SOYBEANS: Improvement, Production, and Uses

Second Edition

J. R. Wilcox, *editor*

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SOYBEANS: Improvement, Production, and Uses

Second Edition

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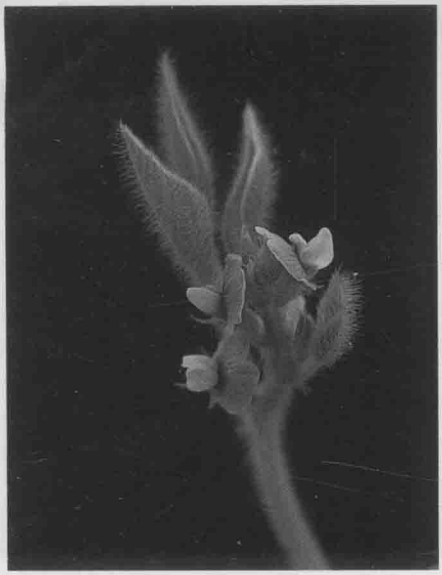

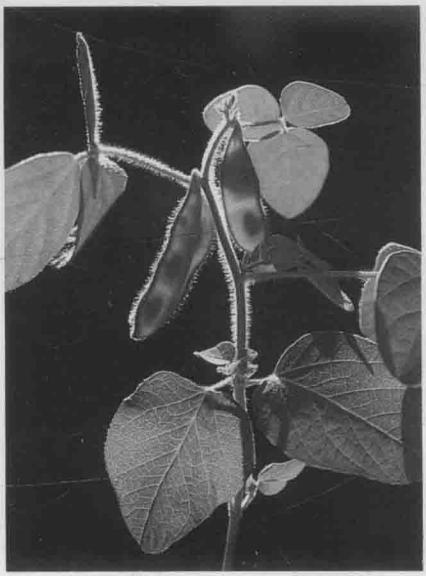

Top left, soybean flower; *top right,* developing soybean pods; *bottom,* raceme of mature soybean pods. Courtesy, Michiel A. Smit, Republic of South Africa.

Foreword

The first edition of *Soybeans: Improvement, Production, and Uses* was published in 1973, when demand for soybean exceeded supplies. World production was continuing to expand and prices had reached unprecedented highs. Fourteen years later, the U.S. cropland planted to soybean has stabilized at levels somewhat lower than the record high in 1982. Ample world supplies of soybean has resulted from U.S. production and greatly increased production in South America, primarily in Brazil and Argentina.

The high demand for soybean at the time the initial edition of this monograph was being prepared stimulated increased research. This research focused on production practices that would have an immediate effect on increasing soybean supplies. Additional research efforts were directed toward protecting the crop from losses due to pathogens, insects, and weeds. Research efforts also concentrated on improving its productivity (yield) through breeding and genetics. Increased research was also directed toward increasing our knowledge of physiological processes of the plant that would open the way for further improvements in soybean production efficiency and in quality of soybean products.

The increased research effort on soybean rapidly expanded our knowledge of this crop. This edition of the soybean monograph is a reflection of that increased research effort. This edition summarizes our current knowledge on the soybean as a plant, as a crop, and on the utilization of soybean products. It will be a useful reference on the state of our current knowledge and should serve as a basis for continuing research on this economically important crop plant.

D. N. Moss, *president,* 1986
American Society of Agronomy

J. B. Beard, *president,* 1986
Crop Science Society of America

John Pesek, *president,* 1986
Soil Science Society of America

Preface

Soybean, *Glycine max* (L.) Merr., has become the major source of edible vegetable oils and of high protein feed supplements for livestock in the world. A native of Eastern Asia, the soybean was introduced into the USA where it has become a major agricultural crop and a significant export commodity.

Research on soybean has been in proportion to production of the crop. As demand for soybean increased and area planted to the crop expanded, research support for the crop was also increasing. The increased support for soybean research has resulted in a rapid increase in the breadth and depth of our knowledge about this major crop. The second edition of *Soybeans: Improvement, Production, and Uses*, presents the current status of our knowledge at a time when this knowledge base is expanding rapidly.

This edition has been organized to reflect those areas where recent research has had the greatest impact. In all chapters, authors have reviewed our knowledge in specific areas but emphasis has been on research progress during the past 14 yrs.

Chapter 1 documents recent changes in world distribution and production of soybean and the economic and political reasons for those changes. Chapter 2 reports changes in the taxonomic history of the Phaseoleae with respect to the genus *Glycine* and our current knowledge of relationships among species in this genus.

There are two chapters on morphology, one each on vegetative and reproductive morphology. These were included in this edition of the monograph because information on anatomy and morphology are basic to our understanding of all plant processes. These chapters are a consolidation of this information where it will be readily accessible to those involved in soybean research and technology.

Information on genetics, cytogenetics, and breeding methods is included in chapters 5 through 7. There has been a rapid increase in our knowledge of the genetics of this crop, including the identification of over 200 genes and several linkage groups. The rate of cultivar development has increased rapidly during the past 14 yrs with the research efforts of commercial plant breeders. These changes have had a major impact on cultivar development and on the wide choice of cultivars available to soybean producers.

Various aspects of soybean production are reviewed in chapters 8 through 12. Seed production and technology is an important aspect of soybean production that is covered for the first time in this edition of the monograph. Chapter 9 on crop management reflects the rapid changes

in production practices that have occurred during the past 14 yrs. Edaphic factors, including fertility, liming, tillage practices to minimize soil erosion, and effective water management are reviewed in these chapters of the monograph.

Perhaps our greatest advances in knowledge about the soybean has been in plant metabolism. This is reflected in individual chapters 13, 14, and 16 on N, C, and seed metabolisms. Included with these is chapter 15 on stress physiology since the soybean plant may be subjected to stress throughout its development.

Chapter 17 documents the recent advances in our knowledge of fungal disease of soybean. Although no new serious fungal diseases of soybean have been identified, many new races of specific pathogens, such as *Phytophthora megasperma* f. sp. *glycinea* have been identified. Locating genes for resistance to these races and incorporating the genes into new cultivars has been an integral part of most soybean improvement programs. Chapter 18 documents information about viral and bacterial diseases that are naturally occurring on soybean.

Nematodes, major pathogens of soybean in the South, have become a significant factor affecting soybean production in the Midwest. Chapter 19 reviews the progressive increase in the area infested by the soybean cyst nematode and strategies to limit losses associated with these pathogens.

Losses due to many soybean pests are limited by integrated systems of pest management. This recently developed control strategy is illustrated in chapter 20 on controlling insect pests of soybean.

Chapter 21 is on processing and utilization. This chapter describes in detail how soybean crops are processed, utilized, and require special handling. The final use of the crop will affect research to expand our knowledge of the crop and to improve production efficiency.

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My appreciation and gratitude is expressed to the Editorial Committee of this edition of the soybean monograph, Drs. H. R. Boerma, E. J. Kamprath, and L. E. Schrader. They represent different disciplines in soybean research and as members of the Editorial Committee have been fully involved in the development of chapter subjects, selection of authors, and in reviewing completed manuscripts. My appreciation is also extended to the many scientists who assisted with chapter reviews. I am especially grateful to Domenic Fuccillo and the staff at the American Society of Agronomy Headquarters who have been responsible for the myriad of details involved in the final editing of the manuscripts and the printing of this monograph.

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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 $(10^{-6} m)^2$	square inch, in^2	645
	Volume		
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
9.73×10^{-3}	$meter^3$, m^3	acre-inch	102.8
35.3	$meter^3$, m^3	cubic foot, ft^3	2.83×10^{-2}

continued on next page

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
		Mass	
2.20×10^{-3}	gram, g (10^{-3} kg)	pound, lb	454
3.52×10^{-2}	gram, g	ounce (avdp), oz	28.4
2.205	kilogram, kg	pound, lb	0.454
10^{-2}	kilogram, kg	quintal (metric), q	10^{2}
1.10×10^{-3}	kilogram, kg	ton (2000 lb), ton	907
1.102	megagram, Mg (tonne)	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
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	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
10^{3}	square meter per kilogram, m^2 kg^{-1}	square millimeter per gram, mm^2 g^{-1}	10^{-3}

Pressure

9.90	megapascal, MPa (10^6 Pa)	atmosphere	0.101
10	megapascal, MPa (10^6 Pa)	bar	0.1
1.00	megagram per cubic meter, Mg m^{-3}	gram per cubic centimeter, g cm^{-3}	1.00
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_2O) per square meter second, mg m^{-2} s^{-1}	micromole (H_2O) 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}

Angle

57.3	radian, rad	degrees (angle), °	1.75×10^{-2}

continued on next page

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
	Electrical Conductivity		
10	siemen per meter, S m^{-1}	millimho per centimeter, mmho cm^{-1}	0.1
	Water Measurement		
9.73×10^{-3}	cubic meter, m^3	acre-inches, acre-in	102.8
9.81×10^{-3}	cubic meter per hour, $m^3\ h^{-1}$	cubic feet per second, $ft^3\ s^{-1}$	101.9
4.40	cubic meter per hour, $m^3\ h^{-1}$	U.S. gallons per minute, gal min^{-1}	0.227
8.11	hectare-meters, ha-m	acre-feet, acre-ft	0.123
97.28	hectare-meters, ha-m	acre-inches, acre-in	1.03×10^{-2}
8.1×10^{-2}	hectare-centimeters, ha-cm	acre-feet, acre-ft	12.33
	Concentrations		
1	centimole per kilogram, cmol kg^{-1} (ion exchange capacity)	milliequivalents per 100 grams, meq 100 g^{-1}	1
0.1	gram per kilogram, g kg^{-1}	percent, %	10
1	megagram per cubic meter, Mg m^{-3}	gram per cubic centimeter, g cm^{-3}	1
1	milligram per kilogram, mg kg^{-1}	parts per million, ppm	1
	Plant Nutrient Conversion		
	Elemental	***Oxide***	
2.29	P	P_2O_5	0.437
1.20	K	K_2O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602

23 April 1986

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