Sulfur Deficiency Widespread

areas in 34 of California's 58 counties found to have soils deficient in nutrient essential for normal growth of plants

W. E. Martin

The frequency of sulfur deficiency in California soils ranks sulfur a close third—after nitrogen and phosphorus—as a major plant nutrient which must be supplied to maintain crop production.

Sulfur is an integral part of several amino acids found in plant proteins and is taken from the soil as the sulfate ion.

Where sulfur is a primary deficiency it must be supplied before other fertilizer nutrients can be effective. Examples of primary sulfur deficiency are commonly found in alfalfa, range clovers, and seeded legumes like vetch. Such legumes are usually pale green, show weak growth, and respond quickly to addition of sulfur or any soluble sulfate.

In many locations sulfur is a secondary deficiency, exhibiting itself only after some other nutrient deficiency has been corrected. Examples of secondary sulfur deficiency often occur in sugar beets, cereals, or range grasses where nitrogen is also in low supply.

Materials supplying sulfur alone may have no effect in cases of secondary sulfur deficiency unless nitrogen is also applied. A straight nitrogen material may give a limited improvement with the plants a pale green. However, striking increases in plant growth may be obtained from sulfate additions made after nitrogen applications. Under those conditions a fertilizer supplying both nitrogen and sulfur—ammonium sulfate—will give much better growth than a straight nitrogen material such as ammonium nitrate or urea.

Similarly, a secondary sulfur deficiency exists in many phosphorus deficient soils. In some cases—in Siskiyou County—phosphorus, boron, and sulfur are concurrently deficient and all three must be added for satisfactory results.

Statewide Survey

In April 1957 a statewide survey was initiated to record known sulfur responses, the crop involved, the soil series, and the location of each observed deficiency. Responses to gypsum or sulfur in the improvement of alkali soils were not recorded, nor were the cases where acid-forming properties of sulfur or ammonium sulfate improved growth by increasing soil acidity and thereby improving the supply of native phosphorus.

Sulfur deficiency was recorded in 34 of the 58 counties of the state. A large number of sulfur deficient locations occurred in the northern part of the state, particularly in the intermountain valleys of the coast range and at the northern end of the Sierra Nevada mountains. Also, a large number were found in the grassland and oakgrass woodland range areas along the eastern edge of the San Joaquin Valley, particularly in Fresno, Madera and Tulare counties. A similar concentration was observed on the western and northern edges of the Sacramento Valley where most of the deficiencies were primary on range legumes or on non-irrigated crops such as vetch and alfalfa.

A number of sulfur-deficient areas were located on the floor of the San Joaquin Valley in Stanislaus, Merced and San Joaquin counties. A much larger number of points—nearly all in irrigated crops—were found on the floor of the Sacramento Valley in Tehama, Butte and Shasta counties.

Tabulation of the sulfur responses by crops showed that of the 242 observed, 103—43%—were primary deficiencies and showed greatly increased growth of native or planted legumes. The next most frequent response was alfalfa—69 cases—closely followed by irrigated pasture at 42 locations, and vetch with 16 observed responses to added sulfur.

Range grasses, cereals and sugar beets also responded to added sulfur. However, because sulfur is a secondary deficiency in those crops, concurrent or primary deficiencies of nitrogen—or nitrogen and phosphorus—had to be corrected before benefit of added sulfur was observed.

Responses of Legumes

Tests by various California workers have shown that 440 pounds of gypsum—calcium sulfate containing 18.6% sulfur—nearly doubled range and vetch forage yields the first year on soils deficient in sulfur. Similar results with non-irrigated alfalfa showed an average of over a ton extra alfalfa, the first year from application of 400 pounds of gypsum. Increased yields usually persist two seasons with such primary deficiencies, though benefits the second year may be slight in regions of high rainfall.

Sulfur deficiencies of legumes on irrigated soils are less common but do occur on light soils when irrigated with water of low sulfur content. Results on irrigated

Some Sulfur Responses of Legumes in California*

Crop	County	Year	Yields as lbs. Dry wt./A.		Sulfur source
			No sulfur	Plus sulfur	
I. *Range*					
A. Burr and other native clovers	Ventura[1]	1946	3435	4670	440 lbs/ac Gypsum
	Madera[2]	1946	2550	5700	400 lbs/ac Gypsum
	Colusa[3]	1946	1025	3300	440 lbs/ac Gypsum
	Sonoma[4]	1946	3675	6140	440 lbs/ac Gypsum
	Monterey[5]	1948	1770	2700	440 lbs/ac Gypsum
B. Rose clover	Stanislaus[6]	1954	1970	3080	500 lbs/ac Gypsum
II. *Cultivated legumes*					
A. Vetch hay	Lake[7]	1948	2173	4566	200 lbs/ac Gypsum
	Lake[8]	1954	2200	4140	400 lbs/ac Gypsum
B. Dry land alfalfa (1st cutting)	Lake[7]	1947	1879	4809	400 lbs/ac Gypsum
	Modoc[9]	1947	3180	4220	400 lbs/ac Gypsum
	Lassen[10]	1947	1530	4830	400 lbs/ac Gypsum
	Lassen[10]	1952	2740	3780	400 lbs/ac Gypsum
	Lassen[10]	1953	2100	5100	400 lbs/ac Gypsum
	Modoc[11]	1956	3312	4398	400 lbs/ac Gypsum
C. Irrigated alfalfa	Merced[12]	1919–22	8200	20600	Soil sulfur
	Stanislaus[13]	1948	10180	12570	1000 lbs/ac Gypsum
	Stanislaus[14]	1955	9800	13800	400 lbs/ac Gypsum
	Merced[15]	1952	6180	14400	400 lbs/ac Gypsum
D. Irrigated pasture	Lake[8]	1955	1634	5939	400 lbs/ac Gypsum

* Compiled from several sources.

[1] Reported by Conrad, Miller & Hall; [2] Conrad & Garthwaite; [3] Conrad & Mellis; [4] Conrad & Torpen; [5] Conrad & Albaugh; [6] Arkley, Helphenstine & Williams; [7] Stice; [8] Lusk; [9] Hays; [10] Lamborne; [11] Rimbey; [12] Allison; [13] Osterli; [14] Stevenson; [15] Rendig, Weir & Inouye.

pasture and alfalfa indicate that yields may be increased spectacularly if acute deficiency exists.

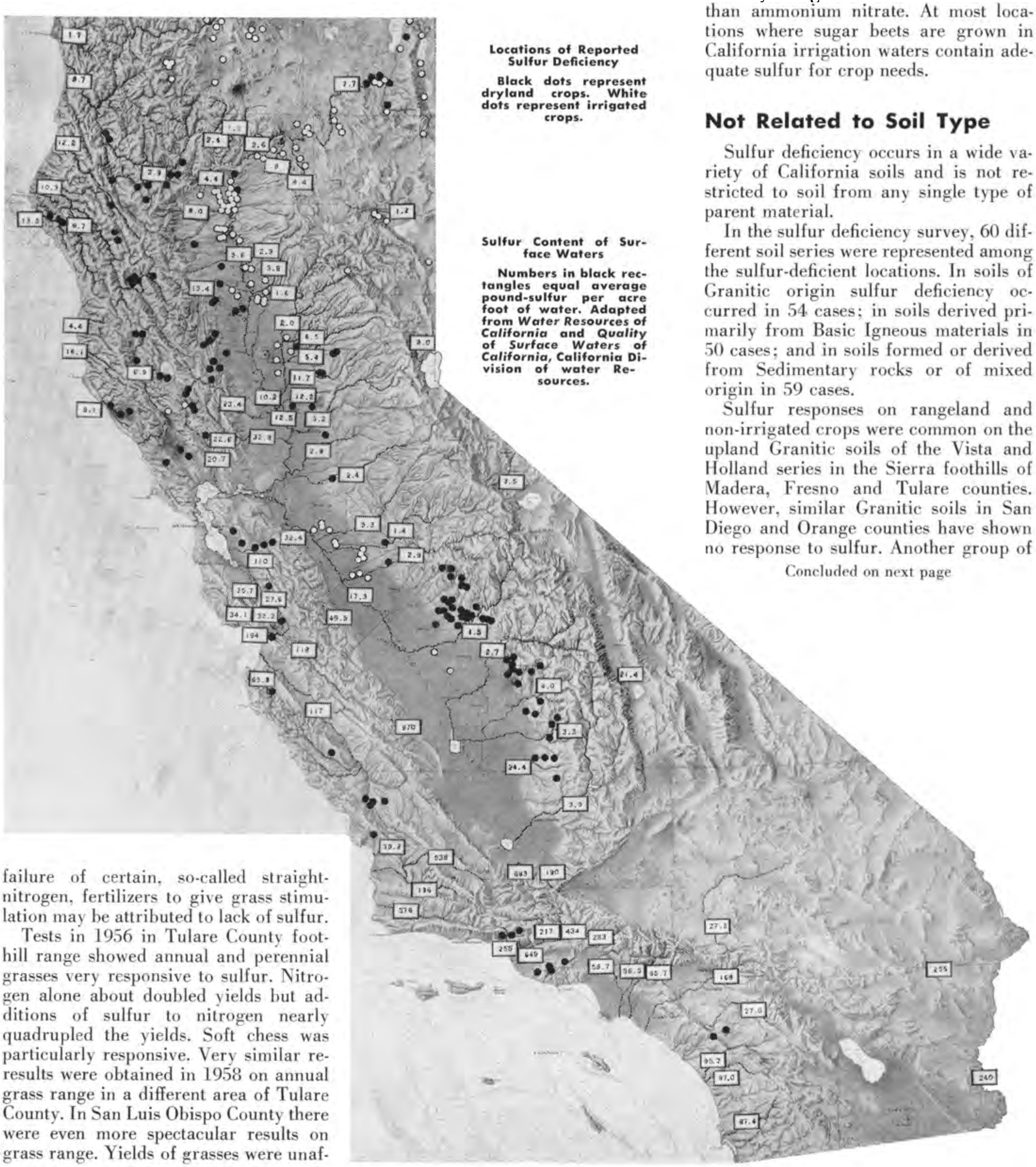
Non-legumes

Benefits of sulfur-bearing fertilizers on non-legumes may be equally spectacular on soils very low in sulfur-supplying power. Recent tests show clearly that failure of certain, so-called straight-nitrogen, fertilizers to give grass stimulation may be attributed to lack of sulfur.

Tests in 1956 in Tulare County foothill range showed annual and perennial grasses very responsive to sulfur. Nitrogen alone about doubled yields but additions of sulfur to nitrogen nearly quadrupled the yields. Soft chess was particularly responsive. Very similar results were obtained in 1958 on annual grass range in a different area of Tulare County. In San Luis Obispo County there were even more spectacular results on grass range. Yields of grasses were unaffected by nitrogen alone, doubled by gypsum, but more than trebled when both nitrogen and sulfur were applied. Similar results have been observed in several other counties on acutely sulfur-deficient soils.

Nitrogen is nearly always deficient on annually cropped grainland and phosphorus deficiency is common but relatively few tests have been made on the sulfur nutrition of cereals. In one test in San Joaquin County, gypsum gave striking increases when applied after initial deficiencies of nitrogen and phosphorus had been corrected. Sulfur alone had no effect. Similar results have been observed in Monterey, Lake and Tehama counties.

Sugar beets responded to sulfur at seven locations in Butte County. At one site yields were increased nearly three tons by using ammonium sulfate rather than ammonium nitrate. At most locations where sugar beets are grown in California irrigation waters contain adequate sulfur for crop needs.



Locations of Reported Sulfur Deficiency

Black dots represent dryland crops. White dots represent irrigated crops.

Sulfur Content of Surface Waters

Numbers in black rectangles equal average pound-sulfur per acre foot of water. Adapted from *Water Resources of California* and *Quality of Surface Waters of California*, California Division of water Resources.

Not Related to Soil Type

Sulfur deficiency occurs in a wide variety of California soils and is not restricted to soil from any single type of parent material.

In the sulfur deficiency survey, 60 different soil series were represented among the sulfur-deficient locations. In soils of Granitic origin sulfur deficiency occurred in 54 cases; in soils derived primarily from Basic Igneous materials in 50 cases; and in soils formed or derived from Sedimentary rocks or of mixed origin in 59 cases.

Sulfur responses on rangeland and non-irrigated crops were common on the upland Granitic soils of the Vista and Holland series in the Sierra foothills of Madera, Fresno and Tulare counties. However, similar Granitic soils in San Diego and Orange counties have shown no response to sulfur. Another group of

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SULPHUR

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rangeland soils often deficient are the upland and alluvial soils derived from Basic Igneous material. The responses on those soils are most common on stony-phase Aiken, Olympic, and the Lassen series. A considerable number of upland soils formed from Sedimentary materials from the west edge of the Sacramento Valley were also deficient; including Altamont, Ayar, Contra Costa, and several others. Some of these same series and related ones derived from sedimentary rocks elsewhere in the state rarely respond to sulfur. In fact, they often even contain free gypsum in the soil profile.

Irrigated Crops

The sulfur content of irrigation water may give an indication of the likelihood of occurrence of sulfur deficiency on irrigated crops, as well as areas where there is no likelihood of response.

Waters derived primarily from snow melt in the high mountains are very low in sulfur. Most streams rising in the coast range carry considerable sulfur. In the Sacramento basin the sulfur content of the main river increases progressively from Redding down to Sacramento. Similar increases were observed in the San Joaquin River from Fresno north to the Delta.

Waters from the upper Sacramento, Feather, American, Tuolumne, Merced and upper San Joaquin rivers are particularly low in sulfur content.

In contrast, waters from central and southern California coastal streams contain large amounts of sulfur. The waters of the Santa Clara and Colorado rivers contain 200–260 pounds of sulfur per acre foot.

In the San Joaquin Valley sulfur deficiency is common in alfalfa grown on light sands, sandy loams of the Dinuba, Delhi and Hanford series where watered from the Tuolumne and Merced rivers which have values of 1.4 and 2.9 pounds sulfur per acre foot. Those same soil series elsewhere rarely show sulfur deficiency if irrigated with pump water or stream water of high sulfur content. One pound of sulfur per acre foot of water is equivalent to 1.1 ppm—parts per million—sulfate.

A previous study of irrigated alfalfa in Merced County showed a yield of about 6,000 pounds and sulfur removal of ten pounds per acre when deficient. Yields were increased to 12,000–14,000 pounds and sulfur removal to 30–45 pounds per acre when the deficiency was corrected. From these figures the sulfur requirement of alfalfa would appear to be about 5–6 pounds per ton of alfalfa harvested.

In the Sacramento Valley sulfur response of irrigated crops is quite common on light textured soils of Conejo, Vina and Columbia series where watered by stream flow from the Feather River with sulfur value of 2.0 pounds per acre foot or from the upper Sacramento River with a value of 4.4 pounds sulfur per acre foot.

In the mountain area sulfur deficiency is common near Susanville where the Susan River has a sulfur value of 1.2 pounds and along Hat and Burney creeks where the values of 4.4 and .08 pounds were reported.

Streams from the coast range in northern and central California contain much more sulfur and sulfur deficiency of irrigated crops is rare. In southern California, where surface waters contain 30 to several hundred pounds sulfur per acre foot, sulfur deficiency is unknown.

Ground water values usually run somewhat higher than surface waters in the same areas and are usually in excess of 10 ppm, or nine pounds sulfur per acre foot. In some areas of northern and central California where surface waters are low in sulfur, ground water is correspondingly low and crops irrigated with pumped water often show sulfur deficiency.

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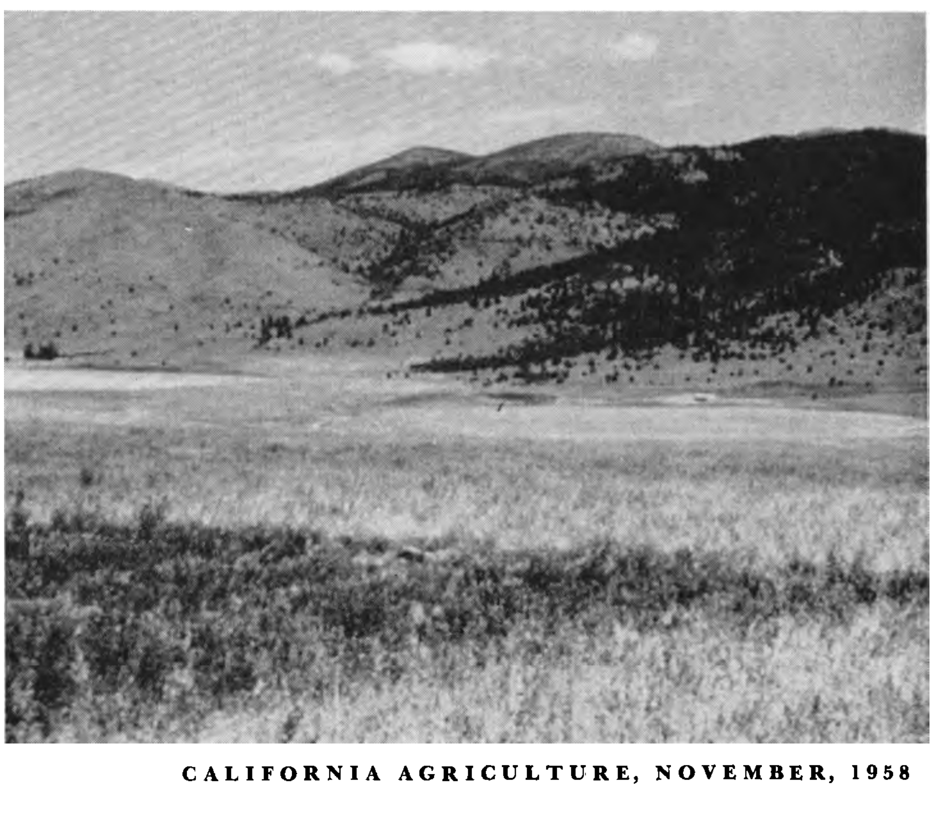
The data for this statewide survey of sulfur deficient areas were furnished by Farm Advisors of the University of California.

Some Sulfur Responses of Non-legumes in California*

Crop	County	Year	Yields as lbs. Dry wt./A.**				Fertilizer Source lbs./A.
			Ck.	S	N	NS	
Range grasses	Tulare[1]	1954	1144	...	2200	4337	N 313 Am. Nitrate
Soft chess			384	...	535	1390	NS 500 Am. Sulfate
Range grasses	Tulare[2]	1958	554	405	1274	2280	S 370 Gypsum N 180 Am. Nitrate NS 280 Am. Sulfate
Range grasses	San Luis Obispo[3].	1958	1400	3101	1428	5045	S 400 Gypsum N 200 Urea NS N + S above
			Ck.	N	NP	NPS	
Cereals—oats for grain	San Joaquin[4] ...	1948	674	917	1195	1565	S 500 Gypsum P 200 Treble Super. N 150 Am. Nitrate
			N		NS		
Sugar beets	Butte[5]	1953	19.0		21.8 T/ac		N Am. Nitrate NS Am. Sulfate

* Compiled from several sources.
[1] Reported by Walker & Evans; [2] Miller; [3] Helphenstine; [4] Baskett; [5] Morse & Hills.
** Ck. = check. S = Sulfur. N = nitrogen. P = phosphorus.



Non-irrigated alfalfa field in Modoc County. Dark portion to the left was fertilized with gypsum.