THE EFFECT OF HOE-OPENER DESIGN ON DRAFT FORCES OF A MINIMUM TILLAGE HOE DRILL

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Introduction

Minimum tillage practices that promote soil and water conservation have become accepted alternatives to conventional summerfallow in western Canada. However, in addition to maintaining the productivity of soils, grain producers have been forced to become increasingly concerned with ways of reducing their input costs in order to survive the present cost-price squeeze in agriculture. Proper implement adjustment and operation speed are two areas that influence both production costs and soil conservation.

Seeding is the only tillage operation directly associated with the production of "stubbled-in" or "zero-tilled" winter wheat (Fowler 1983). Dry, untilled, trash covered seedbeds are very hard to penetrate and drills equipped with hoe openers or knives have been popular choices for this production system. The objective of this study was to determine the effect of seeding depth and opener design on the draft (horizontal component of pull imposed on the tractor drawbar by the implement being pulled) and power requirements of a minimum tillage hoe drill utilized for stubbling-in winter wheat.

MATERIALS AND METHODS

An Edwards HD812 four rank hoe drill with eight inch row spacing was used in all trials (Fig. 5). Draft measurements were made for five depths and three speeds using four types of openers and four different number of openers.

Draft was measured using a bonded strain gauge load cell. This S-shaped force transducer has a capacity of 20,000 lbs. with a 200 percent safe overload. The unit is fully environmentally protected against moisture ingression and by design is insensitive to barometric effects. The load cell was placed between the tractor drawbar and the hitch of the hoe drill. A metal shroud was placed around the load cell for extra protection. A Western Scale DF2000 digital weight indicator was located inside the tractor cab enabling the operator to view the draft values with ease (Fig. 6). Data was directly transcribed from the digital indicator onto a cassette recorder.

The tests were carried out in Watrous, Saskatchewan on a Weyburn clay-loam soil which has a bulk density of 0.04 lb/in^3 (1.10 g/cm^3). Soil moisture content was approximately 20.9 percent on a volume basis. Standing wheat stubble with a medium to light trash cover was present for all trials.

Seeding depths were 0.4, 0.8, 1.2, 1.6, and 2.0 inches. Seeding depths were measured as the distance seeds were placed below the soil surface in the furrow rather than the distance to the bottom of the furrow. Speeds of 4, 5 and 6 mph were chosen because they reflected normal seeding speeds. The four types of openers used were the (1) IHC Hoe, (2) Edwards Hoe, (3) Acra-Plant knife and, (4) Versatile knife (Fig. 1 to 4). The relationship between the number of openers and draft was investigated using four, six, eight and ten openers. When opener numbers were reduced, they were removed from each side of the drill symmetrically to maintain the eight inch row spacing.

A minimum of twenty draft measurements were made for each treatment comparison. Analyses of variance were conducted to determine the effects of the different parameters on draft.

RESULTS AND DISCUSSION

Effect of Opener Type

Figure 7 shows the relationship between draft and seeding depth for four types of openers in trials which had ten openers pulled at a speed of five mph. There was a significant ($P<0.001$) linear increase in draft as seeding depth increased for all openers. The four types of openers responded differently to increasing opener depth. These differences relate to the physical shape of each opener.

The IHC Hoe (shoe) opener (Fig. 1) has a broad surface area which cuts through the soil. However, the shoe is curved such that soil is able to roll up and off the shoe as it travels forward. The Edwards Hoe opener (Fig. 2) is quite blunt and does not roll the soil over. The Acra-Plant knife opener (Fig. 3) has a narrow streamlined shape. The replaceable tip is equipped with side fins which allow soil to be raised up and away from the knife as it moves through the soil. Like the Acra-Plant, the Versatile knife opener (Fig. 4) is also narrow, however, it lacks the fins on the sides of the replaceable tip. Thus, rather than lifting the soil in a rolling motion, the Versatile forces the soil to flow around the knife.

It is evident from Fig. 7 that at shallow depths the two knife openers (Acra-Plant and Versatile, denoted with a "K" in Fig. 7) have lower draft values because of their narrow, streamlined shape. The two hoe openers (Edwards and IHC, denoted with an "H") have large draft forces at shallow depths because of their broader cutting face.

As depth increases, draft of the two hoe openers also increases. The rate of draft increase for these two openers (Fig. 7) is very similar indicating that they react similarly when they are subjected to a change in depth. However, in all cases the IHC openers showed an increase in draft of approximately 150 lbs more than the Edwards openers.

The Acra-Plant knife had the lowest draft forces under almost the entire depth range. The reason for the low draft values, in comparison to other openers, is due to its physical shape. Since the soil is being uplifted by this knife, there is less shear force on the sides of the knife and thus a lower draft force results.

The Versatile opener follows an interesting pattern. Since the shear force on this knife is much higher than that of the Acra-Plant, the draft increases with depth at a much higher rate. At shallow depths, the Versatile has low draft forces because it is narrower than the two hoe openers.

The power curve (Fig. 8) follows the same pattern as draft (Fig. 7) because power is related only to draft and speed such that:

$$P = \frac{Dr \times S}{375} \qquad (1)$$

where P = Power (Hp)

Dr = Draft Force (lbs)

S = Speed (MPH)

375 = Conversion Constant

Figures 7 and 8 include regression equations and coefficients for the various lines in terms of both depth and speed such that:

$$Dr = X_1 + X_2 \times D + X_3 \times S \qquad (2)$$

where Dr = Draft Force (lbs)

D = Depth (inches)

S = Speed (MPH)

X_i = Regression Coefficients

Effect of Speed

Fig. 9 shows draft versus depth at three different speeds for an average number of openers. It is evident from Fig. 9 that speed has only a small impact on draft force, as no large differences between the three speeds at a given depth were observed. The slopes of the three lines are similar indicating that speed has little or no effect on draft, regardless of the depth at which the opener is pulled.

The relationship between power and depth is shown in Fig. 10. As previously mentioned (equation 1), power is directly related to both draft and speed. The percentage increase in power requirements for the openers, due to an increase in speed from four to six miles per hour at 0.4 in depth, is seventy-six percent. The percentage increase in draft under the same conditions (Fig. 9) is only seventeen percent. Thus, speed has a much larger effect on power requirements, than on draft.

Depth has a major effect on both draft and power. When depth is increased from 0.4 in to 2.0 in at a constant speed of five miles per hour, draft and power both increase by one hundred and twenty percent.

Effect of Number of Openers

The relationship between draft and speed is shown for the four different number of openers in Figure 11. This graph exemplifies how number of openers has a direct effect on draft. Each time two openers were added to the drill, draft increased by approximately one hundred and fifty pounds. Again speed is shown to have a minimal effect on draft.

The power curves in Fig. 12 show that when speed increases from four to six miles per hour at an average depth for ten openers, the power increased by eighty-two percent. Draft increased by twenty one percent under the same conditions.

Tractor Sizing

The Prairie Agricultural Machinery Institute makes use of the following mathematical expression to determine tractor size requirements (P.A.M.I. 1984):

$$\text{TRACTOR SIZE} = \frac{\text{DRAFT(lbs)} \times 5280\ (\frac{\text{ft.}}{\text{mile}}) \times \text{SPEED}\ (\frac{\text{miles}}{\text{hr}})}{60\ (\frac{\text{min}}{\text{hr}}) \times 33000\ (\frac{\text{ft.lbs}}{\text{min}})} \times \text{T.E.} \times \text{L.F.} \quad (3)$$

where T.E. =Tractive Efficiency factor of either 1.25 representing a tractive efficiency of 80% on hard soils (heavy primary tillage) or 1.44 representing a tractive efficiency of 70% on loose soils (light primary tillage and all secondary tillage).

L.F. = Tractor load factor (L.F. = 1.25 representing a tractor operating at 80% of maximum pto output).

Table 1. Tractor size required to pull an Edwards HD812 with two types of openers at two depths.[1]

Type	Number	Depth (inches)	Speed (mph)	Draft (lbs)	Tractor Size (Hp)
IHC(H)	10	0.5	5	920	19.2
ACRA-Plant(K)	10	0.5	5	645	13.5
IHC(H)	10	2.0	5	2020	42.0
ACRA-PLANT(K)	10	2.0	5	1388	29.0

[1]A tractive efficiency of 1.25 was used because of the presence of standing stubble (primary tillage).

When the draft and speed values observed in the present study are entered into the Tractor Size equation (3) it can be demonstrated that, at a seeding depth of one-half inch, the horsepower requirements for the Acra-Plant knife are forty percent lower than those of the IHC Hoe (Table 1). When seeding depth increases from one-half inch to two inches, tractor size requirements for both openers more than doubles.

In addition to large reductions in power requirements (Table 1), there is also an added bonus to the winter wheat producer with shallow seeding. The probability of a successful winter wheat harvest increases significantly if the crop is sown shallow (Lafond and Fowler 1986, Hultgreen et al 1987). Lafond and Fowler (1986) observed a delayed emergence in winter wheat of between three to five days, depending on temperature, due to an increase in seeding depth from one-half inch to two inches. Hultgreen et al (1987) found a direct relationship between seeding depth and yield of winter wheat. In this instance, when seeding depth was increased from one to two inches there was a drop in yield of seventeen percent.

Soil Disturbance

The physical shape of opener has a major effect on soil and stubble disturbance. Both the Versatile and Acra-Plant knife openers had quite low soil disturbance. This is due largely to the fact that they are knife openers, and are thus relatively thin in width. In contrast, the IHC and Edwards Hoe openers have a larger leading surface area, resulting in more soil disturbance. No relationship between soil disturbance and draft was found during these tests.

Conclusions

Depth of seeding has a major effect on draft. Power is also greatly affected by seeding depth.

Speed has only a small effect on draft forces. However, power requirements are directly related to the speed at which the implement is being pulled and can be lowered by decreasing speed.

Increasing the number of openers caused a constant increase in both draft and power.

The physical shape of each opener plays a large role in determining draft characteristics. The Acra-Plant knife is a narrow opener with fins located on the sides of the tip. Since the knife is narrow, the draft at shallow depths is low. Because of the fins on the sides of the tip, the soil is lifted as the knife moves forward. If the soil is lifted as well as pushed to the sides of the openers, the draft force is less than if the soil is not lifted. Thus, at deeper depths the Acra-Plant opener has a lower draft force than the Versatile opener because the Versatile opener does not have the fins on the knife tip.

Openers which have broad fronts tend to have moderately high draft forces at shallow depths (e.g. IHC and Edwards Hoe openers). As these openers are placed deeper into the soil, their draft increases at a rate determined by the amount of soil that is either uplifted to the surface or forced to the sides. Opener type influences power requirements for seeding.

Opener types that have higher power requirements for similar seed placement will result in higher input costs.

Seeding winter wheat at deep depths translates into higher input costs in terms of power requirements, slower emergence and lower yields.

ACKNOWLEDGEMENTS:

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Fig. 1 IHC HOE OPENER

Fig. 2 EDWARDS HOE OPENER

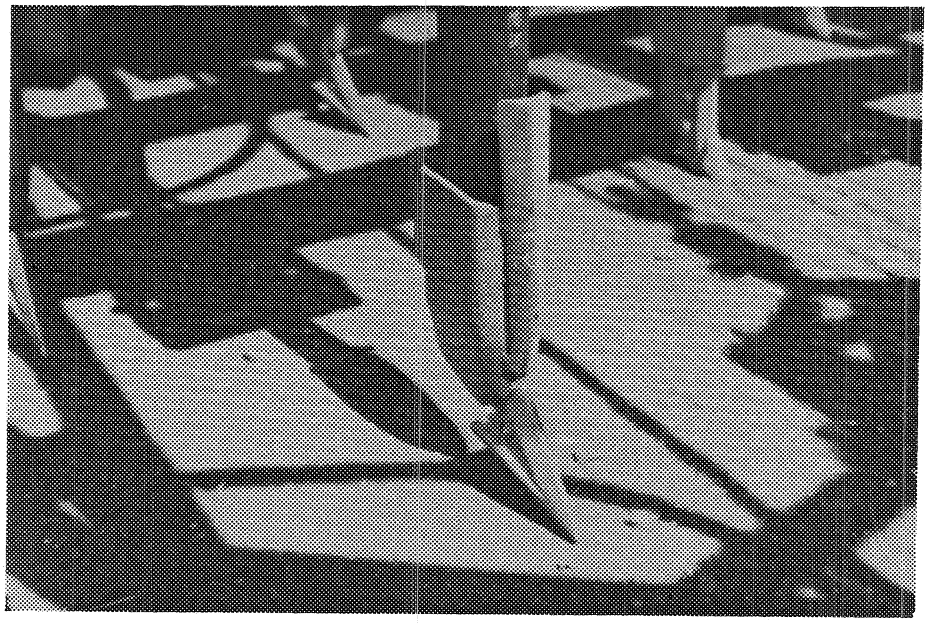

Fig. 3 ACRA-PLANT KNIFE OPENER

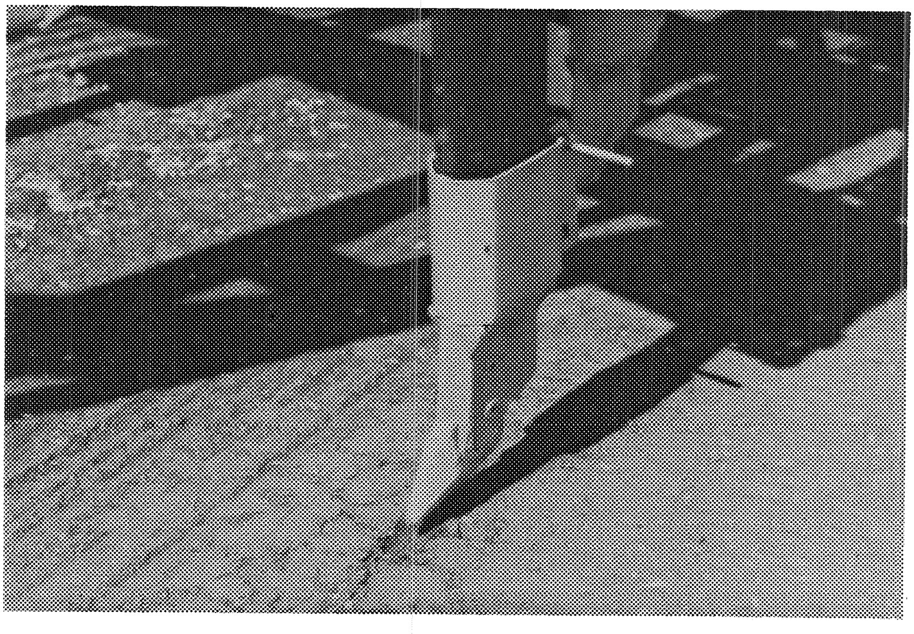

Fig. 4 VERSATILE KNIFE OPENER

Fig. 5 EDWARDS HD812 HOE DRILL

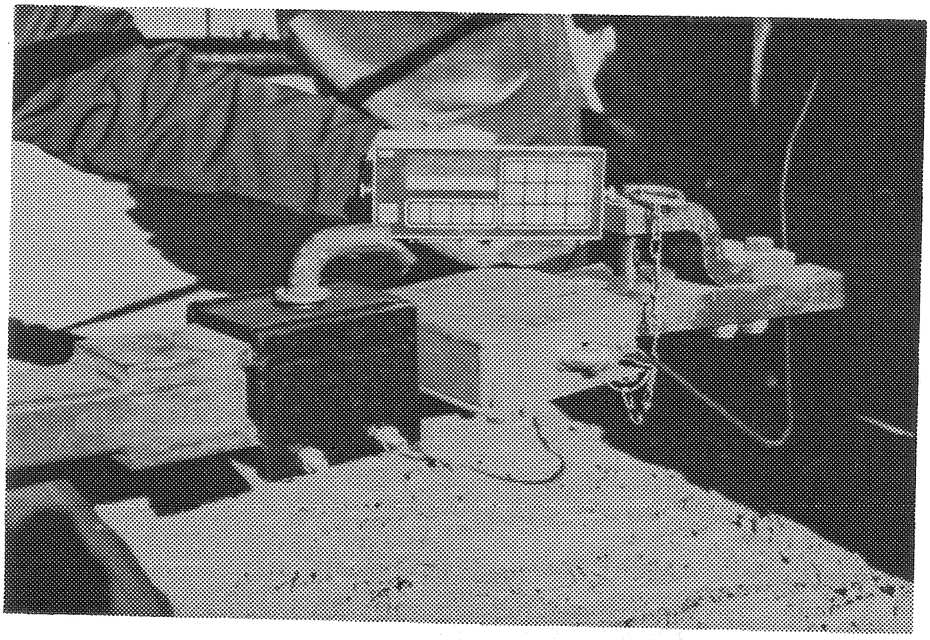

Fig. 6 FORCE TRANSDUCER AND DF2000
DIGITAL WEIGHT INDICATOR

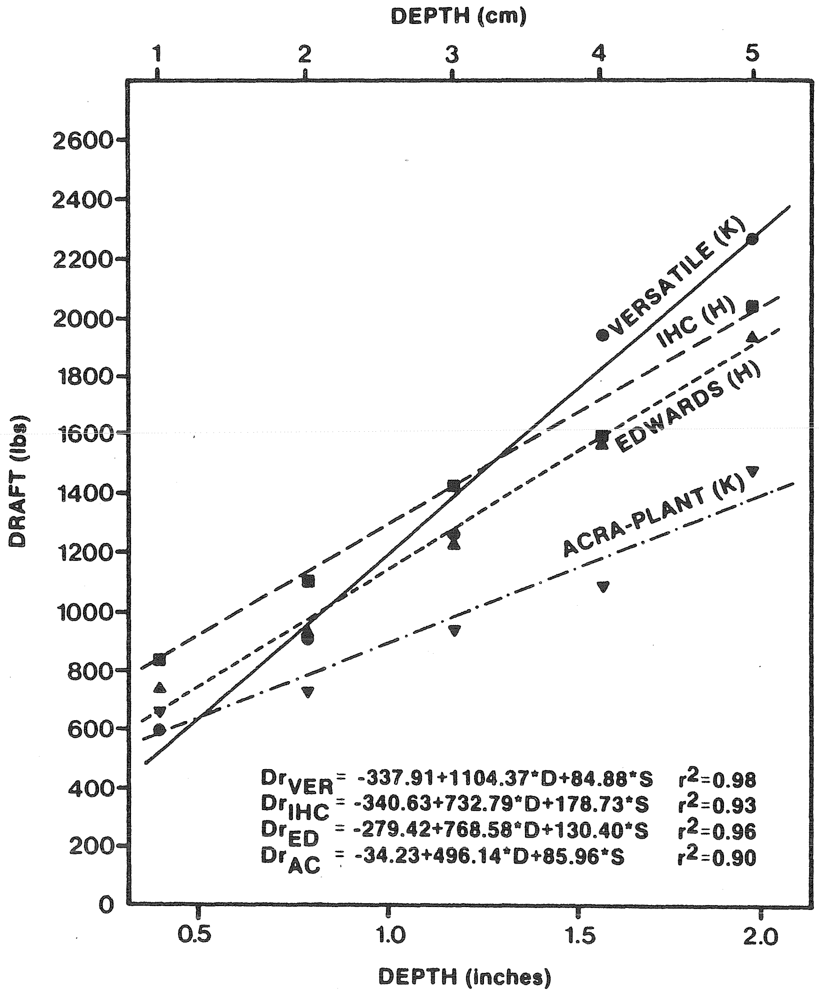

FIGURE 7. DRAFT VERSUS SEEDING DEPTH FOR FOUR TYPES OF OPENERS. AVERAGE SPEED WITH TEN OPENERS.

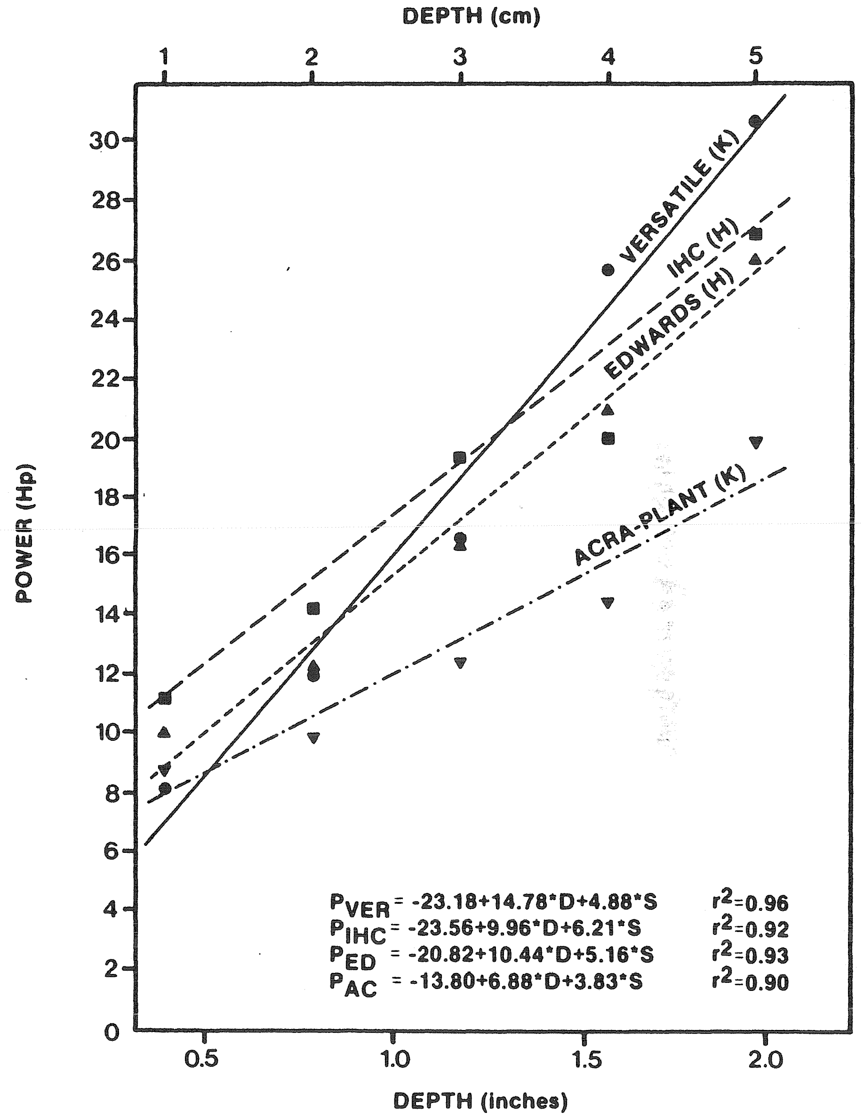

Figure 8. POWER REQUIREMENTS VERSUS SEEDING DEPTH FOR FOUR TYPES OF OPENERS. AVERAGE SPEED WITH TEN OPENERS.

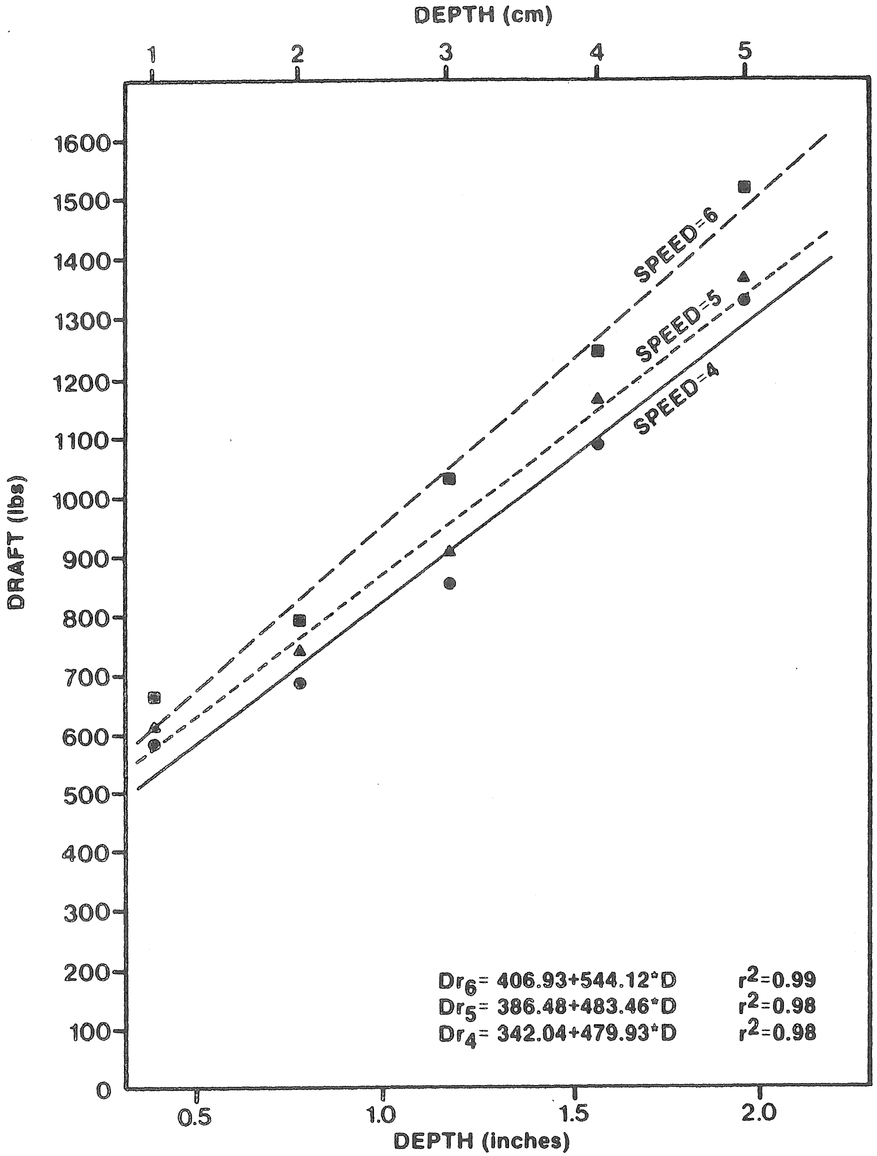

Figure 9. DRAFT VERSUS SEEDING DEPTH FOR THREE SPEEDS. AVERAGE DRAFT FOR ALL OPENER TYPES IN TRIALS WITH FOUR, SIX, EIGHT AND TEN OPENERS.

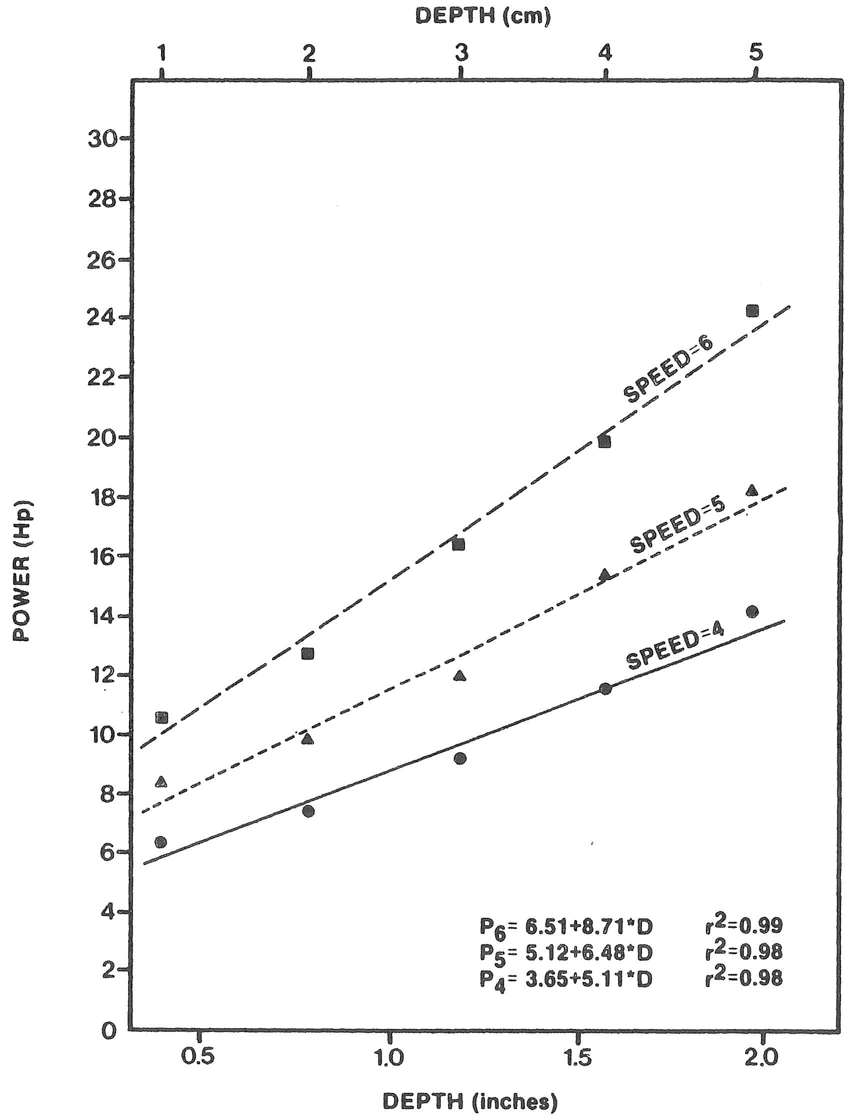

Figure 10. POWER VERSUS SEEDING DEPTH FOR THREE SPEEDS. AVERAGE POWER FOR ALL OPENER TYPES IN TRIALS WITH FOUR, SIX, EIGHT AND TEN OPENERS.

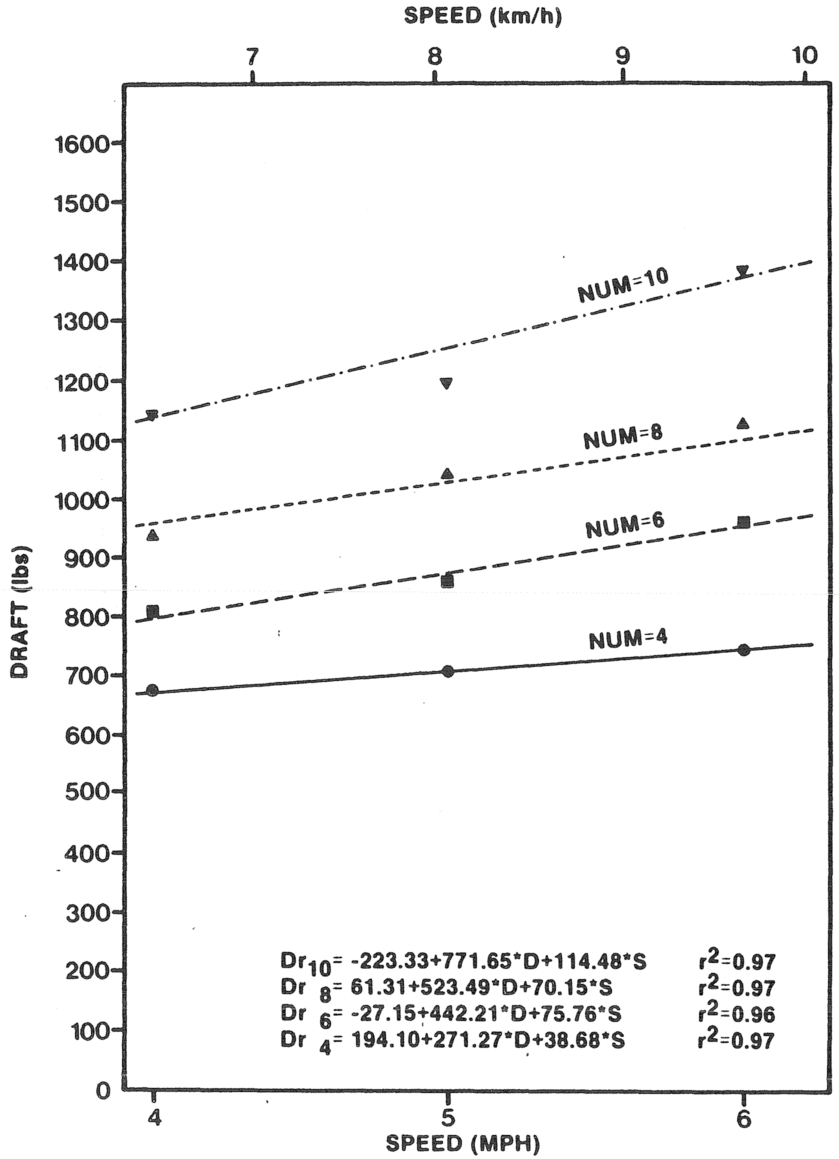

Figure 11. DRAFT VERSUS SPEED FOR FOUR, SIX, EIGHT AND TEN OPENERS, AVERAGE OF FOUR OPENER TYPES AND FIVE DEPTHS.

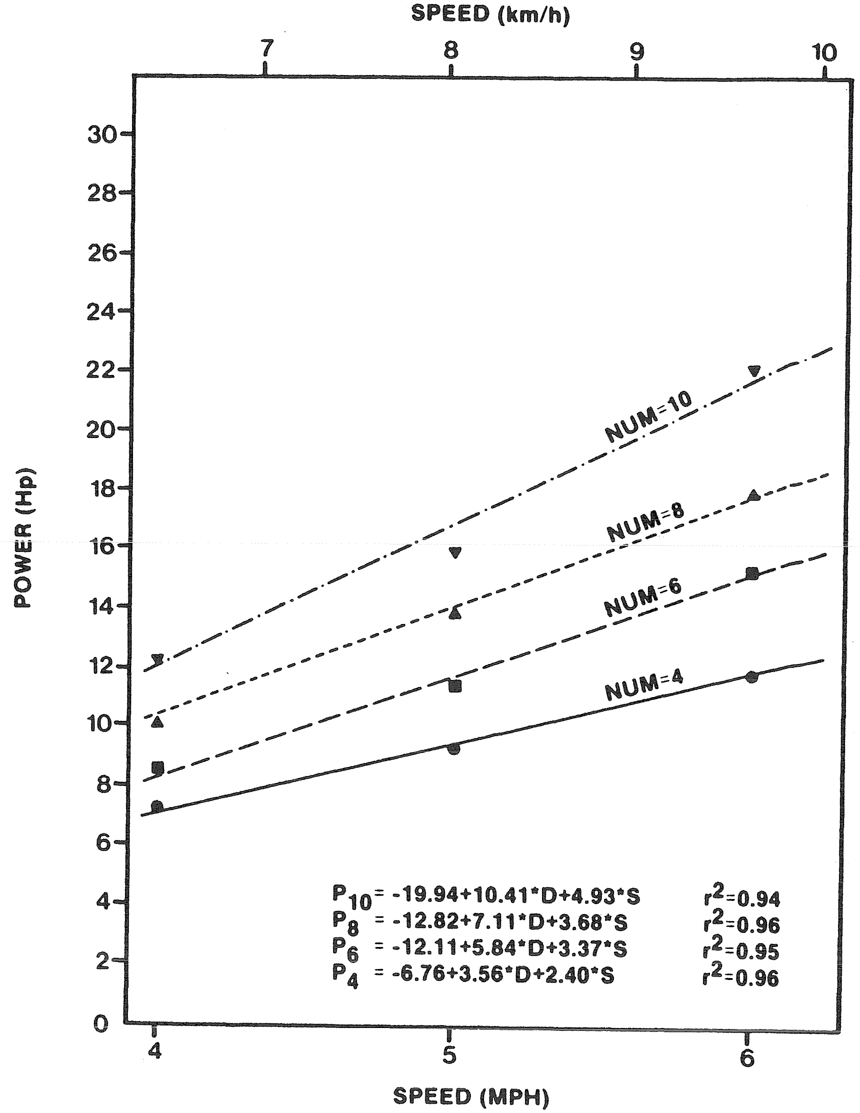

Figure 12. POWER VERSUS SPEED FOR FOUR, SIX, EIGHT AND TEN OPENERS. AVERAGE OF FOUR OPENER TYPES AND FIVE DEPTHS.

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