Comparison of Agricultural Gypsum with Power Plant By-Product Gypsum for South Texas Potato Production

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ABSTRACT

Field studies were conducted in 1998 and 1999 in Frio County to evaluate the effects of power plant by-product gypsum in comparison with agricultural gypsum applied at planting on potato (Solanum tubersum) production. 'Atlantic' and '1625' potato varieties were grown using rates of 1000 to 4000 lb/A of commercial agricultural grade gypsum and power plant by-product gypsum. Potato yield and quality were not affected by gypsum rate regardless of product source. In addition, no heavy metal accumulation in plant tissue was noted with by-product gypsum.

KEYWORDS: Atlantic, tuber, quality, yield, 1625.

Gypsum (calcium sulfate) is a common source of calcium and sulfur for many crops. It has a relativity high solubility and therefore is quickly available to plants. Because gypsum is a neutral salt, it will does not increase soil pH.

Gypsum is especially recommended as a source of calcium for peanuts (*Arachis hypogaea* L.) and potatoes (*Solanum tuberosum* L.) (Grichar et al. 1986; 1990; Harris, 1982; Vitosh, 1990). High yielding and good quality peanuts require adequate Ca in the top 3 in of soil during pegging and pod filling (Cox et al. 1982; Gascho et al. 1993). Gypsum has been reported as being effective in reducing the incidence and severity of bacteria potato soft rot (*Erwinia carotovora*) (Hooker, 1981; Wright 1995). Corn (*Zea mays* L.), cotton (*Gossypium hirsutum* L.), and tobacco (*Nicotiana tabacum* L.) have responded to gypsum under acid soil conditions.

Calcium in potato tubers is primarily concentrated in the peel, and the lowest concentration is in the medullary tissue in the center of the tuber (Harris, 1982). The means by which calcium affects soft rot pathogenicity is not fully understood, but it seems likely that calcium improves the structural integrity of cell walls and membranes. It also may interfere with the activity of the pectic enzymes produced by the soft-rotting bacteria (Wright, 1995).

Fertilizer placement can significantly affect uptake of calcium by the potato tuber. Calcium can move directly into potato tubers via the stolon and tuber roots, so it is important that gypsum be placed near the zone in which the young tubers will grow (Wright, 1995).

The potato ranks fourth after wheat (*Triticum aestivum* L.), rice (*Oryza sativa* L.), and corn as an important source of food worldwide (Ulrich, 1993). In the United States, the potato has essentially moved to second place, replacing rice and even corn as a direct food source because of its culinary adaptability and the popularity of french fries at fast food establishments (Wright, 1995).

Potato production in south Texas has continued to increase in the past five years. Production in Frio County in 1999 was over 9000 acres. Due to demand and greater economic potential, more growers are interested in potato production (Scott Russell, personal communication). Gypsum is applied over many of the potato fields in south Texas without regard to gypsum calcium concentration. No information is available on use of gypsum on potatoes in the south Texas growing region. Therefore, the objective of this study was to evaluate the effects (if any) of power plant by-product gypsum on potato yield and quality in fields with high calcium levels.

MATERIALS AND METHODS

Field studies were conducted during the 1998 and 1999 growing seasons at three locations in Frio County to determine the effects of two sources of gypsum upon potato yield and quality. Agricultural gypsum obtained from a local distributor[1] was compared with gypsum obtained as a by-product of a coal-generated power plant[2] located near LaGrange, TX. Representative samples of agricultural gypsum and by-product gypsum were collected prior to study initiation and submitted to the Texas Agricultural Extension Service Soil Test Laboratory for chemical analysis.

Soils at all locations were a Duval loamy fine sand (fine-loamy, mixed, hyperthermic Aridic Haplustalfs) with < 1% organic matter and a pH of 7.1 to 7.3. The '1625' potato variety was planted 28 January 1998 while the 'Atlantic' variety was planted 16 January 1998 and 11 January 1999. Potatoes were mechanically planted approximately 12 in apart using a commercial planter furnished by a local potato grower-distributor.[3]

Gypsum at rates of 1000, 2000, 3000, and 4000 lbs/A were hand applied to plots within three wk of potato planting. The gypsum for each plot was pre-weighed, spread over the potato row and lightly raked into the soil surface. Within 1 to 2 wks of application, the test area was furrow-diked and potatoes 'hilled' with 2 to 4 in of soil pulled from middles over each row. Fungicide, herbicide, and insecticide programs closely followed standard industry practices.

Plot size was 4 rows 12 ft wide by 30 ft. The treatment design was a factorial (two types gypsum by four rates) randomized complete block with four replications. An untreated check was included for comparison. Rainfall for the 1998 growing season was 6.0 inch while in 1999 rainfall was 10.7 inches. Supplemental irrigation was applied in each year to bring up the water applied to test plots of approximately 21 inches.

Treatment response data were obtained from the middle two rows of each plot to prevent edge effects from adjacent plots on soil chemical properties and potato yield. Soil core samples were taken prior to the initiation of each trial and at the conclusion of each growing season for soil chemical analysis. Soil cores were divided into increments of 0 to 6, 6 to 12, 12 to 28, 18 to 24, and 24 to 36 in. Samples were analyzed by the Texas Agricultural Extension Service (TAES) Soil, Water, and Forage Testing Laboratory in College Station, Texas. Since no differences were noted at any depths, only those at the 0 to 6 inch depth are reported.

At harvest, plots were hand dug in 1998 and mechanically dug in 1999. All potatoes greater than 1.0 inch in circumference were collected and total weight was determined for each plot. In 1998, three potatoes were collected at random from each plot of the untreat-

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[1]Hoe-Down, Standard gypsum Crop, 1650 Gypsum Mine Rd., Fredricksburg, TX 78624.

[2]Boral Material Technologies Inc., San Antonio, TX 78216.

[3]Black Gold, Pearsall, TX.

ed check and the 4000 lb/A rate of agricultural and by-product gypsum for laboratory analysis. Samples were thin cut into 1/4 in sections, allowed to dry for 7 d at 65°C and ground to a pass a 1/16 in screen. Tissue samples were analyzed by the TAES Soil, Water, and Forage Testing Laboratory for N, P, K, Ca, Na, S, salinity and selected heavy metals.

Yield data were evaluated using analysis of variance. Since there was not a variety by location interaction, potato yield data were combined for analysis. Means were separated using Duncan's multiple range test (P = 0.05), where appropriate.

Potato tissue data were statistically analyzed by variety to evaluate differential absorption of elements. The numeric values for each element were subjected to ANOVA and means separated using Duncan's multiple range test (P = 0.05).

RESULTS AND DISCUSSION

Gypsum composition. Chemical analysis of the two gypsum sources indicated that by-product gypsum contained greater concentrations of boron, chloride, fluoride, magnesium, potassium, and sodium (Table 1). Concentrations of Ca and S were similar for the two products, thus any differences in plant uptake likely would be attributed to variations in solubility (author's personal opinion). Moisture levels were higher in by-product gypsum compared to agricultural gypsum.

Table 1. Chemical composition of by-product gypsum and agricultural gypsum.

Component	By-product gypsum	Agricultural gypsum
	------------------------mg/kg	----------------------
Aluminum	< 0.05	< 0.05
Arsenic	< 0.01	< 0.01
Barium	0.09	0.06
Boron	0.25	0.12
Calcium	590	570
Cadmium	< 0.005	< 0.005
Chromium	< 0.01	< 0.01
Copper	< 0.02	< 0.02
Iron	< 0.02	< 0.02
Lead	< 0.005	< 0.005
Magnesium	12.0	< 0.5
Manganese	< 0.01	0.01
Mercury	< 0.0002	< 0.0002
Molybdenum	< 0.02	< 0.02
Nickel	< 0.02	< 0.02
Phosphorus	< 1.0	< 1.0
Potassium	3.7	< 1.0
Selenium	< 0.01	< 0.01
Silver	< 0.01	< 0.01
Sodium	41.0	0.92
Vanadium	< 0.02	< 0.02
Zinc	0.06	0.1
Chloride	40.0	< 1.0
Sulfate	1580.0	1500.0
Sulfur (%)	14.3	16.3
pH	7.3	8.0
Moisture (%)	20.0	1.0

Potato yield. Application of either type of gypsum did not increase potato yield compared to the untreated check (Table 2). Yields tended to be greatest in the check plots, averaging over 20,000 lb/A. Yields in the by-product gypsum plots tended to decrease slightly with increasing gypsum rates, although differences among treatments were not significant. Although calcium has been found to aid in reducing potato diseases, calcium in the form of gypsum has not been reported to improve potato yields. In contrast, research in the southeast has shown that calcium deficiency in peanuts limits yields more often than any other plant nutrient (Cox et al., 1982). A portion of the low yield attributed to calcium deficiency is due to pod rot (Walker and Csinos, 1980). Grichar and Boswell (1986; 1990) reported that peanut plots treated with gypsum consistently had higher yields and lower incidence of pythium pod rot (*Pythium myriotylum* Drechs.). Csinos et al. (1984) suggested that fungi are secondary in the peanut pod disease complex with nutritional deficiency or imbalance being the primary cause.

Table 2. Effect of gypsum on potato yield combined over years.

Treatment	Gypsum rate	Yield
	----------------lb/A----	--------------
Untreated	-	20,166 a[1/]
By-product gypsum	1000	19,109 a
By-product gypsum	2000	19,476 a
By-product gypsum	3000	17,444 a
By-product gypsum	4000	16,676 a
Ag gypsum	1000	19,299 a
Ag gypsum	2000	18,773 a
Ag gypsum	3000	19,967 a
Ag gypsum	4000	19,400 a

[1/] Means within a column followed by the same letter are not significantly different at the 5% probability level by Duncan's New Multiple Range test.

Calcium deficient potato plants are spindly, with small, upward rolling, crinkled leaflets having chlorotic margins that later become necrotic. Tubers on calcium deficient plants develop diffuse brown necrosis in the vascular ring near stolon attachments, and later similar flecks form in the pith. Tubers may be extremely small (DeKock et al. 1975; Hooker, 1981; Wallace and Hewitt, 1948). No calcium deficiency symptoms were observed on potatoes in this study.

Heavy metals in tissue. Analysis of potato tissue taken from tubers at harvest indicated differences among treatments relative to nutrient concentrations but no differences in heavy metal uptake (Table 3). Copper concentrations in tuber tissue from commercial agricultural gypsum plots were significantly greater than those in tissue from the untreated check, and a similar trend was observed for by-product gypsum plots.

Table 3. Levels of nutrients extracted from tissue of 'Atlantic' and '1625' potato varieties at harvest using gypsum at 4000 lbs/A.

	Atlantic			1625		
	Untreated	Ag gypsum	By-product gypsum	Untreated	Ag gypsum	By-product gypsum
	mg/kg					
Boron (B)	7.6 ab [1/]	8.2 a	6.1 b	17.1 a	11.8 b	9.3 b
Chromium (Cr)	1.6 a	2.4 a	1.7 a	2.0 a	1.7 a	1.8 a
Manganese (Mn)	13.4 a	15.6 a	15.2 a	12.7 a	1.7 a	1.8 a
Iron (Fe)	616.9 a	779.3 a	760.5 a	134.8 a	238.3 a	232.0 a
Nickel (Ni)	0.5 a	1.5 a	0.6 a	0.5 a	0.6 a	0.5 a
Copper (Cu)	11.6 a	9.1 a	15.5 a	7.9 b	14.5 a	10.0 ab
Zinc (Zn)	16.7 a	21.1 a	20.8 a	23.2 a	24.9 a	25.6 a
Arsenate (As)	3.3 a	4.0 a	3.9 a	2.1 a	2.1 a	2.1 a
Selenium (Se)	1.2 a	1.3 a	0.9 a	1.6 a	1.4 a	0.7 a
Molybdenum (Mo)	1.2 a	0.8 a	0.6 a	2.2 a	1.1 a	1.0 a
Cadmium (Cd)	0	0	0	0	0	0
Lead (Pb)	0.12 a	1.7 a	1.1 a	4.8 a	3.3 a	4.9 a
Aluminum (Al)	522.5 a	645.9 a	669.3 a	134.5 a	239.8 a	199.8 a
Vanadium (V)	1.9 a	2.8 a	2.3 a	1.4 a	1.4 a	1.1 a
Mercury (Hg)	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002	< 0.002
Barium (Ba)	10.4 a	10.5 a	10.8 a	11.1 a	10.0 a	10.0 a

[1/] Means within a row and potato variety followed by the same letter are not significantly different at the 5% probability level by Duncan's New Multiple Range test.

In addition, boron concentrations were significantly lower in plots treated with 4000 lb/A of by-product gypsum compared to untreated plots. No other differences in tissue concentrations of elements were observed among gypsum treatments.

Soil pH. No differences in soil pH due to either gypsum treatment were noted (data not shown). This was expected since gypsum has no effect on soil pH (Buckman and Brady, 1969).

Soil elements. Average extractable soil Ca and S concentrations tended to increase with increasing rates of gypsum application, regardless of product source (Table 4). Extractable soil Ca and S increases were similar for both sources suggesting similar levels of nutrient solubility. Extractable N,P,K, Na and soil salinity were not affected by gypsum treatment.

CONCLUSION

Application of by-product gypsum did not significantly affect potato yield in 1998 or 1999. In addition, although concentrations of several elements were greater in by-product gypsum compared to commercial agricultural gypsum, few differences in tissue concentrations were observed. Increases in extractable soil Ca and S indicated that solubility and potential plant availability are similar for by-product gypsum and commercial agricultural gypsum. One advantage of gypsum may be to aid in the digging process by

Table 4. Concentration of various elements and salinity at the 0 to 6 inch soil depth taken after potato harvest at the three locations.

Treatment	Gypsum rate (lb/ac)	Elements													
		N[a]		P[b]		K[c]		Ca[d]		Na[f]		S[g]		Salinity[e]	
		ppm													
		X[h]	Range	X	Range	X	Range	X	Range	X	Range	X	Range	X	Range
Untreated	-	13	7-23	78	65-99	284	244-323	1463	1411-1515	71	42-113	70	48-135	178	130-398
By-product gypsum	1000	14	5-23	70	64-79	291	269-323	1507	1401-1613	75	35-127	80	52-103	318	208-438
By-product gypsum	2000	13	5-23	54	51-58	277	246-329	1659	1522-1795	83	30-136	84	74-102	284	183-374
By-product gypsum	3000	13	1-28	89	69-101	302	248-379	1664	1559-1768	69	40-112	106	69-171	334	234-419
By-product gypsum	4000	13	4-26	85	52-139	312	288-356	1687	1572-1802	72	30-141	115	78-143	359	208-439
Agricultural gypsum	1000	11	3-19	82	63-118	298	263-362	1610	1374-1846	74	45-110	69	33-93	257	182-310
Agricultural gypsum	2000	11	2-21	85	61-119	320	244-442	1709	1676-1741	72	40-127	82	75-87	325	221-390
Agricultural gypsum	3000	13	2-23	83	59-125	319	239-430	1737	1708-1766	65	35-115	104	75-130	307	201-423
Agricutural gypsum	4000	16	2-33	82	59-113	271	260-277	1712	1687-1737	73	46-114	118	74-162	365	169-553

[a]Values for nitrogen (N) are very low to low
[b]Values for phosphorus (P) are very high
[c]Values for potassium (K) are high to very high
[d]Values for calcium (Ca) are high to very high
[e]No salinity was noted
[f]Values for sodium (Na) are very low to low
[g]Values for nitrogen (N) are very low to low
[h]Mean value

reducing clod size and improving shedding of soil from potatoes (authors personal observation). Since by-product gypsum is about one-half the cost of agricultural gypsum, the reduced cost of by-product gypsum should be an advantage for producers on soils low in Ca and/or S. However the use of gypsum in fields with moderate to high calcium levels will not increase potato yield or quality and would not be economically feasible.

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