グレートプレーン中部における日本育成寒地型牧草品種の生育特性と永続性

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Performance and Persistence of Japanese Cool-Season Forage Grasses in the Central Great Plains of Oklahoma, USA

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Synopsis

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In this study, the performance of nine Japanese cool-season grass cultivars representing five species were evaluated in central Oklahoma, USA. Forage production, persistence data and climatological data were obtained to identify the performance of Japanese cool-season forage grasses and their possible use as a breeding resource. Data from the four year study indicate 'Akimidori' orchardgrass, 'Nanryo' tall fescue, 'Harusakae' meadow fescue and 'Shiwasuaoba' Italian ryegrass have value and a capacity for additional breeding improvements for both central Oklahoma and Japan. 'Akimidori' orchardgrass, 'Nanryo' tall fescue and 'Harusakae' meadow fescue each exhibit tolerance to drought and heat stress. As a consequence, these cultivars indicated good persistence in the years evaluated. 'Shiwasuaoba' annual ryegrass, by virtue of its early maturity, escaped periods of drought and heat stress in central Oklahoma and was well suited to no-till forage-grass-vegetable rotations. Multi-year performance testing of Japanese cool-season grasses in the climatic extremes of central Oklahoma provide a useful selection tool for drought and heat tolerant germplasm for both Japanese and American breeding programs.

Key words : Cool-season, Cultivar, Forage, Grass, Japan, Oklahoma.

Introduction

Annually sown winter wheat is the primary cool-season forage used by livestock enterprises in much of the Southern Great Plains Region of the United States. In recent years, there has been substantial producer interest in options that reduce the annual expenses associated with wheat pasture and thereby enhance long-term sustainability of the land and its natural resources. In addition, the identification and utilization of cool-season grass pasture establishment systems that would reduce summer tillage operations, could reduce soil loss during these summer fallow periods and offer long term soil sustaining benefits to the region's landowners (Smith *et al.* 1991). One option to help sustain the regions livestock and agricultural base is the development of permanent pastures sown to perennial cool-season or perennial cool-season/warm season grass mixtures and their utilization as an alternative source of high quality forage for livestock. Estimates indicate that more than 20,000 ha of marginal farmland have recently been sown to cool-season perennial grasses (NRCS 1999). The transfer of marginal farmland to perennial pastures would likely support a more sustainable agricultural system in the region by reducing overgrazing on native rangelands and soil erosion caused by annual tillage operations. Few improved indigenous or introduced forage-type cool-season grasses are known to be productive or persistent in this region. As a consequence, international cooperation directed at identifying or developing new and unique genetic resources for increasing cool-season pasture productivity would be a desirable endeavor for forage programs located in temperate regions (Tibbits 1994).

In this study, nine cultivars comprising five species of perennial and annual cool-season forage grasses of Japanese origin were sown in central Oklahoma and evaluated for forage production, persistence and tolerance to heat and drought against a set of similar U. S. check cultivars. The objective of the study was to determine if selected Japanese germplasm could exhibit adaptation , productivity and persistence under the climatic conditions of central Oklahoma, USA.

Materials and Methods

The experiments were established on October 19, 1999, on a Brewer silty clay soil type (fine, mixed, superactive, thermic Undertic Argiustoll) at the

USDA-ARS Grazinglands Research Laboratory, USDA-ARS, El Reno, OK (North 35.5°, West 98°). Experimental plots (1.25 m×55 m) were established with seed sown on 23 cm centers at 55 m row lengths. The cool-season forage grasses Table 1) were seeded at a rate of 150 pure live seed (PLS) per m^2 at a depth of 3.7 cm. The high sowing rate was chosen to provide each entry the maximum opportunity to become completely established within the plots. The prepared seedbed was firm and well packed and resided on a level, well-drained site with a relatively low degree of prior weed infestation. Prior to sowing, soil tests at El Reno indicated availability of 39 ppm NO_2-N, 51 ppm P_2O_2 and 403 ppm K_2O at a pH of 6.9. From 1999 through 2002, annual ryegrass cultivars were sown during late September to early October. However, following this first year of evaluation, it was observed that some of the cultivars would have greater potential at a more southern Oklahoma testing location. As a consequence, the facilities of the South Central Regional Research Laboratory at Lane, OK, were incorporated into the research study. The soil type at the Lane location is a Bernow fine-loamy, siliceous, thermic Glossic Paleudalf. At both locations, yearly soil tests revealed that levels of P and K were adequate. Nitrogen inputs during the trials were kept to a minimum to apply an additional component of stress to all entries. Annual applications of granular nitrogen occurred in October at a rate of 43 kg/ha utilizing a calibrated broadcast spreader. 2,4-dichlorophenoxyacetic acid amine was applied at a rate of 2.5 L/ha at various times during the season to control annual broadleaf weeds.

The experiment was conducted utilizing Japanese cultivars consisting of two perennial ryegrass varieties, two orchardgrass, one meadow fescue, one tall fescue and three Italian ryegrass (Table 1). Both proprietary and public U.S. cultivars were utilized as checks (Table 1). When entries reached an average height of 35 cm, they were clipped to a uniform height. Generally only one or two clippings were performed during each season with a Hege brand forage harvester (Kollmering, Germany) set at a height of 5-8 cm to simulate rotational grazing. All entries were exposed to a final cutting in June-July, just below the seed heads, to allow for seed removal and prevent seed maturation. Seed removal was performed to limit volunteer seedlings in the plots in the following growing season. In addition, a granular Balan/Treflan© herbicide was broadcast throughout the plots each fall and spring to prevent volunteer seed germination. As a consequence, stand counts were a true representation of actual plant survival. Plots were not irrigated during the research study.

Stand counts were performed in May of the second year following establishment utilizing a frequency grid method to estimate plant population densities (Vallentine 1990). These data were used to define persistence to heat and drought of the different entries. Data pertaining to forage quality were generally not obtained since analysis of all cultivars in the first year of the study indicated each were comparable to U.S. check cultivars (Table 2). When required, forage sample analyses were performed by Dairyland Research Laboratories, Beloit, WI.

Climatological data were obtained from a Mesonet weather station located on the Grazinglands Research Laboratory (Illston and Basara 2003). Data relevant to monthly accumulated precipitation, average temperature, high temperature, total heat degree growing days, and average solar radiation levels were provided by this site. Data were analyzed by analysis of variance (ANOVA), using a randomized, block design, with three replications. Mean separations were accomplished utilizing the LSD statistic. The trials were terminated in May, 2003.

Results and Discussion

1. Overview of Climatic Conditions (1999-2003)

During the evaluation period (1999-2003), the summers were generally dryer than normal. Drought conditions occurred during the summer of 1999 (August through November); winter of 2000-2001 (November-April) and winter-spring of 2002-2003 (January through May). Measurable precipitation in Oklahoma typically occurs in the fall and spring (Fig. 1) with drought periods typically occurring from July through September (Fig. 1) (Illston and Basara 2003). However, winter droughts are also common. Humidity is relatively low throughout the year in Oklahoma, and air temperature is typically lowest in the winter and highest from July through September (Figs. 2 and 3).

Generally, the climate of central Oklahoma varies considerably and is considered a more stressful environment for producing cool-season grass forage than Japan. Droughts are common during the summer, which is typified by high temperatures, often exceeding 35℃. During such periods, considerable physiological stress is placed on cool-season species, testing their productivity and persistence. Precipitation is also generally lower than in even the most southerly regions of Japan. The highest period of precipitation usually occurs from October through December and March through April. Yearly total accumulation of precipitation rarely exceeds 1100 mm. During the performance trial, total precipitation was low and averaged 85% of normal expected historical levels. Heat degree growing days (HDD) are more numerous

Table 1. Cool-season forage grasses utilized in the study, relative flowering maturity at El Reno, OK and the source of that germplasm.

Species/Variety	Maturity	Seed Source
Perennial Ryegrass		
Yatsuyutaka	medium	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Yatsukaze	medium	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Linn	late	Ross Seed Co., El Reno, OK, USA
Mara	medium-late	Barenbrug USA, Tangent, OR, USA
Zero Yatsyn	medium-late	Barenbrug USA, Tangent, OR, USA
Calibra	medium-late	DLF-Jenks, Albany, OR, USA
Italian Ryegrass		
Shiwasuaoba	very early	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Minamiaoba	early	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Waseyutaka	early	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Marshall	medium-late	Ross Seed Co., El Reno, OK, USA
Ribeye	medium-late	Ross Seed Co., El Reno, OK, USA
Rustmaster	medium-late	DLF-Jenks, Albany, OR, USA
Bartali	medium-late	Barenbrug USA, Tangent, OR, USA
Zorro	medium-late	DLF-Jenks, Albany, OR, USA
Abundant	medium	DLF-Jenks, Albany, OR, USA
Hercules	medium-late	Smith Seed Services, Halsey, OR, USA
Jumbo	medium-late	Smith Seed Services, Halsey, OR, USA
Tetra	medium-late	Smith Seed Services, Halsey, OR, USA
Tall or Meadow Fescue		
Nanryo	medium	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Harusakae	late	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Barcarella	late	Barenbrug USA, Tangent, OR, USA
Dovey	medium	Barenbrug USA, Tangent, OR, USA
Kentucky 31	medium-late	Ross Seed Co., El Reno, OK, USA
Maximize	medium-late	Pure Seed Testing Inc., Hubbard, OR, USA
EA79	medium	Cascade Intl. Seed, Aumsville, OR, USA
Carmine	medium	DLF-Jenks, Albany, OR, USA
Fawn	early-medium	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Penngrazer	medium	Pennington Seeds, Madison, GA, USA
Orchardgrass		
Akimidori	medium	Japan Grassland Farm. Forage Seed Assoc., Tokyo, Japan
Akimidori II	medium	Japan Grassland Farm, Forage Seed Assoc., Tokyo, Japan
Paiute	medium	Ross Seed Co., El Reno, OK, USA
Renegade	early	Smith Seed Services, Halsey, OR, USA
Potomoc	early	Smith Seed Services, Halsey, OR, USA
Bronc	medium	Smith Seed Services, Halsey, OR, USA
Grazing Bromegrass		
Stocker	late	Ross Seed Co., El Reno, OK, USA

than in central Japan and monthly solar radiation levels exceed levels recorded in central Japan (Figs. 1 and 2). As a comparison, Miyazaki Japan receives its highest solar radiation levels during July-August with a range of 15-20 MJ/m^2 day (Wadi *et al.* 2003) while in El Reno, Oklahoma, the highest solar radiation levels are achieved in June-August with a range of 20-27 MJ/m^2 day. Figures detailing precipitation, temperature, heating degree days and solar radiation throughout the evaluation period are provided as a general reference (Figs. 1, 2 and 3).

2. Forage Productivity

For convenience, results of the performance trials are presented by species and genus. Data are provided for Italian ryegrass trials conducted at both Lane and El Reno, OK, and trials including perennial ryegrass, orchardgrass and a fescue trial performed at El Reno, OK. Forage production of some Japanese cultivars, when compared to similar U.S. checks, were considered competitive. Tables 1-7 show the

Table 2. Dry matter forage yields and nutritional information of varieties evaluated in the 2000 forage performance trials conducted at El Reno, OK.

Variety	Est. kg/ha	%CP	%ADF	%NDF	%TDN
Akimidori II	1,157.20	19.44	21.62	44.35	72.06
Akimidori	1,505.20	14.76	15.53	32.88	76.80
Fawn	2,200.11	17.47	22.32	43.16	71.51
Harusakae	745.03	18.52	19.39	38.02	73.80
Maximize	1,888.88	16.22	17.06	35.26	75.61
Nanryo	1,497.16	17.60	20.02	39.36	73.28
Paiute	1,435.10	16.88	16.21	36.84	78.01
Penngrazer	2,255.72	17.95	22.31	41.92	71.52
Stocker	937.40	21.09	25.67	45.91	73.90
Yatsukaze	419.13	15.83	19.26	38.86	73.90
Yatsuyutaka	441.13	16.12	26.02	45.67	68.63
Mean	1,316.55				
LSD 0.05	373.14				
CV %	30.90				

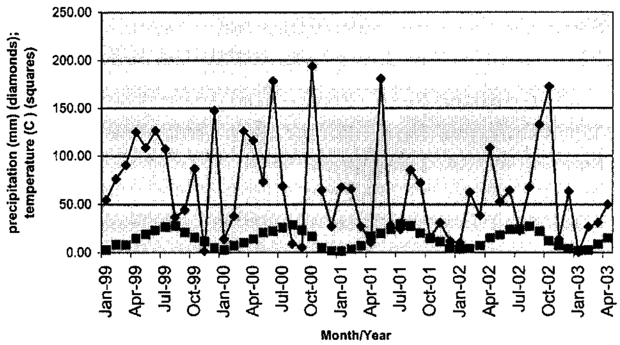

Fig. 1. Measureble Precipitation (-◆-) and Average Temperatures (-■-) at El Reno, OK, USA.

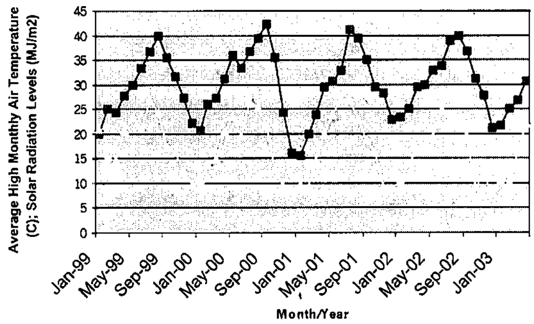

Fig. 2. Average Monthly High Air Temperatures (-■-) and Solar Radiation Levels (-△-) at El Reno, OK, USA.

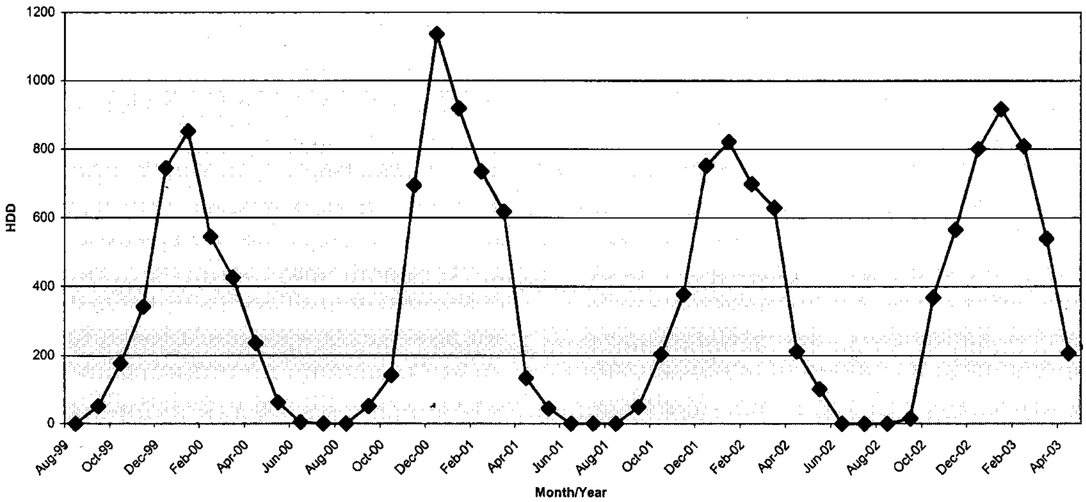

Fig. 3. Total Heat Degree Growing Days (HDD) at El Reno, OK, USA.

seasonal clipping and yearly biomass production totals for all entries.

(1) Italian Ryegrass

Italian ryegrass is generally the latest maturing of the winter seeded annual grasses and can be grazed until mid-May in most areas of Oklahoma. The long term maturity, forage quality and palatability make this a highly desirable species for forage-livestock enterprises. However, in the wheat producing areas of the southern plains, such as Oklahoma, annual ryegrass is often considered a noxious weed due to its prolific seed production and its potential for competition with, or contamination of wheat grain production fields.

Regardless of testing location, annual forage production of 'Shiwasuaoba', 'Minamiaoba' and 'Waseyutaka' were consistently lower than that of several U.S. check cultivars (Tables 3 and 4 and 7). These results were likely due to the early maturity of the Japanese entries. At both trial locations, 'Shiwasuaoba' flowered approximately 21 days earlier than the later maturing, long season, U.S. check cultivars. The Japanese cultivars 'Minamiaoba' and 'Waseyutaka' were approximately 14 days earlier than the earliest U.S. checks. Since most U.S. Italian ryegrass cultivars are developed for long season productivity, the early maturity of the Japanese entries placed limitations on their production potential. However, as was the case for 'Shiwasuaoba', its early maturity proved to be a beneficial character. In Oklahoma, periods of lower precipitation and increased temperature typically start in mid-May. Since 'Shiwasuaoba' completes its life cycle by late March or early April, it is able to escape this period of drought and high temperature. Irrespective of its early maturity, April performance data indicate 'Shiwasuaoba' yields were competitive with the early yields of later maturing U.S. cultivars such as 'Marshall', 'Zorro' and 'Ribeye' (Tables 3, 4 and 7).

Table 3. 2001 Dry matter forage yields of perennial and Italian ryegrass varieties taken at various clipping dates, sown at El Reno, OK, September 19, 2000.

Variety	4/20/01 Est. kg/ha	5/10/01 Est. kg/ha	6/6/01 Est. kg/ha	Total Est. kg/ha
Bartali	992.09	7,728.90	2,507.58	11,796.80
Linn	2,797.81	5,942.66	1,282.11	10,022.58
Marshall	2,260.16	9,135.37	2,721.75	14,117.28
Minamiaoba	2,750.92	8,297.14	1,967.53	8,822.78
Ribeye	1,720.22	7,728.90	1,966.93	11,416.05
Shiwasuaoba	1,745.27	3,234.70	1,239.45	6,219.41
Waseyutaka	2,326.01	6,108.14	2,661.55	11,095.70
Zorro	1,934.76	11,295.73	3,394.60	16,625.09
Mean	2,065.91	6,980.86	2,217.66	11,227.47
LSD	—	—	—	296.22
CV %	—	—	—	26.39

Table 4. Italian ryegrass dry matter hay yields from Lane and El Reno, OK. Sowing and clipping dates at Lane, OK were Sept. 9, 2001 and April 20, 2002, respectively. Sowing and clipping dates at El Reno, OK were Sept. 10, 2001 and May 22, 2002, respectively.

Variety	Lane, OK Est. kg/ha	El Reno, OK Est. kg/ha
Marshall	2,915.64	1,310.66
Minamiaoba	1,714.41	593.43
Ribeye	—	854.23
Rust Master	—	1,173.46
Shiwasuaoba	2,547.95	829.33
Waseyutaka	1,870.35	862.78
Mean	2,262.09	937.32
LSD	291.86	133.71
CV%	15.45	48.82

When sown in October, 'Shiwasuaoba' demonstrated the capacity to be an early maturing, single cut variety. Due to its forage production potential during the spring, 'Shiwasuaoba' could be utilized in the U.S. with crop rotations of summer vegetables or melons. Trials to identify which summer crops are appropriate for this type of rotation are underway.

(2) Perennial Ryegrass

In much of the USA, perennial ryegrass can be grown as a permanent pasture or for forage, haying, silage, and as a ground cover crop to extend the grazing season. However, in the trials, perennial ryegrass was not particularly productive or persistent because of intolerance to heat, drought and multiple clippings. Data obtained from the perennial ryegrass trials continue to indicate that a major effort is required to identify genotypes that are productive and persistent for this region.

Forage production data are not provided in 2001, 2002 and 2003 for 'Yatsuyutaka' and 'Yatsukaze' perennial ryegrass entries since none of the cultivars reflected any significant tolerance to the summer drought conditions. The study indicated that none of the Japanese or U.S. cultivars exhibited adaptation, productivity or persistence under the study conditions. Stand counts of both Japanese cultivars in 2003 showed a loss of approximately 40% of the original 2000 stand (Table 8). The U.S. perennial ryegrass cultivars also performed poorly, and as a consequence, the perennial ryegrass forage performance trials were terminated in 2002. In the cases of

'Yatsuyutaka' and 'Yatsukaze' perennial ryegrass, environmental stresses were exceptionally severe and inhibited the initiation of flowering in 2001, 2002. and 2003. From this study, no perennial ryegrass entries exhibited an acceptable level of adaptation and persistence to climatic conditions in central Oklahoma. Surviving individuals of the initial stands of both 'Yatsuyutaka' and 'Yatsukaze' likely represent genotypes most adapted to the heat and drought conditions that are common in central Oklahoma. Sampling of individuals from the remaining stands should provide foundation material for the future development of drought and heat tolerant germplasm.

(3) Orchardgrass

Though orchardgrass is not a commonly sown species in Oklahoma, its performance was satisfactory in the trials and data suggest some tolerance to heat and drought conditions of central Oklahoma. Throughout the trial period, 'Akimidori' consistently exhibited greater forage production than 'Akimidori II' and was slightly superior to the check cultivars (Table 5). When compared to the leading check cultivar ('Paiute'), 'Akimidori' was competitive in forage production, persistence and apparent adaptation. Stand counts of both 'Akimidori' and 'Akimidori II' diminished throughout the trial period which suggest some susceptibility to drought. In May 2000, stand counts of both 'Akimidori' and 'Akimidori II' were nearly 100%, indicating excellent germination and stand establishment. However, by May 2003, stand counts of both cultivars were reduced to approximately 80% and 88% (Table 8).

Table 5. Dry matter yield of orchardgrass cultivars grown at El Reno, OK. Two sowing dates are represented. Data represented for clipping dates of May 22, 2002 and May 29, 2003 were sown on Sept. 14, 2001. Sowing date for clipping date taken on April 29, 2003 was Sept. 19, 2002. Due to the severity of a 2002 winter-fall drought, considerable stress was placed on the 2002 results.

Variety	5/22/02 Est. kg/ha	5/29/03 Est. kg/ha	4/29/03 Est. kg/ha
Akimidori	2,412.94	4,728.37	7,551.02
Akimidori II	2,122.68	no data	no data
Bronc	1,461.01	2,313.64	5,154.63
Paiute	2,591.02	4,716.52	6,465.94
Potomoc	1,108.60	3,146.24	4,969.66
Renegade	1,296.43	2,274.55	4,382.09
Mean	1,832.12	3,435.87	5,704.66
LSD	275.02	199.42	298.71
CV%	21.55	27.04	27.53

Research utilizing orchardgrass and various bromegrass species have suggested that plant seeding rates, plant spacing and environment have major effects on pasture and forage production and it is likely the original high seeding rate and population stand exceeded the level for all plants to be vigorous and persistent (Muir *et al.* 2001 ; Smith *et al.* 1991). It is likely that a combination of environmental stress, seeding rate and optimum spacing of plants affected performance. Determination of optimum seeding rates for orchardgrass in central Oklahoma would likely provide benefits to stand establishment and stand persistence. In addition, selection of surviving plants within the remaining 2003 stands should provide a productive and more drought and heat tolerant population for further selection and development.

(4) Fescues

Tall fescue is the most popular perennial cool-season forage grass in the United States and numerous cultivars are available. Forage production by 'Harusakae' meadow fescue and 'Nanryo' tall fescue were competitive with several U.S. check cultivars (Table 6). Data indicate that the U.S. cultivars 'Maximize' and 'Penngrazer' tall fescue were the most adapted and productive entries in the trials. However, results also suggested the Japanese cultivar 'Nanryo', could be equally competitive. Among the fescue cultivars evaluated in the trial, it was observed that 'Harusakae' reached reproductive maturity later than 'Nanryo', 'Maximize', 'Penngrazer' and 'Fawn' tall fescue. 'Harusakae' forage production data were consistently lower than other tall fescue entries ; however, due to its later maturity, it is anticipated that the forage quality of this entry could be maintained longer into the summer than with the earlier maturing tall fescue cultivars. This later maturity, either induced by stress or controlled by genotype, could provide a definite advantage in forage

Table 6. Dry matter yield of fescue cultivars grown at El Reno, OK. Sowing date was Sept. 19, 2000. Clipping dates are April 18, 2002 and April 30, 2003.

Variety	4/18/02 Est. Kg/ha	4/30/03 Est. Kg/ha
Fawn	3,383.18	3,686.21
Harusakae	3,041.73	4,551.86
Maximize	4,745.67	3,939.78
Nanryo	4,597.77	5,627.29
Penngrazer	5,195.75	5,637.26
Mean	4,192.78	4,688.49
LSD	362.61	458.67
CV%	42.84	30.54

production systems used in Oklahoma. Though forage quality data was not obtained during all years of the trials, in 2000, near infrared (NIR) estimates indicated that 'Harusakae' meadow fescue exhibited slightly higher levels of crude protein, and slightly higher levels of digestibility. Additional studies are in progress to determine if these results are consistent across years and environments.

3. Persistence

In the United States, approximately 23 million ha of cropland and 53 million ha of non-arable land, exclusive of rangelands, are used for pasture (Vogel and Masters 2001). One of the primary aims of a forage breeder is the need to increase the persistence and productivity of these pastures with improved forages requiring minimum inputs. Over time, it has been shown that the genetic composition of sown species will change under different stress factors related to environment, grazing and poor management (Brummer and Bouton 1992 ; Brummer and Moore 2000). In essence, the tendency of a population's genetic composition to shift in response to these pressures can be a measure of a cultivar's persistence.

Research relevant to the persistence of perennial cool-season forage grasses is essential for the development of a truly sustainable agriculture in Oklahoma. As persistent and productive germplasm are identified and developed, agricultural managers will be in a superior position to effectively manage agricultural production systems and reduce risks associated with ever-changing economic and environmental stresses. Two primary factors limiting productivity of cool-season perennial grasses in Oklahoma are poor responses to limited moisture and high temperatures that increase transpiration (Colville *et al.* 1963). In central Oklahoma, limited precipitation and high temperatures are the normal condition for the summer growing season (Illston and Basara 2003). Also, the cost of ammonium nitrate fertilizers and poor pasture management which limit nitrogen inputs also place stress on plant persistence, water use efficiency, tillering, root growth, forage production and reproductive development (Muir *et al.* 2001 ; Power 1985). To maximize the productivity of cool-season perennial grasses in a non-water limiting environment, a medium nitrogen application rate of 200–300 kg/ha with a split application in the fall and spring is recommended in Japan and the Northeast USA (Hall *et al.* 2003 ; Wadi *et al.* 2003 ; Wedin 1974). In Oklahoma's water limiting environment, such an application would be extravagant. The suggested rate of N application in Oklahoma is 110 kg/ha in two applications (Redmon 1999). However, in this study, only a single application rate of 43 kg/ha was applied in October. The lowered nitrogen input is anticipated to reduce the water use efficiency, efficiency of transpiration, mineral uptake and photosynthate transfer (Power 1985 ; Sosebee and Wiebe 1971 ; Volaire and Thomas 1995). As a consequence, such a reduction in water use efficiency, would apply an additional stress to each Japanese entry, and the cultivars response would be identified by stand persistence.

In Oklahoma, the USDA-NRCS has suggested that a satisfactory stand for a perennial forage pasture should exhibit 1 plant per 160 cm^2 (NRCS 1999). In these studies, stand counts in May 2000 compared with that of May 2003 showed that the only Japanese entries capable of maintaining this population criteria were 'Nanryo' tall fescue and 'Harusakae' meadow fescue (Table 8). Since 'Harusakae' meadow fescue was developed in Hokkaido, Japan, and was selected for cold tolerance, it is surprising that the 'Harusakae' entry showed little stand reduction during the trials. 'Harusakae' meadow fescue is

Table 7. Dry matter yield of Italian ryegrass sown at Lane, OK on Sept. 20, 2002. Clipping Dates were April 7 and April 22, 2003.

Variety	4/7/03 Est. Kg.ha	4/22/03 Est. Kg/ha	Total Est. Kg/ha
Abundant	3,574.20	473.80	4,048.00
Hercules	3,140.48	338.89	3,479.37
Jumbo	2,514.50	494.84	3,009.34
Marshall	3,158.45	683.49	3,841.95
Minamiaoba	2,502.21	330.27	2,832.48
Shiwasuaoba	2,798.95	700.50	3,499.46
Tetra	2,843.53	998.62	3,842.15
Waseyutaka	2,455.30	745.17	3,201.02
Zorro	3,309.15	890.56	4,199.71
Mean	2,921.86	628.52	3,550.39
LSD	—	—	373.14
CV%	—	—	22.22

Table 8. Percent stand counts of perennial Japanese cool-season forage grasses grown at El Reno, OK in first (2000) and fourth (2003) year of growth.

Variety	May 17, 2000	May, 15, 2003
Yatsuyutaka	99.67	58.33
Yatsukaze	99.67	58.33
Akimidori II	98.33	79.67
Akimidori	100.00	88.67
Harusakae	100.00	79.33
Nanryo	100.00	99.67

known to contain 75% endophyte infected individuals (Takai *et al.* 2001) and this endophyte infection rate corresponds well to the estimated 21% stand reduction (Table 8). In November, 2004, a preliminary microscopic survey of new roots from 8 surviving individuals indicated the presence of viable endophyte. Consequently, it is possible that the endophyte or the particular race of endophyte associated with this entry is conferring the tolerance to heat and drought (Fujimori, 2003, personal communication). Additional studies are necessary to explain the unanticipated persistence of 'Harusakae' in Oklahoma.

The perennial ryegrass cultivars 'Yatsuyutaka' and 'Yatsukaze' were not persistent. Heat, drought and low nitrogen inputs applied major stresses to all Japanese and U.S. perennial ryegrass cultivars regardless of whether they represent a diploid or tetraploid form. Stand counts of the Japanese perennial ryegrass entries, as well as U.S. check entries, conducted in May 2003, indicated major stand reductions (Table 8). The additional pressure of livestock grazing would likely eliminate all evaluated cultivars of perennial ryegrass. However, within these stands, numerous individuals possessing apparently stress tolerant genotypes remained.

The 'Akimidori' and 'Akimidori II' orchardgrass entries survived from the date of sowing through the fourth year of the trial. This period included two summer droughts and one winter drought. Performance trials conducted with 'Akimidori' in both Japan and France suggest this variety exhibits superior summer growth, suggesting a tolerance to lower precipitation and elevated temperatures (NGRI 1993). Stand counts obtained in Oklahoma during May 2003, indicate that both cultivars have undergone stand reduction (Table 8). However, with the reduction in stand, productivity of 'Akimidori' remained competitive with the primary check cultivar of U.S. orchardgrass (Table 5). Since 'Akimidori' is indicated to have good persistence and productivity when grown under drought and elevated temperatures, this cultivar is anticipated to possess adequate levels of drought and heat tolerance.

Both 'Harusakae' and 'Nanryo' fescue entries were adapted and indicated good persistence. Previous performance trials in Japan have indicated 'Nanryo' is a highly productive tall fescue with stable year-to-year performance (NGRI 1993). Final stand counts obtained in 2003 were similar to stand counts obtained in 2000 (Table 8). Tall fescue is well known for its tolerance to heat and drought, and the Japanese cultivars were found to be equivalent in their tolerance to these environmental conditions. When compared to the orchardgrass cultivars, the effect of low nitrogen input, heat and drought did not appear to affect the stand count of the fescue cultivars.

Conclusions

The productivity of a small number of Japanese cultivars of perennial cool-season grasses was found to be competitive with a series of U.S. check cultivars when grown in central Oklahoma, USA. Generally, stand counts declined in all Japanese entries, but satisfactory numbers of surviving plants suggest that genotypes having adaptation to climatic conditions in Oklahoma can be identified. Of particular interest was the performance data of 'Akimidori' orchardgrass and 'Nanryo' tall fescue that suggest these entries could be useful as cultivars per se, or as genetic resources for the development of drought and heat tolerant germplasm. None of the Japanese or U.S. perennial ryegrass entries demonstrated value as a forage suited to central Oklahoma. Of the Italian ryegrass entries, the 'Shiwasuaoba' cultivar exhibited value as an early maturing annual ryegrass for yearly rotations with warm-season vegetable or melon cropping systems. Generally, Japanese cultivar performance was comparable to, and in some instances, exceeded that of available germplasm. Results of the study suggest that, when carefully selected, Japanese cool-season forage grasses may provide competitive genetics and an elite and productive germplasm capable of providing new introductions with persistence to the climatic extremes of central Oklahoma. The varieties of 'Akimordi' orchardgrass, 'Nanryo' tall fescue and 'Shiwasuaoba' Italian ryegrass are at present included in several additional performance evaluations and selection improvement programs at various locations in the USA.

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* : In Japanese with English summary.

要　　旨

Bryan Kindiger*・Vincent Russo**・中川　仁*** (2004) : グレートプレーン中部における日本育成寒地型牧草品種の生育特性と永続性. 日草誌 50, 271-279. * USDA-ARS, Grazinglands Research Laboratory (7207 West Cheyenne St., El Reno, OK 73036, USA). ** USDA-ARS, South Central Agricultural Research Laboratory (P. O. Box 159, Hwy. 3 West, Lane, OK, 74555, USA), *** 独立行政法人農業生物資源研究所放射線育種場 (319-2293 茨城県那珂郡大宮町上村田 2425)

日本で育成された5草種9品種の生育特性をアメリカ合衆国オクラホマ州中央部において調査した。調査項目は収量および永続性に関する項目であり，気象データとあわせて日本で育成された品種の生育特性と育種素材としての可能性を考察した。4年間の調査の結果，オーチャードグラス「アキミドリ」，トールフェスク「ナンリョウ」，メドウフェスク「ハルサカエ」およびイタリアンライグラス「シワスアオバ」はオクラホマ州中央部や日本での栽培に適した種々の重要形質を備えていることを明らかにした。「アキミドリ」，「ナンリョウ」および「ハルサカエ」は耐乾性と耐暑性を備え，その結果，調査した4年間の永続性が高かった。「シワスアオバ」は，これまでのアメリカ育成品種にはなかった極早生の特性によってオクラホマ州中央部の干ばつと暑熱を回避でき，さらに牧草-野菜の不耕起連続栽培システムに適した品種であると考えられた。本試験で行ったような，干ばつと暑熱ストレスが高いオクラホマ州中央部での数年時にわたる多年生寒地型牧草の特性検定試験や個体選抜は，日本とアメリカで行われている育種事業における，耐乾，耐暑性遺伝資源の選抜や育種に有効である。

キーワード : イネ科牧草，オクラホマ州，寒地型牧草，日本，品種.