

# Sandy Soil and Soil Compaction

## ABSTRACT

Plant growth characteristics indicating soil compaction problems were observed on sandy, irrigated soils. Soil bulk density, roots per cubic centimeter, and above-ground plant growth were measured. Compaction, as measured by bulk density, extended to more than 19 inches deep with maximum compaction occurring from 3 to 14 inches. Volume weights of 1.76 grams per cubic centimeter and higher occurred where machinery had traveled. Root length in the compacted soil in the 6- to 12-inch depth was only about one-third that in loosened soil. Above-ground plant dry weight in the compacted areas also was only about one-third that of areas where soil was loosened by harvest equipment. Subsoiling has been the most practical method of loosening compacted soil.

## INTRODUCTION

Considerable acreage of native land adjacent to the Columbia River recently has been brought into irrigated agricultural production. Most of the soil is sandy textured and is classified in the Quincy, Adkins, Sagehill, Koehler, Burbank, or Winchester series. Progressive agricultural operators on these soils must use a high degree of mechanization. Large tillage, planting, and harvesting implements are pulled by equally large, powerful tractors. Trucks capable of hauling heavy loads are used to remove the harvest. Pressures exerted on and below the soil surface by these machines are causing soil compaction. The trend toward heavier and more powerful equipment is anticipated to continue, thus equal or even more soil compacting forces can be expected.

The information presented in this publication deals with a soil management-compaction problem that is being encountered on Quincy sandy soils. The work was initiated when poor growth of winter wheat along wheel track patterns left from potato digging operations indicated that adverse effects of compaction might exist. Specific data from the study site on volume weight (bulk density) and winter wheat growth are reported.

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A brief review of soil and plant response to compaction is presented. Management practices which minimize compaction and additional reference material are listed.

## SOIL AND PLANT INFORMATION RELATING TO SOIL COMPACTION

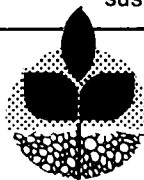
### The Normal Soil

A soil favorable for plant growth consists of approximately one-half solid mineral particles and one-half pores, voids, and cracks between the particles. Pores, voids, and cracks are of irregular size and shape and are filled with air and water. A mixture of large and small pores is desirable. Large and small pores as used in this report are relative to the thickness of a root. For wheat, root thickness varies from 1/64- to 1/16-inch. Roots enter large pores and cracks freely or with little mechanical resistance. Large pores allow rapid air movement and water infiltration, whereas small pores are better able to hold water against the pull of gravity. Sandy soils have larger and fewer pores than finer-textured soils; also, pores of sand are rigid and not easily enlarged by roots, making penetration difficult.

Soil mineral particles are incompressible. Change in soil volume during compaction is a change in volume of pores, voids, and cracks. Forces causing the compaction slide, roll, and pack the soil particles into a smaller volume.

Particle size distribution of the sandy soils along the Columbia River is nearly ideal for maximum compaction. These soils contain 60 to 85 percent sand, much of it fine sand, 10 to 25 percent silt, and less than 5 percent clay. Pores formed by sand are large enough to hold clay and small silt particles. Many of the larger pores, when rearranged and reduced in size during compaction, are filled with smaller particles. The resulting soil has smaller and fewer pores, a higher bulk density (volume weight), and greater soil strength. All these features are detrimental to good plant growth.

Soil can be compacted most easily when the moisture content is near optimum for plant growth (field capacity). Many of the field operations necessary with irrigated agriculture on sandy land are performed when the soil is at or near field capacity and, therefore, most susceptible to compaction.



## Adverse Effects

Restricted depth of penetration of roots is the primary adverse effect of compaction on these sandy lands. The plants utilize less volume of soil for moisture and nutrient absorption. A reduced rate of water infiltration, slower exchange of air between the atmosphere and the soil, and slower air movement within the soil are other possible problems occurring from this condition.

Some of the adverse effects of soil compaction observed with finer-textured soils are not apparent with the sandy soils. Increased clod formation, which may interfere with seedbed preparation, tillage, and harvesting in finer-textured soils, does not occur. Internal soil drainage is not so slow that water ponding or water logging occurs for days or even hours. Surface crusting is much less of a problem with sandy soils than with finer-textured soils.

## Causes

Soil compaction considered in this report has developed from pressure exerted on the soil by implements used in agricultural production. Wheels, whether on tractors, planting and harvesting equipment, or trucks, apply pressure to the soil surface. Tillage equipment such as rototillers that are improperly designed or operated and discs exert considerable pressure on the soil below the surface. Wheel slippage and soil vibration when under pressure compact soil. Compaction from pressure exerted on or near the soil surface by equipment may extend as deep as 20 or more inches.

Some common sources of soil compaction are of minor importance. Most of these soils do not have a naturally formed compacted layer. Shrinking and swelling of clay particles does not contribute to the compaction problem for two reasons: (1) These soils have a low clay content—5 percent or less. (2) The clay particles are of a type which exhibit little shrinking and swelling. Extended livestock grazing when the soil is wet compacts these sandy soils to a depth of several inches, but not to the depth or intensity that results from use of machines and trucks.

## Natural Forces Reducing Compaction

Several natural-occurring forces are reported to reduce soil compaction. Freezing and thawing can reduce the volume weight and the strength of compacted soil. The beneficial effects of freezing are usually observed in climates where the annual depth of freezing is a foot or more. In this area of the Pacific Northwest, soil freezing to this depth does not occur annually.

A moderate amount of soil shrinking and swelling reduces compaction. As mentioned previously, local soils contain only a very small amount of clay particles that exhibit a capacity for shrinking and swelling.

Roots, especially those of perennial crops, slowly penetrate moist compacted soil. Roots and organic matter reduce the adverse effects of soil compacting pressures if sufficient time is allowed. An example of the slowness of natural forces to correct soil compaction is the still visible Oregon Trail tracks.

## Measuring Compaction

Volume weight (bulk density) is used to express the relationship between the dry weight of a soil and its volume. Volume weight is expressed in metric units of grams per cubic centimeter ( $\text{g}/\text{cm}^3$ ).<sup>1</sup> For comparative

purposes, the volume weight of water is one  $\text{g}/\text{cm}^3$ . Normal coarser-textured (sandy) soils have a slightly higher volume weight than medium- and fine-textured soils. No definite volume weight designates a soil as being ideal for rooting or being too dense for root penetration. Generally, root penetration difficulties increase as the volume weight of a soil increases. One method of measuring the effects of crops, tillage, and implements on soil compaction is to determine changes in the volume weight of the soil.

Compaction increases soil strength (the ease with which the soil can be penetrated). However, soil strength increases rapidly as the moisture content of the soil decreases. A penetrometer measures penetration resistance and indicates soil strength. Root growth decreases as penetration resistance increases and stops when penetration resistance approaches 350 to 400 pounds per square inch.

## TILLAGE EFFECTS ON VOLUME WEIGHT AND WINTER WHEAT GROWTH

Plant and soil samples were taken in December from a winter wheat field showing uniformly spaced streaks of distinct plant growth differences. The better-looking wheat occurred where the soil had been loosened by potato harvesters. The poor wheat was growing where tractor wheels had compacted the furrows between potato rows, or where trucks hauling potatoes during harvest had been driven. The poor-looking wheat was small, had few tillers, and appeared deficient in nutrients.

Soil in this field is classified as Quincy fine sand. Quincy soil is coarse textured and shows little change in texture, horizons, and color with depth. Darker, coarser sand may occur at 30 to 40 inches. The dry soil is loose, nonsticky, and nonplastic. These characteristics impart a single grain or a weak massive structure if sufficiently compacted. Soil texture at this particular location was more than 85 percent sand, less than 10 percent silt, and less than 5 percent clay.

Soil samples for volume weight determinations were taken from non-farmed soil growing native vegetation, from areas having "normal" wheat growth, and from areas having poor wheat growth. Root and plant samples were taken where wheat growth was "normal" and poor.

## Volume Weight

The volume weight of the surface few inches of the native soil was 1.51 to 1.58  $\text{g}/\text{cm}^3$  (Figure 1). Volume weight increased slightly with depth to the coarser sand at 30 inches. The coarser sand had a volume weight of 1.75 and higher.

Volume weight of the soil loosened by the potato harvester gradually increased from 1.52 at the surface to 1.60 at 7 inches (Figure 1). This is approximately the same as the volume weight found in the native soil. Below 7 inches, the soil was significantly higher in volume weight than the native soil. This higher volume weight continued to a depth of 19 inches.

Where the wheat growth was poor, volume weight increased from 1.51 in the surface inch of soil to 1.72 at the 3-inch depth (Figure 1). Below 3 inches, soil

<sup>1</sup> In engineering, i.e. highway construction, volume weight is expressed in pounds per cubic foot.

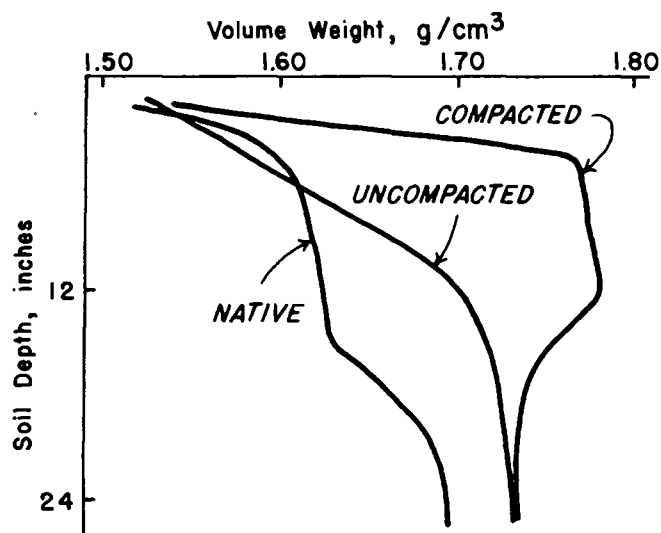


Figure 1. Volume weight ( $\text{g}/\text{cm}^3$ ) of three locations of Quincy fine sand—native, uncompacted soil after potato harvest, and soil compacted by wheel traffic during potato harvest.

volume weight was very high—1.76 and higher. This high volume weight zone extended to a soil depth of 14 inches. Below 16 inches, the volume weight decreased to approximately the same volume weight measured where wheat was growing normally. Volume weights of the 10- to 19-inch soil depths of both wheat growing areas were distinctly higher than the volume weights of the native soil.

These data indicate that the volume weight of the soil to a depth of 18 to 20 inches has increased during the six years it has been cultivated. Unfortunately, this compacting extends much deeper than the normal 10- to 13-inch depth of subsoiling being done. Soil compaction resulting from heavy vehicle traffic on moist soil during harvest develops volume weights around 1.8. This severe compaction extends to a depth of 14 inches or more.

#### Root and Plant Growth

This severe soil compaction had an adverse effect on rooting. Soil cores taken from within wheel tracks, and from the loosened areas between wheels, were washed out and the length of root present in each 6-inch increment of soil was determined. The top 6 inches of soil were well rooted in both situations with a root length density of about  $6 \text{ cm}/\text{cm}^3$  (Figure 2). The compacted soil profile permitted much less root development below 6 inches than did the loosened profile. The difference is especially great in the 6- to 12-inch increment where the loosened profile had about three times more root length than did the compacted one.

Table 1 shows differences in the above-ground parts of plants growing in these two areas. Plants growing over the wheel tracks were smaller, with about one-third the dry weight and one-third the number of tillers as the plants in the loosened areas. Over the compacted tracks, tillers were shorter and had developed slightly fewer leaves. Both sets of plants showed symptoms of nitrogen deficiency with marked senescence of older leaves on all tillers. Table 1 shows data for the main stem where only the two youngest leaves remained green; this same pattern applied to

all the tillers in both sets of plants. Apparently, plants growing in compacted soils suffer stunting in addition to adverse effect on nutrient uptake as shown by the data in Table 1.

Table 1. Wheat plant development in soil loosened by potato digging and in soil compacted in wheel tracks during normal potato management and harvest operations.

Plant property	Loosened soil	Compact soil
Above ground dry matter per $\text{M}^2$ (g)	117.2	27.6
Number of tillers per $\text{M}^2$	1516	624
Average weight/tiller (g)	0.077	0.044
Main stem height (cm)	$22.5 \pm 4.5$	$14.4 \pm 3.1$
Total number of leaves on the main stem	$7.2 \pm 0.6$	$6.3 \pm 0.9$
Dead leaves on the main stem	$5.0 \pm 0.6$	$4.2 \pm 1.4$
Living leaves on the main stem	2.2	2.1

#### MINIMIZING AND REDUCING COMPACTION

A volume of soil which can readily be penetrated by roots is essential to intensive agricultural production and high crop yields. The major value of a deeper-rooting zone compared to a shallower-rooting zone is as a buffer against management errors and sudden, unfavorable climatic changes. Another value of deeper rooting is the recovery of water and nutrients from a greater soil depth. A uniform depth of rooting within a field is necessary if uniform plant response to management is to be obtained.

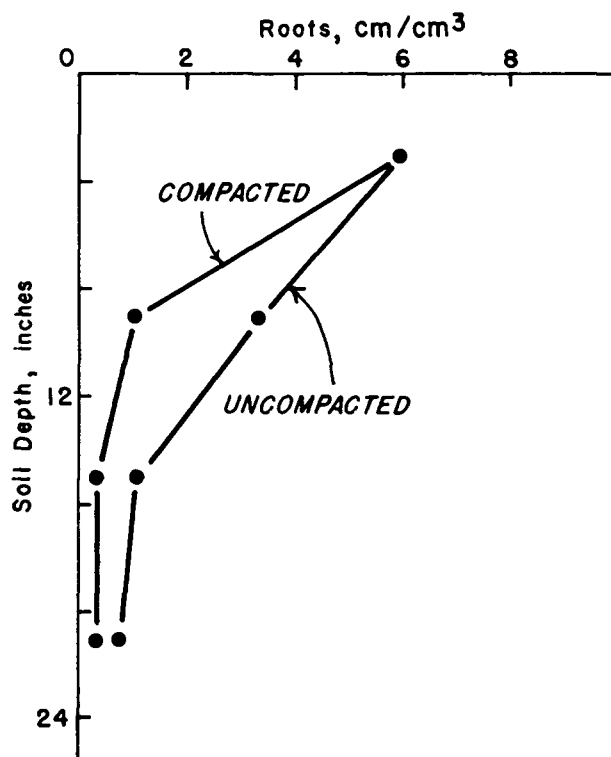


Figure 2. Centimeters of winter wheat roots per cubic centimeter ( $\text{cm}/\text{cm}^3$ ) in uncompacted soil after potato harvest and in soil compacted by wheel traffic during potato harvest.

A few management practices will help minimize soil compaction. Unfortunately, these practices are only mildly effective or are not compatible with modern trends in agriculture and machinery.

1. Work soil when it is as dry as possible; avoid working the soil when moisture content is at or above field capacity.

2. Increase tire size and number of tires; reduce tire pressure. This reduces soil pressure but increases the area compacted.

3. Reduce weight of equipment.

4. Increase speed without increasing tractor-implement weight or slippage.

5. Reduce traffic; combine several operations into one, especially subsoiling and packing after subsoiling.

6. Confine wheel traffic to the same path or location for all field operations.

Subsoiling has proven to be the most effective means of reducing existing compaction. Other tillage practices such as plowing, discing, and rototilling reduce the compaction within the zone in which they are operated. All these operations must be done properly or increased compaction will occur just below the depth of operation.

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