# DISCUSSION PAPER ON SEEDBED FINISHING

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**ABSTRACT**

A literature review of seedbed finishing was completed. Experimental and practical attempts have been made to explain why and how seedbed finishing benefits cropping practices. While research has outlined methods for optimum moisture use and minimum moisture loss, general recommendations on seedbed finishing have not been addressed at the Western Canadian farming level.

## INTRODUCTION

With an increased ability to limit weed growth and supply nutrients for crop growth, moisture has become the limiting factor to crop production in semi-arid regions of Canada (Lindwall 1984). Soil moisture is made available to seed through rainfall and moisture contained in the soil profile. Since the amount of rainfall that occurs cannot be controlled, optimum use of the moisture contained in the soil is important to maximize crop production. Optimum moisture use is achieved through maximizing soil moisture uptake by the seed and minimizing soil moisture loss to the environment. Both maximizing soil moisture use and minimizing moisture loss can be achieved by changing a soil's physical properties through tillage.

Tillage for seedbed finishing on the Canadian prairies has been accomplished using either packers, harrows, rodweeders or a combination of the three implements. Unfortunately, because of the number of physical and chemical factors in soil, concrete recommendations and conclusions regarding seedbed finishing have been difficult to achieve. This paper attempts to outline seedbed finishing research and discuss the practical application of this research to Western Canadian farming. The discussion will emphasize soil physical properties that affect soil moisture use by the seed and soil moisture losses.

## CHANGES IN SOIL PROPERTIES AND HOW THEY MAXIMIZE SEED MOISTURE USE

Before a seed will germinate, favourable soil temperature and sufficient moisture are required. Three soil properties which effect seed moisture use will be discussed; bulk density, soil porosity and plant available water content.

### BULK DENSITY

Seed moisture imbibition and emergence are not directly affected by changes in soil bulk density but rather changes in soil properties due to bulk density variation. Rogers and Dubetz (1980) illustrated that moisture imbibition of wheat seeds was increased by changes in bulk densities, causing movement of capillary water and water vapour to the seed. The movement of water to the seed and thus increased soil bulk densities were the controlling factors for moisture imbibition. Increase in imbibition was not due to the intrinsic effect of bulk density, but the changes in water transmission and soil porosity caused by bulk density. Hanks and Thorp (1955) varied a soil's bulk density from optimum to maximum field compaction. Bulk density was related indirectly to seedling emergence in that any change in bulk density changed other factors such as oxygen diffusion rate and soil crust strength. A similar approach was taken by Stout et al. (1961) and Johnson and Buchele (1961) who indicated the importance of soil seed contact in emergence without explaining water transmission to the seed. Considering the number of soil properties affected by changes in bulk density, practical applications or recommendations are difficult.

## SOIL POROSITY

Changes in soil porosity affect soil water transmission. Decreasing porosity below a seed enhances water movement toward the seed and increases bulk density, creating a firm footing for seedling roots. A firm footing for roots increases a seedling's ability to push through the soil surface. Carnes (1934) concluded soil should be packed below the seed so the seedling has a firm footing for penetrating surface crusts. However, decreasing soil porosity below 10% of the soil volume could restrict oxygen diffusion rates, causing decreases in emergence and plant growth (Hausenbuiller, 1985).

## PLANT AVAILABLE WATER CONTENT

In most field conditions, soil moisture increases with depth. Increasing soil bulk density reduces available pore space to the point where diminished room exists for air and water in the soil at a given depth. Since water is virtually incompressible, water in the compacted soil layer moves upward toward the soil surface. Thus, a compacted soil layer increases the available potential for seed moisture imbibition and emergence. Hakansson and Polgar (1984) concluded a plant available water content of 5% (w/w) below the seed should be enough to produce a good emergence even if the seedbed is dry and no rain falls. This applies if the seedbed provides good protection against evaporation. However, good protection against evaporation may be difficult to achieve.

## PROPERTIES OF SOIL FINISHING TOOLS

Different soil finishing tools have different effects on soil properties. This section outlines packers, harrows and rod weeders and some of the effects they have on soil bulk density, porosity and plant available water content.

## PACKERS

Agricultural packers are commercially available in numerous shapes and sizes. Different packers affect soil properties differently. Packers affect soil physical properties by increasing soil bulk density through decreasing soil particle size and available pore space. Theoretically, the amount packers change soil properties is directly related to the packers' static weight, dynamic weight, velocity, wheel spacing and wheel diameter. However, experimental results indicate theoretical considerations may not always apply to practical applications.

In theory, an implement's static and dynamic weights are directly related to packing effectiveness. Static weight is the mass per unit width of a stationary packer and is determined by a simple weighing process. Dynamic packing ability is the stress concentration applied per unit time on a soil element under a packing tool. Direct comparisons between static weight and dynamic compacting characteristics were done by Djokoto et al. (1971). Tests indicated, for all practical purposes, dynamic compacting characteristics of two packers with different static weights were the same. Changes in dynamic compacting were measured by increases in bulk density and available moisture for germination. Djokoto et al. (1971) concluded an increase in packer weight generally resulted in an increase in dry bulk density of a soil. However, for an increase of 41% in packer static weight, 131.0 to 184.5 kg/m (94.8 to 133.5 lb/ft), there was an average increase of less than 1% in dry bulk density. Tests done by Lindwall and Erbach (1983) illustrated similar conclusions. Results did not show a significant increase in soil bulk density or moisture content with an increase in packer weight at depths greater than 5 cm (1.97 in). Several Western Canadian manufacturers produce packers with a static weight of 138 kg/m (100 lb/ft). Heavier packing implements may not provide the increase in compaction or water available to seeds that is expected of a heavier unit. Research using packers lighter than 138 kg/m (100 lb/ft) may be beneficial to determine packer minimum weights. Since soil properties also effect packing, research should address how soil properties will affect minimum packing abilities.

Implement velocity is an important factor when comparing static weight to dynamic packing ability. Since dynamic compacting is related to the time a stress is applied to a soil element, the dynamic compacting of an implement should decrease as the velocity of the implement increases. No research on the effects of velocity of agricultural packers was found. However, some research on agricultural vehicle speeds has been completed. A literature review done by Soane et al. (1980) found research on the effect of speed on compaction was often limited and conflicting. In general, Soane et al. (1980) found that increases in speed decreased compaction. Similar work done by Cohron (1971) indicated an increase in speed results in less compaction and should be considered to decrease unwanted compaction by tractors and heavy machinery. Relating the work done by Cohron (1971) to packers, a slower, lighter packer may compact the soil more or the same as a heavier packer moving at a greater speed.

Using Boussinsq's theories on soil stress (Bernacki 1972), calculations indicate the majority of stress transferred to a soil particle located under a packer wheel is from the packer wheel directly above the particle. Less than 5% of the total stress on the soil particle under a packer wheel is transferred from an adjacent packer wheel on the gang. This would indicate that spiral packers and crowfoot type packers, which do not specifically pack above the seed, may not provide the same increases in soil stress as round or v-shaped packers would. However, tests done by Djokoto et al. (1971), showed no significant difference existed between the bulk density obtained at numerous depths for wheel spacings of 2.5, 5.1, 7.6 and 12.7 cm (1, 2, 3 and 5 in). In addition, dry bulk density of soil was not affected by packing implements used. Packing directly over the seed may not be necessary, as theory would imply. However, emergence may be affected by seed row compacting because the depth of soil above the seed is reduced which allows young plants to come up more rapidly.

Wheel diameter affects soil packing and rolling resistance. An increase in wheel diameter decreases a soil's reacting force, causing a decrease in rolling resistance and energy requirements. An increase in wheel diameter increases the amount of wheel surface area on the soil. Theoretically, as the diameter and surface area of a wheel increases, pressure on a specific point of the soil under a packer will decrease. However, Djokoto et al. (1971) showed that changes in the diameter of a packer wheel had no significant influence on resulting dry bulk densities of test soils. No significant difference in bulk density was found when varying the diameter of packer wheels from 20 to 61 cm (8 to 24 in), keeping static weight constant. These results indicate large diameter packer wheels are desirable since less power will achieve the same packing results.

**HARROWS**

Many different types of soil finishing harrows are available. The basic purpose of harrows is to level the soil surface and distribute aggregate sizes in the soil. Harrows provide packing on the surface above the seed, but do not provide firm packing around or below the seed. Surface packing which occurs after harrowing will increase the bulk density on the surface and soil water movement to the surface. Unfortunately the surface layer generally has a very low moisture content and increasing the bulk density has very little effect on soil water movement. Packing provided by harrows seals off the surface and prevents evaporation loses.

**ROD WEEDERS**

Rod Weeders are operated just under the soil surface for seedbed preparation or deeper for weed control under summerfallow conditions. Krause (1974) stated to achieve a passageway for a rod, soil flows over the rod forming a dam of material, and passes under the rod creating a compacted layer. Atkins (1979) referred to the two layers of soil created by the division of the rod as the plane of separation. Soil which passes over the rod remains loose, while soil which passes under the rod is compacted. The compacted layer has an increased bulk density which increases available water to the seed. The loose layer of soil above the plane of separation provides a barrier to prevent upward movement of soil water. A loose layer of soil was also suggested by Rathore et al. (1983), who indicated to reduce hazards of surface crusting a stratified seedbed with finer aggregates in the seed zone and coarser aggregates near the surface should be prepared. The fine aggregates around the seed will provide a good seed-soil contact and prevent the soil from drying. Uneven surface consisting of coarse aggregates may be more effective in maintaining a high infiltration rate and be capable of resisting the beating action of rain, reducing the hazards of soil crusting. By turning larger aggregates to the surface and compacting smaller aggregates near the seed, rod weeders can prevent surface crusting and increase emergence. While rod weeders can create a desirable seedbed, rod penetration and soil movement must be considered when shallow seeding. Ground driven rods may enhance problems involving penetration and soil movement in some soil conditions.

Rod weeders have the added benefits of levelling the soil surface and providing complete weed control. Weeds pass over the rod and are inverted and killed. Rod weeders only bury about five to ten percent of surface residue (University of Saskatchewan, 1984), making them excellent soil conservation tools.

Rod weeders provide results that would be achieved with a packer operation followed by a harrow operation. In stony conditions, rod weeders expose rocks to the surface, which may cause harvesting problems. The costs of rod weeders make them an economical seedbed preparation tool.

## CHANGES IN SOIL PROPERTIES AND HOW THEY LIMIT SOIL MOISTURE LOSS

Soil moisture is lost mainly through plant uptake and evaporation. While plant uptake cannot be controlled in a crop production situation, seedbed finishing practices can help to reduce evaporative losses. A literature search by Heinonen (1979) indicated evaporation control is accomplished through changing soil distribution and aggregate sizing.

## AGGREGATE SIZE

Ideal aggregate sizes for seedbeds have been addressed by numerous researchers. Evaporation control and seed moisture uptake have been the focal points of aggregate sizing research.

While varying conclusions have been reached, researchers generally accept a seedbed with soil aggregates of less than 2.0 mm (0.08 in) in diameter for dry weather situations. Heinonen (1979) concluded from a literature review a homogenous layer of graded aggregates sized in the 0.5 to 2.0 mm (0.02 to 0.08 in) range, provides the most efficient evaporation control above a seed. In the 0.5 to 2.0 mm (0.02 to 0.08 in) range both capillary flow and turbulent gas flow are small. If aggregate size decreases below 0.5 mm (0.02 in), capillary flow increases and water is lost through increased evaporation due to the water's proximity to the soil surface. If aggregates are over 2.0 mm (0.08 in), turbulent gas and evaporative moisture loss increases. Similar conclusions were drawn by Braunack and Dexter (1988). Experiments with less than 1, 1 - 2, 2 - 4 and greater than 4 mm aggregates indicated dry matter production and grain yield decreased with increasing aggregate size in drier years. However, 1 - 2 mm aggregates gave maximum values in the wetter years, indicating moisture conditions are a key factor in optimum seedbed determination. Hammerton (1961) found a fine soil caused the movement of water to an imbibing seed to increase, resulting in more rapid moisture uptake than in a coarse soil.

Research for optimum aggregate sizing for minimum evaporative losses has been conflicting. Ojeniyi and Dexter (1984) indicated accelerated soil drying was caused by the presence of 4 - 8 and 8 - 16 mm (diameter) voids. Russell (1961) also indicated research generally accepts a soil particle size range of 1 to 5 mm (0.04 to 0.20 in) is required for seedbeds. Hakansson and Polgar (1984) concluded in dry weather situations small grains should be placed directly onto the moist bottom of a harrowed layer, which should be 4 - 5 cm (1.6 - 2.0 in) deep and mainly consist of aggregates smaller than 4 mm (0.16 in). Holmes et. al (1960) found a fine tilth containing soil particles predominantly of the 2.5 mm (0.1 in) diameter size was more effective in slowing the rate of water loss than either the untilled condition or coarse clods at the surface.

Soil moisture conditions may affect ideal seedbed aggregate sizes and distributions. The influence of moisture conditions was apparent in experiments by Agrawal (1984). Tests indicated that under irrigation, coarse tilth seedbeds produced higher grain yields of wheat than fine tilth seedbeds because of better crop growth as indicated by the number of tillers per plant, plant height and dry matter production per plant. As well, coarse seedbeds leached mineral nitrogen from the surface soil.

Practical problems arise with the creation of ideal evaporation control layers. Areas where moisture is the limiting factor in crop production are normally associated with high winds and soil erosion problems. Chepil (1955) stated dry soil particles 0.84 mm (0.03 in) in equivalent diameter and smaller are considered erodible. While the ideal seedbeds of 0.5 to 2.0 mm (0.02 to 0.08 in) suggested by Heinonen (1979) may reduce evaporative soil moisture losses, the adverse effect of soil wind erosion may eliminate any gains in crop yield.

Another problem with ideal seedbeds is proper aggregate sizing. Considering the number of soil properties, moisture conditions, cropping practices, environmental conditions and implements used by farmers, the likelihood of making general recommendations on soil particle sizing for seedbed finishing is difficult. Ojeniyi and Dexter (1979) concluded tillage requirements to achieve changes in soil particle size may not be known or possible.

Long term effects of tillage or seedbed finishing practices may not be a significant factor in crop production. A ten year study by Chang and Lindwall (1990) was completed to compare the long term effects of conventional tillage vs. no till on various soil water properties. Results indicated changes in soil properties did not approach values that would limit crop production. Even if seedbed finishing recommendations were possible, they probably would not mean much if growing season precipitation was adequate. Affects of growing season precipitation far outway the short term affects of seedbed finishing (Campbell et al. 1988).

**DEPTH OF SEEDBED EVAPORATION CONTROL LAYER**

The depth of the seedbed evaporation control layer is critical to the reduction of moisture loss. Hakansson and Polgar (1984) concluded by increasing seeding depth emergence is improved due to the increase in the evaporation control layer. However, when seed placement reaches an adequate depth for evaporation control, emergence may decrease because of an increase in seedling energy required to reach the soil surface. In practical terms, even if specifying precise seeding depths for evaporation control was possible for all crops, soil properties, environmental conditions and soil moisture reserves would still dictate seeding depth. If farmers seed to a depth for maximum evaporation control, the moisture lost due to tillage of moist soil may be greater than the gains from the evaporation control layer. A drought condition may be the only effective application of seedbed finishing practices.

**HOW SOIL FINISHING CHANGE SOIL PROPERTIES**

While packers and rod weeders will affect aggregate size and distribution, harrows may have the greatest influence on moisture loss in the seedbed. The following section outlines the effects of harrows, packers and rod weeders on aggregate sizing, aggregate distribution and seeding depths.

**HARROWS**

Harrows sort aggregates, level the soil surface and provide a loose layer of soil above the seed. Kouwenhoven and Terpstra's (1977) used glass spheres to simulate aggregate distribution in a soil. Tests indicated sorting by tines caused relatively high concentrations of large glass spheres in the higher layers and of smaller glass spheres in lower layers. The degree of sorting increased with the number of operations, but to a lesser extent in each subsequent operation until an equilibrium state was attained. The use of harrows for seedbed finishing was supported by Hakansson and Polgar (1984). The sorting and levelling effect provided by a harrowing operation could create a homogenous layer of soil over the seed, providing evaporation control.

Harrowing could decrease the adverse affects of packing on crop production in certain soil situations. Benefits of a harrowing operation after packing have been supported by the research results of Hakansson and Polgar (1984) and Stout et al. (1961). Hakansson and Polgar (1984) concluded loose soil should be placed above the seed to increase porosity, improve infiltration characteristics and reduce the possibility of rain induced crusting. Stout et al. (1961) concluded better stands can be obtained by pressing the seed firmly into the soil, leaving the soil over the seed loose so it will offer a minimum of resistance to the emerging seedling. However, varying results on loose or crusted soil over the seed have been found. Hadas and Stibbe (1977) suggested crusting in the field may not be the cause of bad stands of wheat, except under extremely adverse conditions. Braunack and Dexter (1988) indicated the presence of a crust increased the time to emergence and reduced the percentage emergence, but had no significant effect on yield. The importance of a loose soil layer over the seed may be over emphasized by some researchers.

While harrowing after a packing operation is beneficial to seed growth in numerous ways, some disadvantages to harrowing after packing are evident. Dry soil surface aggregates should be retained near the surface and the moist soil near the seed. The mixing of the dry surface material and moist soil caused by harrows could cause an increased drying rate of the soil. Another disadvantage of harrowing after packing will occur in rocky conditions. Harrows tend to expose rocks which cause swathing and combining problems. Harrowing benefits crop uniformity due to a creation of a homogenous layer, but eliminate any furrows created by drill packer wheels. Furrows allow rainfall to concentrate at plant roots and provide some wind protection for the soil surface and emerging seedlings. A harrowing operation may be beneficial in some soil conditions, but the disadvantages must be considered for each situation.

**PACKERS**

While packers may play an obvious role in maximizing moisture use by the seed, the ability of packers to limit soil moisture loss is not as evident. The benefit of packers in limiting soil moisture loss is to breakdown soil particles into the correct sizes. Particles can then be sorted for proper evaporation control. Unfortunately, precise recommendations on soil pulverization by packers has not been outlined. Cropping history, soil properties, packer type and travel speed all affect soil breakdown due to packing.

Soil particle breakdown by packers is not without problems. When packers breakdown soil aggregates, they cause a movement of fine soil particles to the upper layer of the soil surface.

Compaction from raindrops by slaking could restrict infiltration. Once the soil surface dries, a soil crust may result and restrict seedling emergence. Stout et al. (1961) simulated a 1/2 inch of rainfall after planting and packing with surface pressures of 0.5, 5 and 10 psi. Severe crusting developed, limiting emergence. Hanks and Thorp (1956) also concluded crusting limited emergence, especially at low soil moisture contents in experiments on wheat. However, research by Hadas and Stibbe (1977) and Braunack and Dexter (1988) suggest crusting may not affect final yields.

**ROD WEEDERS**

Rod weeders can be used in both a packing and sorting role. Rod weeders provide a firm seedbed and a loose soil layer above the seed. The loose soil layer contains larger aggregates near the surface and small aggregates near the seed. The large surface aggregates prevent soil erosion and help limit crusting. Small aggregates improve seed soil contact and increase water available to the seed. However, there is a tendency for rods to lift moist soil lumps onto the soil surface, causing drying and reduced soil moisture content.

**CONCLUSION**

From the literature search and discussion of practical applications the following conclusions can be drawn on seedbed finishing.

Optimum moisture use is achieved through maximizing soil moisture uptake by the seed and minimizing soil moisture loss to the environment. Seed moisture use is not directly affected by changes in soil bulk density but rather changes in soil properties due to bulk density variation. Changing a soil's bulk density affects emergence through changing soil water movement, porosity, oxygen diffusion and soil crust strength. Minimizing moisture loss to the environment is accomplished through changing soil aggregate sizing and distribution. Both aggregate sizing and depth of aggregate layer to the seed are critical in the reduction of soil moisture loss to the environment.

Seedbed finishing research and the practical application of that research was addressed. In theory, the amount packers change soil properties is directly related to a packer's static weight, dynamic weight, velocity, wheel spacing and wheel diameter. However, experimental results indicate theory may not always apply to practical application. Harrows sort aggregates, level the soil surface, provide a loose layer of soil above the seed and pack the surface above the seed. Rod weeders provide a firm seedbed and loose soil layer above the seed by turning large aggregates to the surface and packing small aggregates above the seed.

While research on seedbed finishing outlines methods for optimum moisture use and minimum moisture loss, general recommendations on seedbed finishing have not been addressed at the farming level. Considering the number of soil properties, moisture conditions, cropping practices, environmental conditions and implements used by farmers, making general recommendations on seedbed finishing is difficult. Even if seedbed finishing recommendations were possible, they would not mean much if growing season precipitation was adequate. Perhaps the only effective application of seedbed finishing is in drought conditions. Unfortunately, more research needs to be completed in Western Canadian farming conditions.

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