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Effect of seedbed packing on canola seedling emergence effect of soil characteristics, seeding depth, operation speed, and opener design on direct seeding draft forces

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EFFECT OF SOIL CHARACTERISTICS, SEEDING DEPTH, OPERATION SPEED, AND OPENER DESIGN ON DIRECT SEEDING DRAFT FORCES.

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ABSTRACT

Direct seeding practices that promote soil and water conservation and reduce input costs have become an increasingly accepted alternative to conventional tillage systems in western Canada. The objective of the present study was to determine the relative importance of soil characteristics, seeding depth, operation speed, and opener design on direct seeding draft forces. Draft was measured for nine different openers operated at one to five cm seeding depths and three ground speeds in four untilled fields that differed in soil moisture and/or texture. The average increase in opener draft for all fields was four percent for each km h^{-1} increase in speed. Although the range in soil consistence was small, there was a 24 percent increase in draft in heavy clay compared to sandy loam soil. Draft force of the average opener increased by nearly 20 percent for each cm increase in seeding depth. However, there were large differences in the performance of different openers operated at different depths in soils with different consistence. A 4.5-fold increase in the draft of a low draft versus a high draft opener operated at 1.25 versus 5.0 cm seeding depth at 7.5 km h^{-1} in moist, heavy clay soil emphasized the large influence that opener design and seeding depth have on tractor power requirements and direct seeding input costs.

INTRODUCTION

In the last three decades, direct seeding practices that promote soil and water conservation have slowly become an accepted alternative to conventional tillage systems in western Canada. Improvements in the design of minimum and no-till drills, lower cost and more effective herbicides, a better understanding of the role of tillage in crop production systems, and an increased emphasis on residue management have been key factors in the successful shift to direct seeding. Snow trapped in standing stubble of direct seeded fields also keeps soil temperatures warm enough to allow overwintering of winter wheat in regions with harsh winter climates. Consequently, in addition to providing an alternative to conventional tillage systems for spring sown crops, adoption of low disturbance direct (no-till, stubbling-in) seeding methods has been a critical step in the expansion of the winter wheat production area in western Canada (Fowler, 1983).

Direct seeding requires a drill that will effectively penetrate untilled soil and place the seed at the optimum depth for rapid plant emergence. Many farmers have also been convinced that the total nitrogen fertilizer requirements of the crop should be applied as part of the direct seeding operation (Johnston et al. 1993). In low disturbance direct seeding systems this requires an opener that can achieve separate placement of the seed and fertilizer. However, field experience with seeding winter wheat into dry heavy clay soils indicates that some fertilizer banding seed drill openers create tractor power requirements in excess of 32 kW/m (12.5 hp/ft) of drill width. These observations suggest that draft forces and input costs should not be considered as constants in economic analyses and equipment selection for direct seeding systems. Therefore, the objective of this study was to determine the relative importance of soil characteristics, seeding depth, operation speed, and opener design on direct seeding draft forces and tractor power requirements.

MATERIALS AND METHODS

The effect of opener design, ground speed, and seeding depth on draft was determined in a total of four trials conducted at three locations in the fall of 1986 and 1987. Standing stubble on recently harvested wheat fields provided a medium to light trash cover at all trial sites. The trial sites represented a range of soil textures and moisture contents (Table 1) that were typical of those encountered by farmers who direct seeded winter wheat into standing stubble on the optimum seeding date (Fowler, 1986) in central Saskatchewan. Experimental design was a four replicate, three factor (seeding depth, ground speed, and opener design) factorial. A minimum of twenty draft measurements were made for each level of each factor within each replicate at each site.

Table 1. Test site locations and soil characteristics.

Year	Site	Legal Location	Soil Classification	Texture	Moisture Content	Bulk Density
1986	Watrous	NE 1/4 19-31-24 W2	Weyburn Orthic Dark Brown	Clay Loam	20.9	1.10 g cm^{-3}
1987	Watrous a	SE 1/4 19-31-24 W2	Elstow Orthic Dark Brown	Clay Loam	12.1	1.06 g cm^{-3}
1987	Watrous b	NE 1/4 13-32-25 W2	Weyburn Orthic Dark Brown	Sandy Loam	16.2	1.02 g cm^{-3}
1987	Indian Head	SW 1/4 30-18-12 W2	Indian Head Calcareous Black	Heavy Clay	30.2	1.16 g cm^{-3}

Seeding depths were 1, 2, 3, 4, and 5 cm in all trials. Seeding depths were measured as the distance seeds were placed below the soil surface in the seed-row furrow. Ground speed was 6.4, 8.0, and 9.7 km h^{-1} in 1986 and 5.6, 7.2, and 8.8 km h^{-1} in 1987. Draft measurements were made for a total of nine openers: the IHC hoe, Edwards hoe, Acra-Plant shoe, Versatile knife, and Haybuster 46 cm diameter offset double disc in 1986 and the IHC hoe, Edwards hoe, Acra-Plant knife, Versatile knife, Gen tip, Edwards chisel, Thompson banding knife, and Dutch banding knife in 1987. The Thompson and Dutch openers can be used to both seed and band fertilizer at the same time.

The MC hoe had a 7.5 cm wide shovel. The Edwards hoe had a blunt 3.75 cm wide face and a long frontal surface area. The Acra-Plant opener had 4.5 cm wide shoe with fins on a replaceable tip. This opener deposited the seed in a narrow "V" at the bottom of the furrow. The Versatile knife was also a narrow opener with a 1.9 cm wide replaceable tip. The 2.0 cm wide wedge-shaped Gen tip opener was attached to the body of a Dutch banding knife and seed was delivered through the fertilizer tube. The reversible Edwards chisel, which is normally used for primary tillage in stubble fields, expanded to 6.5 cm at its widest point and then narrowed to a uniform 5.0 cm width. The Thompson banding knife, which was 2.0 cm wide, was followed by an equally narrow seed row opener that could be adjusted to place seed above, below, or to either side of the fertilizer band. The 2.0 cm wide Dutch knife placed the fertilizer 2.5 cm below the seed.

A Haybuster 1000 drill with 15 cm row spacing was used to evaluate the draft of the offset double disc opener. An Edwards HD 812 four-rank heavy duty hoe drill with ten openers and 20 cm row spacing was used for all other opener comparisons. The shanks of the Edwards hoe drill were replaced by heavy-duty cultivator shanks to obtain the correct soil entry angle for the Gen tip, Thompson, Dutch, and Edwards chisel openers.

Draft is defined as the horizontal component of pull, parallel to the direction of travel, imposed on the tractor by the implement being pulled. A bonded strain gauge load cell was used to measure draft in the present study. This S-shaped force transducer had a capacity of 9,000 kg with a 400 percent safe overload. The unit was fully environmentally protected against moisture ingression and by design was insensitive to barometric effects. The load cell was placed between the tractor drawbar and the hitch of the 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 in full view of the operator. Data was directly transcribed from the digital indicator onto a cassette recorder.

RESULTS AND DISCUSSION

Soil Characteristics

Significant ($P < 0.01$) differences in draft forces were associated with the different fields (Table 1) in which trials were conducted in this study. The average draft (newtons m^{-1} of width) for all openers was 3179 in the heavy clay soil, 2692 in the clay loam soil, and 2567 in the sandy loam soil. While these fields only provide a snapshot of the range of soil consistence farmers encounter, the 24 percent increase in draft for heavy clay compared to sandy loam soil emphasize the need to consider soil characteristics when determining draft of seeding equipment. A high coefficient of variability (28.9%) also indicated that considerable variation in draft forces can be expected within a given field. Consequently, in order to accommodate high draft variability, a larger tractor unit than is suggested by average draft values is required to provide the necessary power reserves for t he seeding operation.

Opener Design

Opener design had a significant ($P < 0.01$) influence on draft. A significant (P c 0.01) field by opener design interaction also indicated that the relative performance of the openers was not constant for the different soil characteristics (Table 1) encountered in this study (Table 2).

The offset double disc opener had an average draft of 1427 N m^{-1} of width on the clay loam soil at Watrous in 1986 (Table 1). This was the lowest draft of all openers and was due to the very thin cross section of the discs when they penetrate the soil. Draft was low for both the Edwards chisel point and the wedge-shaped Gen tip openers. Performance of these two openers was also relatively constant for the different soil characteristics encountered in this study.

The Acra-Plant and Versatile knives are both narrow; however, their draft performances were very different (Table 2). The Acra-Plant opener has a narrow streamlined shape and a replaceable tip with side fins that lift the soil up and away from the knife. The Versatile knife is also narrow, but it lacks fins on the sides of the replaceable tip. Consequently, rather than lifting the soil in a rolling motion, the Versatile opener forces the soil to flow around the knife. These design differences resulted in the highest draft in heavy clay for the Acra-Plant and clay loam soil for the Versatile opener.

The Edwards hoe opener, which is blunt and does not lift the soil, had the highest average draft of the hoe openers. The IHC hoe (shoe) also has a broad surface area; however, it is curved so that the soil rolls up and off the shoe as it moves forward. Consequently, although the MC hoe is relatively wide, the draft forces associated with it were low in the 1987 clay loam and sandy loam soils (Table 2).

The fertilizer banding knives had the highest average draft in the 1987 trials. The seed tube of the Thompson knife can be placed higher, lower, or to either side of the fertilizer band. In the present studies, the Thompson knife was adjusted to deliver the seed directly behind and four cm above the fertilizer band. The Dutch banding knife places the fertilizer 2.5 cm directly below the seed. Due to the physical shape of the Thompson knife, the bottom of the opener runs about 2 cm deeper in the soil than the Dutch knife for the same depth of fertilizer placement. These differences were likely responsible for the higher draft observed for the Thompson compared to the Dutch knife, especially in heavy clay soil (Table 2).

Depth

There was a significant ($P < 0.01$) linear increase in draft when seeding depth was increased from one to five cm (Table 2). The effect of increased seeding depth on draft was similar for the sandy loam and clay loam soils. In contrast, the slope of the draft force-seeding depth curve was much steeper for the heavy clay soil. This difference in the relationship between draft force and seeding depth for the different soil types resulted in a significant ($P < 0.01$) seeding depth by field interaction. Significant ($P < 0.01$) opener by seeding depth and opener by seeding depth by field interactions for draft also indicated that

a) the openers responded differently to increased seeding depth, and
b) opener response to changes in seeding depth was a function of soil characteristics.

Differences in draft of conventional openers at the one and two cm depths were smallest for sandy loam soil, larger for clay loam soil, and largest for heavy clay soil. As expected, the draft for fertilizer banding knifes was high at shallow seeding depths (Table 2).

The draft for all openers increased as seeding depth increased. However, there were large differences in the slopes of the seeding depth-draft response curves for the different openers (Table 2). The off-set double disc opener had the lowest draft of all openers over the entire depth range considered in the 1986 evaluation in clay loam soil. The Edwards chisel and Gen-tip openers had the lowest draft of the hoe and knife openers considered in the 1987 evaluations. The low draft force with these two openers was particularly evident in heavy clay soil. Compared to other openers, draft of the Versatile knife increased at a much higher rate as seeding depth increased in the 1986 clay loam soil. Less effective surface scouring also resulted in steeper slopes for the seeding depth-draft response regression lines for the Acra-Plant and IHC openers in the moist, sticky heavy clay soil in 1987. These observations emphasize the importance of evaluating opener performance over a wide range of soil conditions and seeding depths.

Table 2. Relationship between draft force (DF = newtons m^{-1} of width) and seeding depth (SD = cm) for different opener designs and soil characteristics (Table 1). DF = A + B(SD).

	Regression Coefficient		
Opener	**A**	**B**	r^2
A) Sandy Loam 1987			
Edwards Chisel	1251	259	.91
Gen tip	1203	324	.98
IHC	784	389	.97
Dutch	1629	442	.99
Thompson	2633	451	.94
Versatile	737	484	.99
Acra-Plant	533	642	.97
Edwards	563	744	.96
B) Clay Loam 1986			
Haybuster disc	955	157	.98
Acra-Plant	1377	365	.98
IHC	1876	457	.98
Edwards	1318	512	.91
Versatile	424	986	.99
C) Clay Loam 1987			
Edwards chisel	1271	241	.94
Gen tip	1453	297	.89
IHC	1155	332	.97
Acra-Plant	951	389	.96
Thompson	2794	422	.99
Dutch	2012	442	1.00
Versatile	1303	601	.98
Edwards	884	688	.97
D) Heavy Clay 1987			
Edwards Chisel	1257	250	1.00
Gen-tip	1343	329	.80
Thompson	3689	463	.97
Edwards	2191	489	.97
Dutch	1618	599	.87
Versatile	874	712	1.00
Acra-Plant	312	973	.98
IHC	836	1081	.95

Speed

Increased speed produced a small but significant ($P < 0.01$) linear increase in draft. A significant ($P < 0.01$) field by speed interaction indicated that the rate of increase in draft associated with increased speed was also dependent upon soil conditions. Average draft for all openers at all seeding depths increased by 5 percent km^{-1} hr -1 in the 1986 clay loam soil and by 1, 3, and 4 percent km^{-1} hr^{-1} in the 1987 heavy clay, clay loam, and sandy loam soils, respectively (Table 1).

There was a significant ($P < 0.01$) speed by seeding depth interaction. The average increase in draft for all openers for all fields was 4 percent for each km hr^{-1} increase in speed at seeding depths between one and five cm. Consequently, because small increases in seeding depth and differences in soil consistency had a large influence on draft (Table 2), the absolute effect of increased speed was larger at deep compared to shallow seeding depths and for heavy clay compared to loam soils. Nonsignificant ($P > 0.05$) speed by opener and speed by opener by seeding depth interactions indicated that the relative draft performance of openers was not influenced by changes in speed at the seeding depths considered in this study.

General Discussion

Fertilizer banding and no-till, zero-till, and direct seeding are high profile subjects in the modem agricultural community. However, the large field to field variation in power requirements is usually ignored when seeding and fertilizing operations are discussed. Among the factors evaluated in the present study, differences in soil consistence had the largest influence on draft even though dry heavy clay soils, which practical experience has shown to produce very high draft forces, were not considered. An average increase in draft of nearly 20 percent for each cm increase in seeding depth also emphasized the importance of shallow seed placement so that direct seeding tractor power and fuel requirements can be minimized.

Differences in draft due to soil characteristics, speed, and opener design were smallest at seeding depths less than two cm. Consequently, at shallow seeding depths, openers that placed fertilizer below the seed normally had higher draft than conventional openers. For example, when adjusted to band fertilizer four cm below seed sown one cm deep, the Thompson fertilizer banding opener had a draft that was 2.5 and 3.0 times higher than the conventional Acra-Plant opener operated at a seeding depth of one cm in sandy loam and heavy clay soils, respectively.

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