



REDUCING SOIL COMPACTION

Vern Hofman
Agricultural Engineer

Joe Giles
Associate Professor of Soils

Soil compaction is a new management concern for North Dakota producers. Heavy farm equipment and early tillage-planting operations combine to increase the chance of soil compaction to the point of reduced crop production.

Not all soil compaction is harmful. As an example, firming the soil over a seed row prevents excessive drying of the soil and promotes good seed soil contact for fast germination. A firm soil around the seed helps promote root branchings and formation of secondary roots which thoroughly explore the soil for nutrients. The expanded root activity can increase the uptake of nonmobile nutrients such as phosphorus. Moderate compaction on loose tilled soils may also decrease water loss by evaporation.

Root growth decreases when compaction exceeds a critical level. Soil compaction also influences water infiltration and storage, which may be more serious to crop production than the effect on root growth. A compacted soil above the critical level may also show up as reduced plant growth, extended maturity and reduced crop yield.

An ideal crop production soil contains about 50 percent pore space with about 25 percent water and 25 percent air by volume. The remaining 50 percent consists of soil particles. Soil compaction occurs when soil particles are squeezed together by an outside force. Packing the soil particles together results in loss of pore space, which causes reduced internal drainage and aeration.

The extent of compaction on a particular soil is mainly affected by soil moisture, soil texture and the pressure applied to the soil.

CAUSES OF COMPACTION:

Compaction is directly affected by machinery weight, tire size and tire inflation pressure. Combines with a full grain tank may weigh up to 25 tons and a loaded grain

truck may weigh more. Lighter loads may cause as much compaction near the surface as a heavy load, but heavy loads cause compaction to depths difficult to correct with tillage.

Figure 1 shows the effect of soil moisture on the depth of compaction. Shallow compaction is usually considered to be compaction occurring in the tillage zone (top 8 inches). Compaction to this depth can cause problems but is usually temporary as normal tillage operations will remove it. Shallow compaction is directly related to the contact pressure of the tire. Wet soil is capable of supporting much less load than a dry soil. The use of large flotation tires may support machinery and allow field operations when the soil is too wet to work without causing damage.

Deep compaction is usually caused by heavy axle loads and is not normally reduced by distributing the weight among more tires or larger tires. Figure 2 shows

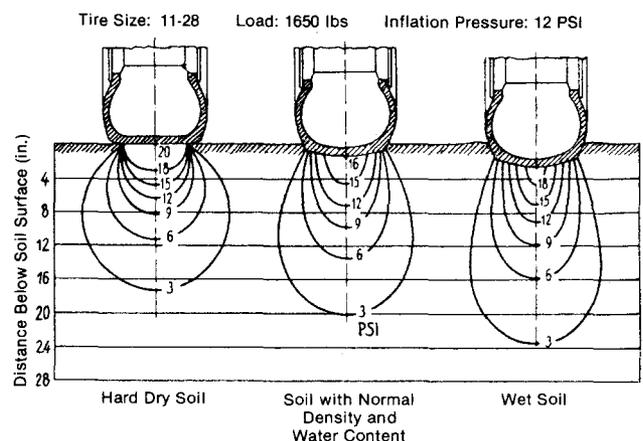


Figure 1. Effect of Soil Moisture on the Depth of Compaction (Sohne, Agricultural Engineering, 1958).



NDSU EXTENSION SERVICE

North Dakota State University, Fargo, ND 58105

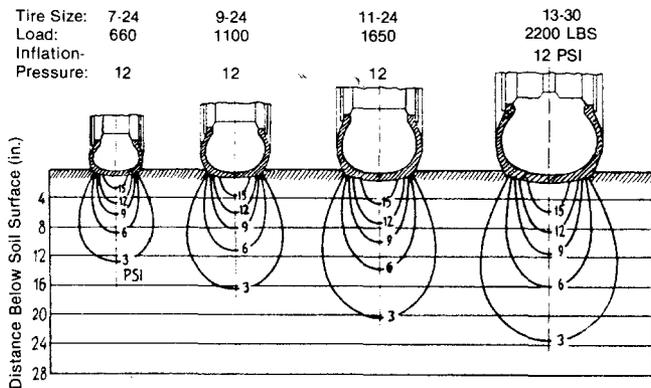


Figure 2. Effect of Axle Load on Compaction Depth (Sohne, Agricultural Engineering, 1958).

the effect of total wheel load with constant contact pressure.

As axle loads and tire sizes increase, compaction near the soil surface covers a larger area, even though the degree of compaction doesn't change. Therefore, contact pressure determines topsoil compaction and axle load determines compaction depth.

Tillage equipment causes compaction by tool action as well as wheel traffic. For example, the moldboard plow may cause a dense layer directly below the tillage zone, and a tandem or offset disk creates a thin compacted layer from the rolling effect of the disc blades.

HOW TO RECOGNIZE COMPACTION:

A simple method to identify compaction is to push a steel rod about 24 inches into moist soil. Do this in a fence row which has not been tilled or received wheel traffic for a number of years. Then push the rod into soil in a representative area of the field. Probing several places is best. Note the relative effort needed to push the rod in. If the effort needed to drive the rod in the field is noticeably greater or meets resistance at a given depth, you have compacted soil.

Another method is to dig a trench about 24 inches deep during the growing season. The trench should be perpendicular to your normal travel pattern. Be sure one side of the trench is free of shovel marks, then use a knife to estimate the force required to penetrate the side. Push the knife in at regular, small depth increments, noting any dramatic change. Some increase in penetration resistance is expected as depth increases in well developed soil profiles, especially with high clay content in subsoil layers.

COMPACTION EFFECTS:

A study on silty clay soil at Grand Forks reduced wheat yields 11 bushels per acre in 1979 on plots compacted in the spring with a single-axle, dual-wheeled truck with gross vehicle weight of 18,500 pounds. In

1980, wheat yields of non-compacted, fall-compacted, spring-compacted and fall- and spring-compacted treatments were not significantly different. However, grain protein content was lower on the spring-compacted (12.7 percent) and fall- and spring-compacted (12.7 percent) treatments compared to non-compacted treatment (13.6 percent).

In a compaction study growing wheat on a silty clay loam soil following sugarbeets at Thompson, neither yield nor protein were significantly different between non-compacted and either a spring-compacted soil with a four-wheel-drive tractor or a fall-compacted soil with a loaded tandem axle truck (49,000 lbs.). The effect of compaction on wheat yields varied among years, but yield differences were significant in only one of the four years (1979).

Compaction may have a detrimental effect on potato yields because the potato tuber growth pattern is sensitive to interruptions of growth in the relatively confined rootzone. Research results show that deliberate packing of a silty clay loam in the Red River Valley decreased potato yields 54 percent. In another two-year study at Grand Forks, spring compaction of a silty clay soil reduced potato yields an average of 21 percent. Potato yields on a clay loam soil at Morris, Minnesota, were reduced 35 percent from wheel traffic. Potato yields on a loamy sand were reduced about 15 percent when planted into a dense seedbed without moldboard or chisel plowing at Becker, Minnesota.

The sugarbeet plant appears to be less sensitive to surface compaction if it does not interfere with plant emergence. The effects of compaction from traffic on a silty clay soil on sugarbeet yields in a North Dakota study are shown in Table 1. Although soil compaction increased beet sprangling, which causes problems at harvest, compaction had no effect on recoverable sugar or root yields in 1980. Soil was compacted by repeated passes with a loaded, single-axle, dual-wheel truck (GVW 18,000 pounds). In 1979, compaction increased yields because of a higher final stand (108 and 79 beets per 100 feet of row for compacted and noncompact treatments).

These results show the detrimental effect heavy spring traffic has on crop production. Fall truck compaction or a four-wheel-drive tractor in the spring has not shown reduced spring wheat, potato or sugarbeet yields in the Red River Valley of North Dakota.

HOW TO MINIMIZE COMPACTION:

The best way to minimize compaction is to avoid field activities which may damage the soil. Stay out of wet fields until the soil has dried. This is the best means of reducing compaction, but can be a difficult decision when considering the economics of late planting and delayed harvest.

At times compaction may be unavoidable. It may be best to restrict wheel traffic to certain areas and confine the compaction. This may work best with row crops and more specifically with ridge till crop production where the crop is grown on ridges year after year.

Radial ply tires have two characteristics that give them some potential advantages over bias ply tires for

Table 1. Effect of spring soil compaction on sugarbeet and total recoverable sugar yields, Grand Forks, North Dakota.

	Soil Properties		1979		1980	
	Density gm/cm ³	Probe Resistance lb./in. ²	Beets Tons/Acre	Sugar Tons/Acre	Beets Tons/Acre	Sugar Tons/Acre
Compacted	1.50	133	11.9	1.53	11.1	1.51
Noncompacted	1.34	78	9.3*	1.23	11.6	1.60

*Difference significant at the 0.10 level from the results of compacted soil. All other comparisons were not statistically significant.

reducing soil compaction. First, radial tires produce a larger footprint, which would reduce the shallow compaction. The footprint is longer, but not wider, so it achieves the larger footprint without compacting a wide track as it passes over the field. Second, radial tires have better traction capabilities that may allow them to perform satisfactorily with less operating weight than bias tires. The present ballasting recommendations generally do not distinguish between radial and bias tires; however, present farm practice is to use less ballast with radial tires than with bias tires.

Large tires and duals have the advantage of increasing the ground contact area, which reduces the degree of shallow compaction; however, due to the larger footprint, more area is compacted. Also, since deep compaction is mostly affected by axle loads, large tires and duals do not significantly reduce this potential.

Avoid carrying too much tractor weight. Excessive weight creates unnecessary soil loads and uses more fuel. A correctly weighted two-wheel drive tractor should have 8 to 16 percent wheel slip for any field operation. Proper weighting is especially important in tillage operations. Avoid using oversized equipment. For example, don't use a 150-horsepower tractor if you have a 75-horsepower tractor that can adequately do the job.

One very effective way to reduce operating weight is to reduce the implement draft and operate at higher field speeds. Pulling a narrower implement at a one-third (33 percent) faster speed (Example: from 4½ to 6 mph) reduces the weight carried on the tractor by 25 percent. The tractor is producing the same horsepower and doing about the same amount of work.

Keep your tillage equipment in top operating condition and be sure the soil-engaging tools are sharp. A dull plowshare or disc blade will cause more compaction than a sharp one and pull harder.

Eliminate unnecessary field operations so you make fewer passes over the field. Many producers are using reduced tillage in their farming operations. It keeps the number of trips over the field to a minimum when fields are the most susceptible to compaction.

Tandem axles will also reduce surface soil compaction, compared to a single axle. Tandem axles compact less area than duals as the weight is spread over two axles. Large diameter single tires on tandem axle tractors are best. This reduces the width of tire tracks in fields while providing adequate tire-to-soil contact area to keep slippage at a reasonable level. Be

Table 2. Typical Recommended Front-to-Rear Weight Split for Tractors.

	Front	Rear
2-WD with towed equipment	25%	75%
Front-wheel drive (2WD)	40%	60%
Four-wheel drive (4WD)	60%	40%

sure to use tires large enough to carry the tractor's total weight without overloading or tire life will be shortened. Triple tires are usually not needed except for high horsepower tractors as they pack a wider area across the field. Also, tracks on tractors have a larger soil contact area than tires and cause less compaction.

Tractor chassis type can have a significant affect on maximum axle loads. Many of the two-wheel (2WD) drive models are available with a front-wheel drive (FWD) option. Axle loads are affected by how the total weight is distributed between the axles. Table 2 lists the generally recommended front-to-rear weight splits for various tractor chassis and implement configurations.

Table 3 gives a comparison of how axle loads can be affected by chassis configuration. Field operation weights are probably the most representative of field operating conditions because they are adjusted for the weight transfer off the front axle and onto the rear axle that occurs when a load is pulled.

Comparing the maximum axle load under field operating conditions shows that front-wheel drive and four-wheel drive can yield a significant reduction in maximum axle loads. When comparing maximum axle loads to two-wheel drive, both FWD and four-wheel drive can give a significant reduction of 15 percent. Also, tires on the FWD and four-wheel drive are larger in size and capable of pulling a larger load than the two-wheel drive. Front-wheel drive and four-wheel drive tractors can also develop the same pull with a lower total tractor weight, because all of the tractor weight is on the drive wheels and available for developing traction. Two-wheel drive tractors must have some weight on the non-driven front wheels to maintain steering control.

Mechanical front-wheel drive and four-wheel drive have significant potential for reducing axle load and thereby reducing compaction. However, their increased traction

Table 3. Axle Loads and Chassis Configuration Example.

	5 MPH - Towed Equipment		
	150 HP (2 WD)	180 HP (FWD)	250 HP (4 WD)
Pound/PTOHP	100 Rear	115 Total	115 Total
Front/Rear Split (%)	25/75	40/60	60/40
Front Weight (lbs.)	3,800	8,300	17,300
Rear Weight (lbs.)	15,000	12,400	11,500
Total Weight (lbs.)	18,800	20,700	28,800

Tractors operating in the field under load transfer weight from front to rear. The following is an estimate of the weight shift.

	2 WD	FWD	4 WD
Front Weight (lbs.)	1,900	6,300	14,400
Rear Weight (lbs.)	16,900	14,400	14,400
% Reduction of maximum axle load from 2WD	0%	15%	15%

capability may lead to their use on wetter soils that are very subject to compaction and may actually increase compaction.

DEALING WITH COMPACTION:

There are two methods of reducing the damage caused by compaction. Attempt to remove the compaction with tillage or attempt to reduce the undesirable effects of compaction without removing the compaction itself. The producer must know how compaction affects the plant in order to accomplish the latter approach. If soil compaction is reducing the uptake of plant nutrients, additional applications of the nutrient such as split applications of nitrogen may alleviate the effect. Rotating crops that produce small amounts of residue with those that produce large amounts will help stabilize organic matter levels and decrease the incidence of soil compaction problems.

Tillage by moldboard or chisel plowing can reduce soil compaction down to 10 inches in the tillage zone. If tillage is done during wet soil conditions, little good may result. During a dry year, plowing deeper than usual would possibly eliminate a compacted tillage layer. Varying the depth of tillage each year will help prevent a compact layer from occurring.

Subsoiling is an alternative to reduce compaction down to 20 inches. Studies in the Northern Plains have shown few cases of yield response, and in some cases subsoiling has shown a yield decrease. Subsoiling is

expensive and chances are small that the cost will be recovered in increased yield. Subsoiling is best completed under dry soil conditions as this causes shattering of the soil profile.

Where no tillage is done, freezing and thawing over winter will reduce the effect of compaction. But, studies have shown that several years of seasonal cycles are required to eliminate the detrimental affects of deep compaction. If traffic occurs on the soil each year, freezing and thawing will do little good. Data from the Red River Valley indicate that wetting and drying of finer-textured soils is very effective in removing compaction. Maintaining crop residue to effectively retain precipitation will enhance the effect of alternate soil moisture cycles.

WAYS TO REDUCE SOIL COMPACTION:

1. Eliminate field traffic on wet soils.
2. Reduce the number of field operations.
3. Vary tillage operations and depth from year to year.
4. Select machinery that minimizes compaction.
5. Reduce tractor weight by using lighter draft implements at higher field speeds. This should reduce both shallow and deep compaction.
6. Consider alternative tractor chassis configurations. Four-wheel drive and front-wheel drive tractors can have significantly lower axle loads than a two-wheel drive tractor of the same horsepower. This should reduce both shallow and deep compaction. Don't use the extra traction capabilities of all-wheel drive to operate on wet fields, which may increase the compaction potential.
7. Radial tires have a larger footprint and can operate with less ballast. This should reduce both shallow and deep compaction.
8. Large tires and duals should reduce shallow compaction but do not significantly reduce deep compaction.
9. Remove extra weight when it is not needed for traction.



4WD and FWD tractors can reduce maximum axle loads over 2WD.

Helping You Put Knowledge To Work

Service, North Dakota State University of Agriculture and Applied Science, and U.S. Department of Agriculture cooperating. William H. Fargo, North Dakota. Distributed in furtherance of the Acts of Congress of May 8 and June 30, 1914. We offer our programs and persons regardless of race, color, sex, religion, age, national origin, or handicap; and are an equal opportunity employer.