldboard plowed and fit with a field cultivator. Seedbed tillage for trial 1 and 3 was a single shallow pass with a spike-tooth/rolling harrow finishing tool within an hour of planting. The seedbed tillage for trial 2 was with a field cultivator followed by a Danish tine cultivator with a rolling basket to level and firm the seedbed. The finishing implement was at a right angle to the direction of planting and at a very shallow depth to level the soil compaction and break the soil crust yet conserve soil moisture. The tractor was a John Deere 2355 two-wheel-drive equipped with dual tires at 10 psi (rear) and at 12 psi on the front.

Figure 1, provides a visual representation of how the design of the study was plotted.

Figure 1. The design and dimensions of the field plot.



Year 2000 (A = 380 feet, B = 100 feet, C = 40 feet, D = 280 feet)

Year 2001 (A = 290 feet, B = 70 feet, C = 40 feet, D = 280 feet)

3.1 PLANTER ADJUSTMENTS

The planters were adjusted to achieve a target plant spacing of about 12.7 to 14 cm (5 to 5.5 in) for the first two trials and 13 cm (5.125in) for the third trial, and planting depth of 2.6 cm (1 in.) for all the trials. Initial planter adjustments were based on manufacturer recommendations. Final adjustments were made in the field based on expert opinion of planter performance prior to planting (Appendix B). Special attention was given to depth seed placement, press wheel adjustment for proper seed-to-soil contact and minimal seed skips or multiple seed drops.

3.2 DATA COLLECTION

3.2.1 Moisture

The first month after sowing was the most critical period for the seed germination and emergence. Given suitable moisture and temperature, sugar-beet seed started to germinate 7 to 10 days after sowing. Thirty days after planting, seed which had not emerged were most probably dead due to problems with: 1) soil moisture, 2) soil temperature, 3) aeration, 4) seed processing, 5) crusted soil, 6) planter skips, and 7) frost.

Soil moisture was measured in three locations in each block. The three locations were evenly distributed throughout each block. Figure 2 indicates which treatments were selected for soil moisture testing.

Figure 2. The selected treatments (shaded) for soil moisture testing.

	1	2	3	4	5	6	7	8	9	10	11	12	13	14	8	9	1	7	13	11	10	14	12	5	3	4	6	2
Block 1														Block 2														

	12	7	10	14	3	6	9	1	2	11	4	8	5	13	4	13	1	7	8	5	9	3	12	14	6	11	2	10
Block 3														Block 4														

	3	8	4	1	14	11	9	13	12	6	2	10	5	7	8	3	9	12	13	2	5	11	4	6	1	7	10	14
Block 5														Block 6														

Cores of soil were extracted from 0-1 inch depth, and 1-2 inch depth. From each of the selected treatments, six soil samples from each block were collected to form a representative sample for each block. The 0-1 inch and 1-2 inch cores were placed in separate air tight bags to prevent soil moisture loss. Prior to drying the soil samples, their weight (grams) was measured. Samples were placed in a forced-air dryer for 5 days at 120° Fahrenheit to dry. After drying, the weight (grams) of the samples was again measured. The percent soil moisture was calculated as:

$$\text{Percent soil moisture} = \frac{(\text{Wet weight} - \text{Dry weight})}{\text{Dry weight}} \quad (18)$$

Graphical representation of the soil moisture of the trials is shown in APPENDIX E.

3.2.2 Rate of Emergence

Stand counts were made at 10, 20 and 30-days after planting. The stand count for the first two studies in 2000 measured the middle 50 feet of the third row from the west for each treatment. The last study of 2001 measured the 70 feet of the second row from south. The second or third row were selected to avoid variations in performance among planter units on the planter.

3.2.3 Plant Spacing

Plant spacing uniformity was measured following the 30-day stand count. Plant spacing measurements were made in the same area where stand counts were made. Plant spacing measurements were made by laying a measuring tape along the row and recording the spacing, to within $\frac{1}{2}$ centimeter (0.2 in) for each successive plant. A new plant-spacing measuring technique was used for trial 3. A beet buggy was equipped with a counter which sensed axle revolution, and translated revolution to distance (cm). An equal number of spacing counts were collected from every row for comparison purposes. The row with the minimum number of plants was the common divisor for all the treatments. From the three studies a minimum of 120 plant spacing were collected. When all the spacing between plants for all the treatments was gathered, the 3 cm mode range was used to measure the ability of the planters to space plants at the target spacing (Smith et. al., 1991b). The 3cm mode range provides the percentage frequency of spacing that occur within the desired range. The desired range includes the target spacing plus or minus 1.5cm (0.6 in.). In other words, from the 120 plant spacing collected for each replication of each treatment, the 3cm mode range measures the percent frequency of plant spacing that were included in the desired range. Each treatment has its own value

that characterize its ability to space plants uniformly. The higher the 3cm mode range value, the better the plant spacing uniformity. The 3cm mode range was calculated as:

$$3\text{cm mode} = \frac{(\text{Frequency of occurrence based on the targeted spacing})}{(\text{total number of observations})} * 100 \quad (19)$$

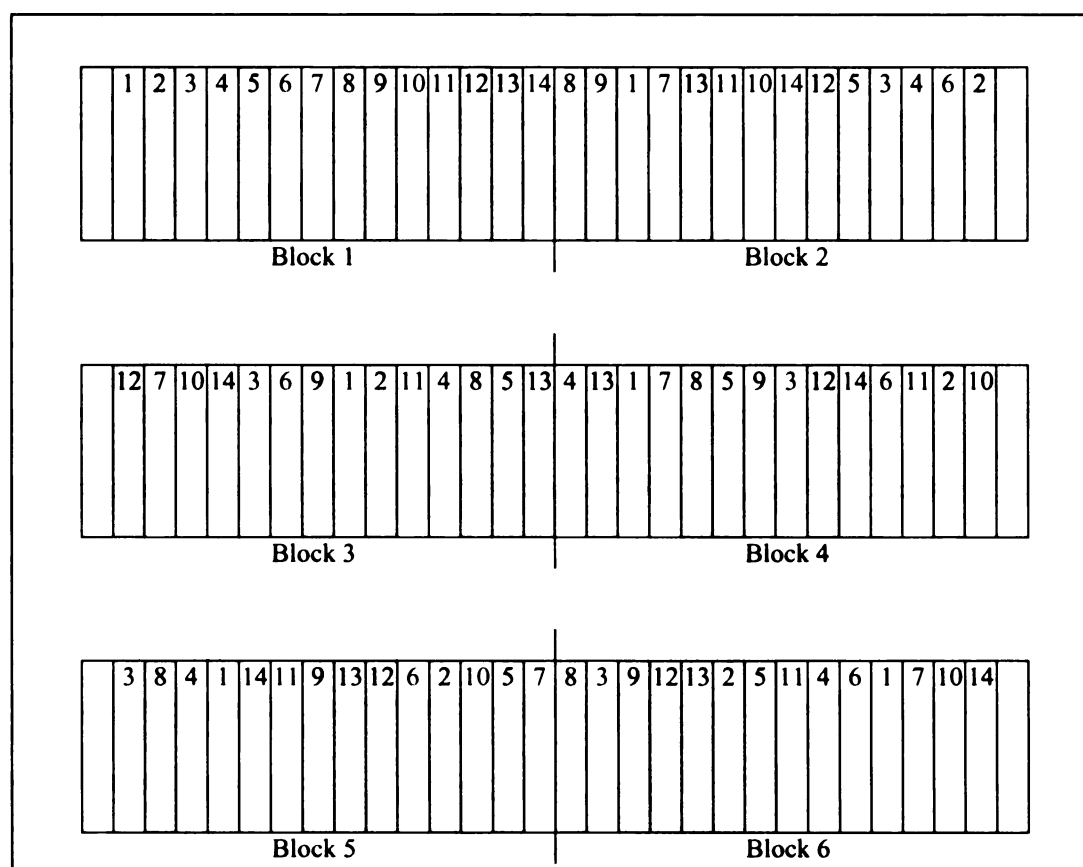
3.3 HARVEST PROCEDURE

3.3.1 Hand Harvest

A sub-sample of 6 treatments was selected to measure beet size uniformity. Treatments were selected based on the 30-day spacing uniformity measurements. The best treatments were those with the greatest frequency of desirable spacing. The treatments selected for hand harvesting provided a range of spacing uniformity from relatively poor spacing uniformity to the best uniformity. Hand-harvest was used to avoid broken beets or skips since small beets could not always be collected by the machine harvester. Figure 3 shows treatments selected for hand-digging.

A representative sample of 40 beets was collected from the middle 50 feet of the 3rd row from the west for each of the best 6 treatments of each block. This representative sample was sorted by size, (0-0.99lbs., 1-1.99lbs., 2-2.99lbs., 3-3.99lbs., 4-4.99lbs., 5 lbs>). The juice extracted from the sorted beets was sampled for percent sugar, percent CJP, RWST and recoverable white sugar per acre (RWSA).

Figure 3. The selected treatments (shaded) for hand harvest.



3.3.2 Machine Harvest

The middle two rows of each treatment were machine harvested for yield per acre. In plots that were hand harvested for beet size, 85% of the weight of the beets that were hand-dug were also added to the yield. Only the 85% of the weight was added in order to account for likely machine loss. Several beets from each treatment were randomly selected for sugar sampling. During harvest, beets were sampled for percent sugar, percent CJP, RWST and recoverable white sugar per acre (RWSA).

3.4 STATISTICAL ANALYSIS

A three factor randomized complete block experimental design was used. Each of the blocked treatments consisted of three factors, planter type, seed treatment, forward speed. Use of the RCBD eliminates experimental error and provides control over environmental variations. The criteria for using the RCBD were: 1) the study was experimental, 2) the number of experimental units (EU) in each block was equal to the number of treatments, and 3) the treatments were randomly assigned within each block. The random allocation of treatments to the EU (1 EU = 1 plot = 1 treatment) simulates the effect of independence and allows the observations to be considered independent and normally distributed. Independent and normally distributed observations were critical for the estimation and the test of hypothesis since they provided valid estimates of experimental error.

Since the study was based on the RCBD with a factorial treatment design, the Statistical Analysis Software, SAS, was used to identify significant factors based on the F-values and P-values derived from the Analysis of Variance, ANOVA. The ANOVA table for a RCBD with a 3-factor factorial design is shown in table 3.

The tests of significance were set at an alpha level, α , of 0.05. After identifying the factors that were significant, the Least Significance Difference, LSD, was used to make multiple comparisons between these factors, and find any differences between planters, seeds, speeds, or interactions of planter*speed and seed*speed.

The multiple linear regression and principal component analysis were tools used to identify a relationship between beet size categories (lbs.) and plant spacing uniformity (CP3).

Finally, an automated variable selection method was used to find out which variables are affecting the depended variable the most The method used is known as the stepwise regression. Stepwise regression begins with no independent variables. It enters the most significant variable first, and continues step by step identifying the most significant variables left, and adds them to the model. While new variables are added to the model, the method checks to see if any variation can be dropped ($P > .15$ can drop a variable).

Table 3. ANOVA table.

Source	D.F	SS	MS	F-value
Total	$rbc-1$	SS total		
Blocks	$r-1$	SS blocks		
A^1	$a-1$	SS A	$MSA=SSA/(a-1)$	$FA=MSA/MSE$
B^2	$b-1$	SS B	$MSB=SSB/(b-1)$	$FB=MSB/MSE$
C^3	$c-1$	SS C	$MSC=SSC/(c-1)$	$FC=MSC/MSE$
$A*C$	$(a-1)*(c-1)$	SS AC	$MSAC=SSAC/(a-1)*(c-1)$	$FAC=MSAC/MSE$
$B*C$	$(b-1)*(c-1)$	SS BC	$MSBC=SSBC/(b-1)*(c-1)$	$FBC=MSBC/MSE$
Error	$(abc-1)*(r-1)$	SS E	MS E	

1 = Planter, 2 = Seed, 3 = Speed

D.F.: Degrees of freedom

SS: Sum of squares

MS: Mean square

CHAPTER 4

4. RESULTS AND DISCUSSION

The study was replicated three times. The first two replications were during the year 2000 and the third replication was in 2001. Trials one and three were planted in late April in a firm, level seedbed following spring seedbed tillage with a single pass combination spike-tooth/rolling harrow perpendicular to the direction of planting. Trial two was planted May 25th in a coarse seedbed created following demolition of an earlier planted sugar beet crop damaged by heavy rains. Tillage was a single pass of a field cultivator (4 inch depth) followed by two passes with a Danish tine/rolling harrow to firm and level the surface. The three trials were analyzed both individually and across years and locations. Individual analysis reveals conditions that might have affected the treatments, group analysis provides an overall performance of the treatments.

Tables 4-11 provide the least significant difference (LSD), the coefficient of variation (CV) and means for each variable (yield, percent sugar, percent CJP, percent RWST, percent RWSA, 3cm mode range, rate of emergence, pre-harvest stand). Figures 4-9 provide a visual representation of how the treatments performed in terms of rate of emergence and plant spacing uniformity. Images in this thesis are presented in color.

4.1 RATE OF EMERGENCE AND FINAL STAND

The rate of emergence was calculated as:

$$\text{rate of emergence (\%)} = \frac{\text{Actual plant population}}{\text{Theoretical plant population}} \quad (20)$$

The actual plant population was the population that was measured in the field. The theoretical plant population was the seeding rate based on the seed spacing expected for the planter setting. The percent germination reported on the seed bag label was 95-97%. Plants may not emerge because of : a) poor seed-to-soil contact, b) environmental stress, c) diseases and d) seed damage during treatment.

Rainfall, soil temperature and soil moisture information is listed in APPENDIX E.

4.1.1 John Deere Planter

In trial 1, the John Deere planter provided rapid emergence and a 10-day stand equal to 79 to 93% of the desired seeding rate (table 4, fig.4). Heavy rains following the 10-day count caused soil crusting and diminished stands in the following weeks. The 20-day and 30-day stands were from 76 to 90% and 76 to 88% respectively. The final stand ranged from 76 to 88% of the desired seeding rate (table 4). The John Deere planter provided a significantly greater 10-day stand than the Accord or Stanhay planters.

There was no significant differences due to seed treatment (table 9). However, the fasonated seed tended to emerge more quickly. The 10-day stand was averaged nine percentage units greater and the pre-harvest stand was seven percentage units greater than the pelleted seed. Pelleted seed has been shown to provide a significant improvement in emergence in cool soil (Poindexter, 1999). Based on this work, that advantage appears to diminish in warm soil.

In trial 2, The John Deere planter provided a 10-day stand equal to 46 to 56% of the desired seeding rate (table 5, fig. 5). The fasonated seed provided a significant improvement in rate of emergence compared to the pelleted seed (table 9). The 10-day

stand was seven percentage units higher and the pre-harvest stand was fourteen percentage units higher than the pelleted seed.

Trial 2 was planted late in the season, May 25th, as a replanted stand following seedbed tillage with a field cultivator (4-inch depth) and two passes with a Danish tine rolling harrow to level and firm the seedbed. The poor emergence might be attributed to the fact that the press-wheels of the planter were unable to close the seed furrow in all locations. Poor seed-to-soil contact likely explains the relatively poor stand.

In trial 3, the John Deere provided a 10-day stand equal to 39 to 45% of the desired seeding rate (table 6, fig.6). The soil was dry and early emergence was relatively slow. Timely rains lead to a large increase in emergence for the 20-day and 30-day stand (table 6, fig. 6). There was little difference in 10-day stand among seed treatment, but the fasonated seed provided a 20-day stand eleven percentage units higher and a 30-day stand 8 percentage units higher than the pelleted seed.

Combined over years and locations, the John Deere planter provided a good rate of emergence comparable to the other planters tested. Other than the difficulty in closing the seed furrow in trial two, the planter appeared to provide good seed-to-soil contact.

Figure 4. Rate of Emergence for Trial 1, year 2000

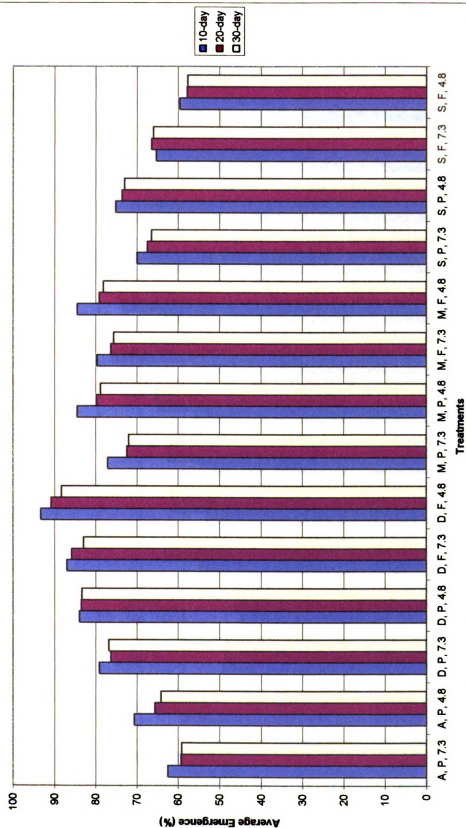


Figure 5. Rate of Emergence for Trial 2, year 2000

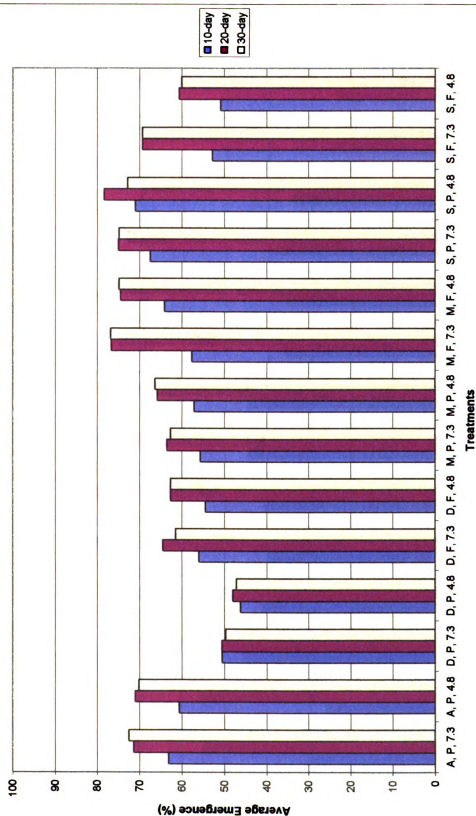


Figure 6. Rate of Emergence for Trial 3, year 2001

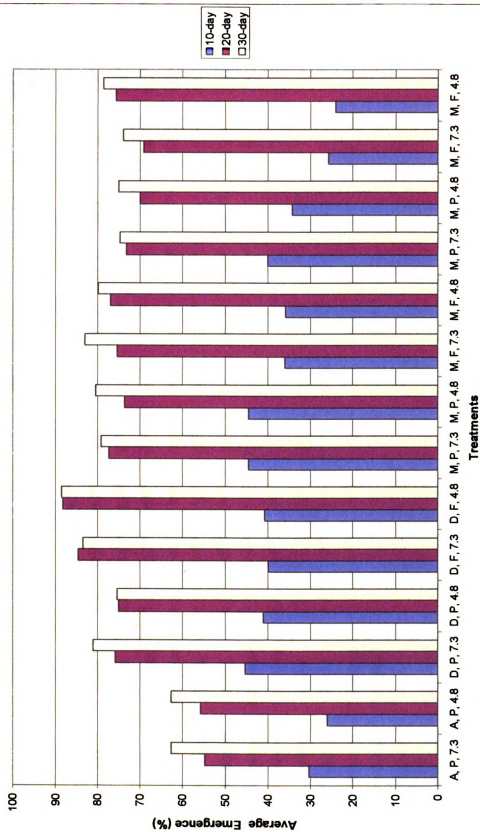


Table 4. Rate of emergence, final stand, 3cm mode range, sugar content, clear juice purity and sugar beet yield for trial 1, 2000.

Treat	Planter	Seed	Speed	Rate of Emergence, % stand				CP3	Sugar	CJP	Yield		
				10day	20day	30day	Pre-harvest				ton/ac	RWST (lbs)	RWSA (lbs)
1	Accord	Pellet	7.3	62 ^f	59 ^e	59 ^f	57 ^g	36.6 ^a	17.4 ^a	94.8 ^b	32.9 ^{fe}	256 ^a	8445 ^{dfe}
2	Accord	Pellet	4.8	70 ^{edf}	65 ^{ed}	64 ^{fo}	61 ^{fg}	38.8 ^a	17.3 ^a	95.0 ^{ba}	34.9 ^{dce}	256 ^a	8956 ^{dce}
3	J.D	Pellet	7.3	79 ^{bdc}	76 ^{bdc}	76 ^{bdc}	76 ^{bdc}	17.9 ^{fg}	17.3 ^a	94.8 ^b	32.9 ^{fe}	254 ^a	8392 ^{fe}
4	J.D	Pellet	4.8	84 ^{bac}	83 ^{bac}	83 ^{ba}	82 ^{bac}	25.7 ^{dce}	17.4 ^a	94.8 ^b	33.4 ^{dfe}	256 ^a	8580 ^{dfe}
5	J.D	Fasonated	7.3	87 ^{ba}	85 ^{ba}	83 ^{ba}	84 ^{ba}	15.5 ^g	17.2 ^a	95.1 ^{ba}	36.8 ^{bc}	255 ^a	9491 ^{bc}
6	J.D	Fasonated	4.8	93 ^a	90 ^a	88 ^a	88 ^a	25.5 ^{dce}	17.4 ^a	95.2 ^{ba}	32.6 ^f	258 ^a	8435 ^{dfe}
7	Monosem	Pellet	7.3	77 ^{bdc}	72 ^{dc}	72 ^{bdec}	71 ^{fdcc}	24.4 ^{dce}	17.4 ^a	94.8 ^b	33.2 ^{dfe}	256 ^a	8509 ^{dfe}
8	Monosem	Pellet	4.8	84 ^{bac}	79 ^{bac}	78 ^{ba}	79 ^{bdc}	35.7 ^{ba}	17.3 ^a	95.0 ^{ba}	37.0 ^{bc}	256 ^a	9491 ^{bc}
9	Monosem	Fasonated	7.3	79 ^{bdc}	76 ^{bdc}	75 ^{bdec}	75 ^{bdec}	21.5 ^{fige}	17.4 ^a	95.1 ^{ba}	36.8 ^{dc}	257 ^a	9077 ^{dc}
10	Monosem	Fasonated	4.8	84 ^{bac}	79 ^{bc}	78 ^{bac}	77 ^{bdc}	28.6 ^{dc}	17.5 ^a	95.1 ^{ba}	31.6 ^f	260 ^a	8238 ^f
11	Stanhay	Pellet	7.3	70 ^{edf}	67 ^{ed}	66 ^{fdcc}	64 ^{feg}	24.0 ^{dfe}	17.3 ^a	95.0 ^{ba}	33.4 ^{dfe}	256 ^a	8529 ^{dfe}
12	Stanhay	Pellet	4.8	75 ^{edc}	73 ^{dc}	73 ^{bdec}	67 ^{fdccg}	30.0 ^{bc}	17.1 ^a	94.9 ^b	40.2 ^a	253 ^a	10182 ^a
13	Stanhay	Fasonated	7.3	65 ^{ef}	66 ^{ed}	66 ^{fdcc}	62 ^{fg}	22.4 ^{dfe}	17.0 ^b	95.5 ^a	38.8 ^{ab}	254 ^a	9883 ^{ba}
14	Stanhay	Fasonated	4.8	59 ^f	57 ^e	57 ^f	55 ^g	26.0 ^{dce}	17.2 ^a	95.0 ^{ba}	32.0 ^f	254 ^a	8170 ^f
LSD(.05)				11	10	10	11	6.42	0.44	0.59	2.29	7	670
CV (%)				12.61	12.03	12.59	13.35	20.90	2.23	0.54	5.74	2	6

1 lb = 0.4536 kg

1 ton/ha = 2.245*tons/acre

1 mile = 1.613 km

a, b, c, d, e, f : means significantly different (P<0.05)

Table 5. Rate of emergence, final stand, 3cm mode range, sugar content, clear juice purity and sugar beet yield for trial 2, 2000.

Treat	Planter	Seed	Speed Km/h	Rate of Emergence, % stand				CP3 %	Sugar %	CJP %	Yield	
				10day 63 ^{bdc}	20day 71 ^{ebdc}	30day 72 ^{ba}	Pre-harvest 69 ^{bdc}				ton/ac 26.1 ^{bac}	RWST (lbs) 253 ^{ba}
1	Accord	Pellet	7.3					49.0 ^a	17.8 ^a	93.2 ^{ba}		6646 ^{bac}
2	Accord	Pellet	4.8	60 ^{ebda}	71 ^{ebdc}	70 ^{bac}	70 ^{bdc}	42.7 ^a	17.7 ^{ba}	93.6 ^{ba}	21.6 ^{dc}	5497 ^{dc}
3	J.D	Pellet	7.3	50 ^{ef}	50 ^{gf}	49 ^{cd}	53 ^{fe}	10.0 ^h	17.7 ^{ba}	93.6 ^{ba}	28.8 ^a	7350 ^a
4	J.D	Pellet	4.8	46 ^f	48 ^g	47 ^e	48 ^f	12.2 ^{hg}	17.8 ^a	93.4 ^{ba}	19.8 ^d	5051 ^d
5	J.D	Fasonated	7.3	56 ^{edfc}	64 ^{cdc}	61 ^c	64 ^{dec}	11.9 ^{hg}	17.8 ^{ba}	93.6 ^{ba}	25.0 ^{bac}	6404 ^{bac}
6	J.D	Fasonated	4.8	54 ^{edfc}	62 ^e	62 ^{bc}	65 ^{bdc}	14.4 ^{hg}	17.7 ^{ba}	94.4 ^a	22.8 ^{bdc}	5927 ^{bdc}
7	Monosem	Pellet	7.3	55 ^{edfc}	63 ^{cd}	62 ^{bc}	62 ^{de}	25.4 ^{ebd}	17.6 ^{ba}	93.7 ^{ba}	23.0 ^{bdc}	5863 ^{bdc}
8	Monosem	Pellet	4.8	57 ^{ebdf}	65 ^{ebdc}	66 ^{bac}	63 ^{dec}	27.3 ^{cb}	17.8 ^{ba}	93.8 ^{ba}	28.6 ^a	7334 ^a
9	Monosem	Fasonated	7.3	57 ^{ebdc}	76 ^{ba}	76 ^a	78 ^a	26.4 ^{cb}	17.7 ^{ba}	94.3 ^{ba}	25.4 ^{bac}	6587 ^{bac}
10	Monosem	Fasonated	4.8	64 ^{bac}	74 ^{bdac}	74 ^a	74 ^{bac}	28.0 ^b	17.5 ^b	93.3 ^{ba}	19.2 ^d	4818 ^d
11	Stanhay	Pellet	7.3	67 ^{ba}	75 ^{bac}	74 ^a	75 ^{ba}	19.2 ^{fed}	17.6 ^{ba}	94.1 ^{ba}	19.0 ^d	4873 ^d
12	Stanhay	Pellet	4.8	71 ^a	78 ^a	72 ^{ba}	76 ^a	16.6 ^{feg}	17.8 ^a	93.4 ^{ba}	23.4 ^{bdc}	5973 ^{bdc}
13	Stanhay	Fasonated	7.3	52 ^{edf}	69 ^{ebdc}	69 ^{bac}	64 ^{dec}	18.8 ^{fe}	17.7 ^{ba}	94.1 ^{ba}	26.5 ^{ba}	6827 ^{ba}
14	Stanhay	Fasonated	4.8	50 ^{ef}	60 ^f	60 ^{dc}	60 ^{de}	21.4 ^{ced}	17.6 ^{ba}	94.5 ^a	19.2 ^d	4951 ^d
LSD(.05)				10	9	8	10	6.36	0.30	1.17	4.76	8
CV (%)				15.20	12.11	11.65	13.13	23.8	1.48	1.08	17.57	2

1 lb = 0.4536 kg

1 ton/ha = 2.245*tons/acre

1 mile = 1.613 km

a, b, c, d, e, f: means significantly different (P<0.05)

Table 6. Rate of emergence and 3cm mode range for trial 3, 2001.

Treat.	Planter	Seed	Speed Km/h	Rate of Emergence			CP3 %
				10day	20day	30day	
1	Accord	Pellet	7.3	30 ^{dc}	54 ^e	62 ^d	34.8 ^{ba}
2	Accord	Pellet	4.8	26 ^d	55 ^e	62 ^d	37.2 ^a
3	J.D	Pellet	7.3	45 ^a	75 ^{cd}	81 ^{bc}	23.6 ^c
4	J.D	Pellet	4.8	41 ^{ba}	75 ^{cd}	75 ^c	23.8 ^c
5	J.D	Fasonated	7.3	39 ^{ba}	84 ^{ba}	83 ^{ba}	20.1 ^{ef}
6	J.D	Fasonated	4.8	40 ^{ba}	88 ^a	88 ^a	18.3 ^f
7	Monosem ¹	Pellet	7.3	44 ^a	77 ^{bc}	79 ^{bc}	32.9 ^{bac}
8	Monosem ¹	Pellet	4.8	44 ^a	73 ^{cd}	80 ^{bc}	33.4 ^{bac}
9	Monosem ¹	Fasonated	7.3	36 ^{bc}	75 ^{cd}	83 ^{ba}	24.3 ^{cd}
10	Monosem ¹	Fasonated	4.8	35 ^{bc}	77 ^{bcd}	79 ^{bc}	30.7 ^{bc}
11	Monosem ²	Pellet	7.3	40 ^{ba}	73 ^{cd}	74 ^c	28.8 ^{dc}
12	Monosem ²	Pellet	4.8	34 ^{bc}	70 ^{cd}	75 ^c	31.5 ^{bc}
13	Monosem ²	Fasonated	7.3	25 ^d	69 ^d	74 ^c	24.0 ^e
14	Monosem ²	Fasonated	4.8	24 ^d	75 ^{cd}	78 ^{bc}	29.1 ^c
LSD(.05)				7	7	7	4.62
CV (%)				16.92	8.99	7.96	14.27

1 mile = 1.613 km

Monosem¹ : The Monosem planter with the press-wheels adjusted for firming sugar beet seed (1.25 in.)

Monosem² : The Monosem planter with the press-wheels adjusted for firming corn seed (2.25 in.)

a, b, c, d, e, f : means significantly different (P<0.05)

Table 7. Rate of emergence, final stand, 3cm mode range, sugar content, clear juice purity and yield for trials 1 and 2 over two locations.

Treat	Planter	Seed	Speed	Rate of emergence, % stand				CP3	Sugar	CJP	Yield	
			Km/h	10day	20day	30day	Pre-harvest	%	%	%	ton/ac	RWST (lbs)
1	Accord	Pellet	7.3	62 ^{ef}	65 ^{fde}	65 ^{dec}	63 ^{de}	42.8 ^a	17.6 ^a	94.0 ^d	29.5 ^{bc}	7545 ^{bc}
2	Accord	Pellet	4.8	65 ^{edfc}	68 ^{bdac}	67 ^{bdac}	66 ^{de}	40.8 ^a	17.5 ^a	94.3 ^{bdac}	28.2 ^{de}	7226 ^{de}
3	J.D	Pellet	7.3	64 ^{edf}	63 ^{fe}	63 ^{fe}	65 ^{dec}	14.0 ^g	17.5 ^a	94.2 ^{bdac}	30.9 ^{ba}	7871 ^{bac}
4	J.D	Pellet	4.8	65 ^{edf}	65 ^{fde}	65 ^{fde}	65 ^{dec}	19.0 ^f	17.6 ^a	94.1 ^{de}	26.6 ^{efd}	6815 ^{ed}
5	J.D	Fasonated	7.3	71 ^{bdac}	75 ^{ba}	72 ^{bac}	74 ^{ba}	13.7 ^g	17.5 ^a	94.4 ^{bdac}	30.9 ^{ba}	7920 ^{ba}
6	J.D	Fasonated	4.8	73 ^{ba}	76 ^a	75 ^a	77 ^a	20.0 ^{fe}	17.6 ^a	94.8 ^a	27.7 ^{efdc}	7181 ^{edc}
7	Monosem	Pellet	7.3	66 ^{ebdfc}	68 ^{dec}	67 ^{bdac}	67 ^{bdac}	24.9 ^{cd}	17.5 ^a	94.2 ^{bdac}	28.1 ^{edc}	7186 ^{edc}
8	Monosem	Pellet	4.8	70 ^{bdac}	72 ^{bac}	72 ^{bac}	71 ^{bac}	31.5 ^b	17.5 ^a	94.4 ^{bdac}	32.8 ^a	8413 ^a
9	Monosem	Fasonated	7.3	68 ^{ebdac}	76 ^a	76 ^a	77 ^a	23.9 ^{cde}	17.6 ^a	94.7 ^{bac}	30.3 ^{bac}	7832 ^{bac}
10	Monosem	Fasonated	4.8	74 ^a	76 ^a	76 ^a	76 ^a	28.3 ^{cb}	17.5 ^a	94.2 ^{bdac}	25.4 ^f	6528 ^e
11	Stanhay	Pellet	7.3	68 ^{ebdac}	71 ^{bdac}	70 ^{bdac}	70 ^{bdac}	21.6 ^{fde}	17.5 ^a	94.5 ^{bdac}	26.1 ^{efd}	6701 ^{ed}
12	Stanhay	Pellet	4.8	73 ^{bac}	76 ^a	72 ^{ba}	72 ^{bac}	23.3 ^{fde}	17.5 ^a	94.1 ^{bdc}	31.8 ^{ba}	8078 ^{ba}
13	Stanhay	Fasonated	7.3	59 ^{gf}	67 ^{dec}	67 ^{bdac}	63 ^{de}	20.6 ^{fde}	17.3 ^a	94.8 ^a	32.7 ^a	8355 ^a
14	Stanhay	Fasonated	4.8	55 ^g	59 ^f	58 ^f	58 ^e	23.7 ^{de}	17.4 ^a	94.8 ^{ba}	25.6 ^{ef}	6561 ^{ed}
LSD(.05)			7	6	6	7	7	4.57	0.27	0.64	2.59	5.77
CV (%)			13.94	12.26	12.17	13.37	13.37	22.76	1.94	0.85	11.04	2.79

1 lb = 0.4536 kg

1 ton/ha = 2.245*tons/acre

1 mile = 1.613 km

a, b, c, d, e, f : means significantly different (P<0.05)

Table 8. Rate of emergence and 3cm mode range for the first 10 treatments of the three trials.

Treat	Planter	Seed	Speed Km/h	Rate of Emergence			CP3 %
				10 day	20 day	30 day	
1	Accord	Pellet	7.3	52 ^d	61 ^g	64 ^d	40.1 ^a
2	Accord	Pellet	4.8	52 ^{dc}	64 ^{gf}	65 ^d	39.6 ^a
3	J.D	Pellet	7.3	58 ^{ba}	67 ^{ef}	69 ^{dc}	17.2 ^{fg}
4	J.D	Pellet	4.8	57 ^{bdc}	68 ^{edf}	68 ^{dc}	20.6 ^c
5	J.D	Fasonated	7.3	60 ^{ba}	78 ^a	76 ^{ba}	15.8 ^g
6	J.D	Fasonated	4.8	62 ^a	80 ^a	79 ^a	19.4 ^{fe}
7	Monosem	Pellet	7.3	59 ^{ba}	71 ^{edc}	71 ^{bc}	27.6 ^c
8	Monosem	Pellet	4.8	62 ^{ba}	73 ^{bdc}	75 ^{ba}	32.2 ^b
9	Monosem	Fasonated	7.3	57 ^{bac}	76 ^{bac}	78 ^a	24.0 ^d
10	Monosem	Fasonated	4.8	61 ^{ba}	76 ^{ba}	77 ^a	29.1 ^{cb}
LSD(.05)				5	5	5	3.17
CV (%)				14.10	10.99	10.81	18.12

1 mile = 1.613 km

a, b, c, d, e, f : means significantly different (P<0.05)

Table 9. Paired comparisons of the seed used by each planter ($P < 0.05$) in terms of rate of emergence and final stand for trials 1, 2, 3 and combination of the three trials.

Trial	Planter	Seed	Rate of emergence									Final stand		
			10 day (%)			20 day (%)			30 day (%)			Final stand (%)		
			CV	LSD	mean	CV	LSD	mean	CV	LSD	mean	CV	LSD	mean
1	J.D	Fasonated	15.93	11.59	90 ^a	15.46	11.01	88 ^a	15.73	11.04	85 ^a	16.80	11.78	86 ^a
1	J.D	Pellet			81 ^a			79 ^a			80 ^a			79 ^a
1	Monosem	Fasonated	9.61	6.6	82 ^a	11.34	7.39	77 ^a	11.82	7.63	76 ^a	12.61	8.11	76 ^a
1	Monosem	Pellet			80 ^a			76 ^a			75 ^a			75 ^a
1	Stanhay	Fasonated	14.1	8.07	62 ^b	13.81	7.77	62 ^b	14.11	7.86	61 ^b	12.73	6.73	58 ^b
1	Stanhay	Pellet			72 ^a			70 ^a			69 ^a			65 ^a
2	J.D	Fasonated	13.29	5.83	55 ^a	14.31	6.83	63 ^a	14.46	6.77	62 ^a	14.58	7.16	65 ^a
2	J.D	Pellet			48 ^b			49 ^b			48 ^b			51 ^b
2	Monosem	Fasonated	14.59	7.25	60 ^a	12.43	7.38	75 ^a	11.66	6.93	75 ^a	13	7.71	76 ^a
2	Monosem	Pellet			56 ^a			64 ^b			64 ^b			62 ^b
2	Stanhay	Fasonated	19.04	9.76	51 ^b	16.6	9.96	65 ^b	15.68	9.19	64 ^a	15.15	8.89	62 ^b
2	Stanhay	Pellet			69 ^a			76 ^a			73 ^a			76 ^a
3	J.D	Fasonated	18.12	6.40	40 ^a	8.93	6.12	86 ^a	9.59	6.67	86 ^a	-	-	-
3	J.D	Pellet			43 ^a			75 ^b			78 ^b			-
3	Monosem	Fasonated	16.11	5.49	35 ^b	8.29	5.33	76 ^a	5.30	3.62	81 ^a	-	-	-
3	Monosem	Pellet			44 ^a			75 ^a			79 ^a			-
3	Monosem ¹	Fasonated	17.75	4.65	24 ^b	10.63	6.48	72 ^a	8.87	5.68	76 ^a	-	-	-
3	Monosem ¹	Pellet			37 ^a			71 ^a			74 ^a			-
1,2	Stanhay	Fasonated	17.34	6.45	57 ^b	15.44	6.16	63 ^b	14.87	5.83	63 ^b	15.06	5.76	60 ^b
1,2	Stanhay	Pellet			70 ^a			73 ^a			71 ^a			71 ^a
1,2,3	J.D	Fasonated	36.09	10.14	61 ^a	21.38	7.42	79 ^a	22.20	7.76	77 ^a	-	-	-
1,2,3	J.D	Pellet			57 ^a			68 ^b			68 ^b			-
1,2,3	Monosem	Fasonated	31.39	8.87	59 ^a	11.65	4.07	76 ^a	11.57	4.12	78 ^a	-	-	-
1,2,3	Monosem	Pellet			60 ^a			72 ^b			73 ^b			-

Monosem¹: The press-wheels of the Monosem planter are adjusted for firming corn seed (2.25 in. apart) LSD ($P < 0.05$)

4.1.2 Monosem Planter

In trial 1 the Monosem planter provided a 10-day stand equal to 77 to 84% of the desired seeding rate (table 4, fig. 4). The 20 and 30 day stands provided similar emergence rates since few plants emerged following the heavy rains twelve days after planting. The final stand ranged from 71 to 79% of the desired rate (table 4). There were no significant differences in rate of emergence among seed treatments, but the fasonated seed averaged one or two percentage units higher (table 9).

In trial 2, the Monosem planter provided 10-day stand equal to 55 to 64% of the desired seeding rate (table 5, fig. 5). The 20 and 30 day rates of emergence were among the best of all treatments when using fasonated seed. The fasonated seed provided a significantly higher pre-harvest stand, and average of fourteen percentage higher than the pelleted seed (table 9).

In trial 3, the Monosem planter provided a 10-day stand equal to 35 to 44% of the desired seeding rate (table 6, fig. 6). The soil was cool and dry which likely delayed emergence. Rainfall on May 7th, 0.55 inch and May 11th, 0.29 inches (Appendix E) increased emergence at the 20 and 30-day stands to 73 to 77% and 79 to 83% respectively. The pelleted seed provided a significantly higher 10-day stand, but there was no difference in the 20 and 30-day stands.

The Monosem planter was also tested with the V style press-wheels set at the wide setting, 2.25 inch, similar to what would be used in planting corn. This was designed to simulate the press-wheel settings commonly found on other general purpose planters. This press-wheel configuration provided a slower emergence rate than the narrow setting (table 6 and 9, fig. 6). This was likely due to improved seed-to-soil contact

in the dry soil. The 20- and 30-day stands showed a dramatic increase with increasing soil moisture, ranging from 69 to 75% and 74 to 78% respectively (Appendix E).

Pelleted seed provided a significantly higher 10-day stand than fasonated seed in each press-wheel configuration (nine percentage unit advantage with the press-wheel in, thirteen percentage units with the wide setting) (table 9). However, there were no differences in 20-day or 30-day stands. Increasing soil temperature and moisture allowed the fasonated seed to emerge successfully prior to the final stand counts.

Combined over years and locations, the Monosem planter provided stands among the highest in emergence during the emergence period (table 7, 9). The fasonated seed provided a significantly higher 20-day and 30-day stand than the pelleted seed.

4.1.3 Stanhay Planter

In trial 1, the Stanhay planter provided a 10-day stand equal to 59 to 75% of the desired seeding rate (table 4, fig.4). The 20-day and 30-day stands ranged from 57 to 73% of the desired seeding rate. The final stand ranged from 55 to 67% of the desired seeding rate (table 4). The pelleted seed provided a higher 10-day emergence rate (ten percentage units) and final stand (seven percentage units) than the fasonated seed (table 9).

In trial 2, the Stanhay planter provided a 10-day stand equal to 50 to 71% of the desired seeding rate (table5, fig.5). The pre-harvest stand ranged from 60 to 64% with fasonated seed and 75 to 76% with pelleted seed (table 5). The pelleted seed provided a eighteen percentage unit increase in the 10-day rate of emergence and an increase of eight percentage units in pre-harvest stand (table 9).

In trials 1 and 2, across locations, the Stanhay planter provided for a stand equal to 55 to 73% of the desired seeding rate (table7). The final stand ranged from 58 to 72%

of the desired rate (table 7). In general, the Stanhay planter may have been too light to provide adequate seed depth and coverage in the seedbeds tested. Planters such as this are generally designed for a more intensively tilled seedbed. The runner opener did not allow the planter units to maintain a constant depth and the press-wheel was designed for tilled soil. The planter would likely perform better in more intensively tilled fields. The Stanhay planter was not available for trial three in 2001.

4.1.4 Accord Planter

The Accord planter was designed for seeding sugar beet with pelleted seed. Similar to the Stanhay, the Accord was a relatively light planter designed for tilled soil. In trial 1, the Accord planter provided a 10-day stand equal to 62 to 70% of the desired seeding rate (table 4, fig. 4). The 20-day and 30-day stands ranged from 59 to 65% and 59 to 64% of the desired seeding rate, respectively. Some features of the Accord planter which may hinder planting in a firm seedbed are: a) light weight, b) the runner style opener and c) press-wheels. These design features may cause the planter units to ride over the seedbed, place the seed at a shallow depth and provide little loose soil for covering and firming around the seed. The final stand ranged from 57 to 61% of the desired rate (table 4).

In trial 2, the Accord planter provided a 10-day stand equal to 60 to 63% (table 5, fig. 5). There was an increase to the seeding rate in the 20 and 30-day stands, ranging from 70 to 72%. The seedbed was very coarse and little loose soil was available for covering the firming around the seed. However, when ranked with all treatments, the Accord was among the best in 10-day, 20-day, 30-day and pre-harvest stand.

In trial 3, the Accord planter provided a 10-day stand equal to 26 to 30% of the desired seeding rate (table 6, fig. 6). Rate of emergence and pre-harvest stand were among the lowest of the planters tested. The average 30-day stand was about 60%, 10 to 20 percentage units lower than the other planters. The soil was dry after planting and the seedbed was firm. The Accord planter was designed for a tilled seedbed.

In trials 1, 2 and 3, across years and locations, the Accord planter provided a 10-day stand equal to 52% of the desired seeding rate (table 8). There was a slight increase in the seeding rate during the 20 and 30 day stands, but still lower than the seeding rate provided by other planters. This indicates poor soil-to-seed contact in the firm seedbeds tested.

4.2 PLANT SPACING UNIFORMITY

4.2.1 John Deere Planter

The 3 cm mode range (CP3) was used together with plant spacing frequency histograms to analyze plant spacing uniformity. The 3 cm mode range is a measure of the percentage of plants established within 1.5 cm of the target spacing for each planter. A higher CP3 value indicates better planter performance. Frequency histograms provide a visual representation of the planter performance by grouping plant spacing by frequency of occurrence in 3 cm increments. An ideal histogram would show a single, high spike at the 12 to 15 cm increment indicating all plants spaced at the targeted spacing. An undesirable spacing could be shown as several spikes of intermediate height, or high spikes at an interval other than that which includes the target spacing.

In trial 1, the John Deere planter provided a 3cm mode range ranging from 15.5 to 25.7% (table 4, fig. 7). When planter speed was held constant at 4.8 km/h, (3.0 mph)

there was little difference due to seed treatment. The CP3 was 25.7% for the pelleted seed and 25.5% for the fasonated seed (table 10). Pelleted seed (17.9%) performed slightly better than fasonated seed (15.5%) at the faster travel speed of 7.3 km/h (table 4) but the difference was not statistically significant.

Spacing uniformity was significantly better at the slower travel speed. Pelleted seed sown at 4.8 km/h (3.0 mph) provided a CP3 of 25.7% while a speed of 7.3 km/h (4.5 mph) provided a CP3 of 17.9% (table 4). Similar results were found with fasonated seed. At 4.8 km/h (3.0 mph) the CP3 was 25.5%, falling to 15.5% at 7.3 km/h (4.5 mph).

Figure 7 indicates that the John Deere planter provided frequent narrow plant spacing. Narrow seed spacing can be explained by: a) a long drop distance from the metering mechanism to the furrow (53 cm/21 in), b) fast forward speed and c) poorly functioning seed delivery units. Based on the high frequency of plants at a frequency narrower than the target spacing, the John Deere planter may have been delivering seed at a higher rate than intended.

In trial 2, the John Deere planter provided a 3cm mode range ranging from 10.0 to 14.4% (table 5, fig. 8). Figure 8, indicates that the planter provided many narrow spacing and a lot of skips. In the coarse seedbed characteristic of trial two, the planter press-wheels did not effectively close the furrow. As the soil dried in the days after planting the seed furrow opened in numerous locations, exposing the seed to dessication and other hazards.

In trial 3, the John Deere planter provided a 3cm mode range ranging from 18.3 to 23.8% (table 6, fig. 9). At a forward travel speed of 4.8 km/h (3.0 mph), pelleted seed, 23.8% provided a significantly better seed spacing uniformity than fasonated seed, 8.3%.

Table 10. Paired comparisons for the 3cm mode range value (CP3) within and across trials.

Planter	Speed	Seed	CP3				
			Trial 1	Trial 2	Trial 3	Trial 1, 2	Trial 1, 2, 3
Accord	4.8	Pellets	38.8 ^a	42.7 ^a	37.2 ^a	40.8 ^a	39.6 ^a
Accord	7.3	Pellets	36.6 ^a	49 ^a	34.8 ^a	42.8 ^a	40.1 ^a
J.D.	4.8	Pellets	25.7 ^a	12.2 ^a	23.8 ^a	19 ^a	20.6 ^a
J.D.	4.8	Fasonated	25.5 ^a	14.4 ^a	18.3 ^b	20 ^a	19.4 ^a
J.D.	7.3	Pellets	17.9 ^a	10 ^a	23.6 ^a	14 ^a	17.2 ^a
J.D.	7.3	Fasonated	15.5 ^a	11.9 ^a	20.1 ^a	13.7 ^a	15.8 ^a
J.D.	4.8	Pellets	25.7 ^a	12.2 ^a	23.8 ^a	19 ^a	20.6 ^a
J.D.	7.3	Pellets	17.9 ^b	10 ^a	23.6 ^a	14 ^b	17.2 ^b
J.D.	4.8	Fasonated	25.5 ^a	14.4 ^a	18.3 ^a	20 ^a	19.4 ^a
J.D.	7.3	Fasonated	15.5 ^b	11.9 ^a	20.1 ^a	13.7 ^b	15.8 ^b
Monosem	4.8	Pellets	35.7 ^a	27.3 ^a	33.4 ^a	31.5 ^a	32.2 ^a
Monosem	4.8	Fasonated	28.6 ^b	28 ^a	30.7 ^a	28.3 ^a	29.1 ^a
Monosem	7.3	Pellets	24.4 ^a	25.4 ^a	32.9 ^a	24.9 ^a	27.6 ^a
Monosem	7.3	Fasonated	21.5 ^a	26.4 ^a	24.3 ^b	23.9 ^a	24 ^b
Monosem	4.8	Pellets	35.7 ^a	27.3 ^a	33.4 ^a	31.5 ^a	32.2 ^a
Monosem	7.3	Pellets	24.4 ^b	25.4 ^a	32.9 ^a	24.9 ^b	27.6 ^b
Monosem	4.8	Fasonated	28.6 ^a	28 ^a	30.7 ^a	28.3 ^a	29.1 ^a
Monosem	7.3	Fasonated	21.5 ^b	26.4 ^a	24.3 ^b	23.9 ^b	24 ^b
Stanhay	4.8	Pellets	30 ^a	16.6 ^a	-	23.3 ^a	-
Stanhay	4.8	Fasonated	26 ^a	21.4 ^a	-	23.7 ^a	-
Stanhay	7.3	Pellets	24 ^a	19.2 ^a	-	21.6 ^a	-
Stanhay	7.3	Fasonated	22.4 ^a	18.8 ^a	-	20.6 ^a	-
Stanhay	4.8	Pellets	30 ^a	16.6 ^a	-	23.3 ^a	-
Stanhay	7.3	Pellets	24 ^a	19.2 ^a	-	21.6 ^a	-
Stanhay	4.8	Fasonated	26 ^a	21.4 ^a	-	23.7 ^a	-
Stanhay	7.3	Fasonated	22.4 ^a	18.8 ^a	-	20.6 ^a	-
Monosem ¹	4.8	Pellets	-	-	31.5 ^a	-	-
Monosem ¹	4.8	Fasonated	-	-	29.1 ^a	-	-
Monosem ¹	7.3	Pellets	-	-	28.8 ^a	-	-
Monosem ¹	7.3	Fasonated	-	-	24 ^b	-	-
Monosem ¹	4.8	Pellets	-	-	31.5 ^a	-	-
Monosem ¹	7.3	Pellets	-	-	28.8 ^a	-	-
Monosem ¹	4.8	Fasonated	-	-	29.1 ^a	-	-
Monosem ¹	7.3	Fasonated	-	-	24 ^b	-	-
LSD			6.42	6.36	4.62	4.57	3.17
CV (%)			20.90	23.8	14.27	22.76	18.12

Monosem¹: The press-wheels are set 2.25 in. apart
LSD (P<0.05)

Figure 7. Plant spacing uniformity. Trial 1, 2000

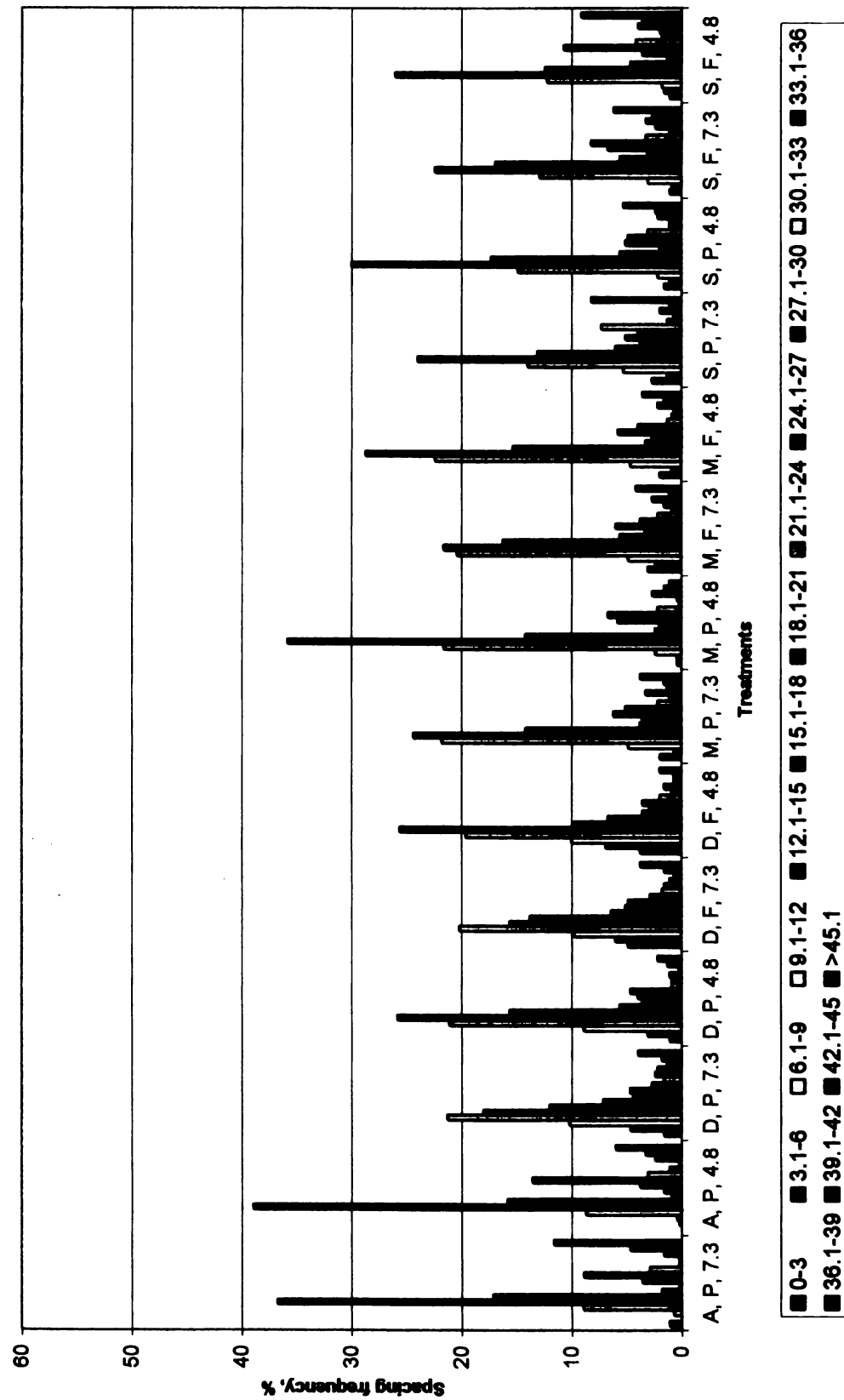


Figure 8. Plant spacing uniformity. Trial 2, 2000

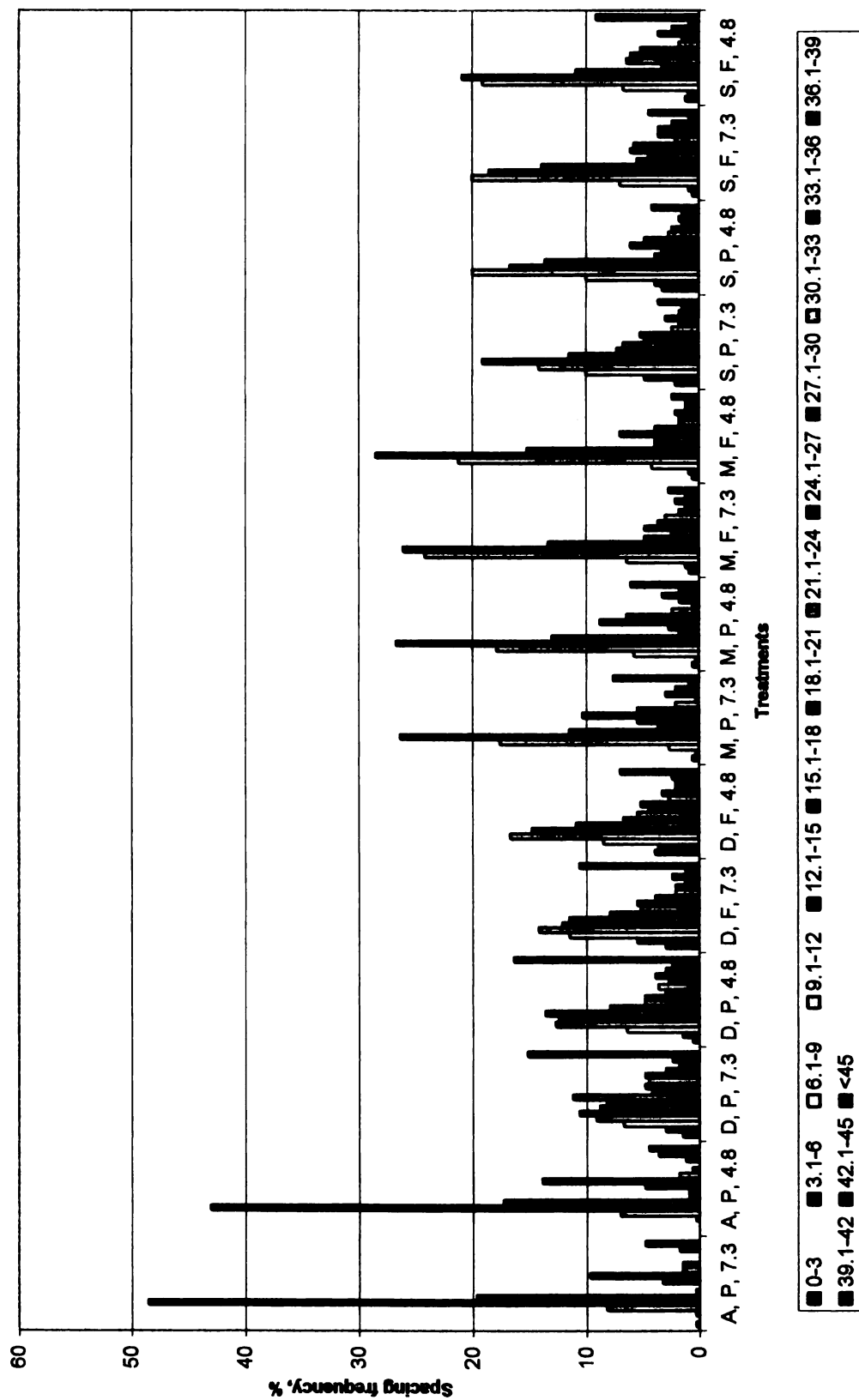
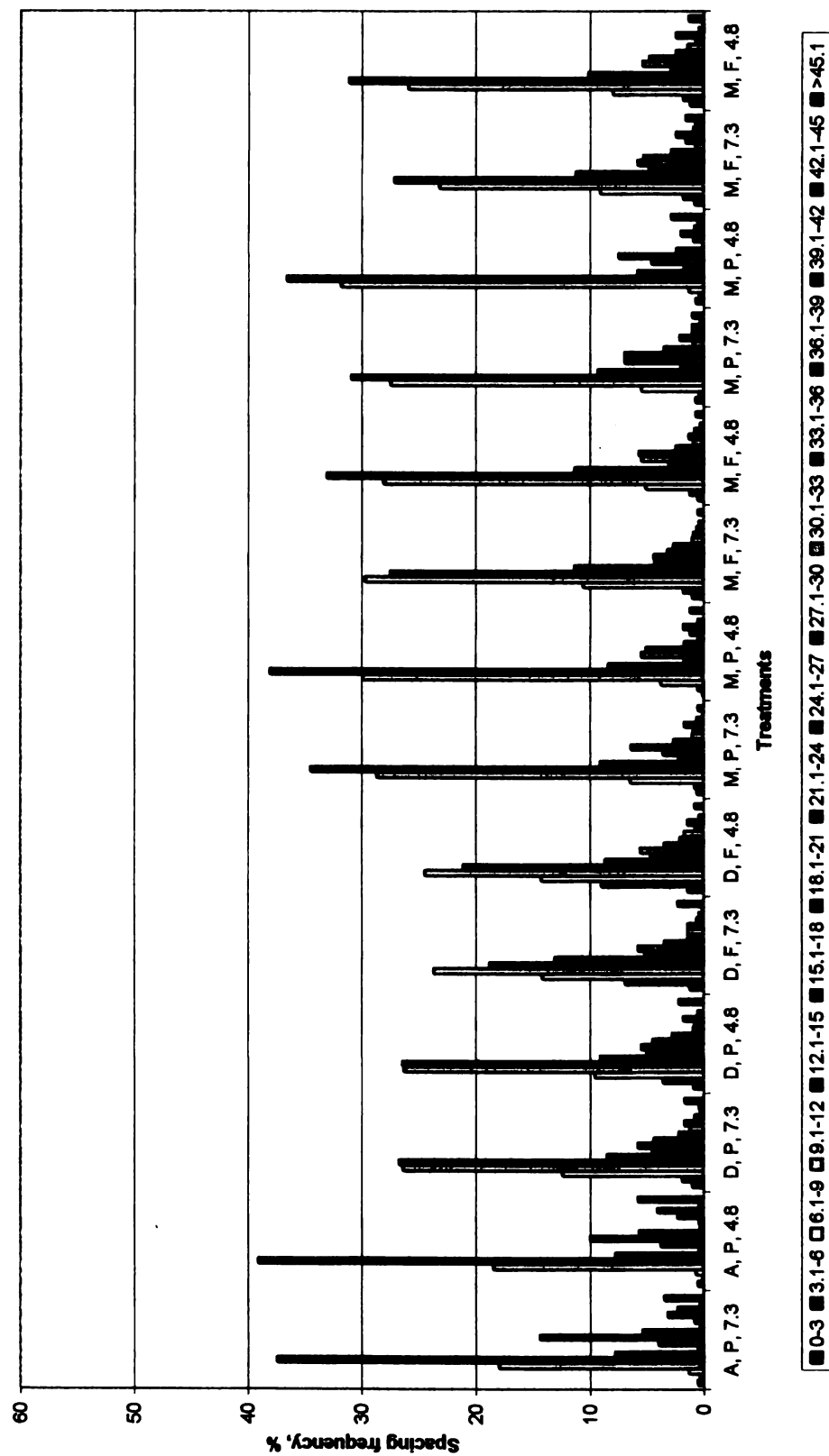


Figure 9. Plant spacing uniformity. Trial 3, 2001



Combined over years and locations, the John Deere planter provided a 3cm mode range ranging from 15.8 to 20.6% (table 10). When speed was held constant, pelleted seed tended to provide a more uniform spacing, but the improvement was not significant. When seed treatment was held constant, the slower forward travel speed (4.8 km/h) provided a more uniform plant spacing than the faster travel speed (7.3 km/h).

4.2.2 Monosem Planter

In trial 1, the Monosem planter provided a 3cm mode range ranging from 21.5 to 35.7% (table 4, fig.7). This trial experienced heavy rains twelve days after planting which likely interfered with emergence. Rapid emergence provided an advantage in this trial since there were no improvements in emergence measured after the 10-day emergence count. At 4.8 km/h (3.0 mph), pelleted seed, 35.7%, provided a better stand than fasonated seed, 28.6%, (table 10). At 7.3 km/h (4.5 mph) there were no differences in spacing uniformity. When seed treatment was held constant and travel speed varied, spacing uniformity was better at the slower travel speed with both pelleted (35.7% at 4.8 km/h, 24.4% at 7.3 km/h) and fasonated seed (28.6% at 4.8 km/h, 21.5% at 7.3 km/h). The spherical shape of the pelleted seed reduces friction in tube and its increased mass reduces seed bounce within the drop tube. The slower speed reduces seed bounce in the furrow.

In trial 2, the Monosem planter provided a 3cm mode range ranging from 25.4 to 28.0% (table 5, fig. 8). In this coarse seedbed, the planter generally provided a more uniform spacing than either the Deere or Stanhay planters. However, there were no significant differences in plant spacing uniformity due to either seed selection or travel speed.

In trial 3 with the press-wheels adjusted to the narrow spacing (3.2 cm, 1.25 in.), the Monosem planter provided a 3cm mode range ranging from 24.3 to 33.4% (table 6, fig. 9). When travel speed was held constant and seed treatment varied there were no differences in seed spacing uniformity at 4.8 km/h (3.0 mph) (pelleted at 33.4%, fasonated at 30.7%), but at 7.3 km/h (4.5 mph), pelleted seed (32.9%) provided a more uniform spacing than fasonated seed (24.3%) (table 10). When pelleted seed was used there was no difference in seed spacing uniformity between 4.8 km/h (33.4%) and 7.3 km/h (32.9%). However, when fasonated seed was used, the slower travel speed provided a more uniform stand (30.7%) than the faster travel speed (24.3%). Pelleted seed was handled better because of its increased weight and its spherical shape.

In trial 3, the Monosem planter was also evaluated with the press-wheels set at the wide spacing (5.7 cm, 2.25 in.), typical of the spacing used for corn and other row crops. This spacing would likely provide less effective firming of the soil around the small sugar beet seed than the narrow setting. At this press-wheel spacing the planter provided a CP3 value ranging from 24.0 to 31.5% (table 6 and 10, fig. 9). Although the use of pelleted seed and a slower travel speed tended to provide a small improvement in seed spacing uniformity, the improvement was not significant.

Table 11. Paired comparisons for the 3cm mode range value (CP3) and rate of emergence on the Monosem planter with the press-wheels adjusted for sugar beet (1.25 in, narrow) and the press-wheels adjusted for corn (2.25 in, wide) in Trial 3.

<u>Press-wheels</u>	<u>Planter</u>	<u>Speed</u>	<u>Seed</u>	<u>CP3</u>	<u>Rate of emergence, %</u>		
					<u>10-day</u>	<u>20-day</u>	<u>30-day</u>
Narrow	Monosem	4.8	Pellets	33.4 ^a	44 ^a	73 ^a	80 ^a
Wide	Monosem	4.8	Pellets	31.5 ^a	34 ^b	70 ^a	75 ^a
Narrow	Monosem	4.8	Fasonated	30.7 ^a	35 ^a	77 ^a	79 ^a
Wide	Monosem	4.8	Fasonated	29.1 ^a	24 ^b	75 ^a	78 ^a
Narrow	Monosem	7.3	Pellets	32.9 ^a	44 ^a	77 ^a	79 ^a
Wide	Monosem	7.3	Pellets	28.8 ^a	40 ^a	73 ^a	74 ^a
Narrow	Monosem	7.3	Fasonated	24.3 ^a	36 ^a	75 ^a	83 ^a
Wide	Monosem	7.3	Fasonated	24 ^a	25 ^b	69 ^a	74 ^b
L.S.D (P<0.05)				4.62	7	7	7
C.V (%)				14.27	16.92	8.99	7.96

In trials 1, 2, and 3, across years and locations, the Monosem planter with the press-wheels set at the narrow spacing provided a 3cm mode range ranging from 24 to 32.2% (table 10). There was no difference in seed treatment at 4.8 km/h (3.0 mph), but at 7.3 km/h (4.5 mph) the pelleted seed improved seed spacing uniformity (27.6% for pellets, 24% for fasonated seed). The slower travel speed provided a more uniform stand (about a five percentage unit increase in CP3) when both pelleted seed and fasonated seed were used.

4.2.3 Stanhay Planter

The Stanhay planter is a vegetable planter with a runner type furrow opener, a short seed drop, vertical press behind the opener and a semi-pneumatic press-wheel behind the furrow closers. The Stanhay was used in trials one and two. In trial 1, the Stanhay planter provided a 3cm mode range ranging from 22.4 to 30.0% (table 4, fig. 7). While the planter tended to provide a slightly more uniform stand with pelleted seed or at

the slower travel speed, the differences between treatments were not significant in trial one (table 10).

In trial 2, the Stanhay planter provided a 3cm mode range ranging from 16.6 to 21.4% (table 5, fig.8). Seed spacing uniformity was not as good as in trial 1 due to the coarse seedbed and difficulty in obtaining good seed-to-soil contact. The differences between treatments were small and not significant (table 10).

In trials 1 and 2, across locations, the Stanhay planter provided a 3cm mode range ranging from 20.6 to 23.7% (table 7). Once again, while the pelleted seed and slower travel speed tended to provide a more uniform stand, the differences between treatments were small and not significant (table 10).

4.2.4 Accord Planter

The Accord planter was designed specifically for pelleted sugar beet seed. It has a ground driven seed delivery mechanism with a short seed drop. Seed spacing uniformity was among the best in each of the three trials (table 10). There were no significant differences in seed spacing uniformity due to travel speed in any of the three trials. The uniform spacing could be due to: a) the short seed drop distance b) the seed packer wheel located right behind the furrow opener which helps eliminate seed bounce, and c) the pelleted seed is heavier and improves the planter handling ability. The Accord planter provided the best seed spacing uniformity across locations and years.

4.3 BEET SIZE UNIFORMITY

Sugar content is partially a function of beet size. Large beets tend to have lower sugar content than small beets. Uniform plant spacing may help provide a more uniform beet size. Uniform plant spacing allows each beet equal access to moisture, nutrients and

sunlight. Based on an optimal sugar content and ease of harvest a desirable beet weight is one to two pounds.

Six treatments in each of trial 1 and trial 2 were selected for beet size sampling (Table 12). Treatments were selected based on the treatment CP3 value to represent a range of plant spacing uniformity from among the most to the least uniform. Prior to machine harvest, fifty consecutive beets from each of six replications of the six treatments were hand harvested. Individual beet weights were recorded. In order to characterize beet size uniformity, a comparison of descriptive statistics, an analysis of variance and mean separation of beet size categories, three dimensional contour charts, correlation coefficients, multiple linear regression and principle component analysis were used.

Table 12. Treatments selected for beet size sampling.

Trial 1	Trial 2	Treatment	CP3	Planter	Seed	Speed, km/h
X	X	1	49.0	Accord	Pelleted	7.3
		2	38.8	Accord	Pelleted	4.8
	X	3	10.0	Deere	Pelleted	7.3
	X	5	11.9	Deere	Fasonated	7.3
X		5	15.5	Deere	Fasonated	7.3
X		8	35.7	Monosem	Pelleted	4.8
	X	8	27.3	Monosem	Pelleted	4.8
X		9	21.5	Monosem	Fasonated	7.3
	X	9	26.4	Monosem	Fasonated	7.3
X		12	30.0	Stanhay	Pelleted	4.8
X		13	22.4	Stanhay	Fasonated	7.3
	X	13	18.8	Monosem ²	Fasonated	7.3

4.3.1 Descriptive Statistics

Standard descriptive statistics for the beet weights of trials 1 and 2 are listed in Table 13. Beets in trial 1 tended to be larger than in trial 2. An average beet weight in

trial 1 was 2.37 lb and the mode was 1.5 lb. In trial 2, an average beet weight was 2.08 lb while the mode was 1.2 lb.

Table 13. Descriptive statistics for trial 1 and 2

Statistic	Trial 1	Trial 2
1 st quartile, lbs	1.4	1.2
3 rd quartile, lbs	3.1	2.8
Mean	2.37	2.08
Standard Error	0.035	0.031
Median	2.2	1.85
Mode	1.5	1.2
Standard Deviation	1.359	1.261
Sample Variance	1.84	1.591
Kurtosis	1.393	1.287
Skewness	0.988	1.006
Range	8.85	7.45
Minimum	0.05	0.05
Maximum	8.9	7.5
Sum	3545.7	3337.8
Count	1495	1602

4.3.2 Analysis of Variance and Mean Separation

An analysis of variance with mean separation was performed to identify important differences in beet size categories among treatments. Beets were sorted by weight in one-pound increments (Tables 14 and 15).

Table 14. Beet weight frequencies as a percent of the beets collected for Trial 1.

Treat #	Planter	Seed	Speed Km/h	CP3	Beet size (lbs)					
					< 0.99	1-1.99	2-2.99	3-3.99	4-4.99	5>
2	Accord	Pellet	4.8	38.8	8.4 ^c	32.4 ^{bac}	30.6 ^a	20.1 ^a	4.6 ^b	3.3 ^{ba}
5	J.D	Fasonated	7.3	15.5	23.1 ^a	38.7 ^a	23.3 ^a	9.8 ^c	3.6 ^b	1.3 ^b
8	Monosem	Pellet	4.8	35.7	11.9 ^{bc}	35.9 ^{bac}	30.0 ^a	14.7 ^{bac}	4.6 ^b	2.6 ^b
9	Monosem	Fasonated	7.3	21.5	17.5 ^{ba}	37.9 ^{ba}	28.6 ^a	10.0 ^{bc}	4.2 ^b	1.4 ^b
12	Stanhay	Pellet	4.8	30.0	11.2 ^{bc}	28.9 ^{bc}	23.7 ^a	16.2 ^{bac}	11.5 ^a	8.2 ^a
13	Stanhay	Fasonated	7.3	22.4	8.0 ^c	28.0 ^c	26.1 ^a	16.7 ^{ba}	12.7 ^a	8.3 ^a
LSD (.05)					7.3	9.3	7.8	6.7	6.7	5.5
CV (%)					46.6	23.4	24.6	38.8	83.0	111.7

There was no difference between treatments in the 2-2.99 lb category, and no apparent differences due the CP3 measure of plant spacing uniformity. A similar relationship between beet size and plant spacing uniformity exists for trial 2.

Table 15. Beet weight frequencies as a percent of the beets collected for Trial 2.

Treat #	Planter	Seed	Speed Km/h	CP3	Beet size (lbs)					
					0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5>
1	Accord	Pellet	7.3	49.0	18.1 ^{bac}	42.1 ^a	26.7 ^a	7.0 ^c	4.1 ^{cb}	1.7 ^b
3	J.D	Pellet	7.3	10.0	11.0 ^c	26.0 ^c	27.9 ^a	17.9 ^a	9.9 ^a	7.1 ^a
5	J.D	Fasonated	7.3	11.9	17.2 ^{bc}	34.4 ^{bac}	25.7 ^a	13.9 ^{ba}	5.0 ^b	3.6 ^b
8	Monosem	Pellet	4.8	27.3	18.4 ^{bac}	37.2 ^{ba}	25.7 ^a	12.2 ^{bac}	2.7 ^{cb}	3.5 ^b
9	Monosem	Fasonated	7.3	26.4	26.9 ^a	42.2 ^a	19.8 ^a	9.5 ^{bc}	0.9 ^c	0.5 ^b
13	Stanhay	Fasonated	7.3	18.8	21.0 ^{ba}	28.0 ^{bc}	26.1 ^a	16.7 ^a	5.3 ^b	2.7 ^b
	LSD (.05)				9.3	10.6	9.9	5.8	3.9	3.4
	CV (%)				42.2	25.9	33.1	38.5	71.7	90.2

4.3.3 Three-dimensional representation of plant spacing uniformity (CP3) and beet size frequency (%).

Three-dimensional continuous surface charts displaying CP3 values on the X-axis, beet weight frequencies on the Y-axis and beet size categories on the Z-axis were used to create a visual representation of the relationship between variables and identify potential trends in beet size with plant spacing uniformity (Fig. 10-13). The relationship between CP3 values and beet size uniformity varied among trials. In trial 1 (Fig. 10-11), a greater concentration of the smallest beets appeared to be associated with a poor plant spacing uniformity (low CP3 value). In trial 2 (Fig. 12-13) the greatest concentration of small beets was associated with the best plant spacing uniformity. A low CP3 value indicates few plants within three centimeters of the target spacing. This measure does not differentiate between spacing that was too narrow or too wide. Since a narrow spacing tends to produce a small beet, it appears that the low CP3 values were due to narrow plant spacing in trial 1 and wide plant spacing in trial 2.

Figure 10. 3D chart of beet size frequencies vs beet size categories vs CP3 values for Trial 1

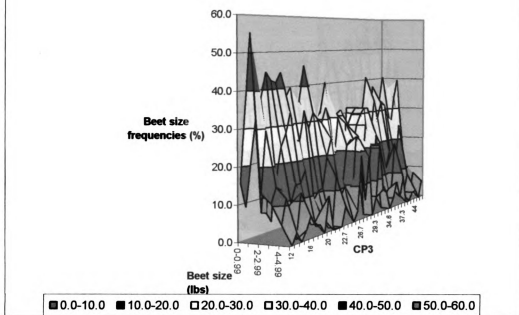


Figure 11. Top view of beet size categories vs CP3 values for Trial 1

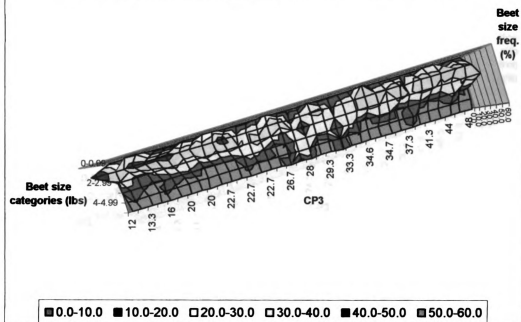


Figure 12. 3D chart of Beet size frequencies vs beet size categories vs CP3 values for Trial 2

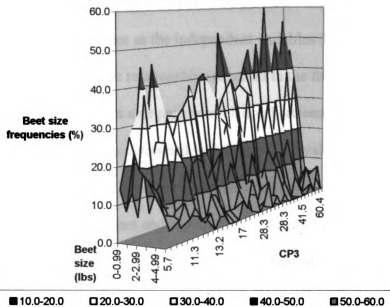
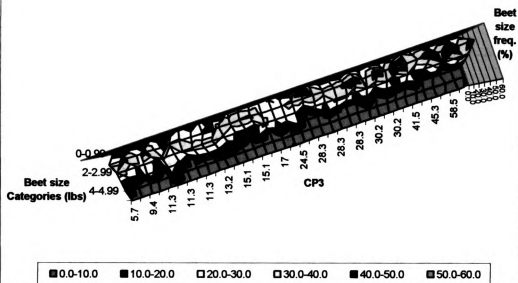


Figure 13. Top view of beet size categories vs CP3 values for Trial 2



4.3.4 Correlation Coefficients

Correlation coefficients were calculated with the CP3 values as the dependent variable and the beet size categories as the independent variables (Table 16, 17). The correlation coefficients support the relationships revealed in the three-dimensional surface graphs. In trial 1, there was a negative correlation between CP3 and the smaller beet sizes. Fewer small beets were associated with higher CP3 values. In trial 2, there was a negative correlation between CP3 and the larger beet categories. As the CP3 value increased there were fewer large beet and a greater percentage of small beet. The correlation coefficients also indicate that a number to the dependent variables were highly correlated.

Table 16. Correlations between CP3 and beet size categories for Trial 1.

	CP3	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5>
CP3	1						
0-0.99	-0.2362	1					
p-value	0.1655						
1-1.99	-0.3630	0.1887	1				
p-value	0.0296	0.2702					
2-2.99	0.3435	0.0485	-0.1647	1			
p-value	0.0402	0.7785	0.3369				
3-3.99	0.2427	-0.5049	-0.3351	-0.1474	1		
p-value	0.1537	0.0017	0.0457	0.3907			
4-4.99	0.1226	-0.5058	-0.5741	-0.2461	0.2293	1	
p-value	0.4762	0.0016	0.0003	0.1478	0.1784		
5>	0.0589	-0.4131	-0.2785	-0.5189	0.0914	0.5917	1
p-value	0.7327	0.0123	0.0999	0.0012	0.5958	0.0001	

Table 17. Correlations between CP3 and beet size categories for Trial 2.

	CP3	0-0.99	1-1.99	2-2.99	3-3.99	4-4.99	5>
CP3	1						
0-0.99	0.0954	1					
p-value	0.5799						
1-1.99	0.4269	0.1435	1				
p-value	0.0094	0.4036					
2-2.99	-0.0023	-0.4277	-0.5585	1			
p-value	0.9890	0.0093	0.0004				
3-3.99	-0.5568	-0.4154	-0.5120	0.0570	1		
p-value	0.0004	0.0118	0.0014	0.7412			
4-4.99	-0.3182	-0.4761	-0.5301	0.2104	0.4335	1	
p-value	0.0586	0.0033	0.0009	0.2179	0.0083		
5>	-0.3443	-0.4979	-0.4666	0.3386	0.3774	0.5231	1
p-value	0.0397	0.0020	0.0041	0.0433	0.0232	0.0011	

4.3.5 Multiple Linear Regression

A multiple linear regression (MLR) was performed to evaluate the strength of the relationship between the dependent variable, CP3, and the beet weight categories. A goal of multiple linear regression is to assign a relative importance to each independent variable. In this case, an objective was to determine how important beet size distribution was in explaining beet spacing uniformity when measured as CP3. The F-test associated with the analysis of variance table is a test of the hypothesis that $\beta_A = \beta_B = \beta_C = \beta_D = \beta_E = \beta_F = 0$. It is a test of whether there is a linear relationship between the dependent variable and the entire set of independent variables.

The preceding correlation matrix indicates a problem of intercorrelated independent variables. In such a situation the overall regression may be significant while none of the individual coefficients are significant. The signs of the regression coefficients may be counterintuitive. The estimates of the β and the sum of squares attributed to each variable are dependent on the other variables in the equation and a unique, unbiased least-squares solution does not exist. However, multicollinearity does not affect the usefulness

of the fitted model for making inferences on the response function as long as the inferences are made within the range of observations. Regression results for trial 1 are provided in Table 18. The fitted equation was significant at the relaxed level of ($p < .10$). The R^2 value was 0.295 indicating a great deal of scatter in the data.

Table 18. ANOVA and multiple linear regression coefficients for trial 1.

	D.F	S.S	M.S	F	Significance F
Regression	6	1102.527	183.7544	2.028053	0.093903
Residual	29	2627.583	90.60632		
Total	35	3730.11			

Variable	D.F	Parameter estimate	S.E	t-value	Pr > t
Intercept	1	12.47	27.11	0.46	0.648
0-0.99 lbs	1	-0.08	0.34	-0.25	0.803
1-1.99 lbs	1	-0.24	0.32	-0.78	0.443
2-2.99 lbs	1	0.71	0.37	1.89	0.068
3-3.99 lbs	1	0.37	0.39	0.94	0.355
4-4.99 lbs	1	-0.19	0.45	-0.44	0.666
5 lbs>	1	0.54	0.52	1.04	0.306
R^2			0.295		

The fitted equation for trial 2 was significant ($p < .017$) and more effectively described the data (table 19). The R^2 was 0.393, again indicating a high degree of scatter about the fitted equation. The fact that some independent variables are intercorrelated eliminates the common interpretation of regression coefficients as measuring the change in the expected value of the dependent variable when an independent variable is increased by one unit when all other independent variables are held constant. However, multicollinearity does not interfere with the ability to obtain a good fit. Although the regression results indicated that there was a relationship between CP3 and beet size, the regression equations were only useful in describing rather than predicting the relationship among variables.

Table 19. ANOVA and multiple linear regression coefficients for trial 2.

	D.F	S.S	M.S	F	Significance F
Regression	6	2722.349	453.7249	3.134563	0.017141
Residual	29	4197.721	144.749		
Total	35	6920.07			

Variable	D.F	Parameter Estimate	Standard Error	t-value	Pr > t
Intercept	1	36.05	41.02	0.88	0.38
0-0.99 lbs	1	-0.35	0.48	-0.73	0.46
1-1.99 lbs	1	0.22	0.48	0.45	0.65
2-2.99 lbs	1	0.18	0.50	0.37	0.71
3-3.99 lbs	1	-1.16	0.58	-1.98	0.05
4-4.99 lbs	1	-0.14	0.78	-0.19	0.85
5 lbs >	1	-0.89	0.81	-1.09	0.28
R ²			0.393		

4.3.6. Principle Component Analysis

Since the problems associated with multicollinearity of the independent variables made it impossible to interpret the coefficients of the multiple linear regression, a procedure known as principle component analysis (PCA) was used to further examine the relationship of CP3 and the beet size categories. PCA transforms a set of correlated variables to a set of uncorrelated variables called factors. Factors are not single independent variables, rather labels for groups of variables. The factors are inferred from the observed variables and can be estimated as linear combinations of them.

There are four steps to factor analysis: 1) compute the correlation matrix for all variables, 2) extract the number of factors necessary to represent the data, 3) transform the factors to make them more understandable, and 4) compute the scores for each factor. For the purpose of this study, a principal components factor analysis with a varimax rotation was performed with Kaiser normalization.

Referring to trial 1, the correlation matrix indicates that there was a highly significant correlation among several variables (Table 20). In order to create a set of uncorrelated factors, principal component factor analysis of the correlation matrix was

performed (Table 21). Factor 1 accounted for 38% of the variance among factors while factor 2 accounted for 24%. These two factors explained 62% of the total variance. Generally, only factors with a variance greater than 1 are used since factors with a variance less than 1 are no better than a single variable.

Trial 20. Correlation (Pearson) coefficients for trial 1.

	CP3	<0.99	1-1.99	2-2.99	3-3.99	4-4.99
<0.99	-0.236					
p-value	0.165					
1-1.99	-0.363	0.189				
p-value	0.030	0.270				
2-2.99	0.344	0.049	-0.165			
p-value	0.040	0.779	0.337			
3-3.99	0.243	-0.505	-0.335	-0.147		
p-value	0.154	0.002	0.046	0.391		
4-4.99	0.123	-0.506	-0.574	-0.246	0.229	
p-value	0.476	0.002	0.000	0.148	0.178	
5>	0.059	-0.413	-0.279	-0.519	0.091	0.592
p-value	0.733	0.012	0.100	0.001	0.596	0.000

Table 21. Factor pattern matrix and communalities for trial 1.

V variable	Factor 1	Factor 2	Factor 3	Communality
CP3	-0.354	-0.699	0.045	0.616
<.99	0.728	0.067	0.416	0.708
1-1.99	0.648	0.406	-0.420	0.761
2-2.99	0.276	-0.841	0.153	0.807
3-3.99	-0.575	-0.214	-0.665	0.819
4-4.99	-0.834	0.134	0.316	0.814
5 >	-0.709	0.478	0.248	0.792
Variance	2.6820	1.6575	0.9782	5.3176
% Var.	0.383	0.237	0.140	0.760

The factor pattern matrix contains the unrotated factor loadings. These are the coefficients that relate the variables to the three factors. They are the standardized regression coefficients in the multiple regression equation with the original variable as the dependent variable and the factors as the independent variables. They indicate how much weight is assigned to each factor. For instance, the CP3 index can be expressed as:

$$CP3 = -.354F_1 - .699F_2 + .045F_3$$

In order to identify meaningful factors that summarize sets of closely related variables, a varimax rotation was performed (table 22). The variables that had large loadings for the same factor were grouped together. Small factor loadings with an absolute value less than 0.5 were removed from the table. The rotated factor matrix indicates that factor 1 was highly negatively correlated with beets of 1-1.99 lb and positively correlated with beets of 4 lb and larger. Factor 2 was positively correlated with the CP3 value and beets of 2-2.99 lb. Factor 3 was highly negatively correlated with the smallest beets and positively correlated with beets weighing 3-3.99 lb. Factor 1 could be labeled Big Beets, factor 2, Desirable Beets and factor 3, Above Average. These are not independent variables, rather labels for groups of variables.

Table 22. Rotated factor loadings and communalities (Varimax rotation).

Variable	Factor 1	Factor 2	Factor 3	Communality
CP3	-	0.726	-	0.616
< .99	-	-	-0.768	0.708
1-1.99	-0.626	-0.598	-	0.761
2-2.99	-	0.801	-	0.807
3-3.99	-	-	0.899	0.819
4-4.99	0.872	-	-	0.814
5 >	0.832	-	-	0.792
Variance	2.1157	1.6226	1.5794	5.3176
% Var.	0.302	0.232	0.226	0.760

Referring to the unrotated factor loadings, the CP3 value can now be expressed as:

$$CP3 = -.354(\text{Large Beets}) - .699(\text{Desirable Beets}) + .045(\text{Above Average})$$

A similar analysis was performed for trial 2. The correlation coefficients are provided in table 23. As in trial 1, several variables are highly intercorrelated.

Table 23. Correlation (Pearson) coefficients for trial 2.

	CP3	< .99	1-1.99	2-2.99	3-3.99	4-4.99
< .99	0.095					
p-value	0.580					
1-1.99	0.427	0.144				
p-value	0.009	0.404				
2-2.99	-0.002	-0.428	-0.559			
p-value	0.989	0.009	0.000			
3-3.99	-0.557	-0.415	-0.512	0.057		
p-value	0.000	0.012	0.001	0.741		
4-4.99	-0.318	-0.476	-0.530	0.210	0.434	
p-value	0.059	0.003	0.001	0.218	0.008	
5 >	-0.344	-0.498	-0.467	0.339	0.377	0.523
p-value	0.040	0.002	0.004	0.043	0.023	0.001

Principal component factor analysis of the correlation matrix provided three factors accounting for about 78% of the variance among variables (Table 24).

Table 24. Factor pattern matrix and communalities for trial 2.

Variable	Factor 1	Factor 2	Factor 3	Communality
CP3	0.574	-0.647	0.140	0.767
< .99	0.631	0.406	-0.573	0.890
1-1.99	0.774	-0.017	0.567	0.920
2-2.99	-0.514	-0.684	-0.418	0.907
3-3.99	-0.719	0.440	0.149	0.732
4-4.99	-0.758	0.006	0.194	0.612
5 >	-0.760	-0.128	0.156	0.618
Variance	3.2571	1.2625	0.9276	5.4472
% Var.	0.465	0.180	0.133	0.778

The CP3 index can now be expressed as: $CP3 = .574F_1 - .647F_2 + .140F_3$

The rotated factor matrix (Table 25) indicates that each of the three factors accounted for a similar proportion of the variance. Factor 1 was highly correlated negatively correlated with CP3 and beets of 3-3.99 lb, factor 2 was highly positively correlated with the smallest beets and negatively correlated with the largest beets, and factor 3 was positively correlated with beets of 1-1.99 lb and negatively correlated with

beets of 2-2.99 lb. Factor 1 can be labeled Above Average, factor 2 Small, and factor 3 Desirable.

Table 25. Rotated factor loadings and communalities (Varimax rotation).

Variable	Factor 1	Factor 2	Factor 3	Communality
CP3	-0.875	-	-	0.767
< .99	-	0.937	-	0.890
1-1.99	-0.574	-	0.763	0.920
2-2.99	-	-	-0.897	0.907
3-3.99	0.759	-	-	0.732
4-4.99	-	-0.608	-	0.612
5 >	-	-0.631	-	0.618
Variance	2.0052	1.8915	1.5506	5.4472
% Var.	0.286	0.270	0.222	0.778

Based on the rotated factor loading, the CP3 can be expressed as:

$$CP3 = .574(\text{Above Average})F_1 - .647(\text{Small})F_2 + .140(\text{Desirable})$$

The use of principle component analysis to characterize the relationship between CP3 and beet size uniformity provided very different results in each of the trials evaluated. A low CP3 score can be obtained by either having excessive narrow plant spacing or excessive wide plant spacing. The effect of poor plant spacing is likely to be quite different in either case. Multiple linear regression and principle component analysis provide a means to describe and understand the impact of CP3 on a particular sampling of sugar beets, but such tools have no useful predictive capabilities. While plant spacing does affect beet size uniformity, a measure of plant spacing uniformity other than CP3 will be needed.

4.4 STEPWISE REGRESSION

Even though the variables, 3cm mode range and rate of emergence, provided significant differences between the treatments, the yield was not affected much. A stepwise regression was performed, to see what is it that affects yield the most. Table 26, shows the independent variables that affect the dependent variables the most.

Table 26. Stepwise regression for the dependent variables of RWSA, CP3, Stand10, Stand20 and Stand30 in trials 1, 2 and 3.

<u>Trial</u>	<u>Depended variable</u>	<u>Independent variable</u>	<u>Partial R²</u>	<u>Model R²</u>	<u>F-value</u>	<u>P-value</u>
1	RWSA	1. Yield	0.9157	0.9157	890.76	0.0001
		2. RWST	0.0836	0.9993	10175.3	0.0001
2	RWSA	1. yield	0.9826	0.9826	4636.58	0.0001
		2. RWST	0.0168	0.9994	2472.34	0.0001
1	CP3	1. Speed	0.1678	0.1678	16.53	0.0001
		2. Seed	0.1217	0.2895	13.88	0.0004
		3. Planter	0.0204	0.3099	2.36	0.1280
2	CP3	1. Planter	0.1331	0.1331	12.59	0.0006
		2. Seed	0.0331	0.2938	3.96	0.0501
3	CP3	1. Seed	0.0784	0.3689	10.06	0.0021
		2. Speed	0.0329	0.4018	4.41	0.0390
		3. Planter	0.0175	0.4193	2.38	0.1269
2	Stand10	1. Seed	0.0488	0.7368	15.01	0.0002
3	Stand10	1. Seed	0.2386	0.4930	38.11	0.0001
1	Stand20	1. Seed	0.0008	0.9812	3.28	0.0738
2	Stand30	1. Seed	0.0015	0.9636	3.28	0.0738
3	Stand30	1. Seed	0.0264	0.7617	2.52	0.1163

4.4.1 Recoverable White Sugar per Acre (RWSA)

The RWSA for trial 1 and 2, was mainly influenced by the yield, tons/acre, with the partial R² ranging from 0.9157 to 0.9826. This outcome was expected because RWSA is related to yield. It is the amount of sugar which was recovered from the crop. The fact that the RWSA was not affected by the plant spacing uniformity implies that the planter's seed and speeds which are directly related to an improved plant spacing uniformity did not help a lot for the improvement of the amount of recoverable white sugar per acre.

4.4.2 3cm Mode Range (CP3)

The CP3 for trial 1, 2 and 3 was influenced by planter seed and speed with a partial R² ranging from 0.0175 to 0.1678. There was not a specific pattern however, on which is first or last. Different trials ranked the three variables in different order. This outcome was again expected and proved that the plant spacing uniformity does get influenced by planter seed and speed. In addition, there was no sign that the plant spacing

uniformity is influencing yield. This might suggest that planter seed speed does not help for an improved yield.

4.4.3 Rate of Emergence

The 10, 20 and 30-day stands, dependent variables were influenced by the type of seed used. The partial R^2 was ranging from 0.0008 to 0.2386. The importance of seed was one of the main issues for an improved rate of emergence. This outcome provides a prove that indeed the seed is an important factor for better rate of emergence. However, the rate of emergence did not improve yield which is one of the goals of the study. This might suggest that seed does not help for an improved yield.

CHAPTER 5

5. CONCLUSION

Evaluating the field performance of sugar beet planters is a useful tool in measuring the suitability of planting systems.

1. Plant-to-stand planter performance was greatly influenced by available soil moisture. When soil moisture was adequate, there was little difference among planters measured as rate of emergence or final plant population. In dry soils the general purpose planters tended to provide a more rapid emergence, likely due to their ability to maintain a constant seeding depth and provide good seed to soil contact.
2. The fasonated seed tended to provide a more rapid rate of emergence in warm soil, the pelleted seed in cool soil.
3. The Accord planter provided the best plant spacing uniformity at both 4.8 km/h and 7.3 km/h.
4. When the forward travel speed of the planter was held constant there was little difference in plant spacing uniformity between the pelleted and fasonated seed treatments.
5. The slower forward travel speed (4.8 km/h) tended to provide for a more uniform plant spacing than the faster travel speed (7.3 km/h).
6. The three centimeter mode range alone was not a good predictor of beet size uniformity.
7. There were no consistent differences in beet yield, sugar content, clear

juice purity or other standard measures of beet yield and quality due to seed treatment or planter selection.

CHAPTER 6

6. RECOMMENDATIONS

One problem that was faced in the analysis was the small number of plant spacing and beets collected. The relatively small amount of data made it difficult to differentiate components. It will be helpful to collect a population of at least 200. That will reduce the standard error and eliminate any misleading issues.

The comparison of plant spacing uniformity with beet size generated problems during analysis. Multicollinearity did not allow a normal explanation of the analysis. A more tedious but more accurate approach would be to compare beets with plant spacing that come from the exact same location. In other words, identify specific locations and from there, count the plant spacing at that location, and also the weight of the beet at that location.

A comparison of the performance of the planter in the field with the performance of the planter in the lab could identify parts of the planter that are not working properly and help in improving the general performance of the planter in the field.

APPENDIX A

Table A. Dated activities of trials 1 and 2, year 2000

Activities	Date
Moldboard plowed	Fall 1999
Fertilizer 46-0-0 application	3/3/00
Field plot traced	4/14/00
Shallow cultivation	4/17/00
Planter adjustments	4/18/00
Planting	4/18/00
soil moisture sampling (wet sample weight)	4/28/00
soil moisture sampling (dry sample weight)	5/4/00
soil moisture sampling (wet sample weight)	5/9/00
soil moisture sampling (dry sample weight)	5/16/00
soil moisture sampling (wet sample weight)	5/15/00
soil moisture sampling (dry sample weight)	5/18/00
soil moisture sampling (wet sample weight)	5/21/00
soil moisture sampling (dry sample weight)	6/1/00
Stand count, 10-day	5/8/00
Stand count, 20-day	5/21/00
Stand count, 30-day	5/31/00
Plant spacing count	5/30/00
Herbicide application (Norton and Pyramin DF)	6/31/00
Fungicide application (Super Tin and Emminent)	6/31/00
Row cultivation	6/5/00
Topping the beets	10/2/00
Final stand measurement	10/2/00
Hand-digging	10/3/00
Machine harvest	10/4/00
Laboratory sample results	11/1/00
Analysis of variables	12/1/00

Table B. Dated activities of trial 3, year 2001.

Activities	Date
Moldboard plowed	Fall 2000
Fertilizer 46-0-0 application	3/20/01
Field plot traced	4/26/01
Shallow cultivation	5/01/01
Planter adjustments	5/01/01
Planting	5/01/01
Soil moisture sampling (Weather station start date)	5/09/01
Soil moisture sampling (Weather station end date)	5/31/01
Stand count, 10-day	5/07/01
Stand count, 20-day	5/20/01
Stand count, 30-day	5/31/01
Plant spacing count	6/07/01

APPENDIX B

Table A. Planter adjustments.

Planter	Accord	John Deere		Monocam		Stanhay
Seed	E-17 4m PAT Pellet	E-17 4m PAT Pellet	E-17 4m PAT Pellet	E-17 4m PAT Pellet	E-17 4m PAT Pellet	E-17 4m PAT Pellet
Tractor gear	5th gear, 1800rpm	5th gear, 1800rpm	5th gear, 1800rpm	5th gear, 1800rpm	5th gear, 1800rpm	5th gear, 1800rpm
Sprocket #1	21Z	Low range driver, #29	Low range driver, #29	Upper (I)		
Sprocket #2	21Z	Low range driver, #28	Low range driver, #28	Lower (B)		
Primary plate	A6			DN 4020 (6112A)	6903862	6903862
Secondary plate	N/A			40	6903861	6903864
Number of holes on plate					25	
Plate's hole diameter (mm.)					2.3	1.2
Vacuum pressure (psig)		3.5	2.0	5.5	70	60
Down pressure (in.)		Third notch from the back	Third notch from the back	1/2	1 3/16	1 3/16
Furrow opener #1, type	V-trench opener	V-trench opener	V-trench opener	V-trench opener	Runner opener	Runner opener
Furrow opener #1, diameter (in.)	9	15.5	15.5	15.5	N/A	N/A
Furrow opener #1, width (in.)	3	4.5	4.5	4.5	N/A	N/A
Furrow opener #2, type	Runner opener	N/A	N/A	N/A	N/A	N/A
Seed knocker				Set to 1	Set to 4	Set to zero
Depth adjustment		Third notch from the back	Third notch from the back	Between B and D	6th hole from the bottom	6th hole from the bottom
Drop distance (in.)	2	21	21	20.5	4	4
Press wheel, type	Single rubber wheel	Two wheels at an angle	Two wheels at an angle	Two wheels at an angle	Single rubber wheel	Single rubber wheel
Press wheel, diameter (in.)	13	12	12	12	11.5	11.5
Press wheel, width (in.)	3.5	1	1	1.2	3.45	3.45
Seed pecker wheel, diameter (in.)	6.5	N/A	N/A	N/A	6	6
Seed pecker wheel, width (in.)	0.5	N/A	N/A	N/A	0.63	0.63
Gauge wheel, type	V-trench opener	V-trench opener	V-trench opener	V-trench opener	Single rubber wheel	Single rubber wheel
Gauge wheel, diameter (in.)	9	15.5	15.5	15.5	12	12
Gauge wheel, width (in.)	3	4.5	4.5	4.5	4.5	4.5

APPENDIX C

Trial 1.

1. Yield .

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	555.10	30.84	7.76	<.0001
Error	65	258.16	3.97		
Corrected total	83	813.26			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	6.22	1.24	0.31	0.90
treat	13	548.88	42.22	10.63	<.0001

2. Sugar.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	2.49	0.14	0.92	0.56
Error	65	9.77	0.15		
Corrected total	83	12.26			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	1.16	0.23	1.55	0.19
treat	13	1.33	0.10	0.68	0.77

3. CJP.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	5.03	0.28	1.05	0.42
Error	65	17.32	0.27		
Corrected total	83	22.35			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	1.66	0.33	1.25	0.30
treat	13	3.37	0.26	0.97	0.49

4. RWST.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	594.26	33.01	0.70	0.80
Error	65	3078.03	47.35		
Corrected total	83	3672.29			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	334.09	66.82	1.41	0.23
treat	13	260.16	20.01	0.42	0.96

5. RWSA.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	32305877.19	1794770.96	5.30	<.0001
Error	65	21991705.38	338333.93		
Corrected total	83	54297582.57			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	364691.29	72938.26	0.22	0.95
treat	13	31941185.90	2457014.30	7.26	<.0001

6. CP3.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	4088.57	227.14	7.17	<.0001
Error	65	2060.23	31.70		
Corrected total	83	6148.80			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	146.61	29.32	0.93	0.47
treat	13	3941.97	303.23	9.57	<.0001

7. Stand 10.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.91	0.05	5.43	<.0001
Error	65	0.61	0.01		
Corrected total	83	1.52			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.15	0.03	3.16	0.01
treat	13	0.77	0.06	6.31	<.0001

8. Stand 20.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.94	0.05	6.61	<.0001
Error	65	0.51	0.01		
Corrected total	83	1.46			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.20	0.04	5.12	0.00
treat	13	0.74	0.06	7.18	<.0001

9. Stand 30.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.88	0.05	5.75	<.0001
Error	65	0.55	0.01		
Corrected total	83	1.43			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.20	0.04	4.80	0.00
treat	13	0.67	0.05	6.11	<.0001

10. Final Stand.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	1.04	0.06	6.30	<.0001
Error	65	0.60	0.01		
Corrected total	83	1.63			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.20	0.04	4.29	0.00
treat	13	0.84	0.06	7.07	<.0001

Trial 2.**1. Yield .**

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	961.76	53.43	3.13	0.00
Error	65	1108.60	17.06		
Corrected total	83	2070.36			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	45.17	9.03	0.53	0.75
treat	13	916.59	70.51	4.13	<.0001

2. Sugar.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	1.26	0.07	1.01	0.46
Error	65	4.50	0.07		
Corrected total	83	5.75			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.54	0.11	1.56	0.18
treat	13	0.72	0.06	0.80	0.66

3. CJP.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	18.00	1.00	0.96	0.52
Error	65	67.82	1.04		
Corrected total	83	85.83			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	3.92	0.78	0.75	0.59
treat	13	14.08	1.08	1.04	0.43

4. RWST.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	848.43	47.13	0.90	0.58
Error	65	3398.52	52.28		
Corrected total	83	4246.95			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	319.81	63.96	1.22	0.31
treat	13	528.62	40.66	0.78	0.68

5. RWSA.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	64421535.70	3578974.20	3.07	0.00
Error	65	75748358.30	1165359.40		
Corrected total	83	140169894.00			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	3471240.54	694248.11	0.60	0.70
treat	13	60950295.20	4688484.25	4.02	<.0001

6. CP3.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	6366.78	353.71	10.92	<.0001
Error	65	2104.98	32.38		
Corrected total	83	8471.76			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	181.50	36.30	1.12	0.36
treat	13	6185.28	475.79	14.69	<.0001

7. Stand 10.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.51	0.03	3.71	<.0001
Error	65	0.50	0.01		
Corrected total	83	1.01			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.14	0.03	3.60	0.01
treat	13	0.38	0.03	3.76	0.00

8. Stand 20.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.90	0.05	7.71	<.0001
Error	65	0.42	0.01		
Corrected total	83	1.33			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.25	0.05	7.61	<.0001
treat	13	0.65	0.05	7.75	<.0001

9. Stand 30.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.87	0.05	8.22	<.0001
Error	65	0.38	0.01		
Corrected total	83	1.25			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.22	0.04	7.35	<.0001
treat	13	0.65	0.05	8.55	<.0001

10. Final Stand.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.72	0.04	5.32	<.0001
Error	65	0.49	0.01		
Corrected total	83	1.22			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.14	0.03	3.60	0.01
treat	13	0.59	0.05	5.99	<.0001

Trial 3.**1. Stand 10.**

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.47	0.03	6.94	<.0001
Error	65	0.25	0.00		
Corrected total	83	0.72			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.05	0.01	2.88	0.02
treat	13	0.42	0.03	8.50	<.0001

2. Stand 20.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.69	0.04	8.88	<.0001
Error	65	0.28	0.00		
Corrected total	83	0.98			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.05	0.01	2.12	0.07
treat	13	0.65	0.05	11.48	<.0001

3. Stand 30.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	0.45	0.02	6.61	<.0001
Error	65	0.24	0.00		
Corrected total	83	0.69			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.04	0.01	1.93	0.10
treat	13	0.41	0.03	8.42	<.0001

4. CP3 .

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	18	4896.35	272.02	11.24	<.0001
Error	65	1573.28	24.20		
Corrected total	83	6469.64			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	267.68	53.54	2.21	0.06
treat	13	4628.67	356.05	14.71	<.0001

Trial 1, 2.**1. Yield.**

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	6733.54	210.42	20.40	<.0001
Error	135	1392.83	10.32		
Corrected total	167	8126.37			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	25.31	5.06	0.49	0.78
treat	13	1043.94	80.30	7.78	<.0001
trial	1	5242.75	5242.75	508.15	<.0001
treat*trial	13	421.54	32.43	3.14	0.00

2. Sugar.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	8.64	0.27	2.33	0.00
Error	135	15.66	0.12		
Corrected total	167	24.30			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.30	0.06	0.52	0.76
treat	13	0.85	0.07	0.56	0.88
trial	1	6.29	6.29	54.21	<.0001
treat*trial	13	1.20	0.09	0.79	0.67

3. CJP.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	84.71	2.65	4.11	<.0001
Error	135	87.01	0.64		
Corrected total	167	171.73			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	3.71	0.74	1.15	0.34
treat	13	12.69	0.98	1.51	0.12
trial	1	63.55	63.55	98.60	<.0001
treat*trial	13	4.76	0.37	0.57	0.88

4. RWST.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	1021.20	31.91	0.62	0.94
Error	135	6917.93	51.24		
Corrected total	167	7939.13			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	212.53	42.51	0.83	0.53
treat	13	316.46	24.34	0.48	0.94
trial	1	19.89	19.89	0.39	0.53
treat*trial	13	472.32	36.33	0.71	0.75

5. RWSA.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
			13810331.7		
Model	32	441930613.90	0	18.79	<.0001
Error	135	99201661.70	734827.10		
Corrected total	167	541132275.70			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	2374333.80	474866.80	0.65	0.66
treat	13	65882831.90	5067910.10	6.90	<.0001
trial	1	346664799.10	346664799.10	471.76	<.0001
treat*trial	13	27008649.20	2077588.40	2.83	0.00

6. CP3.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	10260.70	320.65	9.86	<.0001
Error	135	4390.38	32.52		
Corrected total	167	14651.07			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	102.93	20.59	0.63	0.67
treat	13	2139.07	164.54	5.06	<.0001
trial	1	30.52	30.52	0.94	0.33
treat*trial	13	7988.18	614.48	18.89	<.0001

7. Stand 10.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	2.86	0.09	10.17	<.0001
Error	135	1.18	0.01		
Corrected total	167	4.04			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.21	0.04	4.78	0.00
treat	13	0.49	0.04	4.29	<.0001
trial	1	1.50	1.50	171.34	<.0001
treat*trial	13	0.65	0.05	5.73	<.0001

8. Stand 20.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	2.01	0.06	8.45	<.0001
Error	135	1.00	0.01		
Corrected total	167	3.01			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.39	0.08	10.38	<.0001
treat	13	0.50	0.04	5.17	<.0001
trial	1	0.23	0.23	30.61	<.0001
treat*trial	13	0.90	0.07	9.27	<.0001

9. Stand 30.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	1.94	0.06	8.47	<.0001
Error	135	0.96	0.01		
Corrected total	167	2.90			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.39	0.08	10.87	<.0001
treat	13	0.43	0.03	4.63	<.0001
trial	1	0.22	0.22	30.81	<.0001
treat*trial	13	0.90	0.07	9.66	<.0001

10. Final Stand .

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	32	1.83	0.06	6.74	<.0001
Error	135	1.15	0.01		
Corrected total	167	2.98			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
block	5	0.27	0.05	6.44	<.0001
treat	13	0.54	0.04	4.90	<.0001
trial	1	0.13	0.13	14.90	0.00
treat*trial	13	0.89	0.07	8.06	<.0001

Trials 1, 2 and 3.

1. CP3.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	44	27463.54	624.17	24.46	<.0001
Error	135	3445.55	25.52		
Corrected total	179	30909.09			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
year	1	14391.91	14391.91	563.89	<.0001
trial*year	1	144.32	144.32	5.65	0.02
block*trial*year	15	244.61	16.31	0.64	0.84
treat	9	3210.36	356.71	13.98	<.0001
treat*year	9	3297.21	366.36	14.35	<.0001
treat*trial*year	9	6849.53	761.06	29.82	<.0001

2. Stand 10.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	44	6.33	0.14	21.19	<.0001
Error	135	0.92	0.01		
Corrected total	179	7.25			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
year	1	3.60	3.60	530.53	<.0001
trial*year	1	1.68	1.68	247.84	<.0001
block*trial*year	15	0.25	0.02	2.47	0.00
treat	9	0.24	0.03	3.96	0.00
treat*year	9	0.17	0.02	2.73	0.01
treat*trial*year	9	0.40	0.04	6.48	<.0001

3. Stand 20.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	44	2.39	0.05	8.68	<.0001
Error	135	0.84	0.01		
Corrected total	179	3.23			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
year	1	0.03	0.03	5.23	0.02
trial*year	1	0.44	0.44	70.17	<.0001
block*trial*year	15	0.33	0.02	3.53	<.0001
treat	9	0.71	0.08	12.62	<.0001
treat*year	9	0.30	0.03	5.26	<.0001
treat*trial*year	9	0.66	0.07	11.68	<.0001

4. Stand 30.

	df	Sum of Squares	Mean Square	F-value	Significance p-value
Model	44	2.30	0.05	8.45	<.0001
Error	135	0.83	0.01		
Corrected total	179	3.13			

Variables	df	Sum of Squares	Mean Square	F-value	Significance p-value
year	1	0.22	0.22	35.71	<.0001
trial*year	1	0.40	0.40	64.44	<.0001
block*trial*year	15	0.32	0.02	3.44	<.0001
treat	9	0.52	0.06	9.36	<.0001
treat*year	9	0.18	0.02	3.24	0.00
treat*trial*year	9	0.69	0.08	12.47	<.0001

APPENDIX D

Figure A. Rainfall data from April 15th to May 31st, 2000.

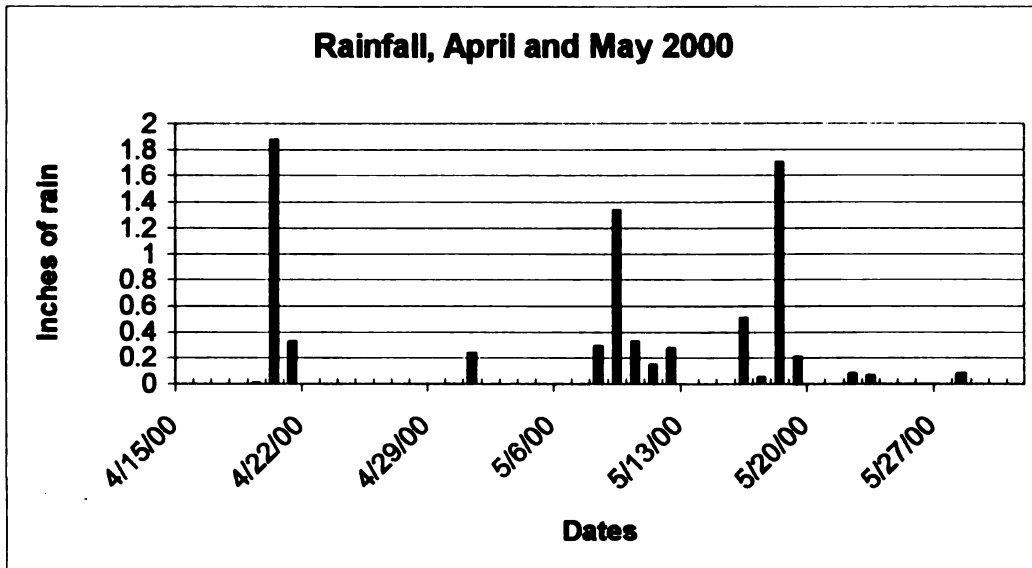


Figure B. Rainfall data from April 15th to May 31st, 2001.

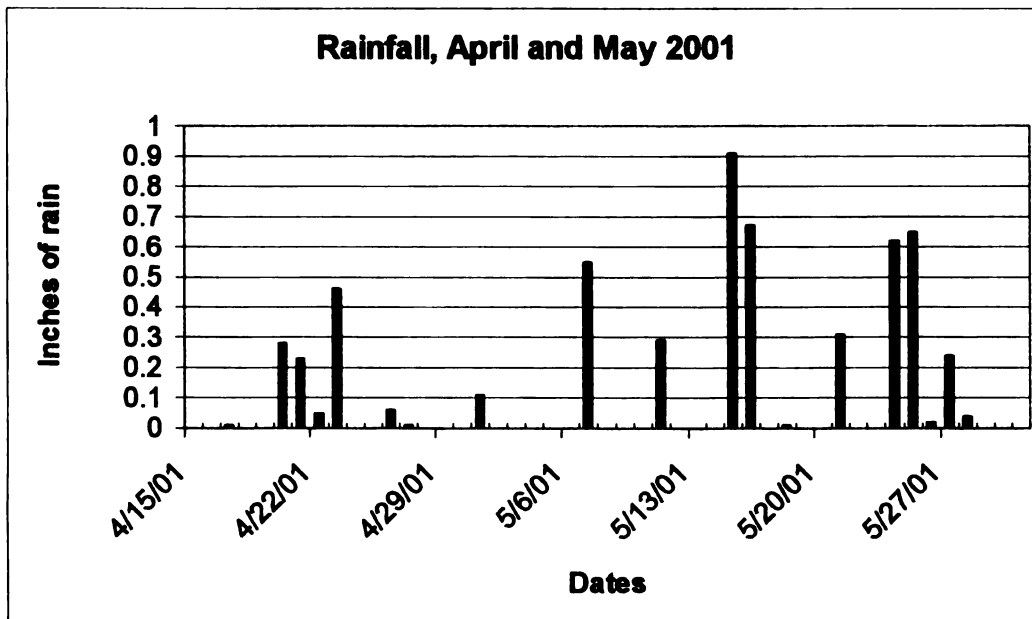


Figure C. Soil temperature data from April 15th to May 31st, 2000.

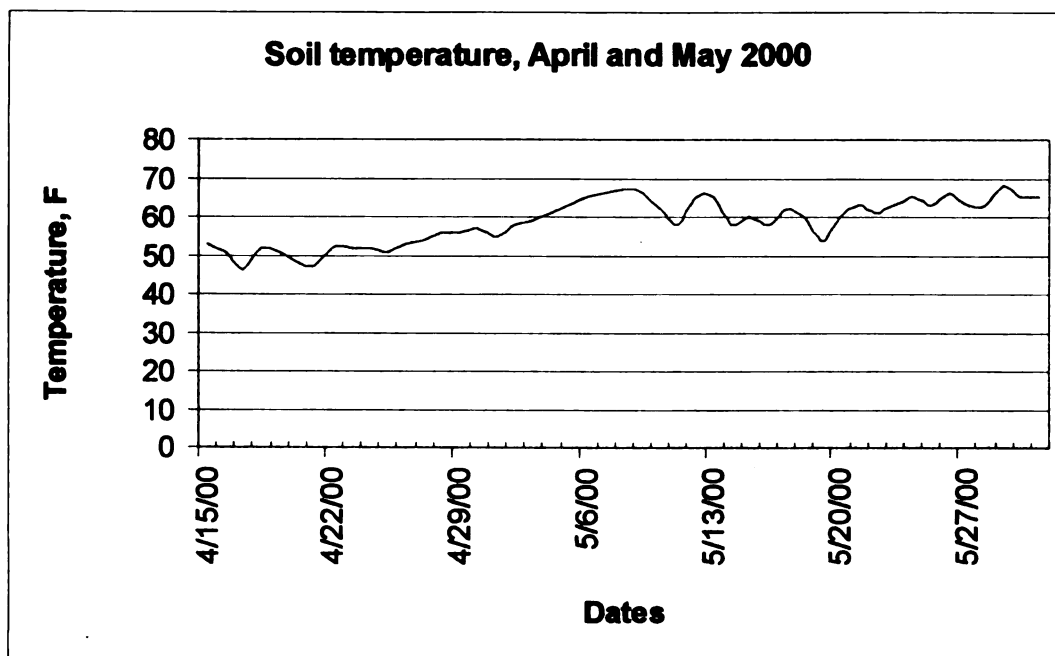


Figure D. Soil temperature data from April 15th to May 31st, 2001.

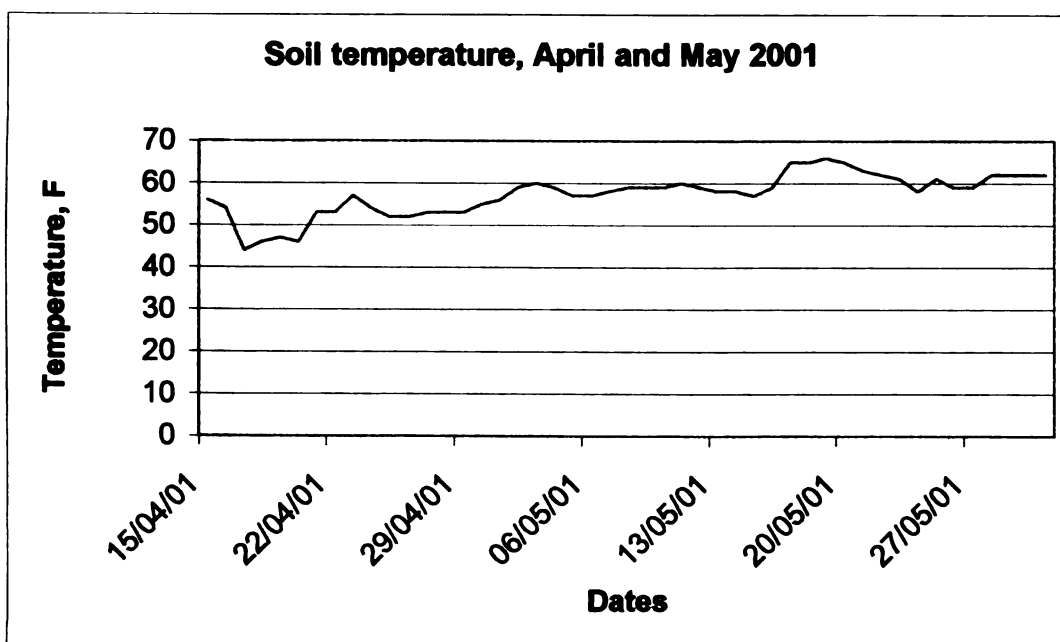


Figure E. Soil moisture data for the first two trials (04/28-05/04).

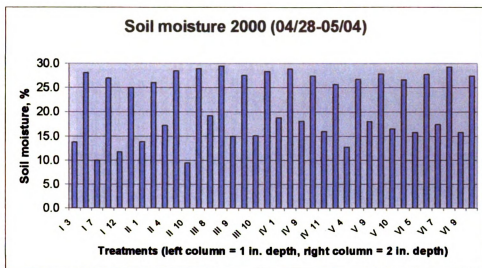


Figure F. Soil moisture data for the first two trials (05/09-05/16).

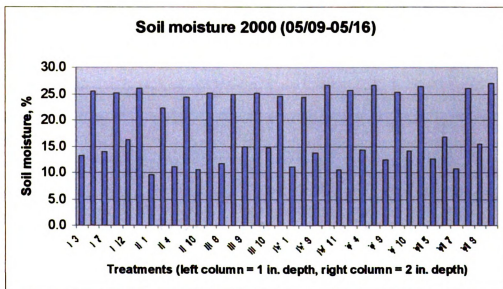


Figure G. Soil moisture data for the first two trials (05/21-06/01).

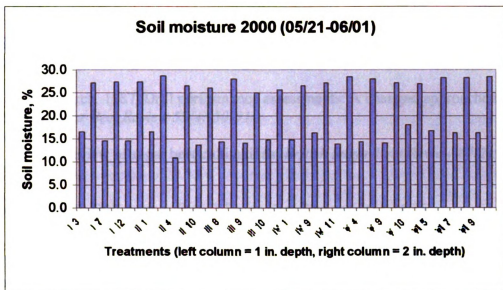
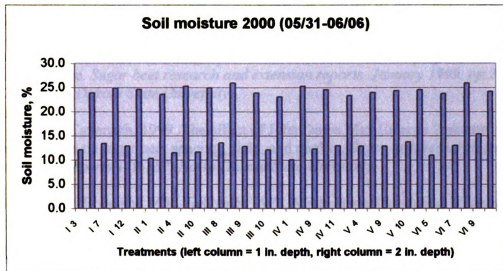


Figure H. Soil moisture data for the first two trials (05/31-06/06).



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