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GYPSUM IN AGRICULTURE: A BRIEF DISCUSSION

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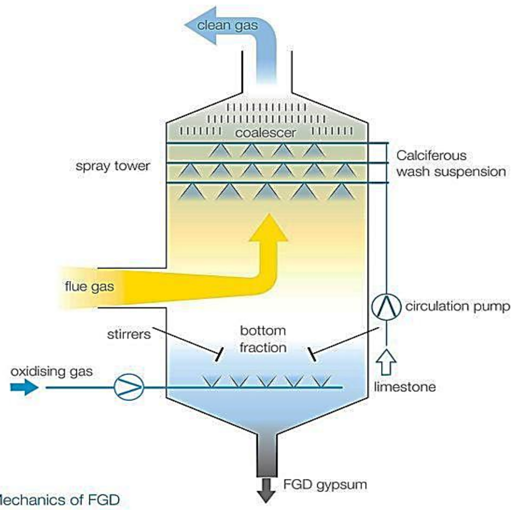
It's been a long time since calcium sulphate otherwise popularly known as gypsum is being used as a "tool of multiple-use" in agriculture around the globe. Full availability, relatively lower price; that is what makes it an excellent agronomic and environmental tool to improve soil physical and chemical property. In this regard, most of the research came out with conclusive results; however, the three-way interaction among local condition, plants response and environmental implications are remained significantly untouched. The primary utility of gypsum is a means to overcome the physicochemical problem in sodic soils as well as a nutrient source of calcium and sulphur to the plants (Shainberg*et al.*,1989). The most recent scientific trends are also suggesting a just opposite turn, i.e., using it to reduce the high level of soil acidity as well as soil dispersion problems. Along with reclaiming sodic soils; the other most common utilities of gypsum are reducing soil crusting in arid and semi areas where it can increase infiltration rate despite scarce rainfall and improving seed germination. In high aluminium- rich soil, gypsum can suppress the Al ions from damaging the root system by replacing it with Ca ions thus helps to establish a sound root system (Ritchey *et al*., 1995).

On the strict sense of plant nutritional point of view; it might seem unnecessary to apply gypsum as a source of calcium in low rainfall areas where the calcium is already present in the soil in plentiful quantity to suppress Phyto- toxic aluminium ions; however; the problem lies somewhere else. The high rate of ammonia-based fertiliser often responsible for the localised or even widespread soil acidification, which causes a sharp increase of Al^{3+} ions in the rootzone. Of Couse, a general lime application can seem to be an easy way out. However, the effectiveness of the lime application is limited to the depth of its incorporation which often results inthe formation of a shallow and deep acid subsoil especially in zero tillage situation where lime can only reduce acidity of the middle layer; the layer of lime incorporation. In this scenario, Gypsum has some advantages over lime such as higher rate of ion mobility, solubility and replacing the Al^{3+} from the exchange medium with calcium and sulphate (Kost*et al*.,2014).

Gypsum: where and howit comes from?

The traditional natural source of gypsum is the geologic depositions which are often excavated, collected, and used fora long time. Different derivatives of gypsum such as the hemihydrate (Plaster of Paris, CaSO4,1/2H2O) and anhydrite (CaSO4) are very common, extensively distributed minerals which can be found as sedimentary evaporative deposits(Chen *et al*., 2010).

When brine marine water is evaporated, the first mineral which gets precipitated is gypsum which is often found beneath the rock salt deposit of salt domes (Murray, 1964). If the temperature is higher, (>42°C) anhydrite (Angelite) may precipitate before gypsum, but upon rehydration, it easily converts back to gypsum. Chemically pure gypsum deposits are although naturally possible; but in general, an impurity such as Ca and Mg carbonate and sulphate salts, as well as Fe oxides, are often remaining mixed with gypsum. Majority of the natural gypsum deposits are found in the USA, France, Canada, England, and some parts of the former Soviet Union. Since a long time, these mined-gypsum has been used as cement additive and soil amendments (Hurlbut and Klein, 1971).



Mechanics of FGD

Another source of gypsum is nongeogenic in nature, such as it is a by-product of phosphoric acid production, which is a part of high analysis prophetic fertiliser production. As compared to the natural gypsum, it is much finer in quality and higher purity and termed as "**Phosphogypsym**". One interesting fact is that; the plants which produce gypsum as a

Volume 2 – Issue 7
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www.agriallis.com

byproduct often consider it as disposal nuisance while it can be a useful agricultural tool elsewhere. Another concern associated with this secondary gypsum production is its association with some degree of radioactivity (Guimond and Hardin, 1989).

A relatively new source of gypsum came into existence when different countries took air pollution seriously; the flue gas treatment plants of different industries which still uses coalremoves and retains the sulphur dioxide. This by-product is called 'flue gas desulphurisation gypsum' (FGD-gypsum).

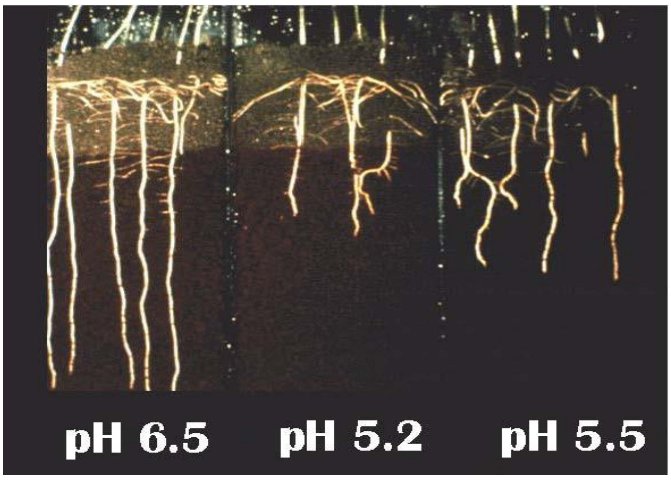

Fig 1: Effect of low pH and Al toxicity on cotton root

The solubility of gypsum

The solubility of pure gypsum in pure water is little, generally 2.5 g L^{-1} (Lide, 2005); however, the solubility increases significantly in complex formation. In case of saline water; the solubility increases based on the presence of other non- Na ions in solution. The other exchangeable ions which can replace the Ca also increase the dissolution of gypsum.

Use of gypsum in Agriculture

Subsoil acidity alleviation

Around the world, a whopping 50% of arable land faces the challenge of soil acidity. The presence of toxic aluminium ions is behind this limitation (Von Uexkull and Mutert, 1995). Soil naturally becomes acidic over time due to removal of base cations, production of organic acids or due to microbial respiration. Crop production hastens the process by increasing all these three factors. When the pH gets below the threshold limit (pH 5.5); the aluminium started becoming available to the plant. The most prominent ill-effect of aluminium is inhibition of the growth of plant roots; even in micromolar concentration! Aluminium does it by inhibiting root cell expansion and elongation (Marschner, 1995). Aluminium tends to interact with multiple sites in the apoplasm and symplasm of root cells as it forms strong bonds with oxygen donor compounds (Martin, 1986). Aluminium also inhibits Ca uptake by blocking Ca^{2+} channels at the plasma membrane.

Volume 2 – Issue 7
Online ISSN: 2582-368X
www.agriallis.com

Gypsum is often superior to limestone-based materials when it comes to subsoil acidity alleviation because of the higher mobility of gypsum dissolution products. This often becomes more important if the land is under no-till cultivation practice where limestone can not be added. Another important fact is that; the solubility of limestone reduces once the pH approaches the near-neutral value. Hence if the soil top layer has a near-neutral pH while the subsoil is acidic; the limestone does not solve the purpose. However; unlike the carbonate in limestone which directly neutralises the acidity; limestone somewhat alleviates the Al toxicity by shifting the soluble Al to less toxic form. Ultimately; the reduction of subsoil acidity leads to better root growth as well as enhanced water As well as nitrogen use efficiency (Hammel *et al*., 1985).

Impact of gypsum application on overall soil pH

Gypsum is not an acid neutralising or acid-forming agent hence the impact of gypsum on overall soil pH is minimal. It can although slightly change the pH, but that totally depends upon the sophisticated soil mineralogy, CEC, and other competing anions. The range of pH change is often ranged between 0.2-0.3 pH units (Pavan *et al.*, 1982).

Effect on base cations base saturation

Gypsum has a high potential to increase the soil fertility especially in the sub-soil due to high solubility of Ca, and S. Gypsum directly improves base saturation, exchangeable Ca and S content in soil moreover; gypsum also increases the leaching loss of Mg and K due to thermodynamics of ion exchange (Oliveira and Pavan, 1996).

Impact of gypsum application on soil physical properties

Gypsum has a long history of being used as a useful tool of soil amelioration for sodic and heavy clay soils. Gypsum also prevents swelling and dispersion and indirectly potentially increase porosity, hydraulic conductivity, structural stability, and drainage. Na^+ and Ca^{2+} possess opposite characteristics; while one has a deleterious effect; the other has a favourable effect on soil. However, the threshold level of exchangeable Na in which a non-dispersive soil becomes dispersive is not entirely defined (Shainberg*et al*., 1989). As per The U.S. Salinity Laboratory Staff (1954), the threshold level is 15 ESP. The higher the ESP (exchangeable sodium percentage), the more chances of dispersion and breakdown of

Volume 2 – Issue 7
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www.agriallis.com

structure when wetted. However, a modification made by Bernstein (1974) concluded that soil texture plays a significant role; hence; the critical ESP is 10 for fine-textured soil and 20 for coarse-textured soil. A soil which has ESP value greater than 15 is scarce even in semi-arid and arid condition while low ESP soil (ranging 1-5) is widespread in arid and semi-arid conditions and even humid regions (Shainberg*et al*., 1989). As a result, the dispersive and unstable soils where gypsum potentially can be used are much more significant. The leaching of sodium as an effective method to prevent soil dispersion is not a new concept, as Hilgard (1906) reported it a hundred years back. Gypsum is the most common sodic soil amendment tools due to its high solubility, lower cost, higher availability, and secure handling. Even in non-sodic soils; gypsum improves soil structure by increasing flocculation, aggregate stability, and water infiltration (Malik *et al*., 1991).

Table1: Potential impact of gypsum application on soil

Mechanism	Potential impact
Increase in soil solution ionic strength with divalent ions	Decreases double layer thickness which leads to improve soil structure and drainage, reduce crusting
	Decreases aluminium ion activity
Increase solution calcium Concentrations	Displaces excessive sodium from sodic soils to permit remediation and reductions in exchangeable sodium percentage
	Provides calcium for growing plants
	Displaces magnesium and potassium from soil CEC: leaching of nutrients
	Displaces aluminium and protons from CEC: slight temporary pH reduction
	Increase base saturation and decrease acid saturation
	Decreases phosphorus solubility due to calcium phosphate Precipitation
Increase solution sulphate Concentrations	Provides sulphate for growing plants
	Complex solution Al^{3+} and Mn^{2+}: decrease aluminium and manganese toxicity
	Allows for more profound movement of Ca and other cations into acid subsurface due to high sulphate mobility and electroneutrality of ion leaching
	Ligand exchange with valence unsatisfied terminal hydroxides on variable charge minerals: slight increase in pH

(**Source:**Zoca and Penn, 2017)

Volume 2 – Issue 7
Online ISSN: 2582-368X
www.agriallis.com

The response of crop toward gypsum application

Direct improvement of crop yield has been observed, which is a contribution to increased Ca and reduced Al status in soil. Scientists also reported that gypsum induced yield improvement is more prominent in the year when the deficit of rainfall has been observed, Ritchey *et al*. (1995).

The environmental footprint of gypsum

Gypsum potentially can be used to increase water infiltration hence reducing runoff of water and nutrients. Gypsum is also used as phosphorus absorbing material. A higher dose application of high analysis phosphatic fertiliser or dumping off manure often leads to eutrophication. This is especially problematic in the case of poultry manure. Application of gypsum along with compost leads to up to 61% less runoff loss of soluble phosphorus (Endale*et al*., 2014). Another critical environmental benefit of gypsum is that it can be used to trap pollutant heavy metals like mercury and lead.

Determinants of gypsum application rate

The agronomic criterion under which gypsum should be applied are given below:

- When the subsurface layer is significantly high in aluminium and low in calcium which inhibiting the root growth
- When there is a high chance of periodic drought occurrence causing water stress to the plant.
- When magnesium level higher than usual and should be reduced.

There are few robust as well as not so robust criteria for gypsum application rate determination based on all available literature. However; there is no single conclusive solution yet which fits all situations. In Brazil; the researchers recommended that gypsum should be used when the subsurface (20-40 or 30-60cm depth)has less than 0.4 $cmol_c$ $dm^{-3}$of exchangeable Ca (measured by resin extraction) and/or more than 0.5 cmolc $dm^{-3}$of exchangeable Al, and/or more than 30% Al saturation. In a single sentenced suggestion recommended by Dematte (1992) is soils which have the highest possible for a retort to gypsum are acid soils with low CEC which includes oxisols, oxidic ultisols, and low-CEC acid entisols and *inceptisols*.

Volume 2 – Issue 7
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www.agriallis.com

When it comes to predictive gypsum requirement dose; the most satisfactory result has been observed while using the following equation:

[GR (kg S ha^{-1})= $-114+82.773A_S - 2.739A_s^2$]

Where A_S is sorbed/S in solution, after 2 g of soil was equilibrated with 20 mL of 0.75 m*M*CaSO4. H2O solution for 18 hours. In case if there is no lab facility; the gypsum requirement can be calculated from the formula which is totally based on the clay content of the soil is:

[GR (kg S ha^{-1}) = 17+6.508 CLAY-PCT (r^2= 0.79)]

Where, CLAY-PCT= percentage of clay present in soil passing a 2-mm sieve.

Conclusion

Gypsum has a long history to be used for agricultural purpose; however, often in real-world scenario crumpled due to not having a proper user manual. A gypsum is a handy tool when it comes to improving soil chemical, and physical conditions and the production of gypsum as a by-product is also increasing day by day. The requirement of the time is a concise meta-analysis-based manual which can be used by the farmers.

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Volume 2 – Issue 7
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Volume 2 – Issue 7
Online ISSN: 2582-368X
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