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Preliminary Evaluation of Tepary Bean (*Phaseolus acutifolius* A. Gray) as a Forage Crop

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Abstract

There is a lack of crop options for planting when summer crops, such as corn and soybean, fail due to drought during late summer period. This study evaluated the potential of using tepary bean as a short-duration forage crop when planted late during summer period. Tepary bean (*Phaseolus acutifolius* A. Gray), a short-duration, drought-tolerant, summer crop, is a potential candidate forage crop for this situation. A study with 31 tepary bean lines indicated that 59 days old crop can be harvested as forage with mean fresh and dry matter yields of 22.2 and 4.4 $Mg.ha^{-1}$, respectively. Tepary bean forage contained 21.4 percent protein, 37.5 percent ADF, 41.1 percent NDF, 0.48 Mcal/pound NE, 60.8 percent TDN, and 1.12 percent fat. Mean values of P, K, S, Ca, Mg, and Na (% dry matter) in tepary bean forage were 0.28, 2.5, 0.28, 2.11, 0.54, and 0.05, respectively. Mean values of Fe, Al, Mn, Cu, Zn, and B ($mg.kg^{-1}$) were 307, 229, 359, 9.3, 39.5, and 20.9, respectively. Tepary bean forage quality compared well with that of alfalfa hay, perennial peanut hay, and soybean forage. These results indicated that tepary bean has potential as a short-duration forage crop.

Keywords: grain legumes, forage composition, forage quality, drought tolerance, minerals

1. Introduction

In many parts of the world there is increasing scarcity of water for agriculture (Jury & Vaux, 2007). During 2012, drought caused severe crop loses in USA, about 21 percent of the value of corn and soybean production was in areas with severe drought (ERS, 2012). Time of the crop loss related to drought is an additional problem for farm productivity given that most summer crops are planted in April-May and the drought losses don't become evident until later in the summer i.e. July-August. The farmers, generally, do not have any alternative crop to plant under this situation. Tepary bean, a drought-tolerant, short-duration summer crop, could be a potential crop for these farmers.

Tepary bean (*Phaseolus acutifolius* A. Gray), indigenous to southwestern USA and northwestern Mexico, has the potential for agricultural production in many parts of the world. Considerable research has been conducted with tepary bean as a food crop (Bhardwaj & Hamama, 2004, 2005; Bhardwaj et al., 2002) and its' Biological N Fixation capabilities (Mapp, 2008; Mohrmann, 2011). However, information about tepary bean's forage potential is not available. Therefore, objective of this study was to determine forage potential of tepary bean.

2. Materials and Methods

2.1 Sites and Their Characteristics

The field experiments were conducted during 2010 at Randolph Farm of Virginia State University at Petersburg (Approximately 37° 15' N and 077° 30.8' W) on Abel sandy loam soil. This location is characterized by sandy loam soil with pH and organic matter content (%) of 6.4 and 1.5, respectively. Contents of P, K, Mg, and Ca in this soil were 77, 54, 68, and 395 ($mg.kg^{-1}$), respectively.

2.2 Treatments and Experimental Design

Thirty one tepary bean lines (Table 1) were grown in the field using a Randomized Complete Block Design experiment with two replications. Twenty-eight lines were obtained from Native Seeds (www.nativeseeds.org) whereas three lines (Sheedy-Black, Sheedy-Tan, and Sheedy-White) were obtained from Mr. Michael Sheedy of University of Arizona.

Table 1. Yield and feed quality of forage of 31 tepary bean lines grown in Virginia (USA) during 2010

#	Line	Moist	FMY	DMY	CP	ADF	ADFN	NDF	NE	TDN	FAT
1	Cumpas	79.4	24.7	5.1	20.1	39.5	0.4	58.2	0.46	59.4	1.47
2	Cocopah White	80.3	20.4	4.0	22.1	36.9	0.6	40.5	0.48	61.1	1.01
3	Guarijio White	81.2	22.8	4.3	25.0	31.5	0.6	33.9	0.54	64.7	0.60
4	Menagers Dam	73.9	21.2	5.5	20.2	41.4	0.5	44.8	0.44	58.2	1.21
5	Blue Speckled	78.0	21.9	4.9	19.2	36.1	0.6	44.0	0.49	61.6	1.07
6	Big Fields Brown	79.5	21.4	4.3	21.0	40.3	0.5	40.6	0.45	58.9	1.26
7	Pima Brown & Biege	80.9	22.3	4.2	22.8	33.5	0.5	38.2	0.52	63.4	1.07
8	Uttle Tucson Brown	80.3	23.7	4.7	22.1	36.8	0.7	35.4	0.48	61.2	1.26
9	Brown Speckled	79.2	20.5	4.3	16.6	41.3	0.4	47.4	0.44	58.2	1.15
10	Sacaton Brown	79.8	21.3	4.3	24.4	34.4	0.7	41.3	0.51	62.8	1.22
11	Cocopah Brown	79.7	20.1	4.1	22.3	37.7	0.3	43.7	0.48	60.6	0.86
12	Colonia Morelos	80.7	22.1	4.2	19.6	33.3	1.0	12.7	0.52	63.5	1.33
13	Kickapoo White	80.8	27.0	5.1	18.0	37.7	0.4	42.6	0.48	60.6	1.50
14	Paiute Mixed	81.3	20.8	3.8	23.1	38.6	1.0	35.3	0.47	60.1	1.27
15	Pinacate Mixed	81.1	23.4	4.4	24.4	33.6	0.5	40.0	0.52	63.3	1.49
16	Santa Rosa Brown	80.0	22.0	4.4	24.9	34.5	0.9	34.9	0.51	62.7	1.28
17	San Felipe Pueblo	79.0	18.8	4.0	22.2	29.6	0.4	33.2	0.56	65.9	1.16
18	San Pablo Balleza	80.6	20.5	3.9	19.8	39.1	0.5	37.7	0.46	59.7	1.10
19	T.O. White	81.0	22.3	4.2	21.4	36.6	0.7	36.2	0.49	61.3	0.94
20	Yoeme Brown	80.5	23.2	4.5	18.0	36.6	0.7	35.7	0.49	61.3	1.57
21	Santa Rosa White	81.8	24.3	4.4	20.4	36.5	0.7	36.1	0.49	61.4	0.95
22	Yoreme White	78.4	22.0	4.7	20.8	35.6	0.7	39.4	0.50	62.0	1.31
23	San Ignacio	79.8	18.8	3.8	17.5	38.7	0.7	40.7	0.47	60.0	1.20
24	Sonoran White	80.7	17.6	3.3	25.0	36.3	0.8	41.0	0.49	61.6	0.69
25	Virus-Free Yellow	81.4	25.6	4.8	18.2	44.9	0.6	47.7	0.40	55.9	0.49
26	Sacaton White	81.4	22.7	4.2	22.5	39.8	0.7	39.1	0.46	59.2	0.72
27	Tohano Brown	81.0	22.0	4.2	23.2	43.9	1.0	45.0	0.41	56.6	1.14
28	Santa Rosa White	81.8	22.1	4.0	18.9	37.2	1.1	46.9	0.48	61.0	1.27
29	Sheedy-Black	79.0	24.6	5.1	23.0	41.3	1.0	47.0	0.44	58.3	1.66
30	Sheedy-Tan	79.6	23.5	4.6	21.1	39.8	0.9	49.1	0.45	59.2	1.13
31	Sheedy-White	81.2	24.5	4.6	24.7	39.1	1.0	42.4	0.46	59.7	0.44
	LSD (0.05)	4.02	6.30	1.54	ns	ns	ns	ns	ns	ns	ns
	Mean	80.1	22.2	4.4	21.4	37.5	0.69	41.1	0.48	60.8	1.12

FMY: Fresh Material Yield ($Mg{\cdot}ha^{-1}$); DMY: Dry Matter Yield ($Mg{\cdot}ha^{-1}$); CP: Crude Protein; ADF: Acid Detergent Fiber; ADFN: Acid Detergent Fiber N (Percentage of total N); NDF: Neutral Detergent Fiber; NE: Net Energy (Mcal/pound); TDN: Total Digestible Nutrients; FAT: Lipids. CP, ADF, ADFN, NDF, TDN, and Fat as percentage dry matter basis.

2.3 Agronomic Practices

The field experiments were planted on June 14, 2010 and harvested as forage on August 11, 2010 (59 Days after planting). Each plot consisted of four rows spaced 37.5 cm apart. Each row was 3 m long. This field received 1 pint per acre of Treflan (Trifluralin) as a pre-plant incorporated herbicide approximately one week before planting. Approximately 100 seeds were planted in each 3m long row.

2.5 Data Collection and Statistical Analysis

All plants in each plot were harvested by hand approximately 3-5 cm above the ground level and data on fresh yield were recorded for each plot. The harvested material was dried until constant moisture to record dry matter yield. All samples were analyzed for forage quality-related traits by a commercial laboratory (A&L Eastern Agricultural Laboratory, Richmond, VA) using Association of Analytical Chemists methods (AOAC, 1995). Protein content was determined by multiplying N content with 6.25. All data were analyzed using PROC GLM and PROC CORR procedures in SAS version 9.1 (SAS, 2003).

Table 2. Mineral composition of forage of 31 tepary bean lines grown in Virginia (USA) during 2010

#	Line	P	K	S	Ca	Mg	Na	Fe	Al	Mn	Cu	Zn	B
1	Cumpas	0.29	2.8	0.29	1.99	0.50	0.05	533	271	237	8.5	36.6	21.1
2	Cocopah White	0.26	3.0	0.27	2.12	0.49	0.06	480	290	583	8.7	51.4	22.1
3	Guarijio White	0.32	2.2	0.35	2.29	0.59	0.05	213	137	594	10.5	43.3	23.1
4	Menagers Dam	0.27	2.5	0.25	2.17	0.58	0.05	544	399	187	9.7	33.5	19.8
5	Blue Speckled	0.30	2.1	0.26	2.01	0.60	0.05	206	182	326	8.8	42.6	22.1
6	Big Fields Brown	0.27	2.3	0.27	1.82	0.53	0.05	360	263	295	8.6	40.1	18.2
7	Pima Brown & Biege	0.27	2.7	0.28	2.09	0.52	0.05	265	250	306	10.4	38.2	21.8
8	Uttle Tucson Brown	0.33	2.6	0.30	2.02	0.52	0.05	324	351	356	8.9	46.7	21.7
9	Brown Speckled	0.28	2.4	0.24	1.53	0.41	0.04	312	223	199	8.1	35.0	20.1
10	Sacaton Brown	0.30	2.7	0.32	2.52	0.58	0.06	309	251	620	8.9	47.0	23.9
11	Cocopah Brown	0.29	2.8	0.24	1.86	0.44	0.05	224	175	269	7.9	32.3	17.7
12	Colonia Morelos	0.26	2.5	0.25	2.24	0.52	0.05	259	223	172	9.0	35.1	21.2
13	Kickapoo White	0.28	2.6	0.28	1.84	0.45	0.05	257	234	414	8.6	41.8	21.4
14	Paiute Mixed	0.27	2.5	0.34	2.16	0.56	0.05	414	333	843	8.6	49.8	21.4
15	Pinacate Mixed	0.25	2.6	0.27	2.16	0.59	0.05	355	250	519	8.8	43.0	18.6
16	Santa Rosa Brown	0.30	2.5	0.29	2.45	0.63	0.05	173	164	363	10.0	36.8	20.8
17	San Felipe Pueblo	0.30	2.8	0.27	2.07	0.55	0.05	183	169	454	8.5	49.8	24.3
18	San Pablo Balleza	0.25	2.3	0.25	1.76	0.44	0.05	756	506	476	8.6	39.0	19.2
19	T.O. White	0.29	2.7	0.27	2.16	0.48	0.06	450	205	467	10.4	47.1	22.4
20	Yoeme Brown	0.28	2.3	0.24	1.97	0.48	0.05	232	217	134	8.0	31.0	20.3
21	Santa Rosa White	0.28	2.6	0.26	2.11	0.50	0.05	175	131	209	9.3	36.3	21.8
22	Yoreme White	0.25	2.3	0.28	2.33	0.60	0.05	277	152	472	10.4	33.1	20.8
23	San Ignacio	0.29	2.2	0.26	1.99	0.56	0.05	257	236	164	8.0	34.9	19.7
24	Sonoran White	0.29	2.4	0.29	2.44	0.64	0.06	232	217	594	11.3	36.2	20.9
25	Virus-Free Yellow	0.25	2.6	0.25	1.92	0.51	0.05	171	126	139	8.5	32.6	19.6
26	Sacaton White	0.25	2.4	0.25	2.51	0.55	0.06	227	167	292	9.4	31.1	18.0
27	Tohano Brown	0.27	2.2	0.28	2.50	0.65	0.08	421	256	263	11.1	43.6	23.6
28	Santa Rosa White	0.23	2.0	0.24	2.00	0.55	0.05	216	149	180	9.8	31.4	17.8
29	Sheedy-Black	0.28	2.6	0.26	2.24	0.55	0.06	295	271	423	9.1	39.8	21.6
30	Sheedy-Tan	0.28	2.4	0.28	1.91	0.53	0.05	225	162	283	9.6	39.2	19.5
31	Sheedy-White	0.27	2.6	0.28	2.20	0.53	0.06	195	135	276	10.4	46.2	21.0
	LSD (0.05)	ns	ns	ns	ns	ns	ns	ns	171	ns	ns	ns	ns
	Mean	0.28	2.5	0.28	2.11	0.54	0.05	307	229	359	9.3	39.5	20.9

P, K, S, Ca, Mg, Na as percentage dry matter. Fe, Al, Mn, Cu, Zn, and B as $mg \cdot kg^{-1}$ dry matter basis.

3. Results and Discussion

3.1 Tepary Bean Lines and Forage Yield and Forage Composition Traits

Variation among tepary bean lines for moisture content, fresh matter yield, and dry matter yield was significant whereas variation for forage composition traits, except content of aluminum, was not significant (Tables 1 and 2). This observation is attributed to use of limited number of lines and use of only two replications. However, use of additional lines and replications would have mandated additional resources for compositional analyses. Tepary bean forage, on an average, contained 21, 37, 0.7, 41, 0.5, 61, and 1 percent (dry matter basis) protein, ADF, ADFN, NDF, NE, TDN, and fat, respectively. Regarding minerals, tepary bean forage contained 0.28, 2.5, 0.28, 2.11, 0.54, 0.05, 307, 229, 359, 9.3, 39.5, and 20.9 mg kg^{-1} (dry weight basis) of P, K, S, Ca, Mg, Na, Fe, Al, Mn, Cu, Zn, and B, respectively. Given that information about composition of tepary bean forage is not available, this study has, at a minimum, established a base line for composition of tepary bean forage.

3.2 Relationships between Tepary Bean Forage Composition Traits

Protein content of tepary bean forage was positively and significantly related to the contents of P, K, S, Ca, Mg, Na, Mn, Cu, and Zn (Table 3) indicating that any tepary bean line with high content of minerals would have high protein content in the forage. Content of acid detergent fiber (Containing cellulose, and lignin as well as heat-damaged protein, cutins, tannins, silica), an important measure of feed digestibility, was positively correlated with content of neutral detergent fiber but exhibited a significant negative correlations with contents of net energy and , total digestible nutrients, P, Ca, and B. Content of neutral detergent fiber (Containing cellulose, hemicellulose, lignin, and resistant non-carbohydrates), an important measure of feed quality, was negatively and significantly correlated with net energy value, content of total digestible nutrients, Ca, and B. Net energy values and contents of total digestible nutrients of tepary bean forage were positively and significantly correlated with contents of total digestible nutrients, P, Ca, and B but were negatively and significantly correlated with content of Fe (Table 3). Based on the results of this preliminary study, it can be suggested that a line with high contents of P, Ca, and B should have forage with high net energy and total digestible nutrients. Animals need P for skeletal growth and for energy metabolism and need Ca for skeletal growth, milk production, nerve impulse transmission, and maintenance of enzymatic systems.

Table 3. Correlation coefficients between forage quality traits of 31 tepary bean lines grown in Virginia (USA) during 2010

	CP	ADF	ADFN	NDF	NE	TDN	FAT	P	K	S	Ca	Mg	Na	Fe	Al	Mn	Cu	Zn
ADF	ns																	
ADFN	ns	+**																
NDF	ns	+**	ns															
NE	ns	-**	-**	-**														
TDN	ns	-**	-**	-**	+**													
FAT	ns	ns	ns	ns	ns	ns												
P	+**	-**	ns	ns	+**	+**	ns											
K	+**	ns	ns	ns	ns	ns	ns	+**										
S	+**	ns	ns	ns	ns	ns	ns	+**	ns									
Ca	+**	-*	ns	-*	+**	+*	ns	ns	ns	ns								
Mg	+**	ns	+*	ns	ns	ns	ns	ns	-*	+*	+**							
Na	+**	ns	+*	ns	ns	ns	ns	ns	ns	ns	+**	+**						
Fe	ns	+**	ns	ns	-**	-**	ns	-*	ns	ns	ns	ns	ns					
Al	ns	ns	ns	ns	ns	ns	+*	ns	ns	ns	ns	ns	ns	+**				
Mn	+**	ns	+**	ns	ns	ns	ns	ns	+**	+**	ns	ns	ns	ns	ns			
Cu	+**	ns	+**	ns	ns	ns	ns	+*	ns	+**	+**	+*	ns	ns	ns	+*		
Zn	+**	ns	+**	ns	ns	ns	ns	+**	+**	+**	ns	ns	ns	ns	ns	+**	ns	
B	ns	-**	ns	-**	+**	+**	ns	+**	ns	+**	ns	ns	ns	-*	ns	+*	+**	+**

CP: Crude Protein; ADF: Acid Detergent Fiber; ADFN: Acid Detergent Fiber N (Percentage of total N); NDF: Neutral Detergent Fiber; NE: Net Energy (Mcal/pound); TDN: Total Digestible Nutrients; FAT: Lipids.

3.3 Tepary Bean Forage in Comparison to other Forages

A generalized comparison of composition of tepary bean forage with that of alfalfa, perennial peanut, and soybean grown in Argentina, Saudi Arabia, and USA is presented in Table 4. Based on crude protein content, tepary bean forage with 21.4 was a superior forage than alfalfa, perennial peanut and soybean forage. Content of ADF in tepary bean forage was greater than that in alfalfa, perennial peanut, and soybean produced in Argentina but smaller than that in soybean produced in USA. Content of NDF in tepary bean was greater than that in alfalfa and soybean produced in Argentina and USA but lower than that in perennial peanut. Content of total digestible nutrients in tepary bean forage was similar to that of perennial peanut but lower than that in alfalfa. Contents of P, Ca, and B (The three minerals important in forage quality) were, in general, similar to those of other forages. These observations indicate that tepary bean forage could be used to replace alfalfa, perennial peanut, and soybean forage. Values of some compositional traits of alfalfa, perennial peanut, and soybean forages were not available for comparison with tepary bean values. However, tepary bean values are presented in this article to be available for future studies.

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Table 4. Forage quality traits of tepary bean, alfalfa hay, and perennial peanut hay

Forage traits[a]	Tepary bean[b]	Alfalfa hay[c]	Perennial peanut hay[c]	Soybean forage (Argentina)[d]	Soybean forage (USA)[d]	Soybean forage 1994 (Saudi Arabia)[e]	Soybean forage 1995 (Saudi Arabia)[e]
CP	21.4	19	14	21.5	19.8	17.6	20.0
ADF	37.5	32	32	30.9	38.2	NA	NA
ADFN	0.69	NA[f]	NA	NA	NA	NA	NA
NDF	41.1	40	42	31.8	38.2	NA	NA
NE	0.48	NA	NA	NA	NA	NA	NA
TDN	60.8	62	60	NA	NA	NA	NA
FAT	1.12	NA	NA	4.4	6.1	NA	NA
P	0.28	0.2	0.2	NA	NA	0.30	0.33
K	2.49	1.8	1.4	NA	NA	1.71	1.87
S	0.27	NA	NA	NA	NA	NA	NA
Ca	2.11	1.3	1.3	NA	NA	2.27	2.27
Mg	0.54	0.4	0.5	NA	NA	0.62	0.56
Na	0.05	NA	NA	NA	NA	NA	NA
Fe	308	NA	NA	NA	NA	NA	NA
Al	229	NA	NA	NA	NA	NA	NA
Mn	359	NA	NA	NA	NA	NA	NA
Cu	9.27	12	6	NA	NA	NA	NA
Zn	39.5	30	34	NA	NA	NA	NA
B	20.9	NA	NA	NA	NA	NA	NA

a: CP: Crude Protein; ADF: Acid Detergent Fiber; ADFN: Acid Detergent Fiber N (Percentage of total N); NDF: Neutral Detergent Fiber; NE: Net Energy (Mcal/pound); TDN: Total Digestible Nutrients; FAT: Lipids. CP, ADF, ADFN, NDF, TDN, and Fat as percentage dry matter basis.

b: Results from our study with tepary bean.

c: Results from Meyer et al., 2010.

d: Results from Lundrey et al., 2008.

e: Results from Assaeed et al., 2000.

f: Not available.

Even though detailed results related to potential of tepary bean as a forage plant in a mono-crop system is not available, it has been observed to compete well with forage sorghum [*Sorghum bicolor* (L.) Moench]. Contreras-Govea et al. (2009) grew forage sorghum with cowpea (*Vigna unguiculata* L.), lablab (*Lablab purpreus* L.), soybean (*Glycine max* L.), and tepary bean (*Phaseolus acutifolius* A. Gray) and observed that tepary bean grown with forage sorghum resulted in highest proportion than other legumes (67 percent for tepary bean as compared to 57 percent for cowpea, 53 percent for lablab, and 37 percent for soybean). Tepary bean and other legumes, grown with forage sorghum, increased the crude protein content of the mixture.

A most interesting observation from this study relates to the potential of tepary bean to provide nutritive forage in a short duration and its' drought tolerance. Most times, April-May planted corn and soybean fail due to drought by July-August when there is a lack of alternative crops. Tepary bean can be a useful crop in such situations. It can be planted in June-July and could produce nutritive forage in about two months. The forage quality of tepary bean when harvested 59 days after planting, in this study, was quite acceptable. We propose that tepary bean be considered as a short-duration source of nutritive forage in situations where summer crops fail due to drought.

4. Conclusion

Our results from this preliminary study indicate that tepary bean is a potential short-duration forage crop in situations where summer crops fail due to drought.

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