Selection and Improvement of Teff Accessions for Improved Forage Growth, Yield, and Nutritional Quality, 2008

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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

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alfalfa stands. We began growing teff in a quasi-commercial field setting in 2003, and 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. Most 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 for 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. 2008 was the third 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 limited seed availability of some accessions, in 2007 we obtained and seeded 73 accessions using new seed obtained from the USDA-ARS, Western Region Plant Introduction Station in Pullman, WA. Of those 73 accessions, we selected 38 that looked promising and seeded those in 2008 using seed harvested from the 2007 study (Roseberg et al., 2007). Two named teff seed brands (VAT-1 and Tiffany), 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.

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 described below. In the morphology/seed trial the 38 accessions and two control brands were planted in un-replicated blocks. 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 38 accessions and two control brands in a separate forage yield/quality trial. In addition, to observe teff's response in mixed stands, we also seeded four teff mixes in the forage trial in 2008, consisting of two accessions each, combining complementary features of different accessions that we thought would make a useful blend of morphological features that might appeal to specific end users. The forage yield and quality trial was arranged in a randomized complete block design with two replications.

For both trials, teff 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 on June 13, 2008. 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. All plots were fertilized with 50 lb/ac N, 50 lb/ac P_2O_5, 50 lb/ac K_2O, and 63 lb/ac S banded at seeding (applying 12-12-12-15 fertilizer at 417 lb/ac). A tank mix of fluroxypyr (Starane®) herbicide was applied at 1.3 pint/ac (0.25 lb a.i./ac) with a commercial mixture of 2,4-D and dicamba (Weedmaster®) herbicide applied at 2.0 pint/ac (0.25 lb a.i./ac of dicamba plus 0.72 lb a.i./ac of 2,4-D) on July 23. No crop injury was apparent at any time after spraying.

Using solid-set handlines, total of 12.15 inches of irrigation was applied on nine dates between June 13 and September 4. Rainfall amounts totaled 0.66 inch in June, 0.03 inch in July, 0.20 inch in August, and none in September before the second harvest date.

Forage Yield and Quality Trial

For the forage yield and quality trial, cutting date was chosen based on physiological maturity of a predominant number of the accessions. Thus the plots were cut when seedheads of most of the accessions were just beginning to emerge. Using these criteria, all plots were harvested for the first time on August 6, and for the second time on September 4. 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 NIRS 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 leaf color, seedhead color, relative maturity (indicated by time of seedhead development) and any other distinctive features observed. On Sept. 23, plots were cut with a walk-behind Suzue grain binder (Willamette Exporting, Inc., Portland, OR.), and placed in porous bags to hang dry. After selections were made based on forage yield, quality, growth and morphological data, seed from these retained selections was threshed using a small scale hammer mill (using a #1/2 screen). Seed was then cleaned using hand-held seed screens to remove coarse material, followed by the first pass through a Clipper table-top seed cleaner (using a #8 screen on top and #6x38 on bottom) and then a second pass through the Clipper (with a #24 screen on top and a #6x38 on bottom).

Results and Discussion

Forage Yield Results

Observed differences in yield between teff accessions were not statistically significant for first cutting, second cutting or annual total yield (Table 1). Statistical significance between treatments is difficult to achieve in trials such as this that have only two replications. Overall, second cutting yielded slightly more than first cutting, even though nearly half the entries yielded higher in first cutting.

First cutting dry matter yield ranged from 0.7 ton/ac to 2.6 ton/ac, with a mean of 1.4 ton/ac. The commercial seed brand Tiffany was the highest yielding entry for first cutting. The other commercial entry (VAT-1) yielded slightly less than average. While the yield values of the commercial seed brands used as controla 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 1.1 ton/ac to 2.2 ton/ac, with a mean of 1.5 ton/ac. The yield of Tiffany and VAT-1 were both very close to the overall second cutting mean.

Annual total dry matter yield ranged from 1.9 ton/ac to 4.0 ton/ac, with a mean of 2.8 ton/ac. The commercial seed brand Tiffany was the highest yielding entry, thanks to its very high first cutting yield. VAT-1's annual total yield was slightly lower than the mean.

Overall mean yields for first cutting, second cutting, and annual total yield were fairly similar to yields in our 2008 teff seed brand trial from the same seeding date, which was grown under the same conditions nearby. The total yield of VAT-1 was nearly identical in both trials. However, Tiffany had a much higher first cutting yield in this accession forage trial, resulting in Tiffany's total yield to be about one ton per acre higher in the forage accession variety trial than in the seed brand by seeding date trial, and about half a ton per acre higher than the second-highest yielding entry in this accession forage trial. With only two replications, one unusually productive plot could skew the results in this manner.

For most entries, yield at one cutting was higher than at the other, suggesting that some accessions have good early vigor, whereas others have better regrowth vigor (Table 1). A few, such as accessions #46 and #48, had good and nearly equal yields at both cuttings. However, only accession #2 was among the top 10 entries in yield for both cutting dates. The mixed teff accession entries did not provide any consistent improvement in yield compared to the individual response of one or the other of the accessions in the mix.

Forage Quality Results

Crude protein as measured by NIRS quality analysis ranged from 11.4% to 17.4%, with a mean of 14.1% for first cutting, and ranged from 13.7% to 17.8%, with a mean of 15.8% for second cutting (Table 2). ADF ranged from 30.6 to 36.6, with a mean

of 33.8, for first cutting, and ranged from 32.5 to 37.4, with a mean of 35.6 for second cutting. NDF ranged from 45.7 to 57.5, with a mean of 53.3, for first cutting, and ranged from 50.5 to 57.0, with a mean of 53.3 for second cutting (NDF mean was the same for both cuttings).

RFV ranged from 98.5 to 130.1, with a mean of 110.0, for first cutting, and ranged from 98.2 to 115.1, with a mean of 104.7 for second cutting (Table 3). RFQ ranged from 100.9 to 117.0, with a mean of 109.9, for first cutting, and ranged from 96.7 to 109.0, with a mean of 102.1 for second cutting.

For first cutting, the commercial seed brand VAT-1 was above the mean for CP, RFV, and RFQ, and below the mean for ADF and NDF. Tiffany was above the mean for ADF and NDF, and below the mean for CP, RFV, and RFQ.

For second cutting, VAT-1 was above the mean for CP, RFV, and RFQ, and below the mean for ADF and NDF. Tiffany was above the mean for ADF, NDF, and RFQ, and below the mean for CP and RFV.

Morphological Results

In previous 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 our selection process also considered features such lodging, seedhead/leaf color (for potential ornamental applications), and cleaned seed color (an important characteristic for human food use). We also incorporated the yield and quality trial data to help make selections for 2009 (data not shown). In general, the selections that were retained from 2008 to 2009 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. In the end, seed from superior groups of plants within the best 11 selections were threshed, cleaned and retained for further evaluation and selection in 2009.

Conclusions

Because of the selections made in 2007, there was not as much variability in growth characteristics in the 2008 selections. However, there was still a fairly wide variation in forage yield and quality among the selections in 2008. Some of them seemed to have quality characteristics that were superior to seed brands that are currently available on the commercial market. While there were no accessions that were clearly superior in all factors measured, a careful evaluation of the factors resulted in selections that were at least ‘better than average’ for most (or all) parameters measured, and were typically superior in at least one some aspect. From these selections, we plan to re-plant the best candidates in 2009 using the saved, cleaned seed from superior plants of the 2008

selections. In addition to conducting another round of selection and seed collection based on morphology and forage quality, we plan to repeat the replicated forage yield trial using standard forage yield plot methods to get a more accurate measurement of forage yield.

References

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Table 1. 2008 Yield summary for the teff accession forage trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

	Yield (lb/ac) O.D.					
Entry Name	Cut 1	Rank	Cut 2	Rank	Total Yield	Rank
1	4022	2	2405	38	6430	7
2	3645	5	3418	5	7060	2
3	2471	26	2508	36	4980	37
5	2398	28	2914	24	5310	30
9	2915	20	2662	31	5580	23
11	2140	33	2594	34	4730	39
16	3282	8	2418	37	5700	21
22	2046	35	4383	1	6430	7
23	3141	10	2848	27	5990	14
27	1795	42	3286	8	5080	36
28	2942	17	2632	32	5570	24
31	2363	29	2900	25	5260	31
33	2208	32	2708	29	4920	38
34	2115	34	3087	17	5200	33
36	1919	37	2346	40	4270	40
37	2287	31	3225	10	5510	26
38	1907	38	3264	9	5170	34
41	3806	3	3137	14	6940	3
42	1850	40	3703	2	5550	25
43	3020	14	2396	39	5420	28
46	3307	7	3188	12	6490	6
47	2021	36	3189	11	5210	32
48	3055	12	3332	7	6390	9
49	2547	24	2614	33	5160	35
53	3752	4	3118	15	6870	4
54	1859	39	2198	44	4060	42
55	3006	15	2718	28	5720	20
56	3093	11	2557	35	5650	22
58	2948	16	3139	13	6090	11
60	3245	9	2959	20	6200	10
62	1405	44	2300	42	3700	44
66	1771	43	2198	43	3970	43
68	3054	13	2920	23	5970	16
69	2941	18	2888	26	5830	19
70	2532	25	3454	4	5990	14
71	2437	27	3534	3	5970	16
72	1838	41	2311	41	4150	41
73	2658	23	3380	6	6040	12
VAT-1	2350	30	2986	18	5340	29
Tiffany	5142	1	2929	22	8070	1
38x46	2769	22	2697	30	5470	27
42x71	2905	21	3104	16	6010	13
46x47	3529	6	2974	19	6500	5
46x60	2930	19	2935	21	5870	18
Mean	2713		2919		5632	
***P* value**	**0.261**		**0.908**		**0.812**	
LSD (0.05)	NSD		NSD		NSD	
CV (%)	34.5		26.3		24.9	

Table 2. 2008 Crude protein, acid detergent fiber, and neutral detergent fiber summary for the teff accession forage trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

	Crude Protein				ADF				NDF			
Entry Name	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank
1	12.0	39	15.8	21	34.5	11	35.8	18	53.7	22	56.2	8
2	12.7	35	16.4	14	34.4	13	36.3	12	51.6	33	55.1	14
3	15.6	10	16.2	16	32.4	37	34.8	37	49.8	39	53.9	31
5	15.4	13	16.5	12	33.4	31	35.8	17	55.1	12	54.1	29
9	12.9	33	16.2	17	34.9	8	35.4	23	54.4	20	54.8	16
11	13.0	31	15.1	33	34.1	16	35.3	31	53.6	23	54.3	24
16	13.2	29	14.7	38	34.3	14	36.6	8	54.8	19	56.6	5
22	17.3	2	13.7	44	30.6	44	35.8	16	47.5	43	56.8	3
23	11.6	42	15.1	35	35.1	7	35.6	19	55.7	9	55.4	11
27	15.7	9	15.9	20	32.3	39	35.2	33	49.6	40	54.5	21
28	14.0	22	17.2	3	34.1	17	34.8	38	51.2	34	52.5	39
31	15.9	7	15.6	24	32.1	42	34.5	42	53.1	26	54.4	22
33	13.5	27	15.1	33	34.5	12	36.2	14	52.0	31	54.2	25
34	13.7	24	16.1	18	34.9	9	35.4	24	54.9	16	53.7	32
36	12.4	37	15.3	32	33.9	22	35.3	28	49.4	41	54.2	27
37	14.4	19	15.7	23	33.8	25	35.4	22	54.9	17	54.2	28
38	16.6	5	15.4	29	32.2	41	35.2	32	50.7	36	52.5	40
41	11.9	40	14.5	40	35.9	3	37.1	2	56.9	3	55.8	9
42	16.0	6	14.6	39	32.5	36	36.9	4	53.0	27	55.3	12
43	12.9	32	16.4	13	33.5	30	35.6	21	55.1	13	53.5	34
46	13.7	25	15.4	30	32.8	34	35.1	34	54.9	18	54.8	17
47	13.3	28	14.7	37	33.9	20	36.8	5	51.8	32	56.5	6
48	14.6	18	14.2	42	33.6	28	37.4	1	54.9	14	54.7	18
49	15.6	11	17.0	5	32.7	35	32.5	44	53.4	24	51.4	43
53	14.1	20	15.9	19	33.5	29	35.4	25	56.0	5	54.9	15
54	13.2	30	15.0	36	33.9	19	36.4	10	49.0	42	53.7	33
55	11.7	41	15.4	27	34.9	10	36.7	7	55.8	8	54.3	23
56	11.4	44	14.0	43	35.4	5	37.0	3	57.5	1	56.9	2
58	12.7	34	15.4	27	35.7	4	36.6	9	54.9	15	56.7	4
60	15.2	14	16.9	7	33.9	21	34.9	36	55.7	10	53.0	36
62	17.4	1	16.8	8	32.4	38	35.3	29	45.7	44	52.8	38
66	16.9	3	17.1	4	31.6	43	34.0	43	49.9	38	50.5	44
68	15.8	8	16.3	15	34.3	15	34.9	35	52.1	30	51.7	42
69	11.4	43	15.5	26	36.6	1	36.7	6	57.0	2	56.5	7
70	12.5	36	17.8	1	35.3	6	34.8	39	55.1	11	51.7	41
71	14.7	17	15.3	31	33.7	26	35.4	26	52.6	28	55.3	13
72	14.8	16	16.6	11	33.8	24	35.4	27	52.3	29	54.5	19
73	15.5	12	14.2	41	33.0	33	36.3	11	51.1	35	55.8	10
VAT-1	16.8	4	17.6	2	32.2	40	34.7	40	50.1	37	52.9	37
Tiffany	12.4	38	15.5	25	36.5	2	36.0	15	56.8	4	57.0	1
38x46	13.9	23	16.8	9	33.8	23	35.3	30	55.9	7	53.5	35
42x71	14.9	15	16.7	10	33.0	32	35.6	19	53.4	24	54.5	20
46x47	13.6	26	15.7	22	33.7	27	36.2	13	54.3	21	54.1	30
46x60	14.0	21	17.0	6	34.0	18	34.6	41	55.9	6	54.2	26
Mean	14.1		15.8		33.8		35.6		53.3		54.4	
***P* value**	**0.171**		**0.529**		**0.280**		**0.233**		**0.424**		**0.004**	
LSD (0.05)	NSD		NSD		NSD		NSD		NSD		2.9	
CV (%)	14.6		8.9		4.9		3.3		7.0		2.7	

Table 3. 2008 Relative feed value and relative forage quality summary for the teff accession forage trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

	RFV				RFQ			
Entry Name	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank
1	107	25	101	36	108	31	99	39
2	112	15	102	32	107	33	97	42
3	120	3	107	11	117	3	107	3
5	106	28	105	21	113	12	101	25
9	106	30	104	27	111	19	105	7
11	109	22	105	17	109	26	97	44
16	107	24	99	42	107	34	105	8
22	127	2	100	38	118	1	102	22
23	103	39	103	31	109	29	102	19
27	120	5	105	20	115	5	105	6
28	118	8	110	5	105	39	99	40
31	112	13	106	14	113	10	106	5
33	111	18	104	26	112	15	102	18
34	105	34	106	15	110	21	100	32
36	118	9	105	16	108	30	109	1
37	106	27	105	19	113	9	104	11
38	117	10	109	6	110	20	100	31
41	100	41	100	37	106	37	100	36
42	112	14	101	34	117	4	103	13
43	106	31	106	12	114	6	107	4
46	108	23	105	22	112	13	103	15
47	112	12	99	41	114	8	97	43
48	106	29	102	33	110	22	98	41
49	110	20	115	1	114	7	109	2
53	105	33	104	28	113	11	104	11
54	119	6	105	18	109	27	100	33
55	103	40	103	29	104	42	100	30
56	99	42	98	44	105	40	101	28
58	105	35	99	43	106	38	101	29
60	105	32	109	7	106	35	100	38
62	130	1	109	9	109	23	102	21
66	120	4	115	2	117	2	103	17
68	111	17	111	4	106	36	102	23
69	99	44	99	40	101	44	101	27
70	104	38	111	3	105	41	103	16
71	111	19	103	30	109	25	102	20
72	111	16	105	23	111	17	104	9
73	115	11	101	35	112	16	101	25
VAT-1	118	7	109	8	111	18	103	14
Tiffany	99	43	99	39	102	43	104	10
38x46	104	36	107	10	109	24	102	24
42x71	110	21	104	25	112	14	100	37
46x47	107	26	104	24	108	32	100	35
46x60	104	37	106	13	109	27	100	34
Mean	110		105		110		102	
***P* value**	**0.285**		**0.021**		**0.660**		**0.097**	
LSD (0.05)	NSD		8		NSD		NSD	
CV (%)	8.6		4.0		5.6		3.3	