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Gypsum: an old product with a new use

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Abstract
Gypsum is calcium sulfate ($CaSO_4$). Refined gypsum in the anhydrite form (no water) is 29.4 percent calcium (Ca) and 23.5 percent sulfur (S). Usually, gypsum has water associated in the molecular structure ($CaSO_4 \cdot 2H2O$) and is approximately 23.3 percent Ca and 18.5 percent S (plaster of paris). Gypsum fertilizer usually has other impurities so grades are approximately 22 percent Ca and 17 percent S.

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Gypsum as a fertilizer?

Gypsum is a fertilizer product and supplies the crop-available form of calcium (Ca_2+) and sulfur ($SO_4 2-$). If these forms are deficient in soil, then crop productivity will benefit if gypsum is applied. This is a big "if" for Iowa soils. Research has not shown deficiency of Ca and normally any potential problem with low Ca levels is taken care of with application of limestone (CaCO3). Acidity problems will occur before a deficiency of Ca, so liming effectively takes care of Ca also. Table 1 lists typical exchangeable Ca levels of several Iowa soils, and they are very high. For calcareous soils (containing free lime) the soil system is saturated with Ca, and Ca supply and soil pH is controlled by the free lime.

For S, it's basically the same. Research conducted for more than 35 years in numerous field trials across Iowa has shown only isolated and very small corn or soybean yield response to S fertilization (two positive and one negative). Table 2 gives results for recent S trials on corn and soybean conducted in 2000 and 2001 at six sites across Iowa. These results are typical of research conducted for many years in that there was no yield increase to applied S, gypsum, or Ca. So, if there is no need for fertilizer application of Ca or S, then gypsum application is simply not needed for fertilization reasons.

Gypsum as a soil amendment

Soil structure is impacted by exchangeable cations (positively charged ions). Multivalent cations (more than one positive charge) help hold soil particles together because they can have electrostatic (magnetic) attraction between two or more negative charge sites (soil clay and organic matter have a net negative charge). Multivalent cations include Ca_2+, Mg_2+, Zn_2+, and

$Al_{3}+$. Monovalent cations (only one positive charge) cannot help with soil structure because of only one positive charge, and with sodium (Na+), for example, can degrade soil structure when large amounts occupy the soil exchange sites (also impacted by large ionic size of Na); thus, soils with low salt but high levels of exchangeable sodium (Na+) have poor soil structure. Except for a very small acreage of Napa soil in the Missouri River valley, excess Na is not a problem on Iowa soils, including those with high pH. In arid regions where salt and Na accumulates (saline-sodic soils), reclamation can include use of gypsum. Gypsum is used to add large amounts $Ca_{2}+$ ions that displace the Na+ ions from the exchange sites, and when flushed with clean water both salts and Na are removed from the soil (gypsum is used instead of limestone because of higher solubility and no increase in soil pH). However, even in these sites this practice is not effective when subsoils have low permeability to water. If a soil only has high soluble salt, then gypsum is not used because it would add to the salt problem.

Soil structure also is greatly improved by soil organic material, which help "glue" soil particles together. Iowa soils have high organic matter content, which is just as important for good soil structure as exchangeable multivalent cations. The most detrimental effect on surface soil structure comes from the physical impact of raindrops. Surface residue is the best defense against this impact, and it comes at no cost from crop residue. Thus, improving water infiltration can be best achieved by limiting tillage to leave the most crop residue as possible rather than applying gypsum. Table 2 shows the lack of corn and soybean yield response to applied gypsum.

In summary, gypsum is an excellent fertilizer source of Ca and S. If application of these plant-essential nutrients is needed, then it works well. However, for Iowa soils both Ca or S are in good supply. Iowa soils inherently have a capacity for providing adequate levels of exchangeable Ca and S for crop production. Thus, more is not necessarily better.

Table 1. Exchangeable calcium and magnesium of several Iowa soils.

Soil	CEC	Ca	Mg	Ca		Mg
		meq/100 g			lb/acre	
Kenyon	14.0	8.5	2.6	3,400		624
Readlyn	19.5	14.5	4.2	5,800		1,008
Klinger	26.2	20.0	5.2	8,000		1,248
Dinsdale	20.5	14.6	4.2	5,840		1,008
Tama	20.6	13.9	3.4	5,560		816
Muscatine	28.3	20.4	7.1	8,160		1,704
Primghar	32.7	22.4	7.4	8,960		1,776
Sac	29.8	20.6	5.5	8,240		1,320
Marcus	43.9	37.5	11.9	15,000		2,856
Ida	22.4	16.9	5.3	6,760		1,272
Monona	22.4	18	6.2	7,200		1,488

Napier	27.6	23.5	3.2	9,400		768

CEC in the table above is cation exchange capacity.

Table 2. Corn and soybean yield response to gypsum and elemental S application, average across six sites in Iowa.

			2000				**2001**			
	Gypsum Application		**Corn**		**Soybean**		**Corn**		**Soybean**	
S Rate	**Product**	**Calcium**	**$CaSO_4$**	**S**	**$CaSO_4$**	**S**	**$CaSO_4$**	**S**	**$CaSO_4$**	**S**
lb S/acre	**lb/acre**	**lb Ca/acre**		**bu/acre**				**bu/acre**		
0	0	0	162	159	50.0	50.1	147	146	48.0	47.8
10	62.5	14	158	160	49.3	49.6	143	147	48.1	47.6
20	125	28	158	159	48.9	49.7	147	149	47.0	48.5
40	250	56	158	159	49.0	49.6	149	144	46.6	46.9
Significance (0.05)			NS		NS		NS		NS	

$CaSO_4$, calcium sulfate (gypsum); S, elemental sulfur (90% S); applied before planting in the spring of 2000.

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