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Sulfur: A Missing Link between Soils, Crops, and Nutrition

Sulfur: A Missing Link between Soils, Crops, and Nutrition

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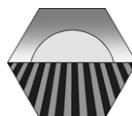
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The American Society of Agronomy, the Crop Science Society of America, and the Soil Science Society of America are pleased to publish this interesting, comprehensive, and very timely treatise on the role of sulfur in plant nutrition. In addition to the comprehensive coverage that readers of our monographs have come to expect, this volume includes a link to human health, which is increasingly critical given the many nutritional problems facing the world today.

As pointed out by the editor, Dr. Joseph Jez, sulfur is an essential mineral nutrient that is often overshadowed by nitrogen, phosphorus, and potassium. This book provides a current snapshot of the relationships between sulfur and nutrition of crops, animals, and humans. It brings a unique perspective of the interrelationships between sulfur and the dietary needs of animals and humans.

The Societies certainly appreciate the efforts of Dr. Joseph Jez, who chose an outstanding group of authors, and who skillfully and carefully guided the development of the book. We anticipate this excellent work will be a highly valued resource in the scientific community.

Kenneth Moore, President of the American Society of Agronomy

William Wiebold, President of the Crop Science Society of America

Gary A. Peterson, President of the Soil Science Society of America

Preface

Sulfur is an essential mineral nutrient, although it is often overshadowed by nitrogen, phosphorus, and potassium. Because of its central role in soil condition, plant growth, and nutrition, understanding how plants utilize sulfur is critical for optimizing crop yield and quality. Moreover, sulfur incorporated into methionine and cysteine in plants directly impacts the nutritional value of human food and livestock feeds. The goal of this book is to provide an overview of sulfur's importance as a link between soil, plants, and nutrition by bringing together a group of authors with backgrounds that span from the molecular level to the field. The following chapters cover how sulfur cycles in the environment, the requirements for this element in soil and plants, the metabolism of sulfur compounds in plants, the importance of sulfur in specific crops, and the role sulfur plays in livestock and human health. As editor, I would like to thank all of the authors who made this book possible and the administrative help of Marti Shafer.

Joseph Jez, Editor

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Conversion Factors for SI and Non-SI Units

To convert Column 1 into Column 2 multiply by	Column 1 SI unit	Column 2 non-SI unit	To convert Column 2 into Column 1 multiply by
Length			
0.621	kilometer, km (10^3 m)	mile, mi	1.609
1.094	meter, m	yard, yd	0.914
3.28	meter, m	foot, ft	0.304
1.0	micrometer, μm (10^{-6} m)	micron, μ	1.0
3.94×10^{-2}	millimeter, mm (10^{-3} m)	inch, in	25.4
10	nanometer, nm (10^{-9} m)	Angstrom, Å	0.1
Area			
2.47	hectare, ha	acre	0.405
247	square kilometer, km ² (10^3 m) ²	acre	4.05×10^{-3}
0.386	square kilometer, km ² (10^3 m) ²	square mile, mi ²	2.590
2.47×10^{-4}	square meter, m ²	acre	4.05×10^3
10.76	square meter, m ²	square foot, ft ²	9.29×10^{-2}
1.55×10^{-3}	square millimeter, mm ² (10^{-3} m) ²	square inch, in ²	645
Volume			
9.73×10^{-3}	cubic meter, m ³	acre-inch	102.8
35.3	cubic meter, m ³	cubic foot, ft ³	2.83×10^{-2}
6.10×10^4	cubic meter, m ³	cubic inch, in ³	1.64×10^{-5}
2.84×10^{-2}	liter, L (10^{-3} m ³)	bushel, bu	35.24
1.057	liter, L (10^{-3} m ³)	quart (liquid), qt	0.946
3.53×10^{-2}	liter, L (10^{-3} m ³)	cubic foot, ft ³	28.3
0.265	liter, L (10^{-3} m ³)	gallon	3.78
33.78	liter, L (10^{-3} m ³)	ounce (fluid), oz	2.96×10^{-2}
2.11	liter, L (10^{-3} m ³)	pint (fluid), pt	0.473
Mass			
2.20×10^{-3}	gram, g (10^{-3} kg)	pound, lb	454
3.52×10^{-2}	gram, g (10^{-3} kg)	ounce (avdp), oz	28.4
2.205	kilogram, kg	pound, lb	0.454
0.01	kilogram, kg	quintal (metric), q	100
1.10×10^{-3}	kilogram, kg	ton (2000 lb), ton	907
1.102	megagram, Mg (tonne)	ton (U.S.), ton	0.907
1.102	tonne, t	ton (U.S.), ton	0.907
Yield and Rate			
0.893	kilogram per hectare, kg ha ⁻¹	pound per acre, lb acre ⁻¹	1.12
7.77×10^{-2}	kilogram per cubic meter, kg m ⁻³	pound per bushel, lb bu ⁻¹	12.87
1.49×10^{-2}	kilogram per hectare, kg ha ⁻¹	bushel per acre, 60 lb	67.19
1.59×10^{-2}	kilogram per hectare, kg ha ⁻¹	bushel per acre, 56 lb	62.71

Table cont.

To convert Column 1 into Column 2 multiply by	Column 1 SI unit	Column 2 non-SI unit	To convert Column 2 into Column 1 multiply by
1.86 × 10 ⁻²	kilogram per hectare, kg ha ⁻¹	bushel per acre, 48 lb	53.75
0.107	liter per hectare, L ha ⁻¹	gallon per acre	9.35
893	tonne per hectare, t ha ⁻¹	pound per acre, lb acre ⁻¹	1.12 × 10 ⁻³
893	megagram per hectare, Mg ha ⁻¹	pound per acre, lb acre ⁻¹	1.12 × 10 ⁻³
0.446	megagram per hectare, Mg ha ⁻¹	ton (2000 lb) per acre, ton acre ⁻¹	2.24
2.24	meter per second, m s ⁻¹	mile per hour	0.447
Specific Surface			
10	square meter per kilogram, m ² kg ⁻¹	square centimeter per gram, cm ² g ⁻¹	0.1
1000	square meter per kilogram, m ² kg ⁻¹	square millimeter per gram, mm ² g ⁻¹	0.001
Density			
1.00	megagram per cubic meter, Mg m ⁻³	gram per cubic centimeter, g cm ⁻³	1.00
Pressure			
9.90	megapascal, MPa (10 ⁶ Pa)	atmosphere	0.101
10	megapascal, MPa (10 ⁶ Pa)	bar	0.1
2.09 × 10 ⁻²	pascal, Pa	pound per square foot, lb ft ⁻²	47.9
1.45 × 10 ⁻⁴	pascal, Pa	pound per square inch, lb in ⁻²	6.90 × 10 ³
Temperature			
1.00 (K - 273)	kelvin, K	Celsius, °C	1.00 (°C + 273)
(9/5 °C) + 32	Celsius, °C	Fahrenheit, °F	5/9 (°F - 32)
Energy, Work, Quantity of Heat			
9.52 × 10 ⁻⁴	joule, J	British thermal unit, Btu	1.05 × 10 ³
0.239	joule, J	calorie, cal	4.19
10 ⁷	joule, J	erg	10 ⁻⁷
0.735	joule, J	foot-pound	1.36
2.387 × 10 ⁻⁵	joule per square meter, J m ⁻²	calorie per square centimeter (langley)	4.19 × 10 ⁴
10 ⁵	newton, N	dyne	10 ⁻⁵
1.43 × 10 ⁻³	watt per square meter, W m ⁻²	calorie per square centimeter minute (irradiance), cal cm ⁻² min ⁻¹	698
Transpiration and Photosynthesis			
3.60 × 10 ⁻²	milligram per square meter second, mg m ⁻² s ⁻¹	gram per square decimeter hour, g dm ⁻² h ⁻¹	27.8
5.56 × 10 ⁻³	milligram (H ₂ O) per square meter second, mg m ⁻² s ⁻¹	micromole (H ₂ O) per square centimeter second, μmol cm ⁻² s ⁻¹	180
10 ⁻⁴	milligram per square meter second, mg m ⁻² s ⁻¹	milligram per square centimeter second, mg cm ⁻² s ⁻¹	10 ⁴
35.97	milligram per square meter second, mg m ⁻² s ⁻¹	milligram per square decimeter hour, mg dm ⁻² h ⁻¹	2.78 × 10 ⁻²
Plane Angle			
57.3	radian, rad	degrees (angle), °	1.75 × 10 ⁻²

Table cont.

To convert Column 1 into Column 2 multiply by	Column 1 SI unit	Column 2 non-SI unit	To convert Column 2 into Column 1 multiply by
Electrical Conductivity, Electricity, and Magnetism			
10	siemen per meter, S m ⁻¹	millimho per centimeter, mmho cm ⁻¹	0.1
10 ⁴	tesla, T	gauss, G	10 ⁻⁴
Water Measurement			
9.73 × 10 ⁻³	cubic meter, m ³	acre-inch, acre-in	102.8
9.81 × 10 ⁻³	cubic meter per hour, m ³ h ⁻¹	cubic foot per second, ft ³ s ⁻¹	101.9
4.40	cubic meter per hour, m ³ h ⁻¹	U.S. gallon per minute, gal min ⁻¹	0.227
8.11	hectare meter, ha m	acre-foot, acre-ft	0.123
97.28	hectare meter, ha m	acre-inch, acre-in	1.03 × 10 ⁻²
8.1 × 10 ⁻²	hectare centimeter, ha cm	acre-foot, acre-ft	12.33
Concentration			
1	centimole per kilogram, cmol kg ⁻¹	milliequivalent per 100 grams, meq 100 g ⁻¹	1
0.1	gram per kilogram, g kg ⁻¹	percent, %	10
1	milligram per kilogram, mg kg ⁻¹	parts per million, ppm	1
Radioactivity			
2.7 × 10 ⁻¹¹	becquerel, Bq	curie, Ci	3.7 × 10 ¹⁰
2.7 × 10 ⁻²	becquerel per kilogram, Bq kg ⁻¹	picocurie per gram, pCi g ⁻¹	37
100	gray, Gy (absorbed dose)	rad, rd	0.01
100	sievert, Sv (equivalent dose)	rem (roentgen equivalent man)	0.01
Plant Nutrient Conversion			
	Elemental	Oxide	
2.29	P	P ₂ O ₅	0.437
1.20	K	K ₂ O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602