Yield and Forage Quality of Six Teff Seed Brands as Affected by Seeding Date in the Klamath Basin, 2008

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Introduction

There are times when forage producers desire a quick-growing, high quality annual forage in mid-summer in situations such as: less-than full season irrigation water supply; need for an emergency crop due to crop failure; or forage rotation crop between alfalfa stands. Currently there are few good options in these situations. Teff is a warm season annual grass that can produce good quality forage during a short, summer time frame, and thus has the potential to be a viable alternative in such situations. Starting in 2003, we have grown teff in quasi-commercial fields and then in small plot research trials at the Klamath Basin Research & Extension Center (KBREC). As we study various

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management options, it has become clear that ongoing research is needed to understand the optimum crop production requirements for this new crop.

Teff (*Eragrostis tef* [Zucc.], *Poaceae)* is a C_4 annual tropical grass. Teff is traditionally harvested for grain in Ethiopia, where it was first domesticated between 4000–1000 BC. Teff flour is preferred in the production of injera, a major food staple in Ethiopia. Teff is grown on a limited basis for livestock forage in other parts of Africa, India, Australia and South America. In the US, small acreages of teff are grown for grain production and sold to Ethiopian restaurants throughout the country. Teff grain is sold in some grocery stores as well. Since the popular press article describing our early efforts was published (Zenk, 2005), many growers, hay buyers, seed companies, and research/extension faculty at other universities have begun studying, growing, or buying this new crop. A recent follow-up article has documented increased national interest in this crop (Zenk, 2008). While our interest in teff has been primarily as a forage, teff's traditional use in food has also received renewed interest due to its very low levels of gluten. Approximately 1 million Americans suffer from Celiac disease (gluten sensitivity) and teff may provide a niche for meeting these dietary requirements as a gluten-free food source.

For a more detailed discussion about teff's history, characteristics, and uses, as well as our early experiences and experiments with this new crop, please refer to our 2005 annual report (Roseberg et al., 2006).

Objectives

Much of the teff available in commerce is common landraces, not released seed brands, and thus has varying degrees of uniformity and unknown performance. Because several seed brands have been marketed in recent years, we realized that a controlled comparison of these commercial seed types was necessary to better understand the genetic diversity and to better advise growers on seed choices. While it has been established that teff is not tolerant to killing frosts at any growth stage, the effects of cool soil and air temperatures during germination and seedling growth is not well understood. Thus, the objective of this study was to evaluate six seed brands seeded on three dates in the spring to evaluate how growth, yield, and quality are affected by date of seeding (thus the differences in weather they would experience during the growing season). This study builds upon results with four commercial seed brands seeded on four dates in 2007 (Roseberg et al., 2007).

Procedures

The trial was planted at the KBREC research farm on a Poe fine sandy loam soil. The previous crop was potatoes in 2007. The teff seed brands tested in this experiment were 'Dessie' and 'Pharaoh' from First Line Seeds (Moses Lake, WA), 'VAT-1' from Hankins Seed (Bonanza, OR), 'Tiffany' from Target Seeds (Parma, ID), 'Emerald' from Green Valley Seed (Kahoka, MO), and 'Excalibur' from United Seed Services (Caldwell, ID). The experiment was laid out as a randomized complete block with four replications of each seed type within each of three seeding date blocks. Teff was seeded at about ¼ inch depth at a seeding rate of 6 lb/ac with a Kincaid (Kincaid Equipment Mfg) research seed drill with a small-seed cone attachment on June 2, June 13, and June 23, 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.

Cutting date was chosen based on overall physiological maturity of the six seed types for each seeding date block. Thus for each seeding date block, the plots were cut when seedheads were just beginning to emerge on the preponderance of plants. Using this criterion, the June 2 seeding date block was cut on July 31 and again on September 2. The June 13 seeding date block was cut on August 6 and again on September 9. The June 23 seeding date block was cut on August 15 and again on September 9. Within a few days after the first harvest of each seeding date block, ammonium sulfate was applied at 255 lb/ac (supplying 54 lb/ac N and 61 lb/ac S).

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, 2008). 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. Irrigation was applied with solid-set handlines. A total of 13.15 inches of irrigation was applied on ten dates between seeding and the second harvest date for the June 2 seeding date block. The June 13 seeding date block received 12.15 inches of irrigation on nine dates between seeding and its second harvest date, while the June 23 seeding date block received 10.72 inches of irrigation on eight dates between seeding and its second harvest date.

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).

Statistical Analysis

Statistics on yield and quality data were calculated using SAS® for Windows, Release 9.1 (SAS Institute, Inc.) software. Treatment significance was based on the F test at the $P = 0.05$ level. If this analysis indicated significant treatment effects, least significant difference (LSD) values were calculated based on the student's *t* test at the 5 percent level. For this report, the experiment was analyzed as a split-block-in-time design, with seeding date as the main plot and seed brand as sub-plot.

Results and Discussion

Yield Results

Observed differences in yield between teff seed brands were not statistically significant for first cutting, but were statistically significant for second cutting and annual total yield (Table 1).

Differences in yield between seeding dates were statistically significant for first cutting, second cutting, and annual total yield. There was no significant difference in seeding date by seed brand interaction for yield for first cutting, second cutting, and annual total yield.

For all seed brands, the June 2 seeding date produced the lowest first cutting yields, reflecting teff's slower growth during the cooler springtime, despite the longer time period between seeding and first cutting compared to the other seeding dates (Fig. 1). The June 2 seeding date resulted in higher yields at second cutting for all entries (Table 1). The reverse was true for the June 23 seeding date, where yield was much higher at first cutting than for second cutting for all brands. Yield was more evenly split between first and second cutting for the June 13 seeding date, where VAT-1, Dessie, and Pharaoh had higher yield at second cutting, but Emerald, Excalibur, and Tiffany tended to have higher yield at first cutting. Total yield was highest for some brands seeded on June 13, but for all others the highest total yield came from the June 23 seeding date. All entries had their lowest seasonal total yield from the June 2 seeding date (Table 1).

The time period between the first and second cutting was less than the time period between seeding and the first cutting for all seeding dates. Second cutting yield for the June 23 seeding date was significantly lower than yield of the earlier seeding dates for all seed brands, despite the fact that the re-growth period between first and second cutting for the June 23 seeding date was only either two or eight days shorter than the re-growth period for the earlier seeding dates (Fig. 2). This suggests that the teff seeded on June 23 did not have adequate time under warm weather conditions to achieve full regrowth by the time second cutting occurred in early September. Interestingly, the highest second cutting yields for all seed brands occurred for the June 13 seeding date, even though the June 2 seeding date had six more days to re-grow between cutting dates (Fig. 2). The time period between first and second cutting would not be limited for the June 2 seeding date (as it appeared to be for the June 23 seeding date), thus it may be that the weather experienced between first and second cutting was simply more conducive to growth for the teff seeded on June 13, allowing it to produce a larger second cutting yield in fewer days.

Even though the June 13 seeding date had the highest overall mean yield, only VAT-1 and Dessie had their highest total yield for that seeding date (Table 1, Fig. 3). Emerald, Excalibur, Pharaoh, and Tiffany had their highest total yield means from the June 23 seeding date. The likelihood of frost in both late May and mid-September in this climate suggests that careful timing is necessary to achieve maximum yield, as seeding too early or too late both have strong negative effects on total yield as well as the proportion of total yield available at either first or second cutting. Differences between seed brands suggest that there is variability in regrowth vigor and yield potential as a function of weather among teff seed that is commercially available. In general, these results suggest that waiting to seed teff until mid- to late June should result in maximum total yield in this region.

Quality Results

Differences between teff seed brands were not significantly different for CP on both cutting dates and for RFQ on the first cutting date (Tables 2 and 3). On the second cutting date, Dessie's RFQ was significantly lower than the other three entries. Emerald and Excalibur had higher RFV values than the other brands in most cases.

Differences between seeding dates were statistically significant for ADF, NDF, RFV, and RFQ for both first and second cutting dates. Differences in CP were significantly different for second cutting only. The seeding date by seed brand interaction was not significant in every case.

Overall mean CP was higher for second cutting than for first. For both cutting dates, CP values tended to increase as seeding date was delayed, although the differences in CP between seeding dates were only significant for the second cutting (Table 2). For a given seeding date and cutting date, Pharaoh tended to have the lowest CP, but differences between seed brands were not statistically significant. No seed brand consistently had the highest CP.

Mean ADF was nearly equal for both cutting dates. However, ADF response to seeding date followed a different pattern on different cutting dates. For the first cutting date, ADF increased as seeding date got later. However, for the second cutting date ADF decreased as seeding date got later. Between seed brands, Dessie and Pharaoh often had higher ADF than the other brands, but this was not true in every case.

Mean NDF was nearly equal for both cutting dates. The highest NDF occurred at first cutting for Pharaoh seeded on June 23, the same combination that produced the highest ADF value overall. Emerald, planted June 2 at second cutting, had the lowest NDF, similar to what was observed for ADF. At first cutting, NDF values increased as seeding date delayed, the same pattern as was observed for ADF at first cutting.

Despite the significant difference in NDF between seed brands, the pattern or response was not always the same. For example, at second cutting, Dessie seeded on June 2, had the highest individual NDF value, whereas Dessie seeded on June 23 had the lowest. The increase in NDF at first cutting as seeding date was delayed (and to a lesser degree ADF also) is opposite of the pattern observed in 2007 (Roseberg et al., 2007). However, in that study seeding dates occurred over a much wider time frame (May 16 to June 27), and the largest decreases in ADF and NDF occurred between the areas seeded in May compared to those seeded in June. In 2008, the differences in ADF and NDF between seeding dates were smaller, and so it may be that the observed trend in 2008 was due more to unknown weather effects during vegetative growth rather than the length of time between seeding and first harvest, as was thought based on the 2007 data.

The overall mean RFV was higher for first cutting than for second, and RFV values generally decreased as seeding dates got later (Table 3). It makes sense that the pattern in RFV values should generally follow the same patterns as ADF and NDF (as fiber increases, feed value decreases), because RFV is calculated using ADF and NDF values. For example, the RFV was clearly higher for the June 2 seeding date at first cutting, reflective of the lower fiber values for that seeding date by cutting combination. Mean RFV was very high (all over 120) for the June 2 seeding date at first cutting.

For second cutting, the June 23 seeding date had the highest mean RFV, reflective of the lower fiber values measured for that seeding date by cutting combination.

Mean RFQ was higher for first cutting than for second, but most of this seemed to be due to differences for the June 2 seeding date. There was not a significant difference in RFQ between seed brands for first cutting (Table 3). Emerald, in the first seeding date, had the highest RFQ. Dessie, in the third seeding date, had the lowest. For first cutting, there was a trend for increased RFQ at the earliest seeding dates, a pattern similar to that observed for RFV.

The pattern of RFQ differed from RFV for the second cutting. Whereas RFV tended to increase for the latest seeding date, RFQ remained almost constant, but perhaps slightly lower than the earlier seeding dates. The difference in the way RFV and RFQ are calculated may explain some of the reason why the overall statistical significance, as well as responses of individual seed brands to different seeding dates, may not be the same for RFV and RFQ. Whereas RFV is a relatively simple calculation derived from ADF and NDF, RFQ is a more complicated calculation derived from non-fibrous carbohydrate, crude protein, fatty acids, nitrogen-free NDF, 48-hour *in vitro* digestibility, and NDF (Undersander and Moore, 2002). Thus, the RFQ calculation attempts to estimate animal intake more accurately than RFV by including additional important nutritive qualities in the equation.

Conclusions

Teff grew well and produced fairly good yields and quality for all seed brands, although yields overall were lower than observed in 2007. The pattern in protein was also reversed in 2008, with higher protein at second cutting in every case.

In 2008 there was a strong inverse correlation between yield and quality, especially for first cutting. The earliest seeding date resulted in low forage yields with high quality at first cutting, suggesting that cooler temperatures during the early part of the growing season had a more adverse effect on yield than what was observed from the early June seeding in 2007. Air temperatures in early June were much cooler in 2008 than in 2007 (Fig. 4). In fact, on a few days the 2008 daily maximum temperature was similar to the 2007 daily minimum. There were several days of near or below freezing temperatures in the second week of June in 2008 that did not occur in 2007. A similar pattern occurred in late August- early September in 2008, hastening the end of the teff growing season sooner in 2008. In 2008, the latest seeding date had a strong first cutting yield and somewhat lower quality, but the shorter regrowth period limited second cutting yield, with higher quality as measured by RV (but reduced quality as measured by RFQ). The middle seeding date (June 13) seemed to provide a balance of good yield and good quality on both cutting dates.

Year-to year variation in weather for both the early and late part of the growing season seem to have significant effects on teff growth, yield, and quality. Thus, while in warmer climates teff growers may have more margin for error in seeding date while still achieving a good balance of yield and quality, in the Klamath Basin it is beginning to appear that a mid-June seeding date is most likely to produce a good balance of yield and forage quality. To further sort out these interactions between seeding date, weather, and resulting crop yield and quality, this study will be repeated to better determine the best seeding window to maximize seasonal yield and quality while trying to avoid growth reduction or frost damage due to cool weather both in the spring and early fall.

References

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Table 1. 2008 Yield summary for the teff seed brand x seeding date trial.
Klamath Basin Research & Extension Center, Klamath Falls, OR.

		Yield (lb/ac) O.D.					
Seed Brand	Seeding Date	Cut 1	Rank	Cut 2	Rank	Total Yield	Rank
VAT-1	June 2	858	17	1817	10	2680	18
Dessie	June 2	1398	15	2855	7	4250	14
Emerald	June 2	1268	16	1480	12	2750	17
Excalibur	June 2	1411	14	1768	11	3180	16
Pharaoh	June 2	1422	13	3027	3	4450	13
Tiffany	June 2	852	18	2753	8	3610	15
VAT-1	June 13	2465	12	2928	5	5390	10
Dessie	June 13	3096	9	3317	2	6410	4
Emerald	June 13	3756	6	2860	6	6620	2
Excalibur	June 13	3233	8	2248	9	5480	9
Pharaoh	June 13	2652	11	3452	1	6100	6
Tiffany	June 13	3073	10	3021	4	6090	7
VAT-1	June 23	3679	7	1365	15	5040	12
Dessie	June 23	4539	4	842	18	5380	11
Emerald	June 23	5733	1	1075	17	6810	1
Excalibur	June 23	4509	5	1211	16	5720	8
Pharaoh	June 23	4888	3	1478	13	6370	5
Tiffany	June 23	4989	2	1465	14	6450	3
Mean		2990		2165		5154	
***P* (Seeding Date)**		**<0.001**		**<0.001**		**<0.001**	
LSD (0.05)- Seeding Date		860.7		383.6		839.2	
***P* (Seed Brand)**		**0.056**		**0.001**		**0.042**	
LSD (0.05)- Seed Brand		NSD		475.6		922.3	
CV (%)		31.1		26.5		21.9	
***P* (Seeding Date X Seed Brand Interaction)**		**0.802**		**0.135**		**0.480**	

Table 2. 2008 Crude protein, acid detergent fiber, and neutral detergent fiber summary for the teff seed brand x seeding date trial. Klamath Basin Research & Extension Center, Klamath Falls, OR.

		Crude Protein				ADF				NDF			
Seed Brand	Seeding Date	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank	Cut 1	Rank	Cut 2	Rank
VAT-1	June 2	14.6	8	15.4	15	32.3	18	35.8	6	37.2	17	54.2	7
Dessie	June 2	13.1	17	14.5	17	33.5	14	36.4	1	44.4	14	54.9	1
Emerald	June 2	14.7	4	15.6	13	32.5	17	35.1	11	36.7	18	51.1	12
Excalibur	June 2	14.2	9	15.7	11	33.0	15	35.2	10	42.0	16	52.4	10
Pharaoh	June 2	12.9	18	14.2	18	33.8	13	36.0	5	48.4	13	54.7	5
Tiffany	June 2	14.6	7	14.9	16	32.5	16	35.2	9	43.8	15	53.4	8
VAT-1	June 13	14.1	11	15.9	10	34.4	12	35.5	7	54.2	12	54.6	6
Dessie	June 13	14.1	10	16.3	9	35.5	6	36.2	2	54.9	10	54.8	4
Emerald	June 13	13.6	15	16.4	8	35.2	8	35.2	8	55.8	7	52.8	9
Excalibur	June 13	14.0	12	17.7	7	35.6	5	34.3	12	55.4	8	51.4	11
Pharaoh	June 13	14.6	5	15.6	14	34.9	10	36.2	3	54.8	11	54.9	3
Tiffany	June 13	13.9	13	15.6	12	35.7	4	36.1	4	55.4	9	54.9	2
VAT-1	June 23	16.4	1	19.2	4	34.7	11	32.3	16	56.3	6	50.7	14
Dessie	June 23	14.7	3	21.0	1	36.7	2	31.6	18	58.9	2	48.5	18
Emerald	June 23	13.7	14	19.1	6	35.4	7	32.2	17	56.6	5	49.2	17
Excalibur	June 23	14.6	6	19.4	3	36.5	3	32.5	15	58.2	3	49.4	16
Pharaoh	June 23	13.2	16	19.1	5	37.1	1	33.6	13	60.2	1	50.9	13
Tiffany	June 23	15.7	2	19.5	2	34.9	9	32.6	14	57.1	4	50.3	15
Mean		14.3		16.9		34.7		34.6		51.7		52.4	
***P* (Seeding Date)**		**0.075**		**<0.001**		**0.001**		**<0.001**		**<0.001**		**<0.001**	
LSD (0.05)- Seeding Date		NSD		0.8		1.1		1.0		3.4		0.9	
***P* (Seed Brand)**		**0.385**		**0.059**		**0.020**		**0.049**		**0.013**		**<0.001**	
LSD (0.05)- Seed Brand		NSD		NSD		0.9		0.8		2.9		1.2	
CV (%)		12.9		6.2		3.4		3.1		7.2		2.6	
***P* (Seeding Date X Seed Brand Interaction)**		**0.653**		**0.126**		**0.529**		**0.251**		**0.172**		**0.099**	

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

		RFV				RFQ			
Seed Brand	**Seeding Date**	**Cut 1**	**Rank**	**Cut 2**	**Rank**	**Cut 1**	**Rank**	**Cut 2**	**Rank**
VAT-1	June 2	162.3	2	104.7	12	122.4	4	100.8	10
Dessie	June 2	134.6	5	102.5	18	115.8	6	92.7	17
Emerald	June 2	163.5	1	112.3	8	127.0	1	101.8	9
Excalibur	June 2	142.7	3	109.3	9	123.7	2	102.5	3
Pharaoh	June 2	120.7	6	103.4	14	118.0	5	102.1	7
Tiffany	June 2	135.7	4	107.3	11	123.1	3	102.1	8
VAT-1	June 13	106.6	7	104.4	13	105.5	9	102.1	6
Dessie	June 13	103.9	9	103.2	15	104.1	12	93.3	16
Emerald	June 13	102.4	12	108.2	10	107.6	7	103.9	1
Excalibur	June 13	103.1	10	112.6	7	105.1	10	102.3	4
Pharaoh	June 13	104.9	8	103.0	17	106.6	8	102.2	5
Tiffany	June 13	102.7	11	103.0	16	104.8	11	102.8	2
VAT-1	June 23	102.3	13	117.0	5	102.7	13	94.4	15
Dessie	June 23	95.6	17	123.3	1	96.5	18	92.7	18
Emerald	June 23	101.1	14	120.8	2	99.2	15	100.3	11
Excalibur	June 23	96.7	16	120.0	3	99.0	16	100.0	12
Pharaoh	June 23	92.8	18	114.7	6	97.1	17	98.0	13
Tiffany	June 23	100.5	15	117.6	4	101.4	14	96.3	14
Mean		115.1		110.4		108.9		99.4	
***P* (Seeding Date)**		<0.001		<0.001		0.002		0.043	
LSD (0.05)- Seeding Date		9.9		3.1		7.1		3.3	
***P* (Seed Brand)**		0.028		<0.001		0.771		<0.001	
LSD (0.05)- Seed Brand		10.8		3.4		NSD		2.5	
CV (%)		11.4		3.7		8.6		3.3	
***P* (Seeding Date X Seed Brand Interaction)**		0.166		0.092		0.930		0.453	

Fig. 1.Teff First Cutting Yield at the Klamath Basin Research & Extension Center, 2008.

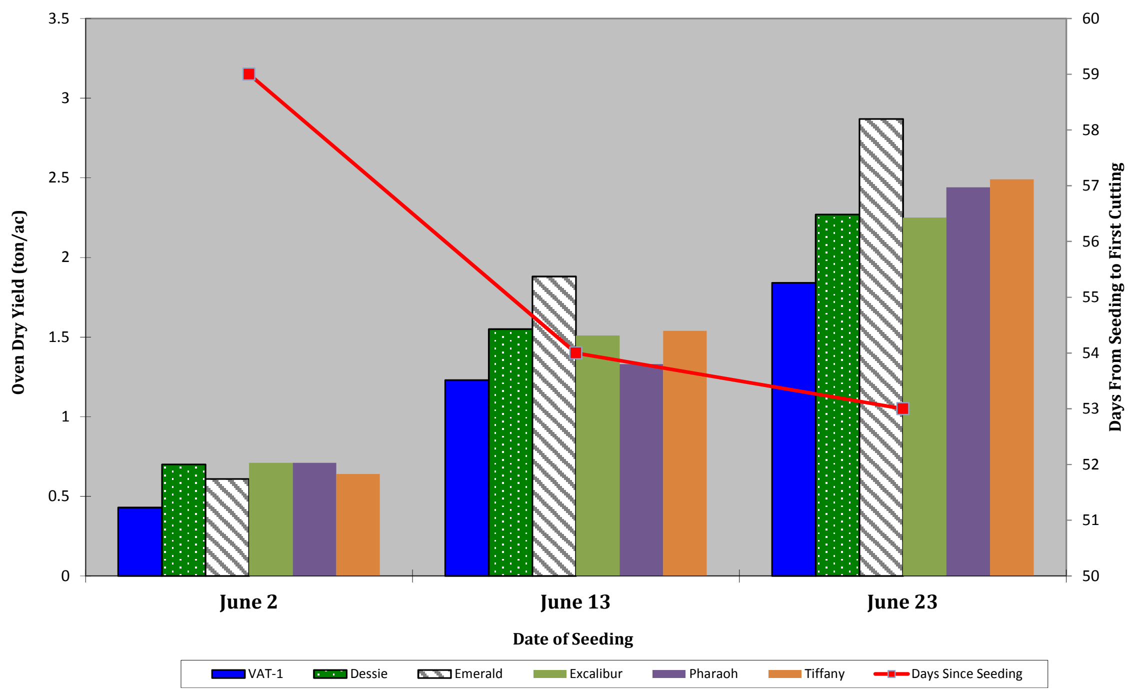

Fig. 2.Teff Second Cutting Yield at the Klamath Basin Research & Extension Center, 2008

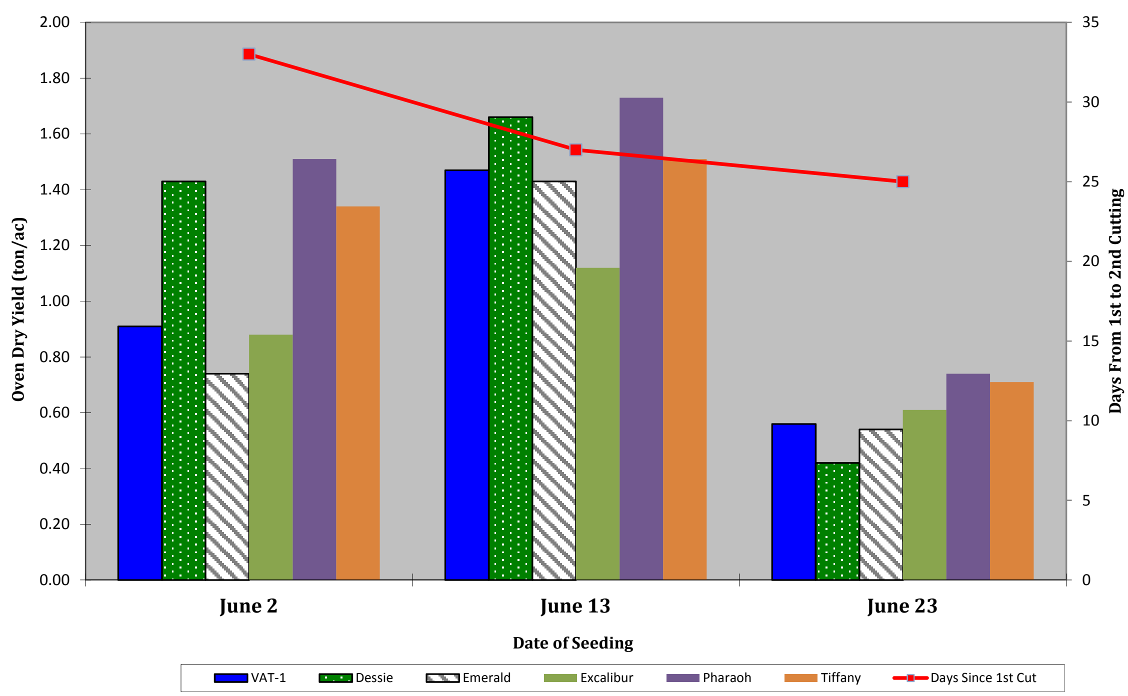

Fig. 3.Teff Season Total Yield at the Klamath Basin Research & Extension Center, 2008