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Plant Breeding and Sustainable Agriculture: Considerations for Objectives and Methods

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Proceedings of a symposium sponsored by Division C-1 of the Crop Science Society of America in Las Vegas, NV, 17 Oct. 1989.

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FOREWORD

History is replete with famines and food shortages that have caused incredible human suffering. During the 20th century the application of scientific principles and practices to agricultural production has revolutionized food production. Hunger has been conquered in those nations where scientific agriculture is widely practiced. This is arguably the greatest scientific success story of the 20th century. Plant breeders and geneticists, in both the private and public sectors, have been the pacesetters in this revolution and deserve a great deal of credit for its success.

Appropriately, questions are now asked as to whether these productivity gains can be continued, or even whether the gains of the past can be sustained, without compromising the productive capacity of the natural resource base for future generations. Sustaining this natural resource base, long a goal of responsible agriculturalists, is receiving heightened emphasis in research and educational programs.

Plant breeders hold the key to achieving these long-term goals. Biologically and economically sustainable systems of the future will require, to the fullest extent possible, exploitation of available germplasm and application of the vast array of new biological research tools. This symposium and resulting publication provide a springboard for discussion of the important topics related to the contributions of plant breeding under alternative production systems and under selection criteria in which sustainability of the system is paramount. The authors have done an outstanding job addressing this topic and we commend their efforts.

V. L. LECHTENBERG, *president*
Crop Science Society of America

D. R. NIELSEN, *president*
American Society of Agronomy

PREFACE

This symposium was designed to address sustainable agriculture issues that affect plant breeding. To begin with, sustainable agriculture was defined as an approach to farm management, as a means to the following ends:

1. Farm profitability
2. Yield stability
3. Food quality and safety
4. Environmental quality and safety
5. Erosion control

Goals of sustainable agriculture are increasing in prominence due to a rising concern about the environment and profitability. These concerns are driving a movement in agronomic research and extension to look at sustainable and lower chemical input methods of farming. It is beyond the scope of these proceedings to comment in depth on the benefits, justification, or many facets of sustainable agriculture. A review of key factors in sustainable or "alternative" farming practices was recently published by the National Academy of Sciences (NAS) (Anonymous, 1989. Alternative Agriculture. National Academy Press, Washington, DC). The NAS review points out that "instead of rejecting modern agricultural science, farmers adopting alternative systems rely on increased knowledge of pest management and plant nutrition, improved genetic and biological potential of cultivars and livestock, and better management techniques." Examples of the practices or principles most highly emphasized in the report are crop rotation, management systems for weed and pest control, soil- and water-conserving tillage, and "genetic improvement of crops to resist insect pests and diseases and to use nutrients more efficiently." We would add to the final component, genetic improvement, the need to enhance productivity of cultivars under novel stresses imposed by other practices mentioned. Plant breeding can serve an important role in the success of sustainable farming because production requires seed or other propagules, regardless of management system. By introducing superior genetic materials at competitive prices, productivity is enhanced cost effectively. This is the central theme of all plant breeding. One purpose of this symposium was to stimulate thinking toward what types of demands or environments may be increasing in prominence as sustainable agriculture concepts spread.

The organizing committee asked authors and speakers to address plant breeding objectives and methods that will contribute to sustainability and productivity of agriculture. A series of key questions was formulated, then individuals with appropriate experience to address these issues were identified. These issues are:

1. What global trends in terms of economics, population, environment, and genetic diversity will influence the types of crop cultivars needed in the future?

2. What are or should be the roles of private industry, public institutions, and international agricultural research centers in assessing germplasm needs, conducting research, providing germplasm resources, and providing final products?
3. How sustainable are gains in genetic improvement such as resistance to pests?
4. What are key components and problems in programs to breed for adaptation to varying production or stress levels?
5. Given that many of the benefits from practices in sustainable cropping patterns are based on complementary interactions among species in multiple cropping or rotations, how might these interactions be enhanced by breeding?
6. Are there cropping patterns emerging that change varietal requirements to the extent that we need to reassess breeding objectives and methods and to anticipate future needs?

Invited authors have devoted a substantial portion of their careers to studying aspects of sustainable agriculture. Their presentations at the 1989 American Society of Agronomy annual meetings in Las Vegas generated a great deal of discussion and enthusiasm regarding the role of plant breeding in furthering the goals of sustainable agriculture. For the benefit of breeders, agronomists, policy makers, farmers, and others interested in this topic, it was decided to publish the proceedings of the symposium. The papers presented here provide a more detailed and thorough discussion that was possible during the brief presentations. Thus, the organizing and editorial committees hope that these proceedings will be of value to individuals attempting to modify policy, practice, or objectives with regard to plant improvement.

The symposium was organized by P. Bramel-Cox (chair), T.C. Barker, C.A. Francis, and M.E. Smith. The editorial committee was composed of D.A. Sleper (chair), T.C. Barker, and P. Bramel-Cox. These individuals wish to thank the numerous persons who contributed time in preparing and reviewing manuscripts, as well as those who participated in the symposium and subsequent discussions. The committees also thank Drs. C.O. Qualset, R.R. Smith, and J.A. Schillinger for their support of this symposium.

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Conversion Factors for SI and non-SI Units

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, 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	tonnes 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
	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}

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

	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-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	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_2O_5	0.437
1.20	K	K_2O	0.830
1.39	Ca	CaO	0.715
1.66	Mg	MgO	0.602