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Using Gypsum in Southwestern Soils

Gypsum can help stabilize aggregate structure in some soils. Use of gypsum in other soils will not improve soil physical or chemical properties, so it is important to understand the processes that occur when gypsum is added to soil.

Water, air, and roots move between soil aggregates, which are clumps of soil particles cemented together. The pores between aggregates are fairly large, whereas the pores within aggregates and between particles are often too small for effective water movement or root penetration. Soil aggregate formation and stability, also called soil structure, is one of the most important manageable soil physical properties. In all but the sandiest soils, good aggregate structure is needed for water infiltration and soil drainage.

Soil aggregates are held together by cations (positively charged molecules), among other things. Soil particles are negatively charged, and so repel each other. Cations can act as a bridge, essentially pulling soil particles together into aggregates. The process of soil particles forming into clusters or aggregates is called flocculation. Not all cations are created equal when it comes to flocculating soil particles or stabilizing soil structure. The relative flocculating ability of common soil cations is shown in Table 1. Because sodium is a very poor flocculator, it takes a lot of sodium to cause soil aggregate formation. Calcium and magnesium, on the other hand, are very good flocculators, so just a little is enough to stabilize soil structure. Sodium is the most common Apoor flocculator@, and calcium and magnesium the most common Agood flocculators@. We can get a rough idea of how stable a soil's structure is by looking at the relative amounts of these cations. This is done with the Sodium Adsorption Ratio (SAR), where cation concentrations are in mmol/L.

$$SAR=\frac{[Na^+]}{\sqrt{[Ca^{2+}]+[Mg^{2+}]}}$$

An alternative equation for expressing the impact of sodium on aggregate stability is Exchangeable Sodium Percentage (ESP):

$$ESP=\frac{[Na^+]}{\text{cation exchange capacity}}$$

In addition to the relative proportions of flocculating cations, it is also important to know the total concentration of soluble salts in the soil. Cations are always accompanied by negatively charged ions (anions), and together they are called salts. Salts dissolved in water conduct electricity, so we can measure the electrical conductivity or EC of a soil-water mixture to determine the amount of salt.

Together, the SAR and EC of a soil can be used to predict its aggregate stability, as shown in Figure 1. If a soil has a combination of high SAR and low EC, the aggregates will tend to disperse. If it has a high EC and/or low SAR, the soil particles will be aggregated.

Table 1. Relative flocculating power of soil cations.

Ion	Chemical Symbol	Relative Flocculating Power
Sodium	Na^+	1.0
Potassium	K^+	1.7
Magnesium	Mg^{2+}	27.0
Calcium	Ca^{2+}	43.0

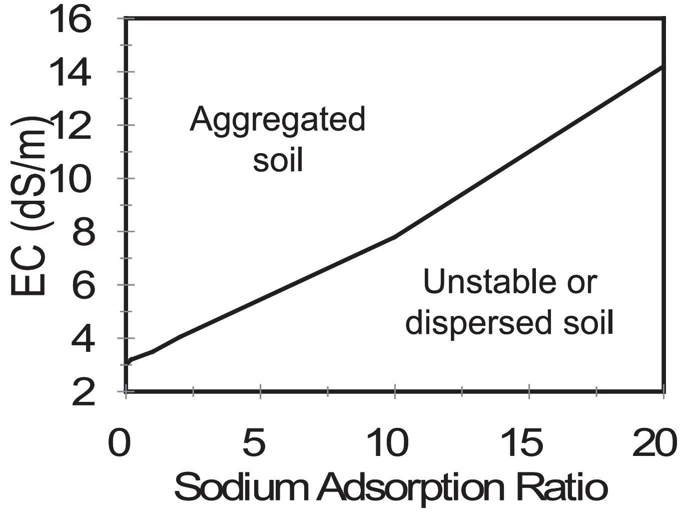

Figure 1. Soil electrical conductivity (EC) and Sodium Adsorption Ratio (SAR) determine aggregate stability.

It is easy to conduct a simple soil test to determine soil stability. Put about 1 tablespoon of soil and 2 cups of water in a jar and shake. Let it settle for at least 15 minutes. If the soil settles out of the water, the soil particles are aggregated. If the soil does not settle out of the water, the soil aggregates are unstable and susceptible to dispersion.

In soils with unstable structure, gypsum ($CaSO_4.2H_2O$) can help promote and stabilize structure by providing a good source of calcium. Calcium acts as a "glue" that holds soil particles together into aggregates and stabilizes soil structure. Powdered gypsum or waste gypsum (for example, from phosphate fertilizer production) are usually the least expensive forms. Prilled gypsum is effective at reducing dust, but is somewhat more expensive. Regardless of the form of gypsum used, it is important that the quality of the gypsum be determined by a reputable laboratory. (Note: knowing the calcium content of gypsum is not sufficient, as calcium may be present in other forms such as lime, $CaCO_3$, which is not an effective calcium source in high pH soils.)

The amount of gypsum that should be applied is best determined by a soil analysis. Soil analyses should be conducted to determine soil sodium status, either as "sodium adsorption ratio" (SAR) or as "exchangeable sodium percentage" (ESP). Either provides a good indication of the need for gypsum and the two measures are roughly equivalent. Approximate amounts of gypsum to add, based on soil analyses, are shown in Tables 2 and 3. Gypsum can also be added directly to irrigation water; amounts should be determined by laboratory water analysis.

Table 2. Gypsum requirements in tons per acre as influenced by soil texture and sodium adsorption ratio.

Soil Texture	Sodium Adsorption Ratio					
	10	15	20	30	40	50
	Gypsum (tons per acre)					
Coarse	1	2	3	5	7	9
Medium	1.5	3	5	8	11	14
Fine	2	4	6	10	14	18

Table 3. Gypsum requirements in pounds per one thousand square feet as influenced by soil texture and sodium adsorption ratio.

Soil Texture	Sodium Adsorption Ratio					
	10	15	20	30	40	50
	Gypsum (lbs per 1000 ft^2)					
Coarse	50	100	150	250	350	450
Medium	75	150	250	400	550	700
Fine	100	200	300	500	700	900

Alternatives to gypsum include sulfuric acid and elemental sulfur, although these are effective only in calcareous soils that contain solid phase calcium carbonate. Sulfuric acid dissolves calcium carbonate in the soil, forming gypsum and releasing calcium.

$$H_2SO_4 + CaCO_3 \rightarrow CO_2 + H_2O + CaSO_4$$

Elemental sulfur is converted to sulfuric acid by sulfur oxidizing bacteria, producing the same effect as sulfuric acid. Sulfur conversion is a biological process, however, and requires several weeks to several months to take place, depending on soil conditions.

With any of the soil additives described here, getting the amendment into the soil can be problematic. Gypsum is slightly soluble in water, and will slowly move into the soil with precipitation or irrigation water, but physical incorporation will improve subsurface soil structure more rapidly than unincorporated surface applications. Sulfuric acid is much more soluble and is rapidly transported into the soil with infiltrating water. For a soil with poor aggregation, moving water into the soil can be extremely difficult, and in these cases soil amendments may have to be physically incorporated.

If your soil does not have stable structure, then gypsum, sulfuric acid, or elemental sulfur can help to improve soil physical properties. However, if your soil has good structure, adding these amendments will not be beneficial. All irrigation water contains salts. It is critical to know the SAR of your irrigation water because this can change the SAR of the soil, and convert a stable soil to an unstable, dispersed soil over time. Irrigation water may require treatment with sulfuric acid, gypsum, or other amendments to prevent the formation of problem soils. *Soil structure problems are much easier to prevent than to cure!*

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This information has been reviewed by university faculty.
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