Selection and Improvement of Teff Accessions for Improved Forage Growth, Yield, and Nutritional Quality, 2009

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Introduction

As we described previously and elsewhere in this annual report, teff (*Eragrostis tef* [Zucc.], *Poaceae)* is a warm season (C_4) annual tropical grass that can produce good quality forage during a short summer time frame, and thus has the potential to be a viable crop choice when forage producers: a) desire a quick-growing, high quality mid-summer annual forage; b) foresee less-than full season irrigation water supply; c) need an emergency crop due to crop failure; or d) need a one-year forage rotation crop between alfalfa stands. We began growing teff in a quasi-commercial field setting in 2003, and

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began more rigorous testing of teff's agronomic requirements in 2005 after unprecedented response from a popular press article about our early efforts indicated widespread national interest in this 'new' alternative forage crop (Zenk, 2005; Roseberg et al., 2006).

Despite the promising results seen thus far, there are very few commercially available brands of teff seed. Much of the teff available in commerce is common landraces, not released varieties, and thus have varying degrees of uniformity and performance. Despite the genetically narrow and uneven commercial seed supply, the USDA germplasm system contains many accessions collected from teff's native habitat in east Africa. These accessions include a wide range of plant morphological types, seed color, and other characteristics. Until recently, most interest in teff has focused on its qualities relative to the seed used in human food (mainly injera, a staple of Ethiopian cuisine), but not its forage qualities. Because of this lack of germplasm evaluation and varietal development, we decided to begin a multi-year evaluation of teff accessions to evaluate the range of yield, quality, and morphological factors available, with the goal of selecting improved cultivars for possible release as commercial seed brands. 2009 was the fourth year of this effort.

Objective

To evaluate the available accessions of teff with a goal of documenting forage growth, yield, quality, and other parameters, and to begin selecting, and saving seed from superior types, with the eventual goal of releasing improved teff seed brands to the commercial market.

Procedures

Based on our results in 2006, we narrowed down the list of likely successful teff accessions from the original 367 accessions to about 90. Based on seed availability, in 2007 we obtained and seeded 73 accessions using new seed obtained from the USDA-ARS, Western Region Plant Introduction Station in Pullman, WA (Roseberg et al., 2007). Out of those 73 accessions, we selected 38 that looked promising and seeded those in 2008 using seed harvested from the previous year's study (Roseberg et al., 2008). For 2009, we used the seed harvested from superior plants from within each of the 11 most promising accessions from 2008. Commercially available teff seed brands (VAT-1 and Pharoah), that we also grew in the concurrent seed brand trial, were seeded in the same way as the numbered accessions to provide a comparison with commercially available seed types.

In 2009, we evaluated the morphological characteristics and relative maturity of these accessions, and harvested seed, separately from the forage yield and quality study. To do this we seeded two trials side by side as follows. In the morphology/seed trial the 11 accessions and one control brand were seeded in randomized complete block design with two replications. As the season progressed, observations were made regarding

relative maturity, seedhead color, and any other distinctive characteristics. To evaluate the forage yield and quality of these accessions we also seeded the 11 accessions and two control brands in a separate trial. The forage yield and quality trial was arranged in a randomized complete block design with three replications.

Seed was planted at about ¼ inch depth at a seeding rate of 6 lb/ac with a Kincaid (Kincaid Equipment Mfg) research seed drill. The accession forage trial was seeded on June 11, while the morphology/seed trial was seeded on June 12, 2009. The plots were 20.0 by 4.5 ft, (9 rows at 6-inch spacing), with a harvested area of 14.0 by 3.0 ft. The trial was fertilized with 55 lb/ac N, 16 lb/ac P2O5, and 60 lb/ac S banded at seeding (applying a custom blend of 19.7-5.6-0-21.5 fertilizer at 280 lb/ac). A tank mix of fluroxypyr (Starane®) herbicide was applied at 1.0 pint/ac (0.19 lb a.i./ac) with a commercial mixture of 2,4-D and dicamba (Weedmaster®) herbicide applied at 3.0 pint/ac (0.38 lb a.i./ac of dicamba plus 1.07 lb a.i./ac of 2,4-D) on July 16. No crop injury was apparent at any time after spraying.

Precipitation and other weather data were measured by the US Bureau of Reclamation Agricultural Meteorological (AgriMet) automated weather station at KBREC (US Bureau of Reclamation, 2009). Using solid-set handlines, a total of 11.73 inches of irrigation was applied on 12 dates between June 22 and August 20. Rainfall amounts totaled 1.84 inch in June, 0.17 inch in July, 0.20 inch in August, and none in September.

Forage Yield and Quality Trial

For the forage yield and quality trial, cutting date was chosen based on overall physiological maturity of the accessions. Thus the plots were cut when seedheads were just beginning to emerge. Using these criteria, all plots were harvested for the first time on August 4, and for the second time on September 9. Within a few days after the first harvest, ammonium sulfate was applied at 255 lb/ac (supplying 54 lb/ac N and 61 lb/ac S).

Forage fresh weights were measured immediately in the field and samples were collected from each plot for drying to correct yields to a dry weight basis as well as perform forage quality analysis. After drying and weighing, samples were ground to 2-mm-sieve size in a Wiley Mill (Arthur H. Thomas Co.) and to 1-mm-sieve size in an Udy Mill (UDY Corporation) before being analyzed in a near infrared spectrophotometer (NIRS) (NIRSystems, FOSS, NA, Minneapolis, MN) to determine forage quality. Quality testing at KBREC was accomplished using the NIRS and equations developed by the NIRS Consortium, Madison, WI (NIRS Consortium, 2007). We used NIRS equations developed for other grasses due to the limited data available for teff. Reported forage quality parameters included crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF), relative feed value (RFV) and relative forage quality (RFQ).

Morphology and Seed Production Trial

Periodically during the season, observations were recorded regarding plant height, stem/leaf morphology, leaf color, seedhead color, relative maturity (indicated by time of seedhead development), lodging, and any other distinctive features observed. On Sept. 30, plots were cut with a walk-behind Suzue grain binder (Willamette Exporting, Inc., Portland, OR), and placed in porous bags to hang dry. After selection of superior entries were made based on forage yield, quality, growth and morphological data, seed from superior plants and all other plants within each selected plot were cleaned as follows. First, seed was threshed using a small scale hammer mill (using a #1/2 screen). Second, seed was separated from coarse material using hand-held seed screens. Third, seed was further cleaned with a Clipper table-top seed cleaner (the first pass through used a #8 screen on top and a #6/38 screen on bottom, and the second pass through used a #24 screen on top and a #6/38 screen on bottom). Clean seed yield was calculated for these retained accessions, and the seed from selected superior plants groups was retained for future evaluation and selection.

Results & Discussion

Forage Yield Results

Observed differences in yield between teff accessions were not statistically significant for first cutting, or second cutting. However, observed differences in annual total yield were statistically different (Tables 1 and 2). Overall, first cutting yielded more than second cutting.

First cutting dry matter yield ranged from 1.54 ton/ac to 2.53 ton/ac, with a mean of 2.03 ton/ac (Table 1). The commercial seed brand Pharoah was the highest yielding entry for first cutting; VAT-1 was the second highest yielding entry. While the yield values of the commercial seed brands used as checks were not used as an independent selection screen, they were used to confirm whether the other screens seemed to

accurately reflect superior-looking plant types. Second cutting dry matter yield ranged from 1.08 ton/ac to 1.77 ton/ac, with a mean of 1.49 ton/ac (Table 2). The commercial seed brands used as checks yielded slightly higher than the second cutting mean, but three numbered entries had equal or higher second cutting yields than the checks.

Annual total dry matter yield ranged from 2.71 ton/ac to 4.15 ton/ac, with a mean of 3.52 ton/ac (Table 2). The commercial seed brand Pharaoh had the highest annual yield, and VAT-1 was the second highest, mainly due to their strong first cutting yield in both cases.

Forage Quality Results

None of the differences in quality parameters between accessions as measured by NIRS were statistically significant at first cutting (Table 1). CP ranged from 12.1 to 15.2%, with a mean of 13.6%. ADF ranged from 35.8 to 39.0, with a mean of 37.4. NDF ranged from 55.8 to 60.1, with a mean of 53.3. RFV ranged from 91 to 101, with a mean of 97. RFQ ranged from 96 to 102, with a mean of 100.

The commercial seed brand Pharoah was above the mean for ADF and NDF and below the mean for CP, RFV, and RFQ. Quality values for VAT-1 were close to the trial mean. In general, RFQ values were much lower than the comparable seed brand trial grown nearby (see other report for those results).

At second cutting, differences in NIRS quality parameters between accessions were significantly different for ADF, NDF, and RFV (Table 2). CP ranged from 13.1 to 15.6%, with a mean of 14.3%. ADF ranged from 35.2 to 37.4, with a mean of 36.4. NDF ranged from 50.9 to 55.7, with a mean of 53.3. RFV ranged from 101 to 109, with a mean of 106. RFQ ranged from 101 to 105, with a mean of 103. It is not surprising that significant differences in ADF and NDF occurred along with significant differences in RFV, as RFV is calculated using the two fiber values.

For second cutting, Pharaoh was above the mean for ADF and NDF, below the mean for CP and RFV, and equal to the mean for RFQ. VAT-1 was above the mean for NDF, below the mean for CP and RFV, and very near the mean for RFQ and ADF.

Morphological Results

In earlier morphology evaluations in 2006 and 2007 we decided that the most desirable plant traits were tall (height), fine (stem & leaf width), erect (growth habit), and late-maturing (delayed seedhead formation). Thus, by 2008 most of the remaining selections were relatively tall, erect, and later-maturing, and so in 2008 and 2009 our selection process also considered features such lodging, seedhead/leaf color (for potential ornamental applications), cleaned seed color (an important characteristic for human food use), and the forage yield and quality results. In general, the selections that were retained from 2009 to 2010 were among the upper half in both protein and yield, and also had other favorable characteristics, or were kept for specialty reasons (e.g. if a potential ornamental selection had more intense purple seedhead or leaf color, or if a potential food

type had either very white or very dark seed color. One type that exhibited lower protein, but higher second cutting yield was also retained. In the end, seed from seven of the eleven 2009 selections were threshed, cleaned and retained for further evaluation and selection in 2010. In 2010 (or future) evaluations we hope to make a more accurate measure of potential seed production (an important factor whether teff seed is used for food or for forage seeding) in addition to forage yield and quality comparisons.

Conclusions

Because of the selections made in 2008 and 2009, there was not as much variability in growth characteristics as in the original set of accessions. However, some of the retained selections seemed to have quality characteristics or other features that were superior to seed brands that are currently available on the commercial market. While there no single accession was clearly superior in all factors measured on both cutting dates, the retained selections are generally 'better than average' for most (or all) parameters measured. Even among the small selected list retained for 2010, a couple appear to be better than others. For example selection #22 was among the best for both first and second cutting yield, as well as quality as measured by RFQ on both cutting dates. We plan to re-seed the superior group of seven accessions in 2010 using the cleaned seed from groups of superior plants from within the 2009 selections. In addition to conducting another round of selection based on morphology, forage quality, and forage yield in a standard replicated field trial, we also plan to more accurately measure potential seed yield of these accessions in a separate, replicated seed yield trial.

References

Roseberg, R.J., S. Norberg, J.E. Smith, B.A. Charlton, K.A. Rykbost, and C. Shock. 2006. Yield and quality of teff forage as a function of varying rates of applied irrigation and nitrogen. *In:* Research in the Klamath Basin 2005 Annual Report. OSU-AES Special Report 1069:119-136.

Roseberg, R.J., B.A. Charlton, and R.A. Shuck. 2007. Selection and improvement of teff Accessions for improved forage growth, yield, and nutritional quality, 2007. Klamath Basin Research & Extension Center Annual Research Report. http://oregonstate.edu/dept/kbrec/research-klamath-basin-2007-annual-report.

Roseberg, R.J., B.A. Charlton, and R.A. Shuck. 2007. Selection and improvement of teff Accessions for improved forage growth, yield, and nutritional quality, 2008. Klamath Basin Research & Extension Center Annual Research Report. http://oregonstate.edu/dept/kbrec/research-klamath-basin-2008-annual-report.

US Bureau of Reclamation, 2009. Agrimet: The Pacific Northwest cooperative agricultural weather network. http://www.usbr.gov/pn/agrimet/.

Zenk, Peg. 2005. Tons of teff. Hay & Forage Grower. February, p.4.

NIRS Forage and Feed Testing Consortium, June 2007 grass hay calibration, file name: gh50-2. Parameters used: DM, CP, ADF, dNDF48, NDF, Ca, P, K, Mg, Ash.

Table 1. Teff Accessions: 2009 Forage yield and quality- first cutting.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Accession Name	Dry Forage Yield			Crude Protein					RFQ	Heading	Height
	lb/ac	ton/ac	Rank	(%)	ADF	NDF	RFV	RFQ	Rank	(%)	(inch)
2	4448	2.22	3	13.3	38.2	58.5	94	100	8	63.3	33.3
9	4048	2.02	7	13.6	39.0	57.0	96	96	13	28.3	29.7
22	4125	2.06	5	12.1	37.7	57.8	96	102	1	13.3	28.0
41	4071	2.04	6	13.6	36.9	56.8	99	100	7	38.3	33.3
46	3879	1.94	9	15.2	35.8	56.2	101	99	9	36.7	33.7
53	4228	2.11	4	12.2	38.6	60.1	91	97	12	41.7	34.0
60	3742	1.87	11	13.8	36.9	58.4	96	98	11	16.7	35.3
66	3717	1.86	12	14.6	37.5	55.8	100	101	5	40.0	31.3
68	3774	1.89	10	14.3	37.2	56.4	99	101	3	40.0	30.3
70	3073	1.54	13	14.4	37.1	56.7	99	101	6	25.0	32.7
71	3943	1.97	8	14.3	36.3	55.9	101	101	4	11.7	27.3
VAT1	4536	2.27	2	13.7	36.9	58.7	95	101	2	18.3	31.3
Pharaoh	5069	2.53	1	12.2	38.3	60.1	92	98	10	16.7	30.7
Mean	4050	2.03		13.6	37.4	57.6	97	100		30.0	31.6
***P* Value**	**0.380**	**0.380**		**0.194**	**0.368**	**0.251**	**0.365**	**0.768**		**0.066**	**0.005**
LSD(0.05)	NSD	NSD		NSD	NSD	NSD	NSD	NSD		NSD	3.8
CV (%)	19.2	19.2		10.1	3.9	3.8	5.5	3.8		60.6	7.1

Table 2. Teff Accessions: 2009 Forage yield and quality- second cutting and annual yield total.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

Accession Name	Dry Forage Yield			Crude Protein				RFQ	RFQ Rank	Heading	Height	Annual Total Dry Forage Yield		
	lb/ac	ton/ac	Rank	(%)	ADF	NDF	RFV			(%)	(inch)	lb/ac	ton/ac	Rank
2	3296	1.65	3	14.0	37.1	54.9	102	101	13	5.3	15.0	7745	3.87	3
9	2592	1.30	11	14.5	37.1	52.5	106	103	8	10.0	15.3	6639	3.32	10
22	3488	1.74	2	13.2	36.7	53.2	105	105	2	8.3	15.3	7613	3.81	4
41	2871	1.44	10	14.8	36.2	52.7	107	102	10	13.3	16.7	6943	3.47	7
46	2965	1.48	8	15.2	35.2	52.4	109	104	3	8.0	17.3	6844	3.42	8
53	3122	1.56	6	13.9	36.5	53.9	104	102	11	1.7	14.7	7350	3.68	6
60	3083	1.54	7	14.5	35.9	53.3	106	101	12	4.0	16.7	6826	3.41	9
66	2877	1.44	9	15.0	36.1	52.0	109	105	1	6.7	16.7	6594	3.30	11
68	2159	1.08	13	15.6	35.7	50.9	112	104	4	3.7	15.0	5933	2.97	12
70	2356	1.18	12	15.2	35.9	52.0	109	103	9	4.0	13.7	5429	2.71	13
71	3548	1.77	1	13.2	36.6	54.6	103	103	5	4.3	16.7	7491	3.75	5
VAT1	3283	1.64	4	13.3	36.8	55.7	101	103	7	7.3	14.7	7819	3.91	2
Pharaoh	3223	1.61	5	13.1	37.4	54.3	102	103	6	1.7	15.0	8292	4.15	1
Mean	2989	1.49		14.3	36.4	53.3	106	103		6.0	15.6	7040	3.52	
***P* Value**	**0.186**	**0.186**		**0.106**	**0.003**	**0.004**	**0.003**	**0.796**		**0.211**	**0.526**	**0.007**	**0.007**	
LSD(0.05)	NSD	NSD		NSD	1.0	2.1	5	NSD		NSD	NSD	1285	0.64	
CV (%)	19.7	19.7		8.0	1.6	2.3	2.9	2.9		80.2	12.5	10.8	10.8	