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Compaction Has Critical Consequences For Crops

Soil compaction restricts root growth and reduces crop yields.

INSIDE THIS ISSUE:

Soil compaction is defined as a reduction in a soil's pore space; the pores contain air and water necessary for good plant growth. Compacted soils are dense and have smaller pores which restrict air and water movement and limit crop root growth. Soil compaction can reduce crop yields by 25-50%.

Compaction can develop due to either natural or manmade factors in all soil types, ranging from light sandy soils to heavy clay soils. Natural consolidation, shrinkage, and raindrop impact can lead to soil compaction. However, external influences which farmers can control usually have greater importance. These external causes of compaction include pressure from wheels and tillage equipment, trampling by animals, and irrigation impacts.

The signs of soil compaction can often be seen by observing the crops growing in a compacted soil. Slow plant emergence and thin stands or uneven early growth can be a reflection of compaction. Abnormal rooting patterns, shallow or horizontal root growth, and impaired nodulation and nitrogen

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Use Household Tools To Scout For Compaction

Build your own penetrometer for evaluating compaction in the field.

Scouting for soil compaction does not require expensive or sophisticated equipment. With some easily obtained materials and moderate welding skills you can construct a penetrometer for identifying compaction problems in the field.

You will need a ¼ to ½ inch diameter steel rod about 3 feet long and a bathroom scale. Use a smooth steel rod; such a rod can be obtained at most lumber yards. Wood or plastic rods generally are not sturdy or rigid enough to be used for the penetrometer probe. Sharpen the tip of the rod to a point with a 30º cone angle. It is also useful to mark the probe at 6 inch increments along the shaft. At the other end of the probe, weld on a 4 inch x 4 inch base. The base is used to support the bathroom scale and also serves as a handle for removing the penetrometer from the soil after taking the readings. To take penetrometer readings, place the tip of the penetrometer on the soil surface and put the bathroom scale on the base. Push on the top of the scale to force the penetrometer into the soil. Make sure to push vertically on the scale to minimize sidewall friction on the penetrometer probe. Note the maximum reading on the scale for the first 6 inches of soil. Continue taking measurements, noting the maximum scale reading for each 6 inch interval to give a penetrometer resistance profile. If you wish to convert the bathroom scale readings (in pounds) to pounds per square inch, simply divide the reading by pi x the radius of the rod squared.

Determine the extreme variations of penetrometer resistance for each field. You can determine this by probing different areas of the field. One area that is not normally compacted is along a fencerow. Another area to probe is an area of known compaction such as in a field entrance. Measurements in these areas will give the range of penetrometer resistances for the field.

One factor that can make a tremendous difference in penetrometer comparisons is the water content at the time of sampling. For instance, if you took a penetrometer reading from the fencerow with grass growing on it and then took a reading from a fallow field, the readings from the fencerow could be much greater than in the field, leading you to conclude that the fencerow is more compacted than the field. One way to equalize the water contents is to use a 5-gallon bucket with the bottom cut out. Push the bucket into the soil to a depth of 2 or 3 inches. Fill the bucket with water and allow the water to drain into the soil. Cover the top of the bucket with a sheet of plastic to prevent evaporation. Allow the water to drain for about 3 days. A foot of water in the bucket would wet about 3 feet of soil to field capacity. Do this in each place that you want penetrometer readings. You can then take penetrometer readings and have similar water contents at each site. To get penetrometer readings in dry soil, take readings in an actively growing crop after several weeks without rain. A growing crop will deplete the water in the soil, but this method usually has greater

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Scouting

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variability in water content. It is best to take a soil sample to determine the water content at the same time you take the penetrometer readings.

Penetrometer measurements are useful for comparative purposes. The effects of wheel-track compaction can be determined by taking readings from tracked and non-tracked areas in the field. The compactive effects of using cattle to glean a field after harvest can be determined by taking penetrometer readings in areas where the cattle congregate, such as around the water trough or salt feeder, and then taking comparative penetrometer readings in the rest of the field. Avoid the use of a blanket critical level or cutoff reading at which you will recommend chiseling. The critical level in pounds per square inch at which chiseling will pay will vary tremendously depending on soil texture, soil moisture, and crop type.

Some special precautions should be used to determine the effectiveness of compaction alleviation treatments, such as deep chisel plowing. Take measurements before and after tillage to determine the change in soil penetrometer resistance caused by the tillage operation. Readings should come from the soil between the chisel shanks to determine the amount of fracturing caused by the chisel operation. Repeat the measurements 3 to 6 months after the chiseling operation to determine the longevity of deep tillage. Soil has a tendency to reconsolidate over time, and you will want to know how long the effects of tillage will last and when you will need to chisel again.

Penetrometers can be useful tools for evaluating compaction. Correctly used, they can give you good information about the compactive state of the soil and whether compaction alleviation methods are needed or have been effective.

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Consequences

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fixation by legumes are often signs of compaction. Shallow rooting may cause plants to be droughty and more susceptible to lodging, or poor drainage caused by a compacted layer may cause plants to look nitrogen or oxygen stressed.

Compaction stresses roots so that they become more susceptible to other crop stresses, such as heat, insects, and disease. Herbicide injury and root diseases, such as Pythium, Rhizoctonia, and Fusarium root rots, can increase with increasing soil strength. In addition, nutrient deficiencies, especially of nutrients which are immobile in soil such as phosphorus or zinc, may develop due to limited root growth.

Jessica G. Davis
Associate Professor and Soil Specialist
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Roots Exert Pressure To Fight Soil Compaction

Alfalfa and sunflower roots are the strongest contenders.

Once we have some measure of how compacted soils have become, an important question is often asked of field agronomists and scientists: will the roots have the power to extract the moisture and nutrients?

It is important to understand the kind of forces we are dealing with when soils are compacted. Soils compacted by natural forces like the weight of the overlying surface soil, gravity, and water drop impact will usually not impede root penetration. Earthworms, microbes, insects, root growth, organic matter decay, shrinking and swelling of clays, and gas and heat exchange, these all play important roles in natural amelioration processes which maintain the soils natural density. Yeah, that is fine and dandy but will this crop be able to root through a zone of compaction that is so dense the penetrometer reading was greater than 400 pounds/square inch (psi)?

Researchers in the Corn Belt have determined that some crops can force a root through very dense or tight soils. Corn, the dominant irrigated agricultural crop in Colorado, can exert 400 psi to extract moisture away from the soil matrix, then it runs out of sucking power. In the world of bantam class weight lifters that is quite impressive. In the realm of root force, corn is somewhat of a 98 pound weakling. Other researchers have discovered that small grains, such as wheat, can exert 350 to 400 psi. Barley, a tough contender, comes into the ring with a root penetration force of 450 to 475 psi. Alfalfa and sunflowers are the two in a class by themselves. They have been found to exert 600 to 675+ psi of pressure. The verdict is still out for dry edible beans.

Crop	Strength (psi)
Corn	400
Wheat	350-400
Barley	450-475
Alfalfa	600-675+
Sunflower	600-675+

When soils are severely compacted, the soil may require more than 750 psi to be penetrated by a growing root tip. That is a challenge for even the mightiest of roots!

Michael L. Petersen
Resource Soil Scientist
USDA-NRCS

Grazing Cattle Compact Wheat Ground

A CSU study showed that although soil strength was increased, wheat yield was not decreased.

From 1994 to 1997, a study was conducted by CSU and NRCS to determine the effects of cow-calf grazing of wheat fields on soil compaction and wheat yields. The study was led by Tom McBride, Cooperative Extension Director for Boulder and Adams counties. While grazing clearly increased soil compaction (as measured using a drop-cone apparatus), any resulting detrimental effect on yield was not apparent. Since grazing reduces feed cost by an estimated $0.73 per cow-calf unit per day, it appears that cattle can graze growing wheat and stubble in northeast Colorado, thus lowering feed costs and having little or no negative impact on yield.

Although grazing of wheat ground is commonplace in some states, no research had previously been conducted to determine if grazing has a negative effect on wheat yield in Colorado. Many Colorado wheat producers have not been willing to rent their growing wheat and/or stubble because of their concerns about yield reduction. Producers who both farm and ranch have been unsure of the net gain or loss as a result of such grazing practices. Most, if not all, cow-calf producers in northeastern Colorado have the opportunity to graze green growing wheat as well as wheat stubble to assist in reducing production costs. With uncertain beef cattle prices being the norm, the potential for reducing feed cost in the cow-calf industry is significant. Millions of wheat acres in Colorado could be made available to both increase revenue for the wheat producer and decrease feed costs for the cow-calf producer.

Typical agricultural fields are commonly compacted by tractor and other heavy equipment traffic. Soil compaction by livestock has also been shown to reduce pasture yields. Livestock tend to create higher contact pressure than many tractor tires, thus they produce higher levels of soil

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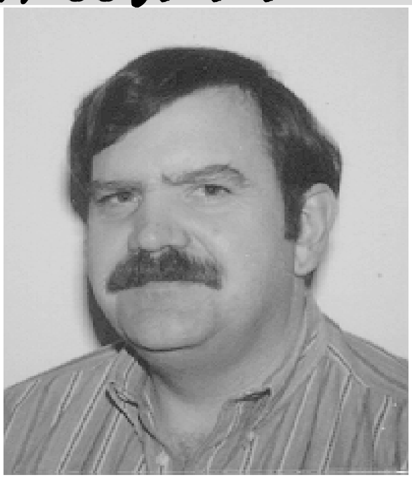

Dr. Joseph Benjamin

Dr. Joseph Benjamin is a soil scientist with the USDA-ARS located at the Central Great Plains Research Station in Akron, Colorado, and an affiliate faculty member at Colorado State University. His specialties are in soil physics and soil mechanics with an interest in managing the soil to provide the best environment for plant growth. He is currently conducting research on the effects of soil compaction and crop rotations on soil structure, crop water use, and water movement in soil.

Dr. Benjamin originally comes from Iowa, where he grew up on a farm near Onawa. His family grew corn, soybeans, oats, and alfalfa and raised hogs and cattle. He received his Ph.D. in soil physics from Iowa State University. Joe's many hobbies include choral singing (with the Morgan County Chorale), fishing, and traveling.

Wheat

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surface compaction. But, due to the low total weight of livestock (compared to agricultural tractors), the compaction usually is limited to the upper 4 inches of the soil profile.

This study included four treatments: 1) no grazing, 2) grazing the growing wheat in the spring, 3) grazing growing wheat and stubble both in the spring and fall of the same year, and 4) grazing the growing wheat and stubble both in the spring and fall of the same year and then grazing the growing wheat again in the spring two years later. Cow-calf pairs, fenced off with electric fence, were pastured in this section of land for 1-2 weeks, and the sections were intensively grazed at a 1-2 cow-calf unit per acre. Prior to turning the cattle in, drop-cone penetration readings were made to determine surface compaction. Compaction readings were taken again after grazing.

Soil compaction due to livestock traffic was measured using the drop-cone technique. A 2 kg, 30 degree apex angle cone is dropped from a height of 1 meter. The depth of penetration is measured, and this value inversely correlates to soil strength (lower penetration depth indicates higher soil strength). Soil strength is an indicator of soil compaction. Fifty (50) drop-cone measurements were taken randomly in each plot. This testing procedure was repeated 8 times throughout the study for a total of 2900 drop-cone tests.

The effect of grazing on soil strength was seen in both the spring and fall (April and October) measurements. The effect of grazing is apparent to a lower degree almost two years after grazing. Much of the compaction is apparently alleviated by the freeze-thaw cycles of the soil. In the spring of 1996, grazing had a significant effect on soil strength. However, there were no apparent differences in soil compaction due to grazing 2 years before the growing wheat was grazed.

Low summer moisture and hail damage produced low yields. Yield was significantly higher for the grazed treatments. The hail could have damaged the non-grazed wheat more since it was more mature at the time of the hail. Generally, throughout the study, no major differences in wheat yield could be observed.

Cooperative Extension staff in Adams, Arapahoe, Morgan and Elbert County worked jointly on this project with a farmer/rancher cooperator, Zeb Eldringhoff, whose operation is located near Deertrail, in northeast Colorado. Natural Resource Conservation Service personnel located in Byers cooperated in the study. Colorado State University personnel involved in the project were Paul Ayers, John Shanahan, Frank Peairs and Tom Fields.

Paul Ayers
Extension Agricultural Engineer
Department of Chemical and Bioresource Engineering

Compaction Reduces Dry Bean Yield By One-Fourth

Planting time ripping reduced soil resistance and increased yield to non-compacted levels.

Compacted	Planting Time Ripping	Cone Penetration Resistance (pounds per square inch)	Yield (lbs/acre)
yes	no	180 a	1743 b
yes	yes	122 b	2222 a
no	no	118 b	2360 a
no	yes	76 c	2231 a

Means in column followed by same letter did not differ at 0.05 significance level.

With today's emphases on economic sustainability, and the bottom line, there seems to be little time left for a critical review of specific practices that are guaranteed to help each grower improve their operation from both agronomic and economic perspectives. This article is devoted to one of those components, soil compaction, that annually impacts our overall crop productivity in Colorado and consistently reduces most of our growers' yields by 5 to 20%.

Soil compaction is technology-arrogant, because it can reduce a crop's performance, regardless of the variety selected with the newest set of exciting genes, regardless of the most active chemistry applied for pest control, regardless of the most expensive and newest equipment, and regardless of the most sophisticated irrigation system available. Yet, with a modest investment in time and standard agricultural resources, each grower can realize a significant return in performance and economic viability of their crops.

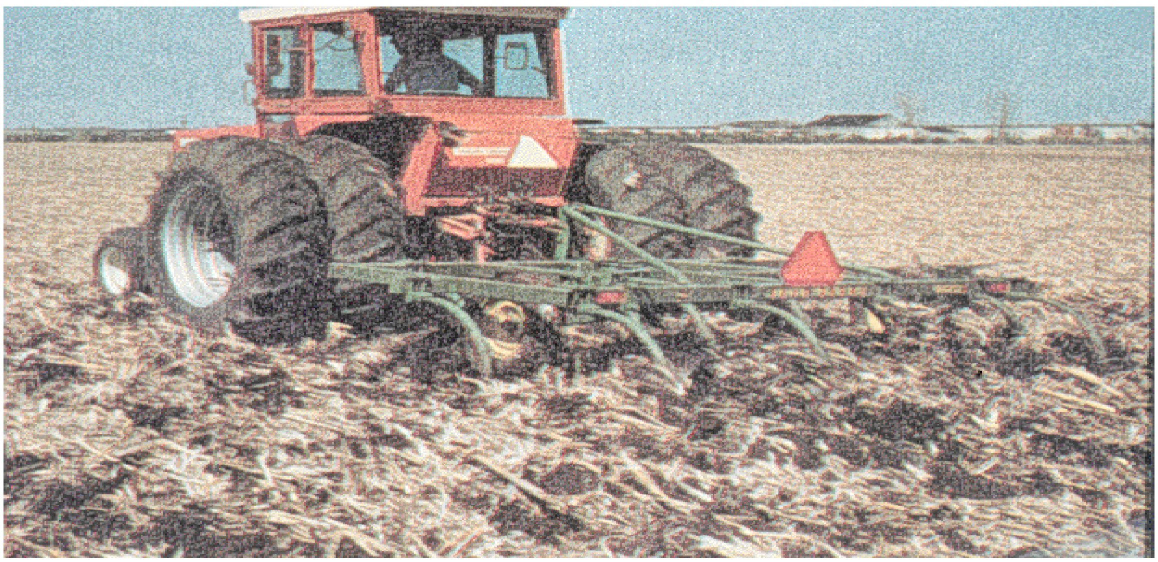
A 3-year study by CSU scientists (R. Croissant, H. Schwartz, P. Ayers; J. Prod. Agr. 4:461-464) at Fort Collins, demonstrated that soil compaction during seedbed preparation reduced furrow irrigated pinto bean yields by 26%. Plants grown on compacted clay loam soils were stunted and exhibited poor root growth and distribution upon excavation. Inter-row ripping of compacted soil to a 8-inch depth with diamond point chisels located 6 inches to each side of the seed row restored the crop yield to levels where no compaction problem existed. Use of the ripper in non-compacted soil did not increase or decrease yield. Soil penetration resistance was greatest in compacted soils that were not ripped, and lowest on non-compacted, ripped treatments.

Economic implications from this study indicated that an investment of $464 to purchase 16 chisels at $29 each, for an eight row cultivator, improved gross income by nearly $72 per acre, using a $15/cwt selling price. Therefore, planting time ripping can reduce the chronic effects of compaction on bean yields, and help each grower achieve healthy and profitable returns for the diverse crops produced in Colorado.

Howard F. Schwartz
Professor of Plant Pathology
Dept. of Bioagricultural Sciences & Pest Management

Choices Can Circumvent Compaction Consequences

Reducing traffic when soils are wet is essential to avoiding soil compaction.



Farmers make numerous decisions which influence whether their land becomes compacted and once compacted, whether productivity will be restored. To prevent compaction from occurring, several options are available to producers.

Reducing traffic, especially when soils are wet, is critical to protecting soil from compaction. Restricting spring use of high compaction tools (disc, anhydrous tanks, tractors with heavy axle loads) will help. The first trip into a field in the spring should be when soil is dry at tillage depth. Avoid trying to dry out a wet spot by working around it. If the soil in the surface 6 inches can be squeezed into a ribbon between your fingers, stay out of the field.

Decreasing tire pressure lessens surface compaction, but this practice spreads out the weight and may increase the area which is compacted. Dual wheels also expand the compacted area, and single tires compact the least area. Controlled traffic (restricted to specific traffic lanes) minimizes the area of the field that becomes compacted. Reducing tractor weight decreases deep compaction; the higher the axle load, the deeper the soil will be compacted. Changing plow depth and implements from year to year also helps to prevent the development of a hardpan.

Maintaining or improving soil organic matter content reduces soil density and promotes soil stability, making soils more resistant to compaction forces. Retaining crop residues or applying manure strengthens soil structure.

Correcting Current Compaction

Crop rotation with deep rooted crops (for example, alfalfa or sunflowers) can break up soil compaction. However, since soil compaction is usually caused by mechanical means, it can also be removed by mechanical means. After you have determined how deep the compaction layer is, subsoil or rip at least 2 inches deeper than the hardpan. Keep tractor speed under 4 mph for the best outcome. Optimum results are obtained when the compacted layer is dry during subsoiling. Fall is the best time to subsoil in Colorado, since soils tend to be dry after harvest.

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web sites

http://www.nsdl.usda.gov/info/info.html
USDA-ARS National Soil Dynamics Laboratory in Auburn, Alabama.

http://www.oznet.ksu.edu/library/CRPSL2/AF115.PDF
Soil Compaction: Problems and Solutions — a Kansas State University publication.

http://www.ianr.unl.edu/pubs/
Several compaction related factsheets can be found among the University of Nebraska soils publications at this address.

http://www.montana.edu/~wwwpb/ag/bauder23.html
Sizing up Soil Compaction — a publication from Montana State University.

http://www.mes.umn.edu/Documents/J/N/JN1109.html
Take Steps to Minimize Soil Compaction from Wheel Traffic, Tillage — a University of Wisconsin factsheet.

http://www.ag.ohio-state.edu/~ohioline/b301/index.html
Soil Compaction and Drainage — an Ohio State University Extension Bulletin.

http://sky.wwdc.com/whitepeabeans/smith.htm
Soil Compaction: A Major Problem in Dry Edible Bean Production — a factsheet from the Ontario White Bean Producers.