

**Ecology, Production, and Management
of *Lolium* for Forage in the USA**

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Ecology, Production, and Management of *Lolium* for Forage in the USA

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FOREWORD

Annual and perennial ryegrasses have provided important pasture, hay, and silage for livestock in the USA. Recent research on this forage crop has been actively pursued primarily in the southeastern and northwestern parts of the USA. By concerted and coordinated efforts of breeders, farmers, commercial enterprises, plant physiologists, entomologists, and agronomists, this resource has increased in acreage, usefulness, and adaptability for specific purposes.

Successes have resulted from efforts by many different disciplines. There have been significant improvements in cultivars available for use, in the development of adapted cultivars for new areas, and in improved management options.

It is appropriate that our new knowledge of this important resource be integrated with previous knowledge and brought together in one place to provide a landmark in the forward progress of this important crop. This volume provides just such a landmark for researchers and for the animal production industry both in this country and abroad.

Betty Klepper
President, CSSA

PREFACE

During the 20th century, there has been an ever-increasing use of *Lolium* sp. as forage for domestic livestock and wildlife in the USA. Annual ryegrass (*L. multiflorum* Lam.) is most often used to complement warm-season perennial pastures from Texas and Oklahoma southward to the Gulf Coast and eastward to the Atlantic seaboard. More than 1 million ha of annual ryegrass pastures are used in the southeastern USA. With about 52% of the beef cow herd located in 13 to 14 southeastern states, sustainable, high quality forage for pasture, hay, and/or silage are necessary for economic survival of these related industries. Improvements in disease resistance, winter hardiness, dry matter production, and seed yield have allowed for expansion of pasture acreage of annual ryegrass. Although perennial ryegrass (*L. perenne* L.) has a wide and extended adaptation for turf, the primary pasture use of this species is in the Pacific Northwest, irrigated intermountain valleys, Midwest, and northeastern USA. Most of the commercial seed production of annual and perennial ryegrass occurs in Oregon, and especially the Willamette Valley. In 1996, more than 50 000 ha each of these two *Lolium* species were harvested for commercial seed purposes.

This special publication provides the most comprehensive review to date of research on annual ryegrass in the USA. The multiple authors of each chapter provide an authoritative, base foundation to previous and current developments in plant breeding, soil-plant nutrient relationships, physiology and ecology, forage quality and livestock use, and biological and economic seed production. The in-depth discussions in these specific areas of ryegrass growth, development, and use will be a valuable complement and extension to the ASA Monograph 34 entitled, *Cool-Season Forage Grasses*.

This special publication consists of eight chapters and will be useful to research, extension, and teaching professionals, as well as managers and producers as they implement application of previous research and seek opportunities for future improvements to *Lolium* for forage, site stabilization, and aesthetic purposes.

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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 Units	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)	454	pound, lb
3.52×10^{-2}	gram, g (10^{-3} kg)	28.4	ounce (avdp), oz
2.205	kilogram, kg	0.454	pound, lb
0.01	kilogram, kg	100	quintal (metric), q
1.10×10^{-3}	kilogram, kg	907	ton (2000 lb), ton
1.102	megagram, Mg (tonne)	0.907	ton (U.S.), ton
1.102	tonne, t	0.907	ton (U.S.), ton

Yield and Rate

0.893	kilogram per hectare, kg ha ⁻¹	1.12	pound per acre, lb acre ⁻¹
7.77×10^{-2}	kilogram per cubic meter, kg m ⁻³	12.87	pound per bushel, lb bu ⁻¹
1.49×10^{-2}	kilogram per hectare, kg ha ⁻¹	67.19	bushel per acre, 60 lb
1.59×10^{-2}	kilogram per hectare, kg ha ⁻¹	62.71	bushel per acre, 56 lb
1.86×10^{-2}	kilogram per hectare, kg ha ⁻¹	53.75	bushel per acre, 48 lb
0.107	liter per hectare, L ha ⁻¹	9.35	gallon per acre
893	tonnes per hectare, t ha ⁻¹	1.12×10^{-3}	pound per acre, lb acre ⁻¹
893	megagram per hectare, Mg ha ⁻¹	1.12×10^{-3}	pound per acre, lb acre ⁻¹
0.446	megagram per hectare, Mg ha ⁻¹	2.24	ton (2000 lb) per acre, ton acre ⁻¹
2.24	meter per second, m s ⁻¹	0.447	mile per hour

Specific Surface

10	square meter per kilogram, m ² kg ⁻¹	0.1	square centimeter per gram, cm ² g ⁻¹
1000	square meter per kilogram, m ² kg ⁻¹	0.001	square millimeter per gram, mm ² g ⁻¹

Pressure

9.90	megapascal, MPa (10^6 Pa)	0.101	atmosphere
10	megapascal, MPa (10^6 Pa)	0.1	bar
1.00	megagram, per cubic meter, Mg m ⁻³	1.00	gram per cubic centimeter, g cm ⁻³
2.09×10^{-2}	pascal, Pa	47.9	pound per square foot, lb ft ⁻²
1.45×10^{-4}	pascal, Pa	6.90×10^3	pound per square inch, lb in ⁻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 Units	To convert Column 2 into Column 1, multiply by
		Temperature	
1.00 (K - 273) (9/5 °C) + 32	Kelvin, K Celsius, °C	Celsius, °C Fahrenheit, °F	1.00 (°C + 273) 5/9 (°F - 32)
		Energy, Work, Quantity of Heat	
9.52 × 10 ⁻⁴ 0.239 10 ⁷ 0.735 2.387 × 10 ⁻⁵ 10 ⁵ 1.43 × 10 ⁻³	joule, J joule, J joule, J joule, J joule per square meter, J m ⁻² newton, N watt per square meter, W m ⁻²	British thermal unit, Btu calorie, cal erg foot-pound calorie per square centimeter (langley) dyne calorie per square centimeter minute (irradiance), cal cm ⁻² min ⁻¹	1.05 × 10 ³ 4.19 10 ⁻⁷ 1.36 4.19 × 10 ⁴ 10 ⁻⁵ 698
		Transpiration and Photosynthesis	
3.60 × 10 ⁻² 5.56 × 10 ⁻³ 10 ⁻⁴ 35.97	milligram per square meter second, mg m ⁻² s ⁻¹ milligram (H ₂ O) per square meter second, mg m ⁻² s ⁻¹ milligram per square meter second, mg m ⁻² s ⁻¹ milligram per square meter second, mg m ⁻² s ⁻¹	gram per square decimeter hour, g dm ⁻² h ⁻¹ micromole (H ₂ O) per square centi- meter second, μmol cm ⁻² s ⁻¹ milligram per square centimeter second, mg cm ⁻² s ⁻¹ milligram per square decimeter hour, mg dm ⁻² h ⁻¹	27.8 180 10 ⁴ 2.78 × 10 ⁻²
57.3	radian, rad	Plane Angle degrees (angle), °	1.75 × 10 ⁻²

Electrical Conductivity, Electricity, and Magnetism

10	siemen per meter, S m ⁻¹	0.1	millimho per centimeter, mmho cm ⁻¹
10 ⁴	tesla, T	10 ⁻⁴	gauss, G

Water Measurement

9.73 × 10 ⁻³	cubic meter, m ³	102.8	acre-inches, acre-in
9.81 × 10 ⁻³	cubic meter per hour, m ³ h ⁻¹	101.9	cubic feet per second, ft ³ s ⁻¹
4.40	cubic meter per hour, m ³ h ⁻¹	0.227	U.S. gallons per minute, gal min ⁻¹
8.11	hectare-meters, ha-m	0.123	acre-feet, acre-ft
97.28	hectare-meters, ha-m	1.03 × 10 ⁻²	acre-inches, acre-in
8.1 × 10 ⁻²	hectare-centimeters, ha-cm	12.33	acre-feet, acre-ft

Concentrations

1	centimole per kilogram, cmol kg ⁻¹	1	milliequivalents per 100 grams, meq 100 g ⁻¹
0.1	gram per kilogram, g kg ⁻¹	10	percent, %
1	milligram per kilogram, mg kg ⁻¹	1	parts per million, ppm

Radioactivity

2.7 × 10 ⁻¹¹	becquerel, Bq	3.7 × 10 ¹⁰	curie, Ci
2.7 × 10 ⁻²	becquerel per kilogram, Bq kg ⁻¹	37	picocurie per gram, pCi g ⁻¹
100	gray, Gy (absorbed dose)	0.01	rad, rd
100	sievert, Sv (equivalent dose)	0.01	rem (roentgen equivalent man)

Plant Nutrient Conversion

<i>Elemental</i>	<i>Oxide</i>
2.29	P ₂ O ₅
1.20	K ₂ O
1.39	CaO
1.66	MgO