Gypsum Is Almost A Universal Soil Amendment

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Abstract: Agriculture has failed to be sustainable several times in the history of the world because of soil failure (Rush, 1987). Irrigated land eventually leads to sodicity and salinity unless extreme care is taken. Gypsum is a key ingredient for the maintenance of agriculture on many types of soils and over a wide pH range including sodicity. Waste-product gypsum is available in a large number of locations at very little or no cost. Advantages of gypsum in addition to prevention and correction of sodicity include greater stability of soil organic matter, more stable soil aggregates, improved water penetration into soil, and more rapid seed emergence. The need for gypsum in amounts varying from small to large is almost universal. Gypsum and water-soluble polymers magnify the value of each other. Together they have an important role in making a better environment, especially for growing plants.

Introduction

Regular use of gypsum is essential to the sustainability of most irrigated soils. It has been used as a soil amendment and fertilizer for over 200 years. Benjamin Franklin was said to have successfully spelled out the sentence on one of his fields with the response from gypsum, “This land has been plastered.” Plaster of Paris is a form of gypsum.

Gypsum is calcium sulfate. The most common form of it is the dihydrate which means that each molecule of calcium sulfate has two water molecules associated with it. It is expressed as $CaSO_4.2\ H_2O$. The plaster of Paris used commercially has only one-half water and another form called gypsum anhydrite has no water. Much of the gypsum used in agriculture is mined and then pulverized to desirable particle sizes. The smaller sizes go into solution more rapidly than do large sizes. Gypsum is also a by-product of various manufacturing operations.

For many reasons, gypsum can be considered to be a farmer’s best friend. Almost 40 benefits from its use on land have been documented. Some of the reasons are multiple and interrelated.

Some Reasons For Using Gypsum

Gypsum Improves Soil Structure.

Gypsum provides calcium which is needed to flocculate clays in acid and alkaline soil (Shainberg et al. 1989, Sumner 1993, Sumner and Miller 1992). It is the process in which many individual small clay particles are bound together to give much fewer but larger particles. Such flocculation is needed to give favorable soil structure for root growth and air and water movement.

Gypsum Helps Reclaim Sodic Soils.

Gypsum is used in the reclamation of sodic soils (Aldrich and Schoonover 1951). Where the exchangeable sodium percentage (ESP) of sodic soils is too high, it must be decreased for soil improvement and better crop growth. The most economical way is to add gypsum which supplies calcium. The calcium replaces the sodium held on the clay-binding sites. The sodium can then be leached from the soil as sodium sulfate to an appropriate sink. The sulfate is the residue from the gypsum. Without gypsum, the soil would not be leachable. Sometimes an ESP of three is too high, but sometimes up to ten or more can be tolerated. The range is partly the result of concentration of soluble salts.

Gypsum Prevents Crusting of Soil and Aids Seed Emergence.

Gypsum can decrease and prevent the crust formation on soil surfaces which result from rain drops or from sprinkler irrigation on unstable soil (Shainberg et al. 1989; Sumner and Miller 1992). It can even prevent crusting that results when acid soils are limed (Sumner 1993), the gypsum is coapplied with the lime. The gypsum is either surface applied or put on in the irrigation system. Prevention of crust formation means more seed emergence, more rapid seed emergence, and easily a few days sooner to harvest and market. Seed emergence has been increased often by 50 to 100 percent. The prevention of crusting in dispersive soils is a flocculation reaction.

Gypsum Improves Low-Solute Irrigation Water.

Gypsum is used to increase the solute concentration of low-solute water used for irrigation (Traynor 1980). Irrigation water from rivers that no longer have sources of leachable salts wither penetrates poorly into soil or causes soil particles to degrade which results in low-water penetration. Rain water can behave the same way and result in soil compaction. The problem can be corrected with surface-applied gypsum or application to the irrigation water.

Gypsum Improves Compacted Soil.

Gypsum can help break up compacted soil (Shainberg et al. 1989) and decrease penetrometer resistance (Hall et al. 1994a). Soil compaction can be prevented by not plowing or driving machinery on soil when it is too wet. The compaction in many but not all soils can be decreased with gypsum, especially when combined with deep tillage to break up the compaction. Combination with organic amendments also helps, especially in preventing return of the compaction.

Gypsum Makes Slightly Wet Soils Easier To Till.

Soils that have been treated with gypsum have a wider range of soil moisture levels where it is safe to till without danger of compaction or deflocculation (Shainberg et al. 1989).

This is accompanied with greater ease of tillage and more effective seedbed preparation and weed control. Less energy is needed for the tillage.

Gypsum Stops Water Runoff and Erosion.

Gypsum improves water infiltration rates into soils and also the hydraulic conductivity of the soil (Shainberg et al. 1989). It is protection against excess water runoff from especially large storms that are accompanied with erosion.

Gypsum Decreased pH of Sodic Soils.

Gypsum immediately decreases the pH of sodic soils or near sodic soils from values often over 9 but usually over 8 to values of from 7.5 to 7.8. These values are in the range of acceptability for growth of most crop plants. Probably more than one mechanism is involved. According to Lindsay (1979), Ca++ reacts with bicarbonate to precipitate $CaCO_3$ and release protons which lessens the hydrolysis of clay to form hydroxides. These reactions can decrease the incidence of lime-and bicarbonate-induced iron deficiency.

Gypsum Increases the pH of Acidic Soils.

One mechanism in which gypsum can increase soil pH enough in some acid soils to sufficiently decrease the level of soluble aluminum to grow crops satisfactorily is replacement of hydroxyl ions from some clay lattices by sulfate ions (Sumner 1994).

Gypsum Improves Swelling Clays.

Gypsum can decrease the swelling and cracking associated with high levels of exchangeable sodium on the montmorillonite-type clays (Aldrich and Schoonover 1951). As sodium is replaced by calcium on these clays, they swell less and therefore do not easily clog the pore spaces through which air, water and roots move.

Gypsum Prevents Waterlogging of Soil.

Gypsum improves the ability of soil to drain and not become waterlogged due to a combination of high sodium, swelling clay, and excess water (Aldrich and Schoonover 1951). Improvements of infiltration rate and hydraulic conductivity with use of gypsum add to the ability of soils to have adequate drainage.

Gypsum Can Help Remove Excess Boron from Sodic Soil.

More boron was leached from sodic soils when gypsum was applied than when the soil was leached without gypsum (Bajwa and Sharma 1990).

Gypsum Increases the Stability of Soil Organic Matter.

Gypsum is a source of calcium which is a major mechanism that binds soil organic matter to clay in soil which gives stability to soil aggregates (Muneer and Oades 1989). The value of organic matter applied to soil is increased when it is applied with gypsum.

Gypsum Makes Water-Soluble Polymer Soil Conditioners More Effective.

Gypsum complements or even magnifies the beneficial effects of water-soluble polymers used as amendments to improve soil structure (Wallace and Nelson 1986). Like for organic matter, calcium, which comes from gypsum, is the mechanism for binding of the water-soluble polymers to the clay in soil.

Gypsum Makes Excess Magnesium Non-Toxic.

In soils having unfavorable calcium : magnesium ratios, such as serpentine soils, gypsum can create a more favorable ratio (Jones et al. 1976).

Gypsum Corrects Subsoil Acidity.

Gypsum can improve some acid soils even beyond what lime can do for them. Surface crusting can be prevented (Shainberg et al. 1989; Smyth and Cravo 1992). The effects of toxic soluble aluminum can be decreased, including in the subsoil where lime will not penetrate. It is then possible to have deeper rooting with resulting benefits to the crops. The mechanism is more than replacement of acidic hydrogen ions which can be leached from the soil to give higher pH. Hydrogen ions do not migrate rapidly in soils containing clay. It is suggested that the sulfate from gypsum forms a complex ($A1SO_4$+) with aluminum which renders the aluminum non-toxic (Shainberg et al. 1989). A1$(OH)_2$+ and A1$(OH)_3$ are also nontoxic to plants (Menzies et al. 1994). Also suggested is that the sulfate ions react with iron hydroxide to release hydroxyl ions which give a lime effect to increase soil pH. Gypsum is now being widely used on acid soils.

Gypsum Can Enhance the Values of Liming.

Addition to soil together with lime increased crop yields (McLay et al. 1994ab, Shkel 1991). The combination also decreased leaching losses of potassium and magnesium (Nogueira and Mozeto 1990).

Gypsum Improves Water-Use Efficiency.

Gypsum increases water-use efficiency of crops. In areas and times of drought, this is extremely important. Improved water infiltration rates (Wildman et al. 1988), improved hydraulic conductivity of soil, better water storage in the soil all lead to deeper rooting and better water-use efficiency (Shainberg et al. 1989, Hall et al. 1994b). From 25 to 100 percent more water is available in gypsum-treated soils than in nontreated soils.

Gypsum Creates Favorable Soil EC.

Gypsum, being readily soluble, results in a proper buffered solute concentration (EC) in soil to maintain soil in a flocculated state (Handbook, 1985). It is better environmentally and costwise to maintain the needed EC with gypsum than with excess application of fertilizers. Regular annual applications of gypsum are needed for this purpose. Many highly weathered soils throughout the world have surface crusting because of low electrolyte content (Sumner 1993). This can be corrected with gypsum.

Gypsum Makes it Possible to Efficiently Use Low Quality Irrigation Water.

Gypsum is essential when low-quality irrigation water must be used (Traynor 1980). The effective sodium adsorption ratio (SAR) of irrigation water should be less than 6 for some crops and less than 9 for others. When it exceeds these limits, gypsum should be applied to the soil or the water. Use of reclaimed municipal waste water is important for conservation of natural resources. Reclaimed water can be satisfactorily used if amendments, such as gypsum and water-soluble polymers are also used. Care must be taken, however, to avoid sodium build up in the lower horizons of soil because of excessive leaching when swelling clays are present (Nader and Magaritz 1986).

Gypsum Decreased Dust Erosion.

Use of gypsum can decrease wind and water erosion of soil (Shainberg et al. 1989). Severe dust problems can be decreased, especially when combined with use of water-soluble polymers. Less pesticide and nutrient residues will escape for the surface of land to reach lakes and rivers when appropriated amendments are used to stabilize the soil. Gypsum has several environmental values.

Gypsum Helps Plants Absorb Plant Nutrients.

Calcium, which is supplied in gypsum, is essential to the biochemical mechanisms by which most plant nutrients are absorbed by roots (Epstein 1961). Without adequate calcium, uptake mechanisms would fail.

Gypsum Decreased Heavy-Metal Toxicity.

Calcium also acts as a regulator of the balance of particularly the micronutrients, such as iron, zinc, manganese and copper, in plants (Alva et al. 1993, and Wallace et al. 1980). It also regulates non-essential trace elements. Calcium prevents excess uptake of many of them; and once they are in the plant, calcium keeps them from having adverse effects when their levels get high. Calcium in liberal quantities helps to maintain a healthy balance of nutrients and non nutrients within plants. Gypsum contains calcium.

Gypsum Increases Value of Organics.

Gypsum adds to the value of organic amendments. Blends of gypsum and organics increase the value of the other as soil amendments, especially for improvement of soil structure. High levels of soil organic matter are always associated with liberal amounts of calcium with is part of gypsum (Muneer and Oades 1989). Calcium decreases burn out of soil organic matter when soils are cultivated by bridging the organic matter to clay.

Gypsum Improves Fruit Quality and Prevents Some Plant Diseases.

Calcium is nearly always only marginally sufficient and often deficient in developing fruits (Shear 1979). Good fruit quality requires an adequate amount of calcium. Calcium moves very slowly, if at all, from one plant part to another and fruits at the end of the transport system get too little. Calcium must be constantly available to the roots. In very high pH soils, calcium is not available enough; therefore, gypsum helps. Gypsum is used for peanuts, which develop below ground, to keep them disease free. Gypsum helps prevent blossom-end root of watermelon (Scott et al. 1993) and tomatoes and bitter pit in apples. Gypsum is preferred over lime for potatoes grown in acid soils so that scab may be controlled. Root rot of avocado trees caused by *Phytophthora* is partially corrected by gypsum and organics (Borst 1986).

Gypsum is a Source of Sulfur.

Gypsum is a source of fertilizer sulfur. Due to the trend to production of high-analysis fertilizers and due to the need of removing sulfur dioxide emissions in industrial operations to give leaner air, more and more sulfur deficiencies are present in agriculture (Tabatabai 1986).

Gypsum Helps Prepare Soul for No-Till Management.

A liberal application of gypsum is a good procedure for starting a piece of land into no-till soil management or pasture. Improved soil aggregation and permeability will persist for years and surface-applied fertilizers will more easily penetrate as result of the gypsum (Shainberg et al. 1989).

Gypsum Decrease Bulk Density of Soil.

Gypsum-treated soil has a lower bulk density compared with untreated soil (Shainberg et al. 1989). Organics can even decrease it more when both are used. The softer soil is easier to till, and crops like it better.

Gypsum Decreases the Toxic Effect of NaC1 Salinity.

Calcium from gypsum has a physiological role in inhibiting the uptake of sodium by plants (Akhavan-Kharazian et al. 1991). For species of plants not tolerant to sodium, calcium protects from toxicity of sodium but not chloride. Calcium overcomes toxic effects of sodium chloride salinity on seed germinations and plant growth (Cachorro 1994).

Gypsum Multiplies the Value of Other Inputs.

Gypsum can improve the response to all other inputs including fertilizers. It more than adds to their beneficial effects; it multiplies them (Wallace and Wallace 1993).

Gypsum Can Decrease pH of Rhizosphere.

Increased calcium uptake by roots when gypsum is applied can decrease the pH of the rhizosphere (Wallace 1963: Wallace and Wallace 1992). In high pH soils, the added availability of iron and zinc is very important to some plant species.

Gypsum Keeps Clay Off Tuber and Root Crops.

Gypsum can help keep clay particles from adhering to roots, bulbs and tubers of crops like potato, carrots, garlic and beets. In combination with water-soluble polymers, it is even more beneficial (Wallace and Nelson 1986).

Gypsum Decreases Loss of Fertilizer Nitrogen to the Air.

Calcium from gypsum can help decrease volatilization loss of ammonium nitrogen from applications of ammonia, ammonium nitrate, UAN, urea, ammonium sulfate, or any of the ammonium phosphates (Fenn et al. 1991, Bayrakli 1991). Calcium can decrease the effective pH by precipitation carbonates and also by forming a complex calcium slat with ammonium hydroxide which prevents ammonia loss to the atmosphere (Evangelou and Lumbanraja 1989). Actually calcium improves the uptake of nitrogen by plant roots especially when the plants are young (Fenn et al. 1993).

Gypsum Can be a Source of Oxygen for Plants.

The sulfate that is taken up by plants and metabolized releases the associated oxygen which is a source of oxygen to plant roots although a limited source. Nitrate nitrogen does the same except it is a larger source of oxygen than is sulfate. Under adverse conditions, the oxygen coming from the sulfate can be important such as with root rot in avocado.

Gypsum Helps Earthworms to Flourish.

A continuous supply of calcium with organics is essential to earthworms that improve soil aeration, improve soil aggregation and mix the soil (Sinnes 1979). Earthworms can do the plowing for no-till agriculture.

Gypsum Can Increase Water Retention in Soil.

Gypsum when applied to sodic soil decreased levels of exchangeable sodium resulted in a large increase in water retention at a given tension compared with controls (Tiwara et al. 1993). Dry matter and seed yield were increased as a result.

Gypsum Can Increase Crop Yields.

Gypsum for various combinations of the above effects can substantially increase crop yields from 10 to 50 percent (Handbook 1985).

Will Your Soil Be Responsive to Gypsum?
(Aldrich and Schoonover, 1951)

Yes, if…

(a) soil pH is over about 8.2 and maybe even if it is less
(b) ESP is over 3 and definitely if it is over 9
(c) Water puddles on it
(d) The particles slake or disperse when added to water
(e) The subsoil pH is lower than 5
(f) There is waterlogging in the soil
(g) There is a crust on the soil after rain or irrigation
(h) There is excessive cracking of the soil after rain or irrigation
(i) The soil contains clay that is dusty when dry
(j) Irrigation water contains substantial amounts of bicarbonate; however, beware of caliche forming in the subsoil
(k) Intense rain falls on soil that is not acidic and where all solutes may be leached from the soil surface
(l) No-till is used