Project No.: RL0288
Date: June l989
Prepared at: Lethbridge

SOIL PACKING USING CONVENTIONAL AGRICULTURAL PACKERS & HARROWS

by the

ALBERTA FARM MACHINERY RESEARCH CENTRE

PROJECT ENGINEER: <u>R.C. MAZE</u>

MANAGER: <u>R.P. ATKINS</u>

ABSTRACT

Packing the soil to benefit seed growth and emergence has long since been known to Canadian farmers. Soil packing benefits crop emergence, crop uniformity, soil moisture retention and overall yields in farming conditions where soil structure and moisture are not ideal for plant growth. This paper attempts to sort out the variety of interactions between soil, seeds and implements and to untangle the misconceptions of prairie farmers about soil packing.

INTRODUCTION

Numerous experiments and practical attempts have been made to explain why packing seeds benefits cropping practices. Unfortunately, because of the numerous factors involved in the agricultural field, no concrete recommendations or conclusions have been made regarding packing the soil after seeding. Some generalizations to maximize the benefits of soil packing have been made by researchers regarding implement type, soil condition and seed characteristics.

Soil, composed of numerous chemical and physical properties, makes up the medium in which packing is transferred from the implement to the seed. Perhaps the only concrete variable in soil packing is the packing implement. The packing implement determines the means at which a stress concentration is applied to the soil surface and determines the effectiveness of a packing operation. Seeding characteristics such as depth of planting, quality, seed moisture requirements and seed type make up the final group of variables involved in packing. The interaction of seed, soil and implement determines the packing effects on the soil and the implements which have the greatest beneficial crop production effect.

PACKING EFFECTS ON THE SOIL

With an increased ability to limit weed growth and supply nutrients for crop growth, in most agricultural situations moisture has become the limiting factor of crop production. Soil moisture is made available to seeds through rainfall and moisture trapped in the soil profile. Packing of the soil after seeding affects the crop use of soil moisture. Soil moisture content and plant use is determined by the level of condensation, evaporation control, aggregate redistribution and increased seed imbibition. Simply stated, moisture can be associated to crop production in two ways. First, through the maximization of available use of soil moisture to plants. Secondly, through the limitation of the loss of soil moisture to the environment.

MAXIMIZATION OF PLANT AVAILABLE SOIL MOISTURE

Before a seed will germinate, numerous conditions must be present in the soil. Favourable temperature, adequate porosity and sufficient moisture are among the conditions that must be satisfied for germination. Where soil or moisture conditions are not adequate, packing operations can usually provide the necessary changes in soil porosity and sufficient moisture as to not restrict crop growth. Rogers and Dubetz (l980) illustrated that moisture imbibition of wheat seeds was affected by changes in bulk densities. Changing bulk densities caused movement of capillary water and water vapour to the seed. Conclusions drawn indicated that the movement of water to the seed and thus increased soil bulk densities were the controlling factors for moisture imbibition. However, Rogers and Dubetz (l980) also indicated that the increase in imbibition was not necessarily due to the intrinsic effect of bulk density, but the changes in water transmission and soil porosity caused by bulk density changes.

Changes in soil porosity affect a soil's water transmission ability, which in turn affect the water uptake of emerging seeds. Soil packing changes the size and number of voids in the soil, resulting in changes to soil bulk density. Decreasing the number of voids below a seed enhances the water movement toward the seed from the soil moisture reserves. In addition, increasing the bulk density of the soil below the seed creates a firm footing for the roots of the seedlings to take hold. A firm footing for roots increases a seedling's ability to push through the layer of soil to the surface.

Under typical field conditions, soil moisture increases with depth. By increasing a soil's bulk density, the available pore space for water is reduced to the point where no room exists for the air, water and soil at a given soil depth. Since water is not compressible, the water in a layer of soil compacted can only move upward through the seeding depth and toward the soil surface. Thus, compacting a soil layer increases the available potential for seed imbibition and emergence. Hakansson and Polgar (l984) concluded from experiments done on packers that for a field situation 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 and seed of good quality is sown at a reasonable depth onto a moderately compacted seedbed.

In addition to providing an increase in the available soil moisture, packing can influence the moisture available to a seed through condensation. Mattes and Bowen (l963) showed experimentally that a soil layer at the low temperature end of a temperature gradient could induce moisture condensation through compaction. By decreasing the vapour diffusion coefficient and increasing the thermal conductivity, the water vapour in the soil can be condensed into a liquid form. The water condensation produced by packing could provide sufficient amounts of water for germination. However, for most situations the process of condensation is limited because temperature gradients and compaction forces are not suitable for the condensation process.

LIMITING SOIL MOISTURE LOSS

The loss of available soil moisture will reduce the overall crop production in soils where moisture is a limiting factor. While elimination of moisture loss is not practical in agricultural situations, numerous steps can be taken to reduce moisture loss due to evaporation. Evaporation control is usually required above seeding depth and is accomplished through proper soil distribution and aggregate sizing.

Packers pulverize soil blocks as they compact the soil. For seedbeds, Heinonen (1979), concluded from literature review that a homogeneous layer of graded aggregates sized in the 0.5 to 2 mm (0.02 to 0.08 in) range, provides the most efficient evaporation control above a seed. In this 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. Correspondingly, if the size of the aggregates increases above the 2 mm (0.08 in) range, the turbulent gas flow increases and thus the evaporative moisture loss. Ojeniyi and Dexter (1979) also indicated that accelerated soil drying caused by increased air flow was evident in soil voids larger than 8 mm (0.3 in). The depth of the evaporation layer is also key to control of moisture loss. Hakansson and Polgar (1984) concluded that down to a certain limit emergence is improved by increasing seeding depth, due to the increase in the evaporation control layer. Once the seeding depth reaches an adequate depth for evaporation control, emergence is decreased because of an increase in energy required for the seedling to reach the soil surface. In experiments done on clay soil for barley, adequate evaporation control was obtained at a seeding depth of 4 cm (1.6 in) with a harrowed layer of mean aggregate size of about 3 mm (0.12 in) covering the seed. Oilseed rape had an optimum sowing depth of between 2.3 and 3 cm (0.91 to 1.2 in) with small aggregates covering the seed and a high moisture content in the bottom layer. Thus the depth of the evaporation layer is dependent on the seed, available moisture and soil conditions.

While there exists a desirable layer of evaporation control, few methods are available to achieve a homogeneous layer of graded aggregates sized in the 0.5 to 2 mm (0.02 to 0.08 in) range to a depth specific to a particular seed and soil condition. One method of creating an evaporation layer readily available to most farmers could involve a harrowing operation over a previously packed seedbed just above the depth of seeding. The sorting and levelling effect provided by a harrowing operation could create a homogeneous layer for evaporation control. Harrowing could also decrease the adverse affects of packing on crop production in certain soil situations. In a typical packing operation a breakdown of the soil aggregates and a movement of fine particles into the upper layer of the soil surface results. A compaction from raindrops by slaking could then restrict further infiltration by water of fine soil particles. Once the soil surface drys, a low strength soil crust may result and cause limitations of seedling emergence. A harrowing operation after packing has been supported by the research results of Hakansson and Polgar (l983) and Stout, Buchele and Snyder (1961). Experiments done indicate that loose soil should be placed above the seed due to a packed soil's tendency to crust after a rain.

Mention of the difficulty of seeds to emerge through a compacted layer, an increase in porosity which increases air availability and infiltration characteristics of a soil which would benefit control of erosion was also made.

While harrowing after a packing operation is beneficial to seed growth in numerous ways, some disadvantages to harrowing after packing are evident. Assuming a normal situation in a seedbed, the dry soil surface aggregates should be retained near the surface and the moist material near the seed. The mixing of the dry surface material and moist soil caused by harrows could cause an increased rate of drying. Thus, the mixing effect of harrows should be minimized to reduce drying while still providing a homogeneous layer for evaporation control. Another disadvantage of harrowing after packing will occur if rocky field conditions are present. The tendency for harrows is to bring rocks to the surface which, in turn, will cause problems with swathing and combining practices. Harrowing of the soil will benefit the uniformity of the crop due to creation of a homogeneous layer. However, harrowing will eliminate any furrows created by drill packer wheels above the seed. Furrows allow rainfall to be concentrated at the plant roots and provide some wind protection for the soil surface and emerging seedlings. The benefits of a harrow operation are evident in some soil conditions, but the disadvantages must be taken into account for each specific cropping situation.

PACKING IMPLEMENTS

Numerous shapes and sizes of agricultural packers are commercially available. Physical characteristics of an implement affects the soil moisture content through condensation, reducing evaporation and increasing available soil moisture to the seed. A variety of characteristics make each type or model of packer unique. Static weight, dynamic packing force, wheel diameter, spacing, soil disturbance, velocity of travel, pulverization of aggregates and compaction effort are all factors which must be examined when determining the benefits of one packing implement over another. These characteristics determine the beneficial effects of that implement on crop production.

DYNAMIC PACKING RANGE

The overall packing caused by an implement is based on the implement's static and dynamic weight. Static weight of a packer refers to the mass per unit width of a stationary packer. To determine the static weight of a packer is a simple process. However, determining the dynamic weight and its possible effects is much more difficult. Dynamic packing ability is related to the stress concentration applied per unit time on a soil element under a packing implement and can be related to the static mass of the packing implement using soil stress theories.

Boussinsq's theories on soil stress provide theoretical solutions to stress analysis by assuming a soil acts like a homogeneous, elastic, semi-infinite, weightless material which obeys Hookes law. In practicality, soil does not always obey Boussinsq's assumptions, but stress analysis may provide some answers into

how stresses are transferred from an implement to the soil. A soil stress analysis was completed assuming an elementary stress solution, packer wheels act at an infinite length, and soil obeys the assumptions made by Boussinsq's equations. The stress analysis on what can be considered a soft soil was done using the dimensions of a typical conventional packer. Results indicate that 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. The results would indicate that spiral packers and crowfoot type packers, which do not specifically pack where the seed is placed, may not provide the same increase in soil stress as round or v-shaped packer would. However, tests done by Ojeniyi, Bigsby and Lal (1970), on how wheel spacing affects dry bulk density of soil found that no significant difference existed between the packed bulk density obtained at numerous depths for wheel spacings of 2.5, 5.1, 7.6 and 12.7 centimetres (1, 2, 3 and 5 in). In addition, dry bulk density of soil was not affected by packing implements used, indicating that packing directly over the seed does not benefit the packing operation as theory would imply.

STATIC WEIGHT

Direct comparisons between static weight and dynamic compacting characteristics were done by Djokoto, Bigsby and Lal (1970). Test results showed that the static weight of two packers can be very different from their respective dynamic compacting ability. For all practical purposes, dynamic compacting characteristics of two packers with different static weights is approximately the same where dynamic compacting is the amount of increase in bulk density of the soil and soil available moisture for germination. Djoko, Bigsby and Lal (1970), concluded that an increase in packer weight generally resulted in an increase in dry bulk density of a soil. However, for an increase of 4l% in typical packer static weight 141.1 to 198.7 kg/m (94.8 to 133.5 lb/ft), there was an average increase of less than 1% in dry bulk density of the soil. Tests done by Lindwall and Erbach (l983) 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). In addition, while increasing the weight of the packer wheels increased the soil bulk density in some cases, there was little effect on plant growth.

A review of the literature on soil packing indicates that a range of surface pressures from 3.5 to 5 kPa (0.51 to 0.73 psi) causes the soil to be stressed. Stressing of the soil results in an increase in bulk density and induces better emergence of crops than at high packing pressures. However, under the experimental conditions used by Stout, Buchele and Snyder (1961), pressures more than 3.5 kPa (0.51 psi) applied at the soil surface usually suppressed emergence of seedlings. Evidence obtained from tests performed by Johnson and Henry (1964) and Bowen (l966) found that wheels that exert 7.0 kPa (1.02 psi) or less reduced the drying rate of soils by consolidating the soil surface, indicating that packing is particular to the seed and soil characteristics. In instances where soil bulk density does not increase, heavier packing implements may not provide the increase in compaction or water available to seeds that are expected of a heavier unit.

PACKING VELOCITY

When comparing static weight to dynamic packing ability, the implement velocity must be taken into account. 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. Thus, a slower, light packer may compact the soil more than a heavier packer moving at a greater speed. The increase in packing of the light packer is due to the length of time the mass of the packer spends on each specific soil element. In addition, the time a packer is on a soil determines the movement of water and air out of the soil environment. No research on the effects of velocity of agricultural packers has been published. However, some research on agricultural vehicle speeds has been completed. In a literature review done by Soane et al. (1980), information on the effect of speed was often limited and conflicting. In general, Soane et al. (1980) found that increases in vehicle speed decreased compaction. Cohron (1971) indicates that an increase in speed results in less compaction and should be considered to decrease unwanted compaction by tractors and heavy machinery.

WHEEL DIAMETER

Wheel diameter can also be considered a factor in an implement's effect on dynamic packing. For a conventional packer the diameter of the wheel will affect the rolling resistance of the packer through the soil. With other factors kept constant, an increase in the diameter of a wheel moving through a soil will decrease a soil's reacting force to the wheel, thus causing a decrease in the rolling resistance of the soil. A decrease in rolling resistance will decrease the amount of energy required to move the wheel through the soil, thus causing a decrease in horsepower and fuel use. However, an increase in wheel diameter increases the amount of wheel surface area on the soil. Theoretically, as the surface area of the wheel increases, pressure on a specific point of the soil under the packer will decrease. Thus, an increase in wheel diameter should decrease the effects of the implement on soil packing. However, Djokoto, Bigsby and Lal (1970), showed that changes in the diameter of the packer wheel had no significant influence on the resulting dry bulk densities of the test soils. No significant difference in density was found by varying the diameter of packer wheels from 20 to 61 cm (8 to 24 in), thus indicating that large diameter wheels would be of benefit on packers since there would be less power required by the implement to achieve the same packing results. However, due to the large forces packing wheels have to endure, wear resistance must be taken into account when designing larger diameter packer wheels.

CONCLUSION

Soil packing can be a benefit to seeding operations to reduce soil moisture loss and increase plant available water. Based on the literature review done, the following general recommendations can be made to maximize the benefit of soil packing. Numerous conditions are present in the interactions between soil, implement and seed. Thus, some alterations for specific soil conditions should be taken into account in the recommendations made.

l. Water condensation, evaporation control and increased seed moisture imbibition can be produced in the soil be a packing operation if conditions are suitable for the specific soil being compacted.

2. Packing pressures of 3.5 to 5 kPa (0.51 to 0.73 psi) result in better emergence of seeds. Good emergence can be expected if a seed is sown into a moist compacted layer of 5% (w/w) plant available water and adequate protection is provided against evaporation. Adequate evaporation control can be accomplished given a mean aggregate size in the 0.5 to 2.0 mm (0.02 to 0.08 in) range and the seed is planted at a suitable depth.

3. Since experiments on changes in packer wheel mass and spacing have shown no significant difference in soil bulk density, packing directly over the seed may not benefit the packing operation as theory would imply.

4. Direct packing can cause reduced crop emergence due to crusting of the soil surface. The adverse effects of soil packing can be reduced using a harrow operation after packing if field conditions facilitate such an operation. However, the mixing of dry surface soil with moist subsoil caused by harrows should be kept to a minimum to reduce evaporation rates.

5. Heavier, more expensive packing implements may not provide the increase in compaction or available water to the seed that is expected if optimum soil conditions are not present. Since wheel diameter does not affect packing, the largest practical cost effective diameter wheel should be used on packing implements to reduce rolling resistance and thus power requirements, assuming other factors are kept constant.