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CULTIVAR

Registration of 'Newell' Smooth Bromegrass

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ABSTRACT

'Newell' (Reg. No. CV-275, PI 671851) smooth bromegrass (*Bromus inermis* Leyss.) is a steppe or southern type cultivar that is primarily adapted in the United States to areas north of 40° N and east of 100° W that have 500 mm or more annual precipitation or in areas that have similar climatic conditions because of elevation or latitude. It was developed to replace 'Lincoln', which is the most widely used smooth bromegrass cultivar in the region, by improving its forage digestibility. Newell bromegrass was developed by four generations of population improvement breeding for in vitro dry matter digestibility (IVDMD) and forage yield using Lincoln as the base population. In regional small plot trials, Newell produced forage with greater IVDMD than Lincoln and equivalent or greater forage yields. In a replicated grazing trial in eastern Nebraska, beef yearlings grazing Newell for a 3-yr period produced significantly greater average daily gains and beef production per hectare than yearlings grazing Lincoln bromegrass.

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Smooth bromegrass (*Bromus inermis* Leyss.) has been widely used in pastures and for soil conservation purposes in temperate regions of North America, although it is native to Eurasia (Vogel et al., 1996). Since the 1940s, it has been the most widely used cool-season grass in pastures and conservation plantings in the Midwest and northeastern states of the United States. The cultivar Lincoln has been the predominant smooth bromegrass because its forage yields were usually equivalent to that of other cultivars, it is broadly adapted, and its seed was readily available due to its excellent seed yields (Vogel et al., 1996; Casler et al., 2000; Casler et al., 2001).

The two main ecotypes of smooth bromegrass grown in North America are the steppe or southern ecotype and the meadow or northern ecotype (Vogel et al., 1996). Most of the smooth bromegrass cultivars used in the United States, including Lincoln, belong to the steppe ecotype group (Vogel et al., 1996). Smooth bromegrass is largely self-incompatible, but plants can produce some seed when self-pollinated (Vogel et al., 1996). The steppe type cultivars grown in North America including Lincoln are octaploids ($2n = 8x = 56$), with a nuclear DNA content of 22.28 pg $2C^{-1}$ (DNA content of a diploid somatic nucleus) (Tuna et al., 2001). They are irregular at meiosis, forming both bivalents and quadravalents (Vogel et al., 1996). The steppe type octaploids were previously reported to be autoallopolyploids (Vogel et al., 1996), but more recent chromosome analyses indicates that the octaploid was probably

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Abbreviations: ARDC, Agriculture Research and Development Center; BWFS, between and within family selection; IVDMD, in vitro dry matter digestibility; NI, Nebraska index; RRPS, recurrent restricted phenotypic selection.

not produced by doubling of tetraploid *B. inermis* (Tuna et al., 2004). The irregular meiosis has undoubtedly affected the ability of breeders to improve it as a pasture species (Casler et al., 2000).

Lincoln was developed largely by natural selection from a bromegrass introduction that was brought into the United States by the USDA. Following the drought of the 1930s, there was considerable interest in smooth bromegrass because of its ability to survive that era's drought conditions. Seed from several old field plantings in Nebraska that traced to a single distribution of seed to state experiment stations, including the Nebraska Experiment Station, from the USDA before 1898 proved to be superior in a series of trials and produced progeny that were similar in type (Hein, 1955). These fields were certified as Lincoln smooth bromegrass by the Nebraska Crop Improvement Association beginning in 1943 (Hein, 1955). Later, foundation seed fields were established from the source fields to perpetuate the variety. Dr. L.C. Newell, a USDA–ARS agronomist stationed at the University of Nebraska, did the collection and evaluation research that led to the release of Lincoln smooth bromegrass.

In a previous comprehensive review, small improvements in forage digestibility of pasture grasses as measured by in vitro dry matter digestibility (IVDMD) were shown to have a significant positive affect on beef production per hectare, the genetic improvements in IVDMD were stable over environments, and these improvements typically did not decrease forage yields (Casler and Vogel, 1999). On average, a 1% increase in IVDMD led to a 3.2% increase in average daily gains (Casler and Vogel, 1999). The breeding objectives for the development of Newell (Reg. No. CV-275, PI 671851) smooth bromegrass were to improve the forage digestibility of a Lincoln-based population while maintaining or improving Lincoln's forage yield.

Materials and Methods

Breeding History

Foundation seed of Lincoln was used to grow seedlings for the cycle 1 selection nursery, which was established in 1977. Principal selection criteria were forage yield and IVDMD. Three breeding generations or cycles of a modified form of recurrent restricted phenotypic selection (RRPS) were used (Vogel and Pedersen, 1993). The space-transplanted selection nurseries were stratified into selection blocks. Based on visual assessment for vigor, forage yield, and other desirable traits, about 25% of the plants were identified for forage harvest and sampling for IVDMD. The number of plants in the selection nurseries for each RRPS breeding cycle ranged from 874 to 1200, the number of plants harvested for forage yield and sampled for forage quality ranged from 20 to 33% of the plants in the nursery, and the number of plants selected for polycrossing ranged from 51 to 87 or a selection intensity of 5 to 7% of the plants in the nurseries or 25 to 31% of the harvested and sampled plants (Table 1). In the fourth breeding cycle the between and within family selection (BWFS) breeding procedure was used (Vogel and Pedersen, 1993). In this breeding system, replicated half-sib family plots of 10 spaced plants were harvested on a plot basis for 2 yr; then in the third year, the families with the largest 2-yr Nebraska index (NI) values were sampled and harvested on an individual plant basis. In cycle 4, about 14% of the families were selected and about 3 plants per family or 17% of the plants within these selected families were selected for polycrossing (Table 1). Depending on weather conditions,

Table 1. Selection information for recurrent breeding for forage yield and in vitro dry matter digestibility (IVDMD) in the Lincoln High Yield-High IVDMD smooth bromegrass population.

	Population size	Harvested plants	Forage yield	IVDMD	Selection index (Nebraska Index)
	n	*n*	g plant^{-1}	g kg^{-1}	
Cycle 1 (RRPS†)			**Mean (SD)**	**Mean (SD)**	**Mean**
Selection nursery plants‡	898	191	490 (80)	474 (34)	
Selected plants	51		538 (60)	492 (27)	
Cycle 2 (RRPS)					
Selection nursery plants	874	181	563 (136)	449 (47)	0.01
Selected plants	57		631 (127)	475 (45)	1.10
Cycle 3 (RRPS)					
Selection nursery	1200	352	384 (86)	513 (29)	0.0
Selected plants	87		454 (88)	534 (56)	1.72
Cycle 4 (BWFS†)			**Family 2-yr mean (SD)**	**Family 2-yr mean (SD)**	**Family 2-yr mean**
Families (plants)§	87 (20)	all	294 (38)	496 (52)	−0.31
Selected families	12	all	309 (45)	530 (16)	1.01
Lincoln cv. check	6	all	280 (31)	492 (18)	−0.41
LSD (0.05)			54	31	
			Within family plant mean	**Within family plant mean**	**Within family plant mean**
Plants within family	221	221	166 (56)	604 (45)	0.0
Selected plants within families	38	38	208 (40)	654 (35)	1.84

† RRPS, recurrent restricted phenotypic selection; BWFS, between and within family selection.

‡ Cycle 1 dry weight yields are 1978 and 1979 means. Cycle 1 IVDMD values are for 1979 only.

§ Families (and numbers of plants within families).

each breeding generation was about 5 yr which included an establishment year in which no data were collected, two to 3 yr depending on the breeding system in which plants were harvested and sampled, 1 yr to establish the polycross nursery, and 1 yr to produce polycross seed from individual plants. In cycle 1, plants were selected that had yields and IVDMD values greater than the population of sampled plants. In subsequent cycles, the Nebraska selection index, NI, which gives equal weight to forage yield and digestibility was used to make selections (see below).

$$NI = (\text{yield} - \text{mean yield})/\text{yield } s) + (\text{IVDMD} - \text{mean IVDMD})/\text{IVDMD } s$$

where s is the standard deviation. Newell was tested as Lincoln HYLD-HDMD C4 in multilocation small plot trials and in a replicated grazing trial in eastern Nebraska.

Selection and Polycross Nurseries

Selection, polycross, and seed increase nurseries used in the development of Newell were located on the University of Nebraska Agricultural Research and Development Center (ARDC) located between Mead (41°09′ N, 96°25′ W) and Ithaca, NE, and is about 50 km west of Omaha, NE. In the space-transplanted selection and polycross nurseries described in this report, rows and plants within rows were spaced on 1.1-m centers and the following cultural practices were used. Space-transplanted nurseries were established by transplanting greenhouse grown seedlings into the selection nurseries. The nurseries were cultivated between plants with 0.6-m-wide roto-tillers creating 0.2-m^2 miniplots for individual plants. Nurseries were fertilized annually with 112 kg ha^{-1} N, and herbicides and hand weeding were used for weed control. Space-transplanted nurseries were mowed each spring to remove the accumulated biomass from the previous year. Plants or plots were harvested with a flail type plot harvester with a cutting height of 10 cm. Selected plants were sampled for forage quality at the time of forage harvest, which was after the plants were fully headed. In the BWFS selection nursery, tillers were sampled from all plants in a family plot and bulked before harvest in the years families were harvested on a plot basis. The subsamples consisted of approximately 250 to 400 g of freshly harvested forage, which was weighed in the field, dried in a forced air oven at 50°C for 48 h, and reweighed to determine dry matter concentration. The dry samples were then used to determine IVDMD as described below. Polycross nurseries were established by digging ramets (clonal pieces) of selected plants and transplanting them into isolated polycross nurseries. Isolation was maintained by mowing all smooth bromegrass before flowering that was within about 150 m of the polycross isolation. Two ramets of each selected plant were transplanted in a completely randomized design in the polycross nurseries for which plant spacing and cultural practices were the same as used in the selection nurseries. Seed was harvested from individual plants in the polycross nurseries and threshed with a small plot thresher. Depending on the breeding method used in the subsequent breeding cycle, the seed harvested in the first year of seed production was bulked by genotype to produce half sib family seed lots, or an equal amount of seed was bulked from each plant to produce a population bulk seed lot. In subsequent years of seed production, the entire polycross nursery was harvested with a plot combine and the bulk seed was used for yield tests and seed increases.

Forage Yield Sward Trials

Multiyear biomass yield sward evaluation trials were conducted in field trials located near Ithaca and Sidney, NE, Mandan, ND, Miles City, MT, and North Logan and Blue Creek, UT, in a USDA–ARS Northern Plains Regional test (Robins et al., 2007). These trials were multispecies trials, but only the yield data for the smooth bromegrass entries in these trials that were not reported previously are provided in this report. Plots were planted in fall 1999 at trial sites using procedures and trial site information fully described by Robins et al. (2007). In brief, they were seeded with small plot drills using row spacings and seeding rates recommended for each location into clean, firm, conventional seedbeds. No fertilizer was applied during the establishment year. In the post-establishment years, growth from the previous year was removed by mowing before the start of the growing season. Nitrogen fertilizer was applied as a single annual spring application of 50 and 112 kg ha^{-1} at Mandan and Mead, respectively, and a single application of 130 kg ha^{-1} at Sidney, NE, in the spring of the second year of the stand. Forage harvests were made at each location using plot harvesting equipment with a cutting height of 10 or 15 cm depending on location. Subsamples were collected for dry matter determinations at the time of forage harvest. The subsamples from the Mead, Sidney, and Mandan locations were also used to determine IVDMD concentration. At these locations, subsamples were collected by sampling tillers from areas within each plot. Forage yields were harvested at each location for three postestablishment years, except at Mead, where harvests were made for 4 yr. Late autumn regrowth harvests also were made in the Mead trial for 2 yr. Drought conditions precluded regrowth harvests in other years. Harvested plot size ranged from 2.5 to 5 m^2 depending on the trial location. The experimental design at all locations was a randomized complete block with four replicates except at Miles City which had three replicates.

Pasture Trial

A replicated pasture trial was established at the University of Nebraska ARDC in 2009 in which Lincoln, Newell (Lincoln HYLD-HDMD C4), and an experimental meadow bromegrass (*Bromus riparius* Rehm.) were evaluated. The experimental units were 0.4-ha pastures of each strain or cultivar that were seeded in a randomized complete block design with three replicates of each strain. Pastures were fertilized with 112 kg ha^{-1} N in spring of each year. The pastures were allowed to become well established in 2009 and 2010, during which the pastures were not grazed. Hay was harvested from the pastures in 2010. Pastures were grazed for 31 d in 2011, 37 d in 2012, and 43 d in 2013. Stocking rate was three steers per 0.4-ha pasture. Only the grazing data for Newell and Lincoln smooth bromegrass are reported here to support the registration of Newell.

Laboratory Analyses

The dried forage subsamples used in the laboratory analyses were ground through a 2-mm screen with a Wiley Mill (Thomas-Wiley Mill Co.). Then a subsample was ground through a UDY cyclone mill (UDY Corp.) with a 1-mm screen for analyses. Before 1999, a modified Tilley and Terry (1963) procedure was used to determine IVDMD. In the modified procedure that was conducted in the University of Nebraska–Lincoln Agronomy Department Analytical Laboratory, 6 g of urea was added to every 3.5 L of rumen fluid, and $HgCl_2$ and Na_2CO_3 were not added after the first stage. In 1999, the USDA–ARS Forage Quality Laboratory at Lincoln, NE, converted to a filter bag method of determining IVDMD using the procedures described by Vogel et al. (1999). The filter bag IVDMD analyses were used to determine the IVDMD of calibration samples that were used to develop near infrared reflectance spectroscopy prediction equations that were used to analyze the forage samples from the multi-site yield tests. All ground samples were scanned on a NIRSystems Model 6500 near-infrared reflectance spectrophotometer (NIRSystems, now Foss NIRSystems Inc.). Calibration samples sets for IVDMD analyses were chosen by cluster analysis of the reflectance data using procedures described by Shenk and Westerhaus (1991). Calibration samples were analyzed in triplicate for IVDMD using the filter bag method of Vogel et al. (1999). Laboratory means were used to develop a calibration equation for IVDMD by partial least squares (Shenk and Westerhaus, 1991), which was used to predict the IVDMD concentrations of the forage samples from the yield trials. Rumen fluid for all tests was obtained from the Animal Science Department at the University of Nebraska.

Characteristics

Agronomic and Botanical Description

Newell is a steppe or southern ecotype octaploid smooth bromegrass cultivar. Because of its genetic background, it is similar to Lincoln in appearance and maturity. Because of the similarity to Lincoln, only certified seed of Newell should be used in commercial planting to ensure its genetic integrity.

Forage Yields and Quality

In the Northern Plains trials, Newell had the greatest forage yield numerically of all the tested bromegrass lines averaged across all locations (Table 2). Forage yields of Newell were significantly greater than those of 'Manchar' and NE BI1 C2 averaged across all locations. NE BI1 C2 is a composite breeding population based on four high-yielding plant introductions. Newell had significantly greater forage yield than Lincoln at Mandan, ND (Table 2). In the three trials in which harvested forage was analyzed for IVDMD, Newell had significantly greater first harvest IVDMD than did Lincoln at Mead, NE (Table 3). Newell's forage had greater second harvest IVDMD at Mead, NE, and greater IVDMD at Sidney, NE, and Mandan, ND, for the single harvest at those locations than forage of Lincoln, although the differences were not significantly different at $p \leq 0.05$ (Table 3). It did not differ from Lincoln at the Nebraska locations for forage yield.

Pasture Trial

Beef yearlings grazing Newell had significantly greater average daily gains and gains per hectare than cattle grazing Lincoln smooth bromegrass for the 3-yr period 2011 to 2013 (Table 4). The increased gain per hectare for Newell resulted in an additional \$30 ha^{-1} in net return. Although these net returns are quite conservative and represent only 15% of the current market value of yearling steers in the United States, they demonstrate the economic value of genetic improvements in forages. The more than 10% increase in average daily gains and gain per hectare is attributed to the small improvement in IVDMD in Newell compared with Lincoln. In a review of previous research with other cool- and warm-season grasses, a one percentage unit breeding improvement in IVDMD led to a 3.5% improvement in cattle gains (Casler and Vogel, 1999).

Discussion

The primary data supporting the release of Newell are the results of the 3-yr grazing trial. The results of the regional small plot yield trials document that its broad adaptation is similar to that of Lincoln, from which Newell was developed by four generations of recurrent breeding for IVDMD and forage yield. The breeding work for both IVDMD and forage yield enabled a small improvement in IVDMD to be achieved while maintaining or in some instances making small improvements in forage yield. The breeding cycle 3 progenitor (Lincoln-HDMDYD-C3) of Newell was included in a study evaluating latitudinal and longitudinal adaptation of smooth bromegrass in the north-central and northeastern United States (Casler et al., 2000, 2001). In

Table 2. Total forage yields for smooth bromegrass strains in the Northern Plains Area cool-season grass trials for the 3-yr period 2001 to 2003. Data for Mead, NE, are the total of first harvest and regrowth yields and include harvest data from 2000.

Entry	Blue Creek, UT†	Green Canyon, UT†	Mandan, ND	Miles City, MT	Mead, NE	Sidney, NE	Mean
	kg ha^{-1}						
Manchar	778	1380	2048	872	5598	1823	2390
NE BI1 C2	777	1994	3536	1072	6558	2681	3092
NE BI2 C0	1134	1906	2982	1426	7105	2908	3257
Lincoln HDMD C4	781	2021	3249	1401	7417	2641	3288
Lincoln	1201	1856	2484	1633	7729	2806	3328
NE BI4 C2	1041	2001	2909	1897	7099	3070	3347
Newell	1066	2115	3325	1979	7650	2314	3457
LSD (0.05)	342	504	630	514	878	683	315

† Other grass species are better adapted to these locations.

Table 3. Forage yields and in vitro dry matter digestibility (IVDMD) for smooth bromegrass experimental strains and cultivars at Mead and Sidney, NE, and Mandan, ND, in replicated (r = 4) small plot yield trials during the period 2000 to 2004.

Cultivar or strain	Mead, NE†				Sidney, NE		Mandan, ND	
	Harvest 1		Harvest 2		Harvest 1		Harvest 1	
	Yield	IVDMD	Yield	IVDMD	Yield	IVDMD	Yield	IVDMD
	Mg ha^{-1}	mg g^{-1}	Mg ha^{-1}	mg g^{-1}	Mg ha^{-1}	mg g^{-1}	Mg ha^{-1}	mg g^{-1}
Lincoln	7.93	673	0.47	690	2.81	685	2.48	605
Lincoln HDMD C4	7.61	665	0.36	682	2.76	692	3.25	607
Newell	7.82	681	0.49	702	2.56	696	3.32	607
Manchar	5.73	664	0.34	699	2.27	698	2.05	555
NE BI1 C2	6.65	697	0.51	710	2.68	697	3.54	596
NE BI2 C0	7.31	663	0.43	708	2.91	685	2.98	585
NE BI4 C2	7.26	665	0.40	674	3.07	701	2.91	605
SE	0.19	3	0.09	8	0.22	2	0.22	7
LSD (0.05)	0.52	9	0.26	23	0.60	ns	0.63	19
LSD (0.10)	0.43	8	0.22	20	0.51	ns	0.62	16

† Mead harvest 1 (post-heading) means are averages over years 2000, 2001, 2002, and 2003; Mead harvest 2 (late fall regrowth harvests) are means for 2001 and 2002; Sidney harvest 1 means are averages of 2001, 2002, and 2003; Mandan harvest 1 mean yields are averages of 2001, 2002, and 2003, and Mandan IVDMD values are means of 2002 and 2003.

these studies, both Lincoln-HDMDYD-C3 and Lincoln were broadly and positively adapted to the entire north-central and northeastern United States for forage yield. In those trials, Lincoln-HDMDYD-C3 averaged numerically greater IVDMD than Lincoln (statistical difference was not reported). Newell is expected to perform better than Lincoln in these regions. Grass varieties that have performed well in trials at the University of Nebraska ARDC, which is in the western Corn Belt, have performed well in trials in the midwestern and northeastern United States (Casler et al., 2000, 2001; Hopkins et al., 1995; Vogel et al., 2014).

Recommended Areas of Use

Newell is adapted to all regions of the United States and other countries where Lincoln smooth bromegrass has been used previously. In the United States, this includes areas north of 40° N and east of 100° W. that have 500 mm or more annual precipitation or in areas that have similar climate conditions because of elevation. It is not adapted to areas with prolonged flooding or saturated soils.

Seed Availability

Newell is a stable, improved random mated population and will be maintained and increased accordingly. Newell was officially released by the USDA–ARS and the Agricultural Research Division of the University of Nebraska on 8 Mar. 2014. Breeder seed will be jointly maintained and produced by the USDA–ARS and the University of Nebraska–Lincoln with random-mated, isolated increase fields originating from Syn 1 breeder seed. Foundation seed production of Newell will be managed by Husker Genetics, the Foundation Seed Division of the University of Nebraska–Lincoln, Lincoln, NE. Foundation seed will be made available for certified seed production on a nonexclusive basis to seed producers who contractually agree to produce and market the seed only as certified seed using the cultivar name Newell. Small quantities of seed for research purposes may be obtained from USDA–ARS, Lincoln, NE. A technology development and transfer fee will be assessed by the University of Nebraska. Seed of Newell has been deposited in the National Plant Germplasm System, where it will be available for research purposes.

Table 4. Mean beef cattle yearling average daily gains (ADG), gains per hectare, and mean net return per hectare for fertilized smooth bromegrass pastures at Mead, NE, in 2011, 2012, and 2013. Pastures were planted in 2009 and grazed for 31 d in 2011, 37 d in 2012, and 43 d in 2013. Stocking rate was three steers per 0.4-ha pasture, with three replicates per strain per year.

Strain	ADG	Gain ha^{-1} yr^{-1}	Mean net return†
	kg animal^{-1} d^{-1}	kg	$ ha^{-1} yr^{-1}
Lincoln	1.25	347	229
Newell	1.43	392	259
Paired t test Prob > t	0.04	0.05	
SE	0.07	20	

† Net return ($ ha^{-1} yr^{-1}) calculated as mean body weight gain ha^{-1} × $0.66 kg^{-1} gain (Mitchell et al., 2005). Net return included 67 to 112 kg N ha^{-1} yr^{-1} fertilizer costs.

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