ADAPTATION OF A PNEUMATIC ROW CROP PLANTER FOR PRECISION DRILLING OF WHEAT

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ABSTRACT

ADAPTATION OF A PNEUMATIC ROW CROP PLANTER
FOR PRECISION DRILLING
OF WHEAT

By

Oscar Antonio Braunbeck

The high capacity of the pneumatic row crop planter offered the opportunity to test the effect of low seeding rates on grain yield of wheat when using a more precise seed distribution.

The planter was tested in the laboratory by measuring seed delivery time and evaluating its variance, which is related to the variance of seed spacing in the furrow. Air pressure, delivery tube configuration, and ground speed were found to significantly affect the uniformity of seed spacing.

The overall performance of the planter was compared with a conventional grain drill by means of grain yield tests repeated during two years. Grain yield was significantly higher and less affected by seeding rate for planting done with the pneumatic planter.

The results indicate that precision drilling of wheat is a promising alternative, especially for high-cost seeds such as hybrid wheat.

Approved Robert H. Wilkinson
Major Professor

Approved B A Stout
Department Chairman

Date Nov. 7, 1973

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By

Oscar Antonio Braunbeck

A DISSERTATION

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I dedicate this work to my parents. My father, Antonio, a hard-working farmer in Argentina, and my mother, Maria, a dedicated housewife, have given me the opportunity to complete a college education -- an opportunity they never had.

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The author sincerely appreciates the guidance and encouragement of Dr. Robert H. Wilkinson on this project and throughout the course of my graduate work.

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CHAPTER I

INTRODUCTION

Wheat is an important crop world wide.

It plays a major role in the feeding of the world and thus is an important commodity on the world market for those countries who are able to produce it for export: Argentina (3.0% of world production), Australia and New Zealand (3.1%), Canada (6.6%), and the United States (13.6%).

Present world conditions, production capabilities, competition from other grains and livestock have kept wheat demand rather stable. However, world population that increases the demand for foodstuffs will greatly increase the demand for wheat.

The population of the world is now approximately 3.6 billion people. In less than 30 years, by the year 2000, world population will be between 6 and 7 billion, approximately double the present number.

When one recognizes that there are many areas of the world today that do not have sufficient food and are starving, the challenge to provide food for more than double this number of people is staggering.

The Green Revolution has been a major breakthrough and at least temporarily has helped to make many starving nations self-sufficient in rice and small grains. However, food production technology coupled with population (birth) control programs must continue if the future challenge is to be met successfully.

Food production technology is progressing in such areas as high-Lysine corn, synthetic meat from vegetable protein, fish meal and algae-produced protein.

Much of the more recent work in developing countries has been to improve wheat and rice production. The main characteristics of the new varieties, as compared to the traditional ones, are their genetic ability to respond favorably to heavier seeding, and their response to fertilizer is expressed not in increased length of straw but in more tillers and more grain per plant. They are relatively insensitive to the length of the daylight, and are therefore adaptable both to a fairly wide range of latitudes and to planting at different seasons.

The development of new hybrid wheat varieties with their potential for higher yields (and higher costs) suggests the need for improved seeding equipment, capable of a minimum accurate planting rate consistent with a high yield.

There are indications that a more accurate seed spacing gives better yields under certain conditions. If plants are spaced uniformly within the row and rows are spaced as close as possible, the plant can make more efficient use of the applied fertilizer, soil water, and can intercept a higher percentage of available solar energy.

Efforts are being made to improve yields in areas such as breeding, soil management, tillage, etc., but very little is being done to improve seeding equipment.

Seeding of many cereals, such as wheat, barley, and oats, has been done for many years in almost the same fashion all over the world. The first drill-type machine was developed in 1636 by Joseph Locatelli. This machine was improved by Jethro Tull at the end of the 17th century. James Cook and Garret (1785) built a drill with basically the present principle of operation in 1844. What is significant is that in the last century there have been almost no changes in principles for seeding small grain cereals.

The reasons for this lack of drill development are basically the rather insignificant response of cereals to a more precise seed spacing, and the fact that the different types of metering devices that have been introduced over the years were either too complex or were unable to handle the large number of seeds per hectare that some cereals require for optimum yield.

The seed of a new high-yielding hybrid wheat is expected to cost considerably more than present wheat varieties. Thus, the minimum planting rate consistent with maximum yield is desired. This lower seeding rate and accurate distribution needed for hybrid wheat makes the development of an improved planter very attractive.

The pneumatic planter invented by two farmers from Minnesota and developed by International Harvester Company

opens to the farmer the possibility of having just one planting machine. This machine has the potential to row crop planting operations, with seeding rates of approximately 40,000 plants/Ha., and will also (with modification) plant high seed density crops such as wheat, barley, rye, etc., with seeding rates of over 2,500,000 plants/Ha.

If a seeding rate of approximately 2,000,000 plants/Ha. is used, the accuracy of placement is not critical and the only advantage the pneumatic planter has over conventional planting machines is that this one machine could plant both row crops and small grains.

However, the I.H. pneumatic planter has the potential for accurate seed placement of low seeding rates. Presently it is sold only as a row crop planter for corn, beans and sorghum. It was the objective of this project to modify the planter for use as a small grain planter (wheat) and evaluate its accuracy and overall performance.

CHAPTER II

REVIEW OF LITERATURE

Determining the best seeding rate or row spacing for cereals is not a new problem, but there is renewed interest with each new improvement in seed bed preparation methods, varieties, and seeding equipment.

The development of the 400 Cyclo planter opens a new possibility to increase yield of cereals because of a more accurate distribution of seeds. A more precise spacing in the row justifies the use of rows set closer together in an attempt to increase as much as possible the distance to the nearest neighbor seed. It will reduce the competition between plants for water, nutrients, light and air.

Some research reports related to this matter have been compiled and summarized below.

J. H. Baldwin, 1963, at the Norfolk Agricultural Station carried out six trials series dealing with row spacing. Winter wheat was used for these tests with three row spacing of 4, 8, and 12 inches. There was a strong trend toward higher yield for reduced row width. The 4-inch rows produced about 4% more grain than 8-inch rows, and 12-inch rows about 4% less.

Although it is sometimes said that higher seeding rate should be used with narrower row spacing, the four-year Norfolk trial did not support this theory.

One objection to a narrower row spacing might be made because it implies purchasing a new grain drill. However, the metering device of the pneumatic planter presents the advantage of a flexible seed delivery system that allows lateral displacement of the furrow openers over a wide range. If the planter is designed to sow high seed density crops, with narrow row spacing, some furrow openers as well as outlets of the metering device can be eliminated to handle row crops with wider row spacing.

Other objections might be a more complex design and higher draft requirements. These objections can be easily answered. The construction of a narrow spacing planter, even though there is a larger number of furrow openers, has some compensation in the air-powered metering mechanism. It is simpler and easier to maintain than the conventional ones. The increase in draft requirements is not a significant disadvantage. The tractors used at the present time to operate planters have sufficient power for the extra draft required for narrower row spacing.

W. J. Promersberger and C. M. Smallers, 1950, North Dakota, found no significant differences in yield between wheat plots planted in rows 6 and 7 inches apart. Number and weight of weeds were not altered by the different spacing. The stubble ability to hold the combine swath was reduced in the wider spacing.

Kinra, et al., 1960, sowed winter wheat in Michigan with four different row spacings, 7-, 9-, 11-, and 14-inch. Yield was reduced by an increase in row spacing in all cases except one. Row width greater than 7 inches resulted in fewer culms per square foot, which means a reduction in ability to hold swaths.

According to R. Young and A. Baver, 1971, on weedy places there were fewer weeds in 7-inch spaced rows than rows spaced wider apart.

N. C. Stoskopf and E. Reinbergs, 1968, tested winter wheat in Ontario, Canada. They used three seeding rates with narrow (4.5-inch) and conventional row spacing (9-inch). At all three seeding rates the upright-leaved varieties showed a greater yield response to narrow rows than the droopy, wide-leaved check varieties. It seems that the short-strawed, narrow-leaved varieties are able to capture more of the sunlight energy striking a field. Since plants convert sunlight into food, the more uniformly they are spaced, the better they will grow.

B. C. Curtis and T. E. Haus, 1967, found that in cool irrigated areas yields were increased by planting low seeding rates in wide row spacing, 16- to 20-inch. These results were obtained in high altitude, with intense solar radiation, minimum relative humidity, below 40%, and few cloudy days. These very special environmental conditions could be responsible for the results of these experiments.

Weeds were considered a potential problem for the wider row spacing and the use of rotary hoe or spraying was recommended.

In general, high moisture, and late seeding favor heavy seeding rates while light rates are common where low moisture and early seeding prevail.

Long, cool growing seasons contribute to the formation of many heads per plant, which in turn gives normal yield even under low seeding rates. This type of climate could be used to reproduce small quantities of seed, such as hybrid wheat seed that promises to be very expensive to produce.

Guitard, et al., 1961, Alberta, Canada, found significant increases in the yield of wheat with increases in seeding rate, at low seeding rates, in rows 6 inches apart. Wheat, barley, and oats were tested. For all crops, the increase in seeding rate caused a linear increase in the number of plants per acre and a curvilinear decrease in the number of fertile heads per plant, as well as number of kernels per head and 1000-kernel weight.

There is a chance that narrower row spacing plus a more accurate seed spacing in the row will increase the number of heads per plant, kernels per head, and 1000-kernel weight in such a way that yield will remain at normal levels even under lower seeding rates.

A. R. Klatt, 1968, in north central Colorado, obtained maximum or near-maximum yields for seeding rates as low as 5.6 pounds per acre. Yield was maintained at low seeding rates due to a large number of heads per plant and large heads. These factors are compensated for the reduction in plants per acre reaching a maximum yield plateau at densities of 1/4 to 1/7 the standard seeding rates in the area.

D. A. Boyd, 1952, studied several English reports on cereal yield as a function of seeding rate. The conclusions are that the normal levels of yield are significantly reduced as a result of sowing less than 1.5 bushels per acre and the optimum seeding rate is about 2 bushels per acre. Row spacing closer than 6.5 - 7 inch gave a small increase of yield. These results seem to be normal in regions of adequate rainfall and good natural fertility. But under more critical conditions, narrower row spacing with low seeding rate may give better results because the plants are in a less competitive situation. Fewer plants with more tillers provide a larger ratio grain weight/weight of straw, which means that less nutrients, water, and energy are used to produce the same amount of grain.

This bibliography provides enough support to promote the concept of planting cereals in narrow rows with precision seed distribution.

Several planter designs have been introduced through the years. Some of them are analyzed below with comparison made to the air-powered 400 Cyclo which was selected for this work.

R. Bainer, 1947, tested the accuracy of vertical and horizontal plate-type planters. Tests were performed in the laboratory and in the field using a dispersion coefficient as mathematical means to compare the performance of different planters for similar seeding rates. Some of the problems found by Bainer in these metering mechanisms are: the seed must have sufficient opportunity to enter the cells. This limits the rim speed of the Cobbley rotor to 33 fpm (10 m/min.). The peripherical speed of the 0.5 m diamter drum of the 400 Cyclo is 54 m/min. Secondly, the type of delivery tube influences the trajectory of the seed, which in turn modifies the seed spacing. The pneumatic planter presents a similar problem in the delivery process. Bainer was able to improve seed spacing by substituting smooth straight seed tubes for the conventional spiral ribbon tubes used on many beet planters at that time.

In considering narrow row spacing (12 cm. or less), the use of a horizontal plate-type planter is limited because of the available space for the necessary components.

R. L. Parish and G. W. Hanger, 1971, developed a vertical plate unit planter as a means of reducing the width of the planter unit and of simplifying the entire mechanism because the vertical plate can drive off the press wheel without angle drive required. Although this design allows narrow row spacing, there still remains the problem of a large number of parts, most of them requiring close tolerances.

H. J. Heege, 1969, found that even though the distribution of seed over the area in case of drilling improves as the row spacing decreases, broadcasting grain still results in a more uniform distribution of seed over the area than drilling does. Yield tests were conducted including conventional grain drills, as well as broadcasters. The results suggest that broadcasting gives a yield increase of about 10% over drilling with a 6-inch row spacing.

The main problem of broadcasting is how to cover the seeds to a uniform depth. Also in case of row crops, the standard harvesting techniques are not applicable.

E. L. Hudspeth and D. F. Wanjura, 1970, used a vacuum wheel with radial fingers to meter single, chemically delinted cottonseed. The vacuum port of the seed-picking fingers is exposed to the seed in the hopper for about 90 degrees of the wheel rotation. The seed was released at the bottom by breaking the vacuum. The performance of this metering device was tested against a conventional double-run wheel grain drill. The superiority of the vacuum wheel was clearly indicated by a coefficient of variability of plant spacing of 25% compared to 80% for the conventional drill. The wheel worked satisfactorily up to a speed of 50 rpm with 20 seed-picking fingers. It indicates a capacity of 17 seeds/sec., which is not enough to sow high seed density cereals at a reasonable ground speed.

The cost of this type of machine would be very high for a high-capacity narrow row spacing cereal planting machine.

A. U. Khan and H. F. McColly, 1968, reported the construction of a new metering and seed delivery mechanism. It had two rotating seed rings with centrifugal force for feeding and discharge. The inner ring with 16 cells contained the seeds. The outer ring with only one cell rotated at 16/15 the speed of the inner ring. One seed feeds from the inner to the outer ring when they line up each revolution. This mechanism is sensitive to seed size, and becomes extremely expensive for a narrow row cereal planter.

CHAPTER III

OBJECTIVES

The overall objectives of this study were:

1. To study the pneumatic planter capacity by identifying the main parameters related to its ability to handle high seed density crops.
2. To investigate the effect of low seeding rates on grain yield of wheat when using a more precise seed distribution.
3. To choose or design a proper test technique for the pneumatic system.
4. To identify and evaluate the main parameters related to the variability of seed spacing.

The principal reason for this investigation was to see if planting rates of hybrid wheat could be decreased by using a precision planting unit.

Seed of hybrid wheat adapted to the Michigan environment was not available during the conduct of these experiments. Hybrid varieties may be able to benefit more from precision planting than the conventional varieties tested herein. Such a possibility cannot be determined until adapted hybrids are available for testing.

CHAPTER IV

THEORY

Seed Distribution Patterns

There are several seed distribution patterns which have been and are being used for different crops according to their requirements. The basic patterns are illustrated in Figure 1.

The trend in cereal planters is toward precision drilling. That is the case of the conventional plate-type planter, the I.H. 400 Cyclo, and the plateless J. Deere planter. These planters are not able to accomplish a perfect precision drilling pattern, but they are considerably more accurate than the conventional grain drill. This investigation is focused on pneumatic planters, specifically the I.H. Cyclo 400.

Principle of Operation

The air-powered metering and delivery system has six main parts:

a) Revolving seed drum (ground driven)

b) PTO or hydraulically driven fan

c) Rubber knock-out wheels

d) Brush cut-off

e) Manifold

f) Delivery hoses

The metering device is a single unit installed in the center of the planter that feeds all the furrow openers.

Seed is gravity fed from a single hopper to the rotating drum through a chute. The distance from the end of the chute to the bottom of the drum as well as the size of the chute determine the level of seed in the drum.

The fan supplies air to the drum and seed hopper. It creates a pressure difference (10 oz/sq.in.) between the inside and outside parts of the drum, which has perforated pockets along its periphery. The pressure difference catches and holds some seeds (1, 2, or 3) in the pocket against the drum as it passes through the bottom part where the seed is accumulated. Just before the seeds reach the top of the revolution, a brush cuts off all but one seed from the pocket. When a line of holes reaches the top of the drum, it passes under the knock-out wheels, which momentarily close off the holes cancelling the pressure difference mentioned before. The seeds separate from the drum by their own weight, and are caught into the air stream that enters the manifold. It conveys them through the delivery hoses to the furrow openers.

To eliminate bounce or scatter of the seed, it is covered almost simultaneously with its deposition in the furrow. Seed spacing in the row is determined by the drive ratio of the ground-driven drum.

The efficiency of the metering device can be expressed in percentage of single, double, triple or missed seeds. The modified sorghum drum used for the wheat

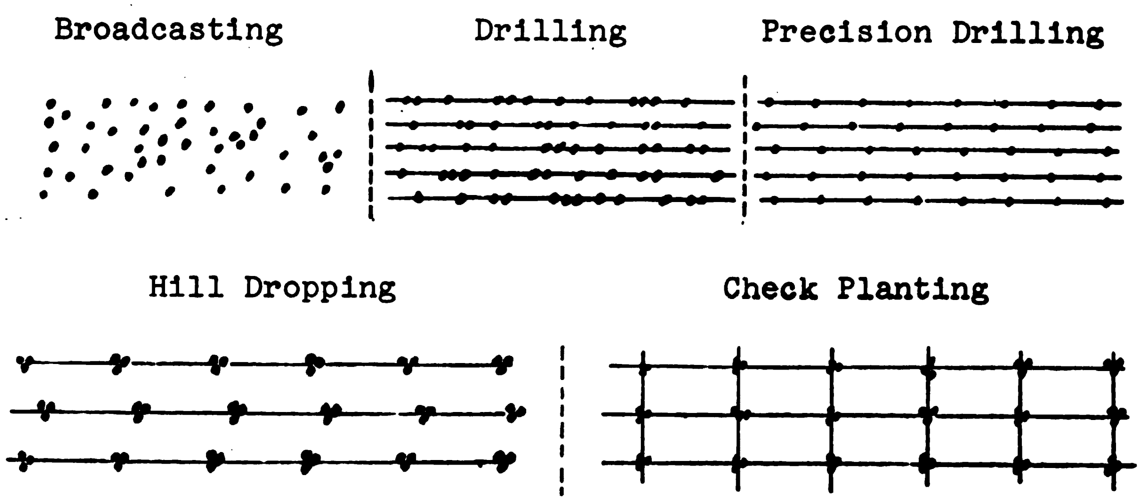


Figure 1. Seed distribution patterns.

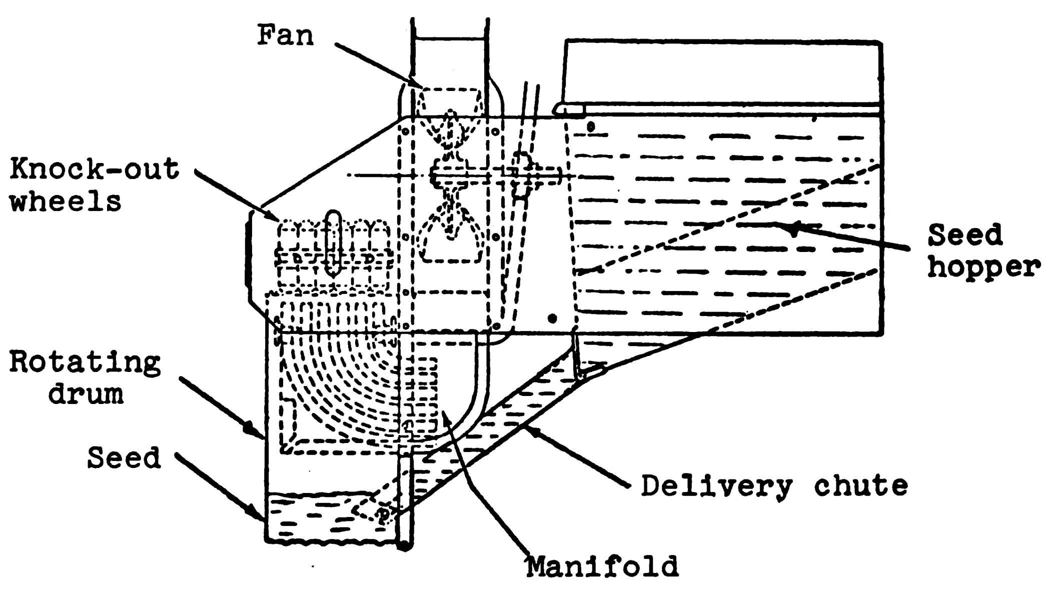


Figure 2. Side view of the air-powered metering and delivery system.

experiments catches over 90% single seeds, almost no triples, and about the same percentages of doubles and missed seeds.

Capacity of the Metering Device

The capacity of a planter can be expressed in different ways such as seeds/Ha or Kg./Ha, but they all depend on ground speed. A low-capacity metering device may be able to plant a high seed density crop working at low speed.

A better indicator of the capacity is the number of seeds per unit time (ST) that the machine can handle. The capacity of the air-powered metering device depends on the following parameters which are related by Equation 1.

d(cm): Distance between holes on the surface of the drum.

D(cm): Diameter of the drum

n(rpm): Rotary speed of the drum.

ST(seeds/sec.): Capacity of the metering mechanism.

$$ST = \frac{\pi}{60} \cdot \frac{n.D}{d} \qquad (1)$$

All the parameters in Equation 1 are limited about the maximum or minimum value they can take on. The diameter of the drum cannot exceed a certain size because of construction impracticality. The minimum value of "d" is limited for similar reasons.

The revolving speed of the drum is limited by the maximum centrifugal force that allows efficient seed release at the discharge point. Centrifugal force must be only a fraction (K) of the seed weight, so as to have a vertical

component of force that will be able to separate the seed from the drum.

Centrifugal force = K · seed weight

$$m \frac{V_t^2}{D/2} = K \cdot m \cdot g$$

$$n = \sqrt{\frac{K \cdot g \cdot 1800}{D \cdot \pi^2}} = 422.76 \sqrt{\frac{K}{D}} \qquad (2)$$

K: Acceleration ratio (centrifugal acceleration/gravity acceleration)

m: Mass of a seed.

g: Acceleration of gravity (980 cm/sq.sec.)

One way to increase the capacity of this metering device is by increasing K. An air jet applied to the seed pocket holes by the rubber knock-out wheels will allow a significant increase in K.

The capacity of the metering device can also be expressed (from Equations 1 and 2) as follows:

$$ST = \sqrt{\frac{g}{2}} \cdot \sqrt{\frac{D \cdot K}{d}} = 22.14 \sqrt{\frac{D \cdot K}{d}} \qquad (3)$$

The number of seeds per unit time to be metered for each row is a function of the ground speed, row spacing, and the optimum seeding rate for the crop being planted.

$$ST = \frac{SR \cdot RS \cdot V}{36} \cdot 10^{-5} \qquad (4)$$

Equation 4 is plotted in Figure 3 for two common row spacings, 12.7 cm (5-inch) and 76.2 cm (30-inch), and different ground speeds.

It can be seen on the plot that high wheat seeding rates (approximately 2.5 million seeds/Ha) can only be planted with a machine capacity of over 70 seeds/sec in narrow rows at normal planting speed (8-9 Km/hr). The capacity of the present design with a 144 pocket drum is about 85 seeds/sec.

Compounding Equations 3 and 4, a general expression is obtained that gives the seeding rate for any set of conditions.

$$RS = 36.0 \cdot \sqrt{\frac{g}{2}} \cdot \frac{\sqrt{D \cdot K} \cdot 10^5}{RS \cdot V \cdot d} = 797.0 \, \frac{\sqrt{D \cdot K} \cdot 10^5}{RS \cdot V \cdot d} \quad (5)$$

From the design standpoint, only the diameter of the drum, acceleration ratio, and distance between holes are variables of interest, which determine the capacity as indicated in Equation 3.

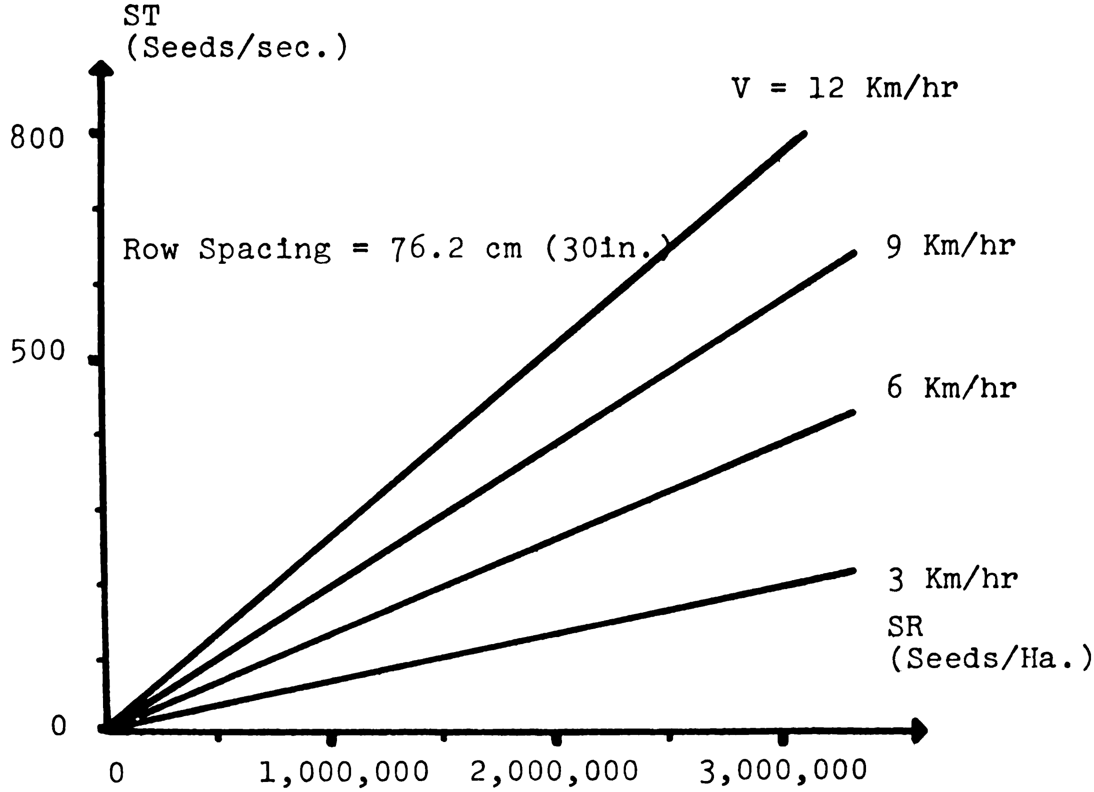
Distance between holes is inversely proportional to the capacity while drum diameter and acceleration ratio are related to ST through a square root. Therefore, any change in "d" produces a more significant variation of ST than a similar change in "D" or "K." Thus the rule to design a high capacity drum is: reduce "d" as much as possible, taking into account construction limitations, and calculate D from Equation 3 after determining the maximum admissible value of K.

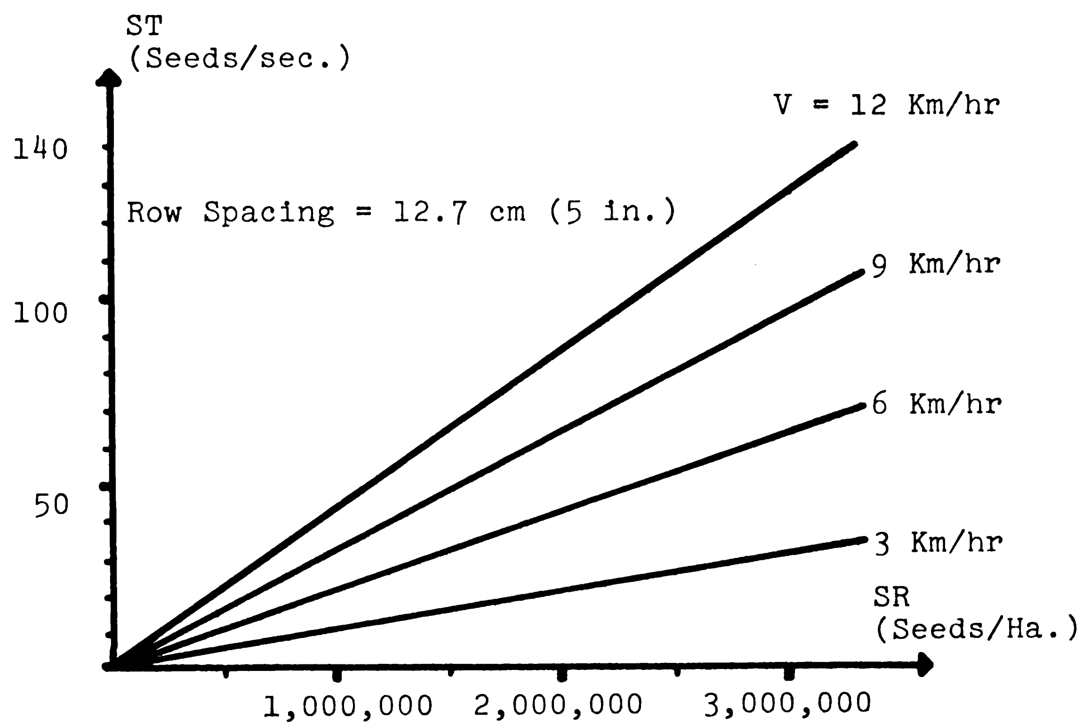
The present design of the 400 Cyclo planter uses a drum with:

$$D = 50 \text{ cm}$$

Figure 3. Machine capacity as a function of ground speed and seeding rate.

SR(seeds/Ha): Seeding rate
RS(cm): Row spacing
V(Km/Hr): Ground speed





$$n = 35 \text{ rpm}$$

which gives K = 0.34 after replacing D and n in Equation 2.

Summarizing, a pneumatic metering device properly designed can handle most high seed density crops.

The weak point of the air-powered metering mechanism is the delivery process which requires special attention.

The variability of seed spacing in the row is a function of the variability of seed delivery time. This can be proved using some of the properties of random variables.

The use of the delivery time as a means to evaluate the variability of seed spacing is due to the fact that delivery time can be measured easier and faster than seed spacing in the furrow or time between seeds at the outlet of the delivery hose. It also permits an evaluation of the variability introduced by the delivery system independently of the furrow opener.

In addition, the delivery hose can be removed and the same evaluation procedure works for the manifold.

The seed spacing at the delivery tube outlet can be expressed:

$$SS = \frac{1000 \cdot V \cdot TS}{36} \qquad (6)$$

SS (cm): Seed spacing in the row.

TS (sec): Time between seeds at delivery hose outlet.

This equation is written under the assumption of no variability introduced by the furrow opener. Even though it is not the actual situation, it is useful to show how the variability of delivery time affects the uniformity of seed spacing.

Seed spacing and time between seeds are normally distributed random variables. From Equation 6 it can be proved that:

$$VAR(SS) = V^2 \times VAR(TS) \times (1000/36)^2 \qquad (7)$$

Measurement of TS is quite difficult because it is a very small quantity for high seeding rates. On the other hand, if the drum skips one seed or picks up two seeds at a time, it will show up in VAR(TS) as a variability due to the delivery process. It can be avoided by working with seed delivery time instead of time between seeds. Both times are related by Equation 8, for which it is assumed that seeds do not pass each other during the delivery process. This will be justified later.

$$TS_i = (t_{i+1} + DT) - t_i \qquad (8)$$

t_i(sec): Delivery time for the i^{th} seed (From the release point at the drum to the outlet of the hose)

DT: Time interval between successive seeds at the release point.

$$VAR(TS) = VAR(t_{i+1}) + 0 + VAR(t_i) - 2Cov(t_i, t_{i+1})$$

t_i and t_{i+1} are successive values of the random variable "t."

Thus: $VAR(t_i) = VAR(t_{i+1}) = VAR(t)$

$$VAR(TS) = 2\ [VAR(t) - Cov(t_i, t_{i+1})] \quad (9)$$

The term $Cov(t_i, t_{i+1})$ represents the interaction between successive values of the delivery time. If a variation in the delivery time of one seed does not affect that of another, it can be said that they are independent, and therefore $Cov(t_{i+1}, t_i) = 0$.

To model TS as in Equation 8 seeds are not supposed to pass each other. For small values of DT this is not the case. To overcome this problem it can be assumed that when one seed reaches the one in front, the latter seed transfers its speed to the former one and vice versa. Under this assumption, seeds will remain in the original order, and the velocity exchange phenomenon justifies the dependence between delivery times for small values of DT[$Cov(t_i, t_{i+1}) \neq 0$] as will be seen when discussing the laboratory data.

From Equations 7 and 9, the variance of seed spacing is:

$$VAR(SS) = 1543.2 \cdot V^2 \cdot [VAR(t) - Cov(t_i, t_{i+1})] \quad (10)$$

According to Equation 4, operation at high ground speed requires a high-capacity metering mechanism. But it is not just a problem of increasing planter capacity to be able to travel at higher speeds, because as shown in Equation 10, the variance of seed spacing increases as a function of the second power of ground speed.

There is a value of VAR(t) for each particular tube. It depends on construction material, length of the tube, and curvature with which the hose has been installed. Attention should be paid to this matter when designing a planter to avoid different quality of seed distribution in different rows.

Figure 4 shows how different quality hoses can make VAR(SS) more or less sensitive to ground speed. One hose (VAR(t) = 0.00025) will only increase the variance of seed spacing by 18.51 sq. cm. when ground speed is taken from 4 to 8 Km/hr. A different hose (VAR(t) = 0.001 sq. sec) increases the variance of seed spacing by 74.08 sq. cm. for similar speed increase. The values of VAR(t) just used are actual values found in the laboratory for different rows of the planter. The tests were conducted on wheat, and include the variability introduced by the manifold and delivery hose.

Variables Involved in a Dynamic Analysis of Pneumatic Conveyance

Most of the research in this area is focused on the evaluation of terminal velocity of particles or pressure drop in ducts, which are important factors when designing a conveyor, but this is not the case of a planter where one seed at a time has to be delivered.

Particles under pneumatic conveyance undergo a number of resistances, such as:

a) Impact

b) Friction

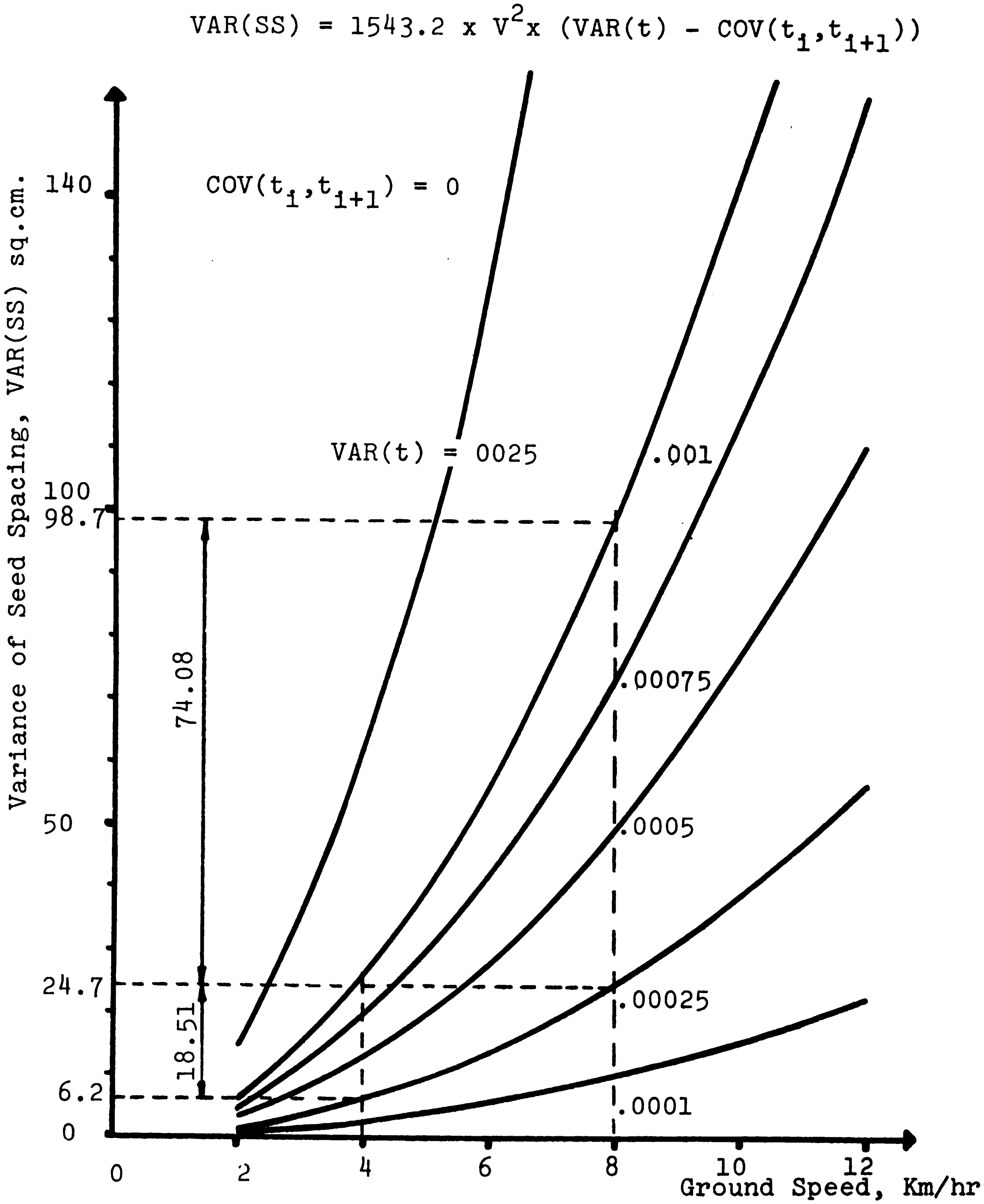


Figure 4. Effects of ground speed on the variance of seed spacing for different values of the variance of delivery time.

c) Gravity

Impact for a high-speed particle means losing a considerable amount of kinetic energy. Therefore, the particle velocity decreases every time an impact occurs and the delivery time increases.

When a seed makes an impact on the tube surface, the coefficient of restitution for normal impact as well as the coefficient of friction between tube and seed are responsible for the energy lost during the impact.

Chand and Ghosh, 1968, gave a formula to evaluate that energy:

$$E = 1/2\ m\ V^2(1 - \cos^2 \emptyset\ \{e_1^2 + [\mathrm{Tan}\ \emptyset - \mu_1(1-e_1)]^2\})$$

μ_1: Coefficient of friction

e_1: Coefficient of restitution*

$\emptyset$: Angle between the trajectory of the particle and a normal line to the tube at the point of impact.

The angle $\emptyset$ will be close to 90 degrees during delivery at high speed in the hose.

Some reduction of the variance of the delivery time was found when the air pressure was increased from 5 to 9 oz/sq.in.

It seems to indicate that the higher energy transferred from air to seed in a higher speed stream is able to restore the energy lost by impact faster and keep the seed

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* e_1 = Velocity after the impact/velocity before the impact

going with less variability in the delivery time.

This analysis does not pretend to give the solution to the variation of the seed spacing of this planter. It is a qualitative study of the variables involved, oriented toward the identification of critical parameters, such as e_1 and μ_1, in order to optimize them.

CHAPTER V

MATERIALS AND EXPERIMENTAL PROCEDURES

Testing Techniques

The most critical part of the air-powered metering and delivering system under study in this investigation is the delivery process because it is the largest source of variability of seed spacing.

A new approach has been used to evaluate the efficiency of seed delivery of the air-powered planter. It allows the study of the delivery system independently from errors introduced by the metering, deposition, germination, or emergence processes.

There are several techniques for testing performance of planters. Most of them test the machine as a whole and not individual components, such as metering mechanisms, delivery systems or furrow openers.

Some of the techniques are:

a) Greased belt seed receiving surface for laboratory evaluation.

b) Field sowing and measuring of plant spacing.

c) Measuring of time between seeds at the outlet of the delivery tube.

d) Planting and measuring seed spacing after searching for the seeds in a sand track.

e) Measuring of the seed delivery time and mathematical evaluation of the variance of the seed spacing.

The first four testing approaches require the measurement of distance or time between successive seeds coming out of the delivery system. It means that if the metering device fails to catch a seed or picks two at a time, it will show up as part of the variability of the delivery process.

The greased belt system is not applicable for a seed delivered by air power because of the high momentum with which it hits the greased surface. The seed will bounce unless a rather thick layer of grease is used.

The variability of seed spacing obtained using the field sowing technique is an indicator of overall planter and seed performance, including all sources of variability. It is metering, delivery, seed deposition, germination and non-coincidence of emergence point with seed location.

Similar statements can be made for the sand track technique. The main difference being that germination and emergence will not affect the measured variability, but a new source of variability is introduced during the seed searching operation.

As a result, measuring of the delivery time as well as a mathematical formulation to evaluate the variance of the seed spacing in the furrow as a function of the variance of the seed delivery time was found to give the most convenient approach for studying the delivery process.

The general arrangement used to measure the delivery time is shown in Figure 5. The electronic counter[1] used to measure the delivery time has a digital display that allows readings within the microsecond. Two electric pulses are required to open and close the electronic gate of the counter at the beginning and end of the time interval to be measured.

The initial electric pulse required to indicate the moment at which the seed is released from the drum was generated by means of a mechanically actuated switch (a). The second pulse, generated at the load cell, indicates the end of the seed trajectory.

Every time switch (a) goes through the release wheels a double function is performed. First, the bottom of the flexible arm closes the hole of the drum to release the seed, simultaneously, the switch closes the circuit of the 12 V battery and the counter starts measuring elapsed time.

When the seed reaches the end of the hose, it hits a load cell, and a new pulse is generated, amplified[2] and filtered. This pulse stops the counter started before by switch (a).

The arrangement just described has only one seed pocket in operation. It is due to the fact that the release wheels are separated from the drum and the only operating seed pocket is the one provided with the electric switch.

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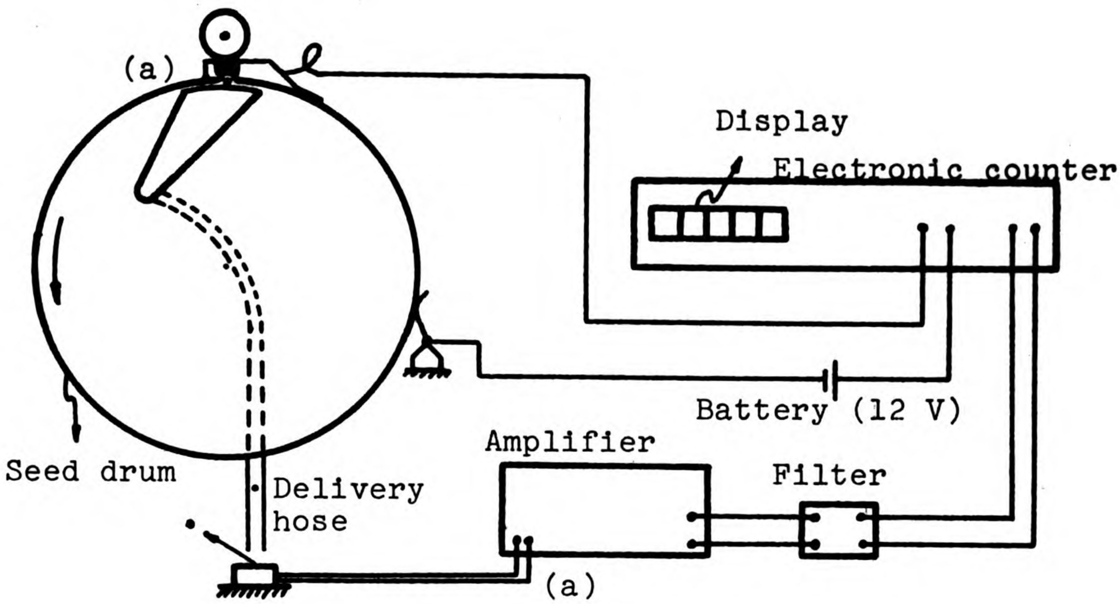
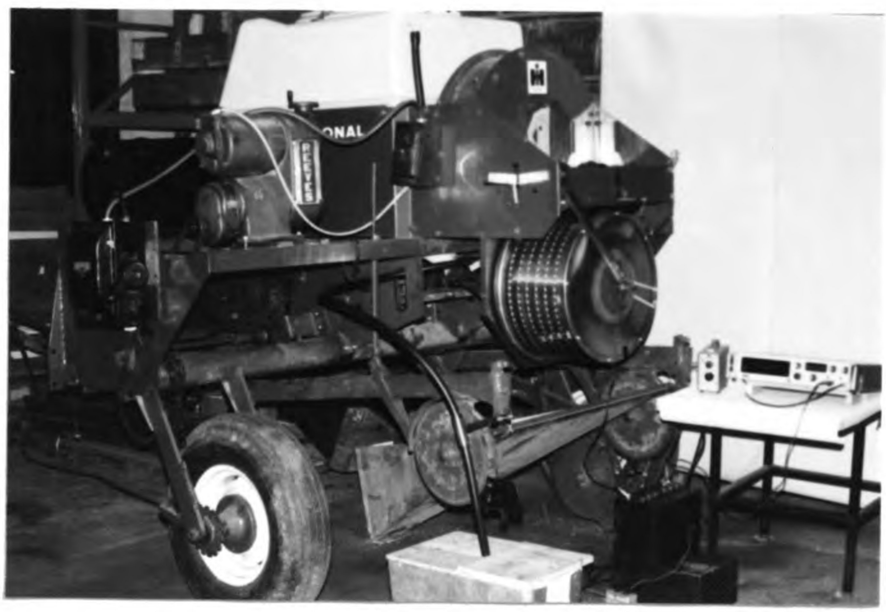
[1] Model 6040 A Beckman Electronic Counter

[2] Model 504 D Dial-Gain Charge Amplifier





(b)

Figure 5. Electronic circuit used to measure the seed delivery time. (a): Schematic circuit; (b); Actual setup

The time is read every other turn of the drum (time interval = 3.4 sec.) in order to obtain random values of the delivery time.

When the seed pocket fails to pick up a seed, the counter continues to run due to the fact that there is no seed hitting the load cell and corresponding pulse to close the electronic gate of the counter. In such a case, it was allowed to run until the next seed stopped it; this reading was obviously invalid and discarded.

It was not possible to identify doubles with this arrangement. In the case of doubles, the time of the faster seed was read by the counter, which is still valid, given that the delivery time is a random variable and assuming no interaction between both seeds during the delivery.

Evaluation of the Manifold

The same technique described before for evaluation of the delivery system can be used to study the seed manifold. It requires the seed delivery hose to be removed and the load cell installed at the outlet of the manifold.

Operation of the Planter in the Laboratory

During the laboratory tests the blower and seed drum were operated by independent electric motors, Figure 6. The blower was driven by a 5-HP motor which was overloaded when the air intake was fully open and all seed delivery hoses operating. But only one row is required to measure the delivery time using the technique described before.

Therefore all air outlets can be closed except the one under test. This greatly reduced the power requirements.

The seed drum was operated by a second electric motor (Reeves variable speed unit). Variable speed was required to check the maximum acceptable speed of the drum when handling wheat because of the high number of seeds per second required to sow this crop.

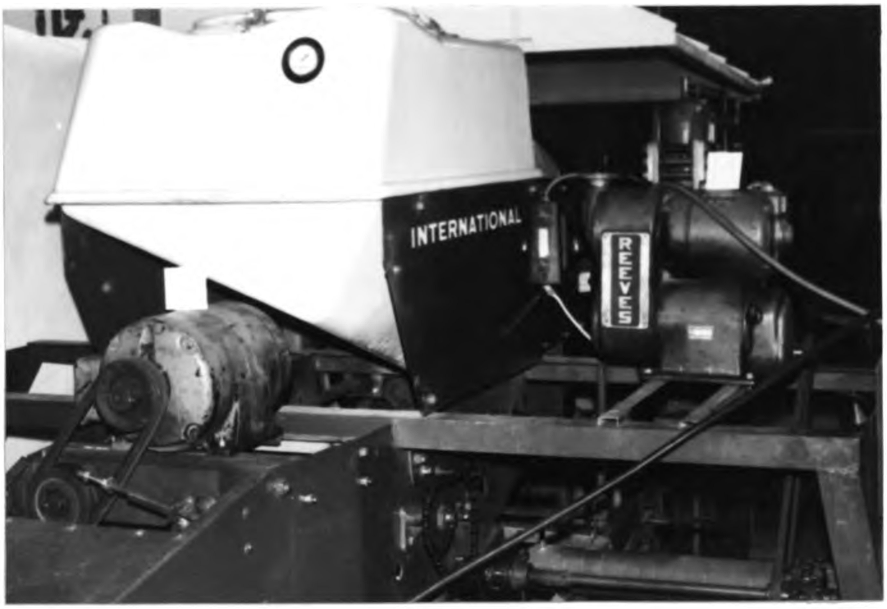


Figure 6. Power units for the laboratory operation of the planter. The Reeves variable speed unit operates the seed drum. A 5-HP electric motor (left) operates the blower.

Design Modifications of a Standard Planter

In order to reduce boundary effects on the yield of wheat plots, a six-row planter (40-in. rows) was modified to twelve 5-inch rows. This gave a total width of 1.52 m (60 in.) which equals the planter wheel spacing so only one pass was required to sow a plot. The tractor wheel base was adjusted to that of the planter, and the 33 cm. track left by the tires made a good separation stripe between plots.

Furrow Openers

Reduction of row spacing to 5 inches (12.7 cm) can be easily accomplished on the 400 Cyclo planter moving the U-bolts and head brackets to a different location on the front rail.

The standard I.H. furrow opener drawbar extensions were made 4 inches longer and installed at every other row to stagger the openers and increase clearance. This avoids interference between openers and clogging when working on very loose soil. According to the performance of the planter in one of the four different locations that was tested, the drawbars should be extended even more (8 in. instead of 4 in.).

Seed Drum

One end of the seed drum is detachable. This permitted attaching a second drum to the original one. The fiberglass transparent end of the original drum was then installed on the second or added drum.

Along with the seed drum, the set of release wheels and the support shaft had to be added.

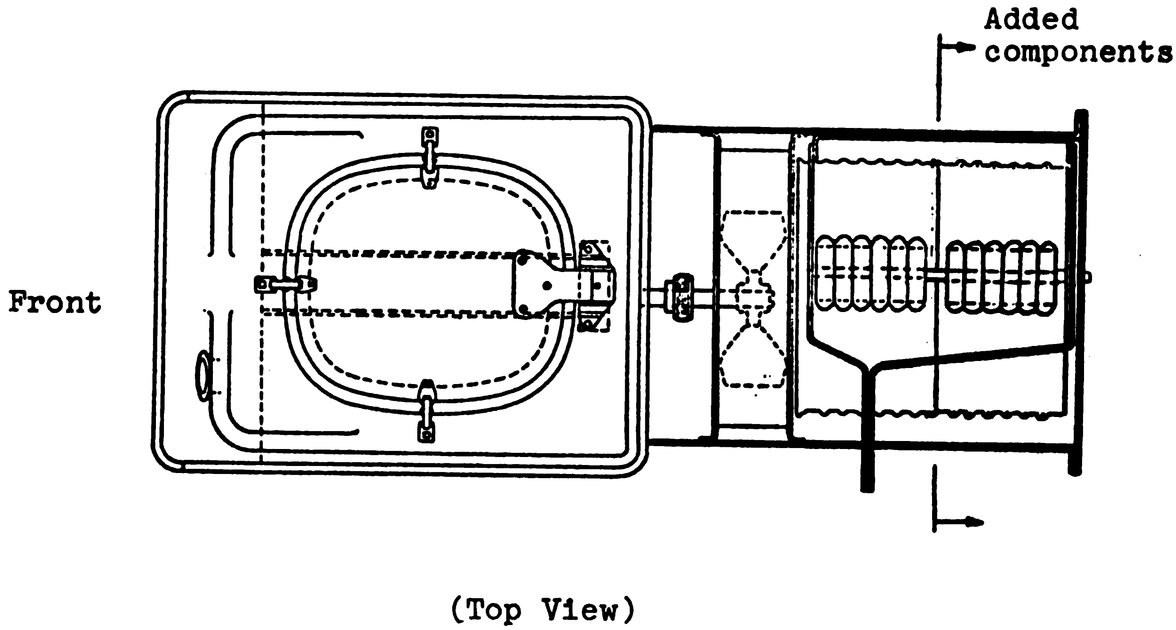


Figure 7. Modifications introduced in the seed metering unit.

Two additional guide wheels were included inside the drum to improve its stability in the manifold area. It helps to avoid rubbing of the drum on the manifold when the release wheel pressure is acting on the drum.

Seed Manifold

It was not possible to add a second standard manifold as it was the case with the seed drum. The manifold design is such that a second unit does not fit properly behind the standard one in the same drum-manifold relative position. The position of the release wheels as well as the gravity effect used for seed release require that the added manifold be in the same position as the original one.

As a result, a new seed manifold was built for the added drum, Figure 8. The convergent part of the manifold inlet was cut from a standard unit. At the end of this portion, the delivery hoses were directly attached to steel nipples glued to the upper portion with epoxy resin.

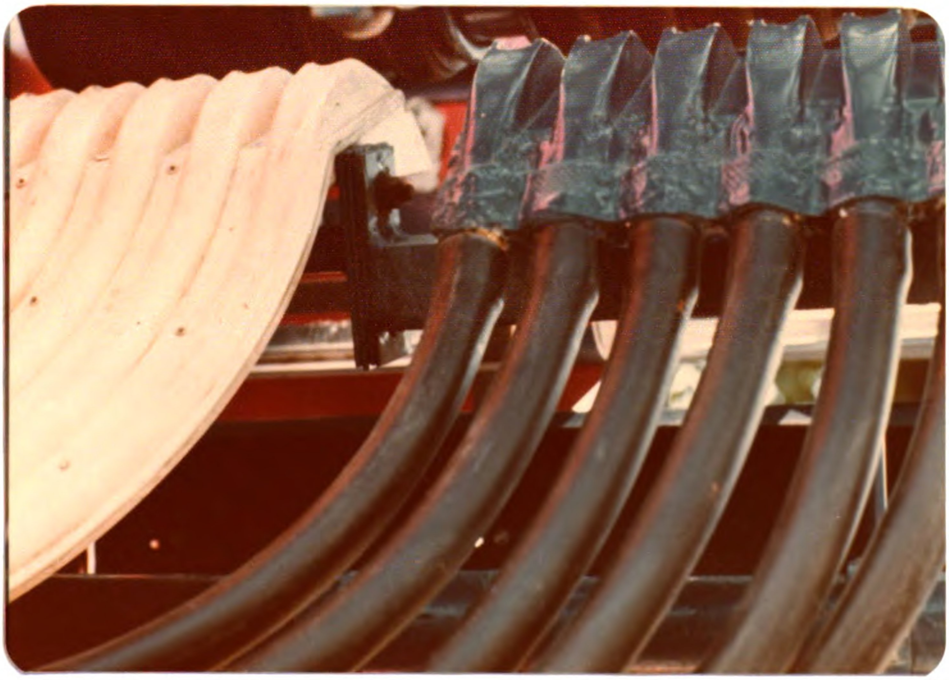


Figure 8. Modified seed manifold (blue) to collect the seed from the added drum.

Seed Cut-Off Brush

An extension of the air inlet chute was built on which a second cut-off brush was mounted to remove excess seeds from the added drum.

Seed Level in the Drum

By tilting the planter rearwards, it is possible to obtain a sufficient flow of grain to the end of the second drum. A hitch attachment was built in oder to reach the optimum level of the planter. The planter did not operate in its normal lowest position (hydraulic cylinder fully retracted) because of interference between the seed drum and the additional furrow openers installed in the center of the planter for narrow row spacing.

Blower

There was no need to modify the blower design for the double number of rows being used. With air intake fully open, the air pressure exceeded 10 oz/sq.in. Power requirements were considerably higher as was noted from the laboratory setup using an electric motor.

Planting Technique

Since the field tests involved different varieties and considerable time is required to change seed in a planting machine, the experiment was designed accordingly.

The treatment combinations were assigned according to a split-split plot design (Appendix K). Each replication had two plots to which two varieties were randomly assigned. Each of those plots was divided in two sub-plots to which two planting machines were assigned at random. Finally, each sub-plot was divided in four sub-sub-plots on which four seeding rates were randomly distributed.

Each sub-plot was then planted with the same machine and wheat variety, the only adjustment left to be made was the seeding rate when going from one sub-sub-plot to the next.

After adjusting the machine for one seeding rate, all sub-sub-plots in all replications taking that seeding rate were planted successively. It was done entering the sub-plot through one end and lowering the machine only at the sub-sub-plot corresponding to the seeding being sowed. Seeding rate was adjusted by changing the number of holes in the drum of the 400 Cyclo, and by measuring the length of the fluted wheel exposed to the grain on the conventional grain drill. Those values were previously determined by calibration of the drill and planter in the laboratory.

Harvesting and Threshing of the Experimental Samples

The experimental sub-sub-plots were 25 feet long by 13 rows wide for the drill sub-plots, and 12 rows wide for the planter sub-plots. From each plot only two six-meter-long rows were harvested. The criterion to choose the rows was homogeneity in all its length, location as far as possible from the boundaries, and minimum damage from wind, birds, etc.

The samples were taken to the laboratory, dried, and threshed with a small thresher for experimental samples. All the material was passed twice through the thresher to make sure all grain had been removed.

CHAPTER VI

RESULTS AND DISCUSSION

Effect of Air Pressure and Row on Seed Delivery Time

Three levels of air pressure were used on four rows of the planter. Delivery time in each row differed due to different hose length and curvature.

The effects of air pressure and row on delivery time were studied with a two-way analysis of variance using 150 replications. The level of significance of each variable is given in Table 1, while more detailed results are included in Appendix C.

Table 1. Air pressure and row effects on delivery time.

Source of Variance	Level of Significance of F Statistics
Air Pressure	< 0.0005
Row	< 0.0005
Row x Air Pressure	< 0.0005

Both variables, as well as their interaction, are highly significant, which indicates that the delivery time will significantly change as a result of variations in air pressure or delivery hose configuration.

An increase in air pressure normally reduces the variance of the delivery time (VAR(t)), (Appendix A).

In some cases this rule does not apply, which seems to indicate that an increase of air pressure causes the seed to reach a critical speed which provokes more bouncing and friction, and therefore more variability. A similar conclusion may be reached about the effect of row configuration on VAR(t), (Appendix A).

The significant effect of air pressure on delivery time is a consequence of the higher velocity reached by the seed when the drum is subjected to higher pressures or vice versa.

The amount of time spent by a seed during the delivery process does not affect the seed distribution in the row, but the speed of the seed at the end of the delivery hose may have some effect since it is related to seed scattering due to bouncing against the furrow walls.

The outlet seed velocity varies with tube length. Table 2 contains values of average seed velocity and variance of delivery time for three different tube lengths. Variance of delivery time increases with tube length. This indicates the need for uniform tube lengths on a planter in order to get similar uniformity of seed spacing in different rows.

The longer the delivery hose the higher the average seed velocity. This indicates that the seed is constantly under acceleration while traveling through the hose.

Therefore, a longer delivery hose is detrimental not only because of the higher value of the variance of the delivery time, but also because of the higher seed velocity which increases seed scattering during the deposition process.

Table 2. Tube length effect on seed velocity and VAR(t).

Tube Length m.; (ft)	Delivery Time t (sec.)	Average Velocity m/sec.; (ft/sec.)	VAR(t)x10^6 Sq. sec.
0.91 (3)	0.2651	3.45 (11.32)	166
1.83 (6)	0.3315	5.52 (18.1)	282
3.66 (12)	0.4661	7.85 (25.74)	793

The significant interaction of row x air pressure indicates that some delivery lines perform differently than others under variations in air pressure.

The reason for this behavior is most likely in the manifold where the smoothness of the seed trajectory depends on the location of the release point, the air flow, and the curvature of the tube. The location of the release point is the same for all the rows, but the curvature of the tube is different for every row and the air flow may also vary as a result of the non-constant spacing between drum and manifold.

Even more important than the delivery time itself, is its variability. Variability in delivery time directly affects the homogeneity of seed spacing.

As was previously shown in the theory chapter, the variance of the time between seeds can be estimated from the variances of the delivery time, provided the covariance ($Cov(t_i, t_{i+1})$) between delivery times is null.

$$VAR(TS) = 2.VAR(t) \qquad (11)$$

From the graphical representation of data in Appendix B, Figure 9, it can be seen that the experimental points fall within the 95% confidence interval of VAR(TS) calculated using Equation 11.

The data correspond to a large time interval between seeds (DT = 1.71 sec.) at the release point (seed drum with only one hole), so as to avoid interaction between seeds during the delivery.

Each value of VAR(t) and VAR(TS) is obtained from a sample with 150 observations (Appendices A(a) and B). Therefore, the confidence limits of VAR(t) are:

$$P\{\frac{(N-1)S^2}{x^2_{(\alpha/2)[N-1]}} \leqslant VAR(t) \leqslant \frac{(N-1)S^2}{x^2_{(1-\alpha/2)[N-1]}}\} = 1 - \alpha \qquad (12)^*$$

S^2: Estimated value of VAR(t) taken from sample.

N = 150 readings of the delivery time.

α = 5%

$x_{(2.5\%)[149]} = 184.2 \qquad x_{(97.5)} = 116.6$

$$0.81\ S^2 \leqslant VAR(t) \leqslant 1.277\ S^2$$

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* Sokal and Rohlf, Biometry, page 153.

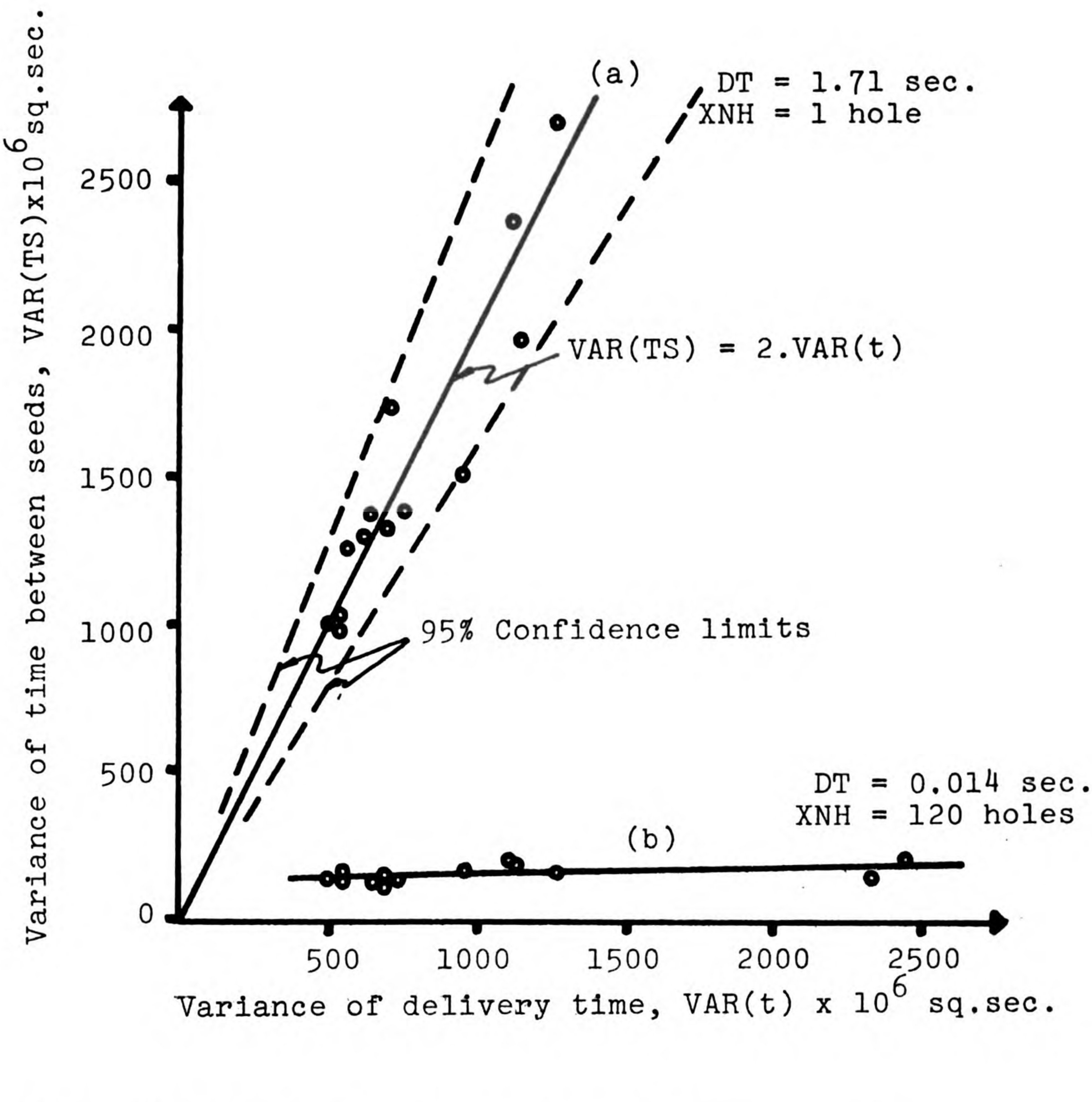


Figure 9. Effect of the variance of delivery time on variance of time between seeds.

(a) No seed interaction $[Cov(t_i, t_{i+1})=0]$

(b) Heavy seed interaction $[Cov(t_i, t_{i+1})\neq 0]$

Substituting Equation 11 in Equation 12:

$$1.625\ S^2 \leq VAR(TS) \leq 2.545\ S^2 \quad (13)$$

Values of VAR(TS) are expected to fall within the interval (13) 95% of the time.

Equation 11 gives the expected value of VAR(TS) for a certain value of VAR(t), while expression 13 gives the confidence limits of such an estimate.

Increasing VAR(t) beyond the limits of Figure 9(a), a point will be reached where seeds start to interact between each other making $COV(t_i, t_{i+1}) \neq 0$. In such cases, Equation 11 does not apply any more to estimate VAR(TS) or its confidence limits. Such would be the case if a delivery tube were made out of a material with a high coefficient of friction or a low restitution coefficient.

The variance of the time between seeds can vary as a result of a variation in the variance of the delivery time or in the time interval (DT) between seeds at the release point. The first case being related to the geometry, material, air pressure, etc. of the seed delivery system and the time interval (DT) being a function of the number of holes in the drum, which in turn determines the capacity of the planter. The larger the number of holes in the drum, the higher the ground speed that can be used for a given seeding rate. This can be seen through Equation 6. For a given seeding rate,

$$SS = \frac{1000}{36} \cdot V \cdot TS$$

the seed spacing (SS) is a constant. Therefore, any variation of TS must be compensated by a corresponding (percentage) variation of V.

A higher ground speed increases the variance of the seed spacing within the row as stated in Equation 7, but

$$VAR(SS) = (\frac{1000}{36})^2 \cdot V^2 \cdot VAR(TS)$$

simultaneously there is a reduction in VAR(TS) when DT is reduced as shown in Figure 10. The net result being that VAR(SS) increases with ground speed but it is partially compensated as DT is reduced.

For example, for the machine used in this experiment the variance of the delivery time is mostly in the interval 0.0005-0.0010 sq.sec. The reduction of VAR(TS) that can be obtained by increasing the number of holes three times (from 24 to 72) is approximately 70%, but as a result of this the ground speed must be increased three times, which means that VAR(SS) will be increased nine (3^2) times.

In the case of a very low seeding rate (XNH = 1, number of holes on the drum), an increase of the number of holes to 2, 3, 4, or 5 will not create any compensation because the time interval between seeds is still large enough to avoid any seed interaction.

Consequently, ground speed should be kept as low as possible provided the capacity of the machine is still acceptable. All these considerations are done under the assumption of constant drum rotation speed, being the maximum value compatible with centrifugal force limitations. The use of lower rotation speeds is equivalent to a lower number of holes operating at maximum speed.

The lower values of variance of time between seeds for smaller release time intervals does not mean that the uniformity of seed spacing has been improved. The variance of a random variable is a measure of its variability but not the only one, and not adequate if comparisons are to be made between variances of samples with different means. A better indicator is the coefficient of variability (Appendix J) for being independent of the mean or time interval at the release point. The coefficient of variability increases as the seeding rate increases (DT decreases), which indicates that the uniformity of seed spacing varies inversely with seeding rate.

The use of variance of the time between seeds is still valid for evaluation of the pneumatic planter if the analysis is made for one seeding rate (DT = constant).

Effect of Manifold Design on VAR(TS)

The modified manifold was built because the geometry of the factory-made manifold does not allow the installation of two units in parallel. This situation gave the opportunity to test how different manifold designs may affect the variability of seed spacing.

Appendix D contains the information for the modified manifold. Part of this data is reproduced in Table 3

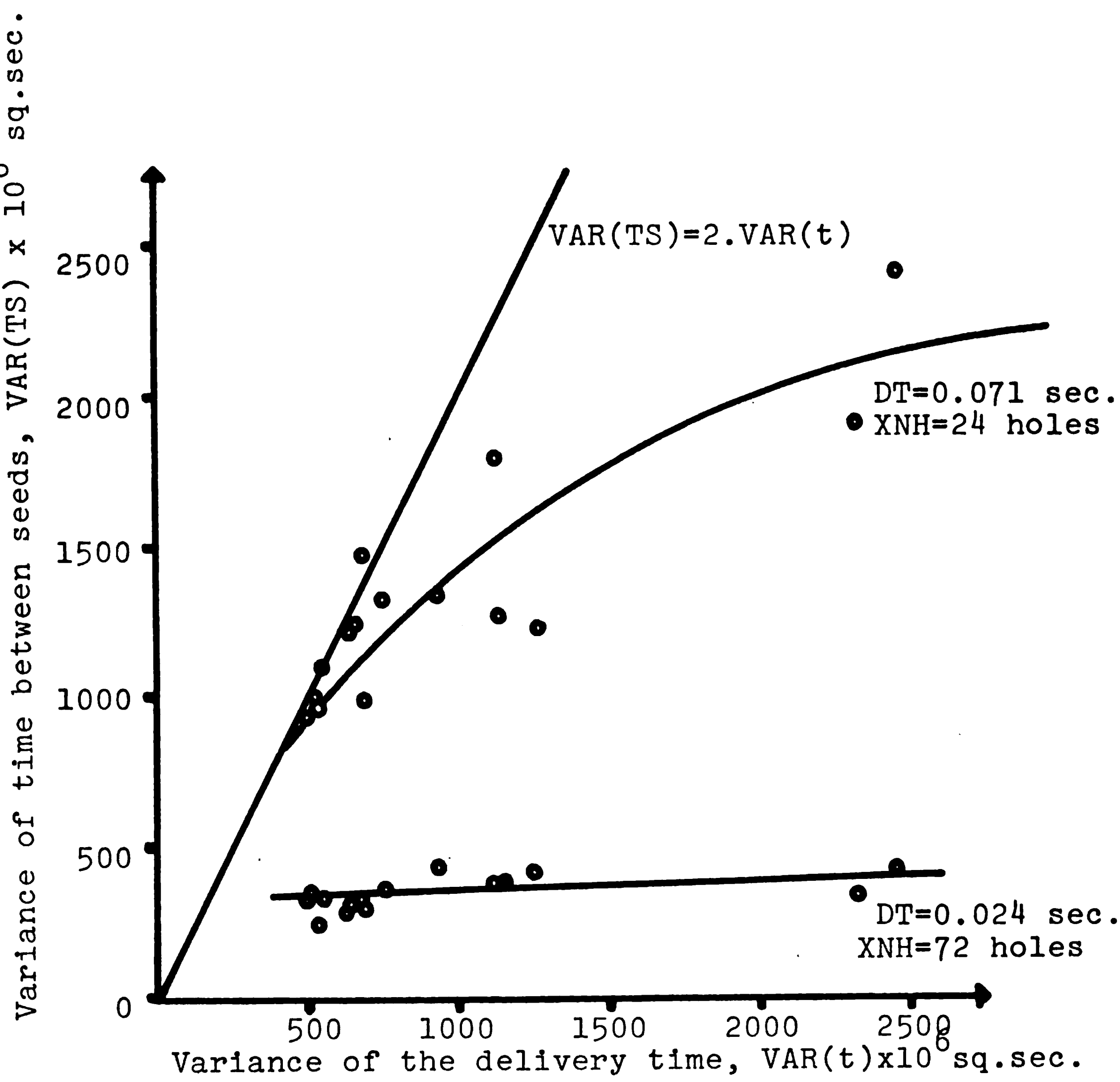


Figure 10. Effect of VAR(t) on VAR(TS) for different degrees of seed interaction.

together with the data corresponding to row number one of the standard manifold, which is the one with the "least variability."

Table 3. Effect of manifold design and air pressure on VAR(t).

Variance of Delivery Time; VAR(t) x 10^6 sq.sec.			
Air pressure cm.H_2O;(oz/sq.in.)	4.13 (5)	5.78 (7)	7.43 (9)
Modified Manifold	573	444	287
Standard Manifold	760	557	547

Values of VAR(t) for different levels of air pressure can be compared using the F statistics, which shows that VAR(t) is significantly lower for the modified manifold.

The tubes of the factory-made manifold have smaller diameter and radius of curvature than the modified unit in which the delivery hoses go into the drum compartment up to funnels of the manifold.

Analysis of Field Data (1972)

The field experiments were conducted over a period of two years. Spring wheat was used for the first year experiments since the pneumatic planter was not available for planting winter wheat in September 1971.

Two varieties, Polk and Fletcher, from Wisconsin and Minnesota, respectively, were planted on May 1, 1972, at East

Lansing, Michigan. A second location was planted on May 12 near Clare, Michigan, 100 miles north of East Lansing, where the growing season is more favorable for spring wheat.

In both cases, the treatments were distributed according to a split-split plot design replicated five times and including the following variables:

Location (2 levels; East Lansing and Clare)

Variety (2 levels; Fletcher and Polk)

Machine (2 levels; Grain drill and planter)

Seeding rate (4 levels; 25, 50, 75, and 100 lb/A)

The original design also included two seeding dates which had to be excluded due to the rainy conditions which considerably delayed the first date of planting, leaving too short a growing season for the second date.

The Clare location had to be discarded due to a heavy rain (3 inches) the day following planting, which packed the top 5 to 7 cm of soil (clay) preventing emergence for over 50% of the seeds. No tillage operation was used to correct the situation since it might have affected the seed distribution patterns being tested.

The minimum seeding rate (25 lb/A) was limited by the grain drill, which damages the seeds and delivers non-consistent seed flow for lower seeding rates.

As expected, spring wheat had the problem of weed competition. Weeds were sprayed with 2,4-D, but effective control was not accomplished using the recommended concentration.

Six meters of two rows were harvested from each 8-m long experimental unit. The rows were selected on the basis of homogeneity and absence of weeds. The boundary rows were avoided unless no better choice was available among the internal rows.

The complete analysis of variance for the split-split plot design is given in Appendix E. Main effects and interactions, along with the levels significance of the F test, are summarized in Table 4.

Table 4. Split-split plot design, 1972.

Source of Variance	Level of Significance of F Statistics (%)
Variety	2.2
Machine	0.6
Seeding Rate	0.1
Machine x Variety	32.2
Variety x Seeding Rate	98.4
Machine x Seeding Rate	10.1
Variety x Machine x Seeding Rate	6.6

Seeding rate was the most significant single effect. There is a 0.1% probability that the difference in yield for different seeding rates have occurred only by chance. A less significant effect may be expected in a dry farming area but for Michigan conditions and especially for spring wheat, this result may be considered normal.

Machine effects were significant at the 0.6% level which indicates that chances are very high that the higher yield obtained with the pneumatic planter is due to a more uniform seed spacing.

Wheat variety was also significant at the 2.2% level. It indicates that the variety Polk (Wisconsin) better fits the Michigan environment than the variety Fletcher (Minnesota).

Among the first order interactions, the most important one in this experiment is machine x seeding rate. As shown in Figure 11 (a) the type of machine influenced the seeding rate-yield relationship. Yield was not affected by seeding rate as much when using the planter as when using the grain drill.

According to Figure 11 (a), the performance of both machines tends to be the same when seeding rate reaches 100 lb/A where both grain yield curves are almost coincident.

The first order interaction machine x variety is not significant. It can be seen on the graphical representation on Figure 11 (b) that the yield advantage of Polk is the same when planting with the pneumatic planter as when planting with the grain drill. This is a desirable feature, since it indicates that the benefits from a more precise seed distribution pattern are applicable in general and not for some particular varieties.

Figure 11. First order interactions. Field experiments 1972.

Levels of Significance: α = 10.1% α = 32.2%

(a): Machine x Seeding Rate (b): Machine x Variety

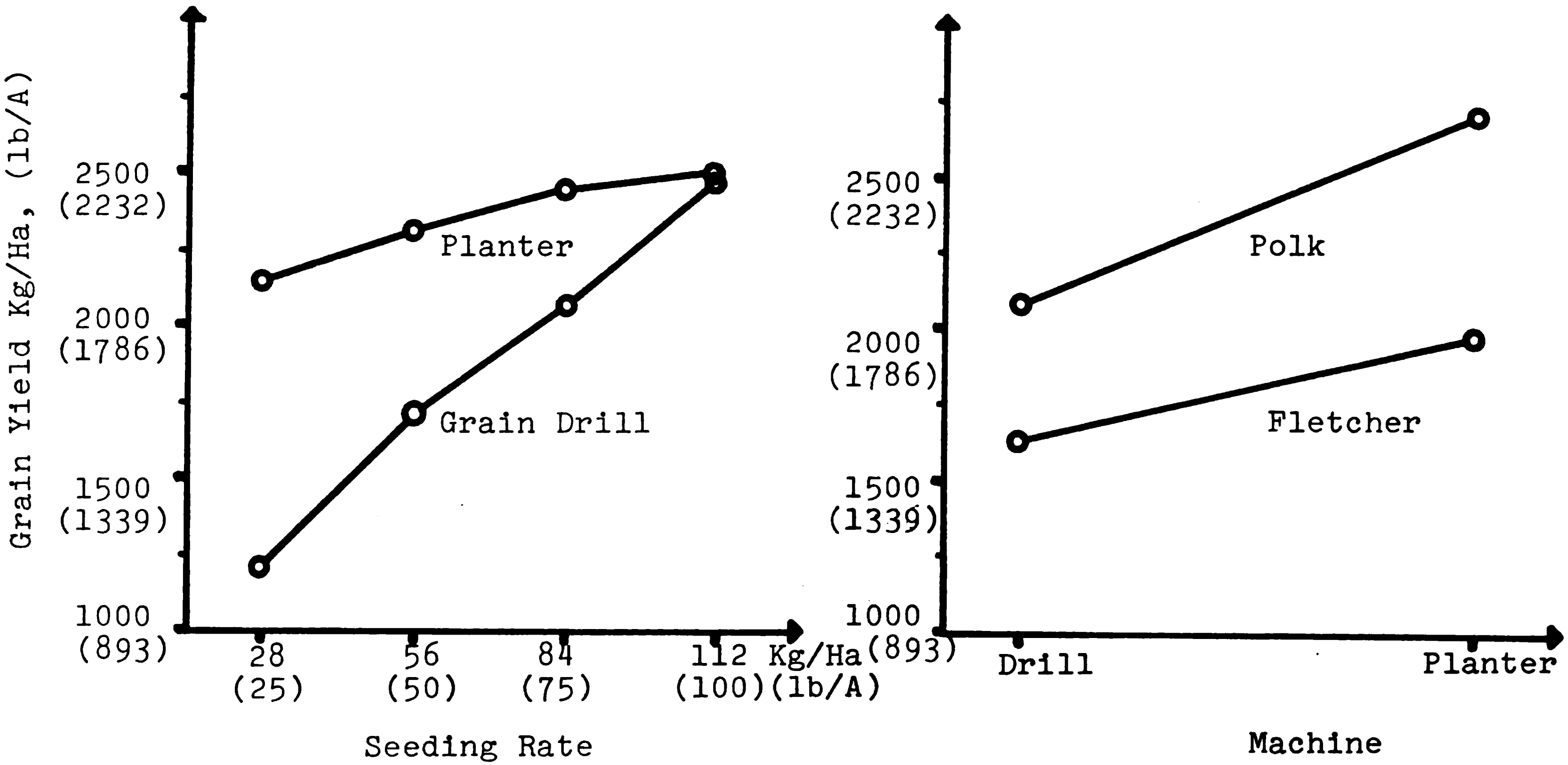
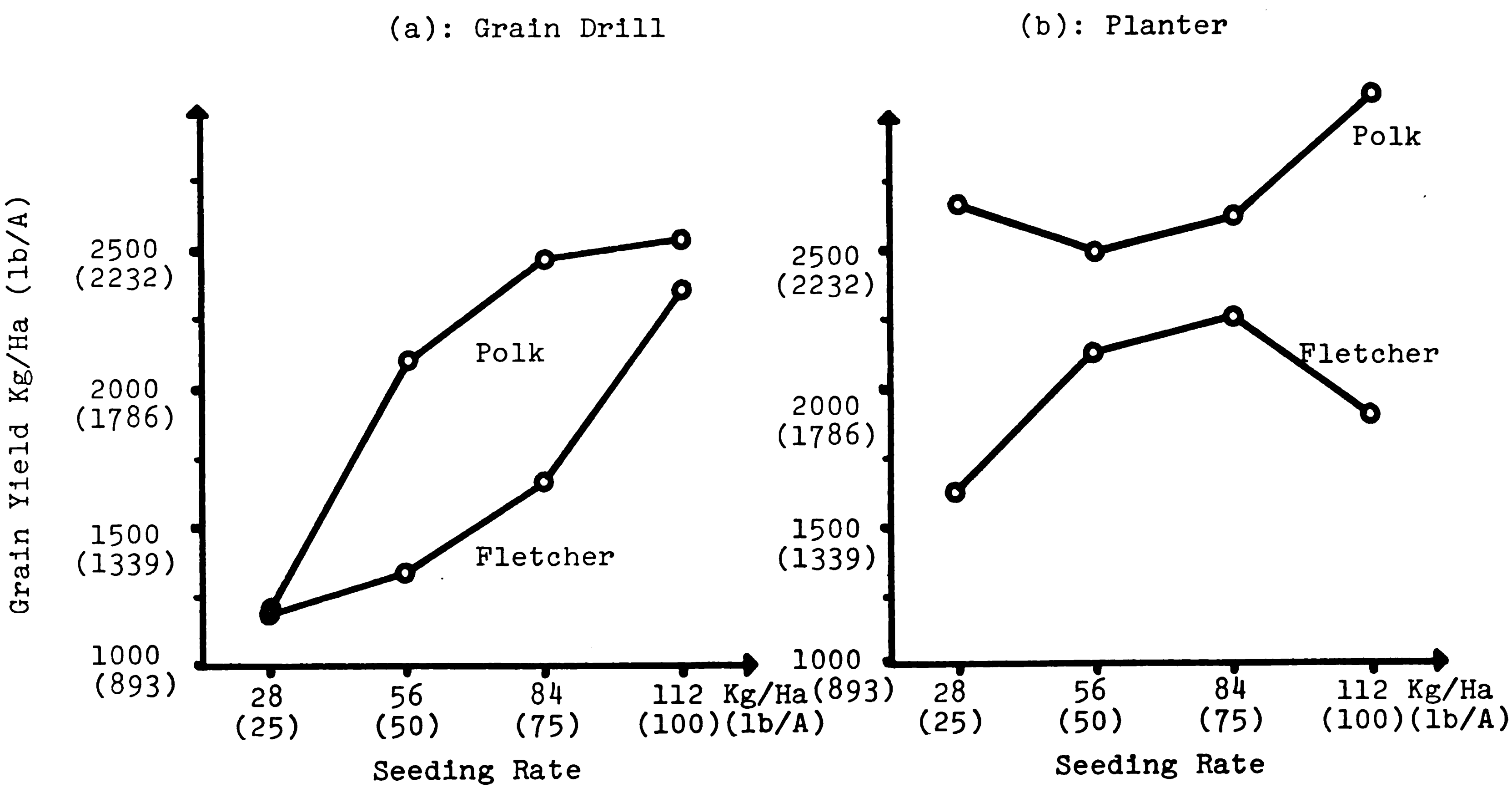


Figure 12. Second order interaction Machine x Seeding Rate x Variety.

Level of Significance: α = 6.6%



The second order interaction machine x seeding rate x variety is significant to the 6.6% level, which indicates that the seeding rate-yield curves for both varieties are very likely to be affected by the type of planting machine used. The curve in Figure 12 (a) and Figure 12 (b) show a greater slope for the grain drill than they do for the planter.

The field experiment as described includes both planting machines. Some interesting conclusions may be drawn from an independent study of each machine separately and considering each experiment as a split-plot instead of a split-split plot design.

Appendices F and G include such analyses for the planter and grain drill respectively.

Seeding rate shows a 63.3% level of significance for the planter and less than 0.05% for the grain drill. This indicates that a more precise seed distribution pattern may reduce the effect of seeding rate on grain yield.

Analysis of Field Data (1973)

The field experiments were repeated in 1973, using winter wheat which was planted on September 25, 1972. Two varieties, Arthur and Genesee, well adapted to Michigan environment, were planted in East Lansing, Michigan, according to a split-split plot design similar to the one used in 1972. The experiment included six replications with the following variables:

Variety (2 levels; Arthur and Genesee)

Machine (2 levels; grain drill and planter)

Seeding Rate (4 levels; 15, 30, 60, and 90 lb/A)

The plot distribution pattern is shown in Appendix K.

The minimum seeding rate was reduced this time by mixing the seed with a filler (same seed but treated in the oven) which allowed the grain drill to sow 15 lb/A live seed with the machine set for 30 lb/A.

Germination, emergence, and growth of the crop were normal. Only a few weeds were present.

The plots were harvested on July 10, 1973, using identical technique to that described for 1972. The samples were not completely ripe at the time they were harvested, but their gathering was anticipated to avoid the increasing bird damage that began to take place. Only two replications ((2) and (5)) were harvested for variety Arthur since the rest of them were considerably damaged. The two replications harvested were analyzed as a split-split plot design as originally stated. The results include a non-significant machine effect (α = 8.9%) and a significant seeding rate effect (α = 1.5%). Similarly to the previous year, the interaction machine x seeding rate had a low level of significance. The interaction variety x seeding rate shows a 5.4% level of significance.

Given that the two replicates of Arthur included in the previous analysis had suffered some damage, and that the results are not consistent with those of 1972, the data is left as stated. A more complete analysis follows for the variety Genesee.

All six replications of variety Genesee were studied as a split plot design with only one variety. Table 5 includes the levels of significance for main effects and interactions of this experiment.

Table 5. Split plot design, 1973.

Source of Variance	Level of Significance of F Statistics (%)
Machine	1.1
Seeding Rate	68.1
Machine x Seeding Rate	29.2

There is only 1.1% probability that the higher yield obtained with the pneumatic planter have occurred only by chance. The high level of significance of machine effect is in good agreement with the results of 1972.

Seeding rate shows no significant effect on yield (α = 68.1), which does not agree with the 1972 trial. The reason for this may be the fact that the longer growing period available for winter wheat offers a better chance for tillering to the low seeding rate plots.

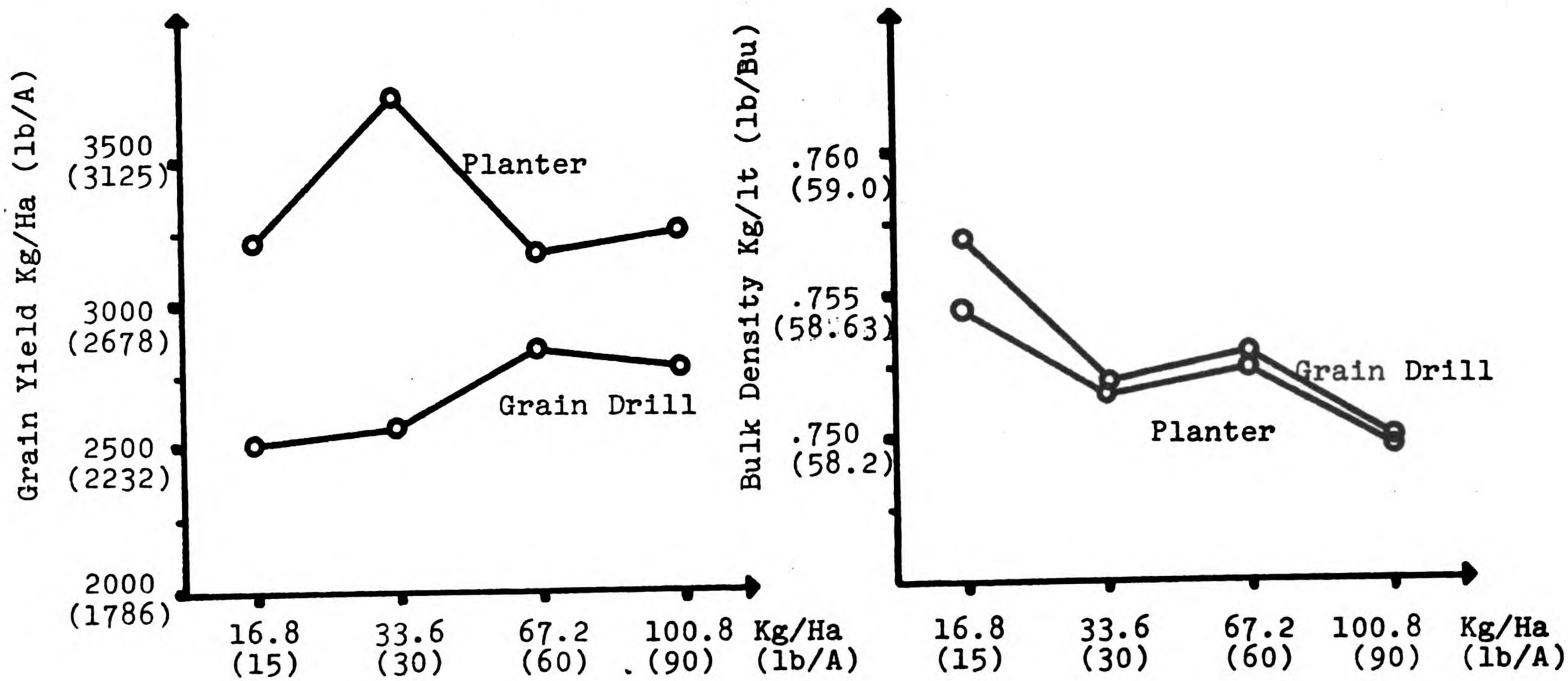
The interaction machine x seeding rate was non-significant (α = 29.2%), which is also in agreement with previous data.

Figure 13. First order interactions: Machine x Seeding Rate

Levels of Significance:

α = 29.2%　　　　α = 99%

(a) Yield　　　　(b) Bulk Density



Although no important machine effect on grain bulk density was expected, it was measured during this second year trial. As indicated in Appendix I and Figure 13 (b), neither machine (α = 75.2%) nor seeding rate (α = 35.7%) have a significant effect on grain bulk density. Figure 13 (b) shows some bulk density decrease as seeding rate increases that can only be detected due to the magnified bulk density scale.

CHAPTER VII

CONCLUSIONS

1. Air pressure affects the seed delivery time of the pneumatic planter. An increase in air pressure increases seed speed. It means more seed scattering during the depositing of the seed in the furrow.

Air pressure also affects the variance of the delivery time VAR(t). The general trend being a reduction of VAR(t) as air pressure is increased.

A compromise must be reached in selecting the optimum air pressure since its effects on seed velocity and VAR(t) are opposite.

2. Delivery tube configuration affects seed velocity and variance of seed spacing in a random fashion.

3. The final seed velocity increases with the length of the delivery hose. It indicates that the seed is under acceleration during the delivery process.

4. An increase in ground speed of the pneumatic planter will reduce the uniformity of seed spacing (Figure 4). The higher speed will require a larger number of holes in the drum (assuming constant seeding rate and maximum drum velocity). It compensates slightly for the increased variability created by a higher ground speed.

5. The uniformity of seed spacing can be improved by modifying the seed manifold. It can be accomplished by taking the delivery hoses into the drum and as close to the seed discharge funnels as possible (minimize length of manifold).

6. The pneumatic planter can sow high seed density crops. The present design with a 144-hole drum can handle 84 seeds/sec. per row, which allows wheat seeding rates of approximately 96 Kg/Ha (85 lb/A) at a ground speed of 8 Km/hr. (5 mi/hr) in rows 12.7 cm (5 in.) apart. Higher seeding rates can be sown increasing the diameter of the drum, but the performance of the pneumatic planter is not better than that of a grain drill for high populated crops.

There are no minimum seeding rate limitations. The only requirement being a drum with the correct number of holes.

7. Wheat grain yield has been significantly higher on the plots planted with the pneumatic planter during the two year experiments (1972, 1973) at East Lansing, Michigan. For spring wheat, this effect was only detectable at low seeding rates. Narrow row spacing as well as a more uniform seed spacing in the row are the factors that may account for most of the yield improvement.

8. Grain yield was less affected by seeding rate for the plots planted with the pneumatic planter.

9. Test weight was not affected by uniformity of seed spacing on the 1973 trial.

10. If hybrid wheat does become a reality and if the cost of seed of it becomes a limiting factor in its use by farmers, then a precision planter such as the one in this study could be used to minimize yield reduction resulting from reduction of planting rate.

APPENDICES

APPENDIX A

Table 6. Effect of air pressure, tube configuration, and tube length on the variance of delivery time (standard manifold).

Variance of the Delivery Time; VAR(t) x 10^6 sq. sec.					
Air Pressure cm. H_2O;(oz/sq.in)	Row Number				
	1	2	3	4	5
4.13 (5)	760	634	2466	1136	647
5.78 (7)	557	1148	2331	702	950
7.43 (9)	547	539	504	1272	690

$F_{(2.5)(150;150)} < 1.27$

(a)

Variance of the Delivery Time; VAR(t) x 10^6 sq. sec.		
Hose Length (m)		
1	2	3
166	282	793

(b)

APPENDIX B

Table 7. Effect of air pressure, release time interval, and tube configuration on the variance of time between seeds.

Variance of Time Between Seeds; VAR(TS) x 10^6 sq. sec.						
Air Pressure cm.H_2O;oz/sq.in		Row Number (configurations)				
		1	2	3	4	5
XNH = 1 (Number of holes in the drum)						
4.13	(5)	1393	1303	5681	1967	1372
5.78	(7)	1268	2367	5423	1737	1513
7.43	(9)	1041	977	995	2716	1326
XNH = 24						
4.13	(5)	1322	1236	2403	1796	1225
5.78	(7)	1102	1263	1909	1480	1341
7.43	(9)	998	956	939	1235	991
XNH = 72						
4.13	(5)	360	309	433	384	292
5.78	(7)	326	368	339	321	428
7.43	(9)	342	246	335	421	291
XNH = 120						
4.13	(5)	136	146	206	204	130
5.78	(7)	128	161	151	118	166
7.43	(9)	162	144	144	178	152

APPENDIX C

Table 8. Effect of air pressure and tube configuration on seed delivery time (Factorial with replications).

The Dependent Variable is Delivery Time

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX. SIGNIFICANCE PROB. OF F STAT.
Air Pressure	2.4895	2	1.2447	1182.34	< 0.0005
Row	1.0765	3	0.3588	340.34	< 0.0005
Air Press.x Row	0.1860	6	0.0310	29.44	< 0.0005
Remaining Error	1.8824	1788	0.0010		
Total	5.6344	1799			

Mean Delivery Time = 0.333277 sec. Standard Deviation = 0.05596 sec.

APPENDIX D

Table 9. Effect of air pressure and release time interval on the variance of time between seeds (modified manifold).

Air Pressure cm H_2O;(oz/sq.in)	4.13 (5)	5.78 (7)	7.43 (9)
Var.of Del.Time VAR(t)x 10^6sq.sec.	573	444	287

XNH = 1 (Number of holes in the drum)	
Air Pressure cm H_2O;(oz/sq.in)	Variance of Time Between Seeds VAR(TS) x 10^6 sq. sec.
4.13 (5)	1246
5.78 (7)	857
7.43 (9)	568
XNH = 24	
4.13 (5)	1117
5.78 (7)	814
7.43 (9)	568
XNH = 72	
4.13 (5)	274
5.78 (7)	302
7.43 (9)	258
XNH = 120	
4.13 (5)	125
5.78 (7)	133
7.43 (9)	126

APPENDIX E

Table 10. Analysis of variance for split-split plot design (1972).

The Dependent Variable is Grain Yield

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX.SIGNIFICANCE PROB.OF F STAT
D (Repl.)	3600629.2	4	900157.3	1.70	0.309
A (Variety)	6970852.8	1	6970852.8	13.20	0.022
Z = B x A	2111475.0	4	527868.7		
B (Machine)	4807391.5	1	4807391.5	13.33	0.006
A x B	401152.8	1	401152.8	1.11	0.322
Z = BD + ABD	2883369.2	8	360421.1		
C (Seeding Rate)	6937034.7	3	2312344.9	6.91	0.001
A x C	53392.9	3	17797.6	0.05	0.984
B x C	2201322.2	3	733774.0	2.19	0.101
A x B x C	2562908.1	3	854302.7	2.55	0.066
Remaining Error	16051007.1	48	334395.9		
Total	48580535.9	79			

Remaining Error is C x D + AxCxD + BxCxD + AxBxCxD.

APPENDIX F

Table 11. Analysis of variance for split plot design (Planter, 1972).

The Dependent Variable is Grain Yield

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX.SIGNIFICANCE PROB. OF F STAT.
C (Repl.)	4155229.3	4	1038807.3	3.72	0.115
A (Variety)	5358240.0	1	5358240.0	19.23	0.012
Z = AxC	1114066.7	4	278516.6		
B (Seeding Rate)	687162.8	3	229054.2	0.58	0.633
AxB	1412124.6	3	470708.2	1.19	0.333
Remaining Error	9453675.5	24	393903.1		
Total	22180499.1	39			

Remaining Error is BxC + AxBxC.

APPENDIX G

Table 12. Analysis of variance for split plot design (Grain drill, 1972).

The Dependent Variable is Grain Yield

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX.SIGNIFICANCE PROB. OF F STAT.
C (Repl.)	964275.2	4	241068.8	0.40	0.797
A (Variety)	2013765.6	1	2013765.6	3.41	0.139
Z = AxC	2361902.2	4	590475.5		
B (Seeding Rate)	8451194.0	3	2817064.6	10.24	0.0005
A x B	1204179.4	3	401392.1	1.45	0.250
Remaining Error	6597331.6	24	274888.8		
Total	21592645.3	39			

Remaining Error is BxC + AxBxC.

APPENDIX H

Table 13. Analysis of variance for split plot design (1973).

The Dependent Variable is Grain Yield

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX.SIGNIFICANCE PROB.OF F STAT.
C (Repl.)	4262356.4	5	852471.2	2.52	0.166
A (Machine)	5347512.6	1	5347512.6	15.84	0.011
Z = AxC	1686940.9	5	337388.1		
B (Seeding Rate)	476852.3	3	158950.7	0.50	0.681
A x B	1225487.8	3	408495.9	1.30	0.292
Remaining Error	9422998.4	30	314099.9		
Total	22422148.6	47			

Remaining Error is BxC + AxBxC.

APPENDIX I

Table 14. Analysis of variance for split plot design (1973).

The Dependent Variable is Grain Bulk Density

SOURCE OF VARIANCE	SUM OF SQUARES	DEGS.OF FREEDOM	MEAN SQUARE	F STATISTIC	APPROX.SIGNIFICANCE PROB. OF F STAT.
C	0.00072412	5	0.0001448	1.47	0.341
A (Machine)	0.00001100	1	0.0000110	0.11	0.752
Z = AxC	0.00049163	5	0.0000983		
B (Seeding Rate)	0.00020872	3	0.0000695	1.11	0.357
A x B	0.00000714	3	0.0000023	0.03	0.990
Remaining Error	0.00186488	30	0.0000621		
Total	0.00330747	47			

Remaining Error is BxC + AxBxC.

APPENDIX J

Table 15. Coefficient of variability of time between seeds.

Air Pressure cm H_2O;(oz/sq.in)		Row Number				
		1	2	3	4	5
XNH = 1						
4.13	(5)	2.18	2.11	4.4	2.59	2.16
5.78	(7)	2.08	2.84	4.3	2.43	2.27
7.43	(9)	1.88	1.82	1.84	3.04	2.12
XNH = 24						
4.13	(5)	50.89	49.23	68.81	59.4	48.93
5.78	(7)	46.27	50.14	61.21	54.01	46.03
7.43	(9)	44.30	43.30	42.78	49.50	44.07
XNH = 72						
4.13	(5)	79.29	73.55	86.91	82.10	71.45
5.78	(7)	74.85	80.72	79.60	75.88	84.98
7.43	(9)	77.88	65.95	76.23	87.5	71.59
XNH = 120						
4.13	(5)	80.93	84.85	96.85	97.44	81.31
5.78	(7)	79.32	88.00	84.50	76.95	89.22
7.43	(9)	88.14	84.67	81.99	93.65	84.68

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