Nitrogen fertilizer in the form of urea (46-0-0) was applied to plots 20 ft (6 rows) wide and 40 ft long. The seasonal nitrogen rates were 0, 50, 100, 150, 200, 250, 300, and 350 lbs N/acre applied at four different times to achieve these total rates (Table 1). The experimental design was a randomized complete block with 4 blocks.

Twenty plants per plot were sampled six times during the season for tissue testing and phytomass in an effort to develop nitrogen fertilizer guidelines. Nitrate concentration was measured on the lower stems and total N was measured on the newest fully developed leaf (showing a collar) and on the total plant. The area of the newest leaf was measured so that total N in the leaf could be expressed on both a mass and area basis. The portion of the lower stem sampled was the crown before stem extension and the lower 4 inches of the stem after stem extension. The crown tissue sampled was about ¼ to ½ inches in length and had minimal leaf and root tissue attached.

The center 5 feet of 4 rows in the plots were hand harvested on 29 Oct 2009 to obtain forage yield. The plants were sampled for moisture determination and the yield was adjusted to 70% moisture content. The data was statistically analyzed using the GLM and REG and procedure in SAS.

Results and Discussion

Maximum forage yield was achieved at a nitrogen rate of 150 lbs N/acre in our study, and nitrogen rates resulted in a yield plateau or slight yield decrease (Table 2). The optimum nitrogen rate under commercial conditions may be different than that in this study depending on the nitrogen contained in the irrigation water and soil, and the efficiency of N application. If nitrogen is applied in the irrigation water or applied in fewer than four split applications, then the optimum N rate may be higher than that in our study. Forage moisture at harvest increased with nitrogen rate and also achieved a maximum and leveled off at a nitrogen rate of 150 lbs N/acre. Stem density at harvest was not affected by N rate and was about 5% less than plant density measured about 3 weeks after planting. The plants had no productive tillers and any tillers present were very small and insignificant. Nitrogen hastened the time to bloom and N rates less than 100 lbs N/acre delayed blooming by 8-11 days compared to the higher N rates. Leaf number peaked at medium N rates, oddly enough, and the decrease in leaf number with higher N rates may also be related to the slight decrease in yield also measured at the highest N rates.

Increasing nitrogen fertilizer rates increased forage yield, nitrogen uptake, and the nitrogen content of various plant tissues sampled on six dates throughout the growing season (Table 3, Fig. 1). The highest yield was achieved at a higher N rate earlier in the season than later.

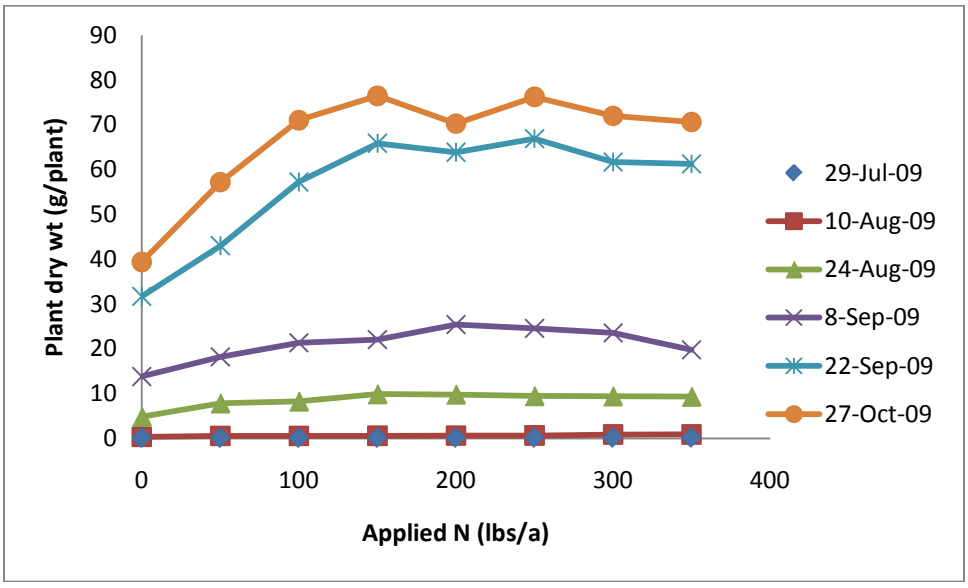

Fig. 1. Applied N effect on plant dry weight measured at various times during the season.

Plant growth was strongly affected by nitrogen in the stem, leaves, and whole plant in samples collected after August 10 (Table 4). Before that date, the relationship between growth and N in tissues was weaker or non-significant. Early in the season, tissue N and plant growth were not closely related. Below is a plot of stem N versus plant dry weight on July 29 as an example (Fig. 2). Plots of other N parameters are similar.

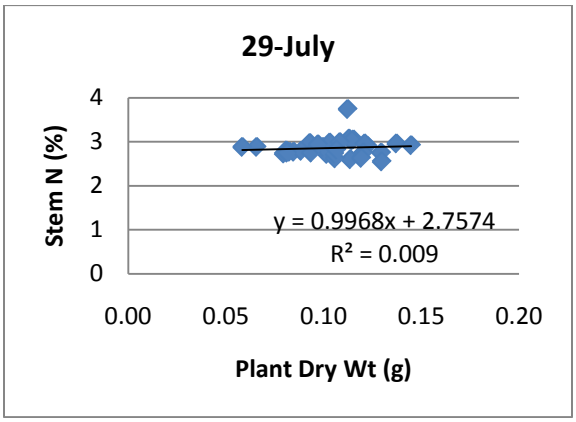

Fig. 2. Relationship between plant dry weight and stem N on July 29.

Mid-August seems to be an important point in the development of the sorghum plants. In the August 24 sampling, all N parameters become highly significant (with the exception of leaf N expressed on a leaf area basis). Although all the other N parameters are significant, the relationships vary quite a bit (Fig. 3). All of the linear R^2 values are similar, but there's smaller range of stem nitrate associated with the largest plants compared to the range of stem N, plant N, or leaf N associated with the largest plants. For example, stem N in the highest yielding plants ranges from 2.52% to 3.30 (approximately a 30% difference), whereas stem nitrate ranges from 5702 to 6489 ppm (only a 13% difference). This suggests that stem nitrate might be most useful as a diagnostic tool.

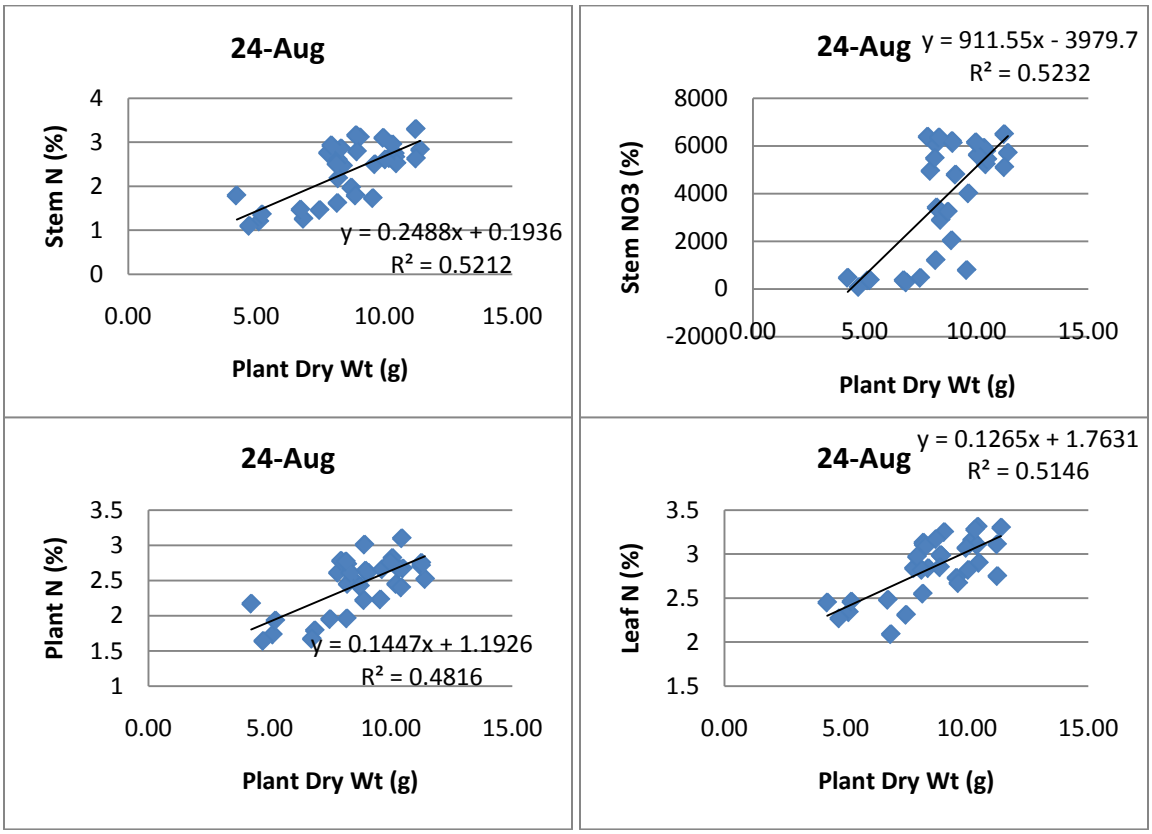

Fig. 4. Relationship between plant dry weight and stem N, stem NO3, plant N, and leaf N on Aug 24.

Mid-August corresponds to the beginning of the exponential phase of growth and is probably a great time to adjust N applications based on tissue analysis.

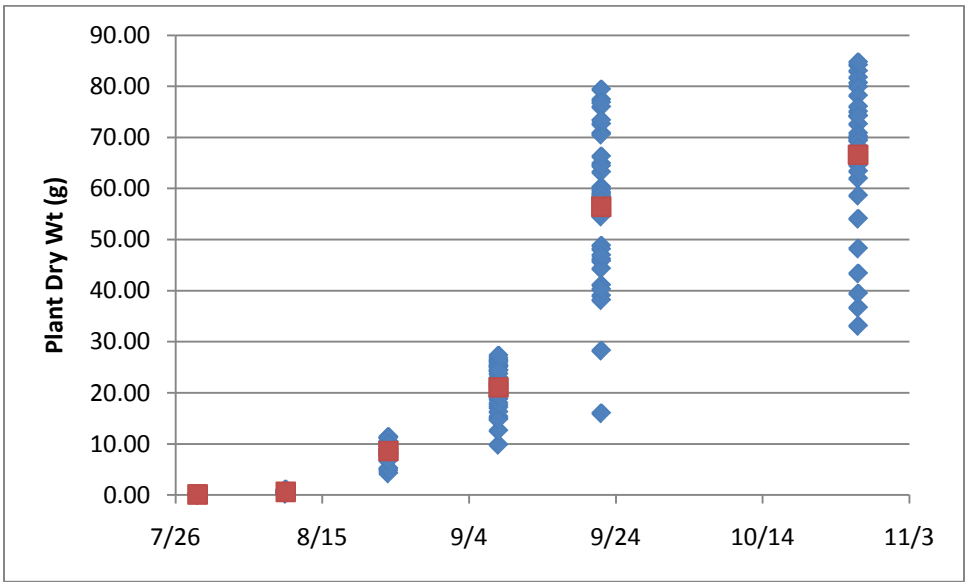

Fig. 5. Plant dry weight accumulation over time for all the N application rates.

Later in the season, stem nitrate is still closely related to plant weight, but the relationship is not as good as in mid-August. The chances of correcting a problem obviously decline as the season progresses as well. The mid-August stem nitrate level that corresponds to the 'optimum' N application rate of 150 lbs/a is 4500 to 5000 ppm (Fig. 6). Preliminarily, we suggest that this might be a safe level for this time of the season. Similarly, for early September 3000 to 3500 is probably a good target. One thing we could do to improve these numbers is to look at accumulated heat units rather than calendar date.

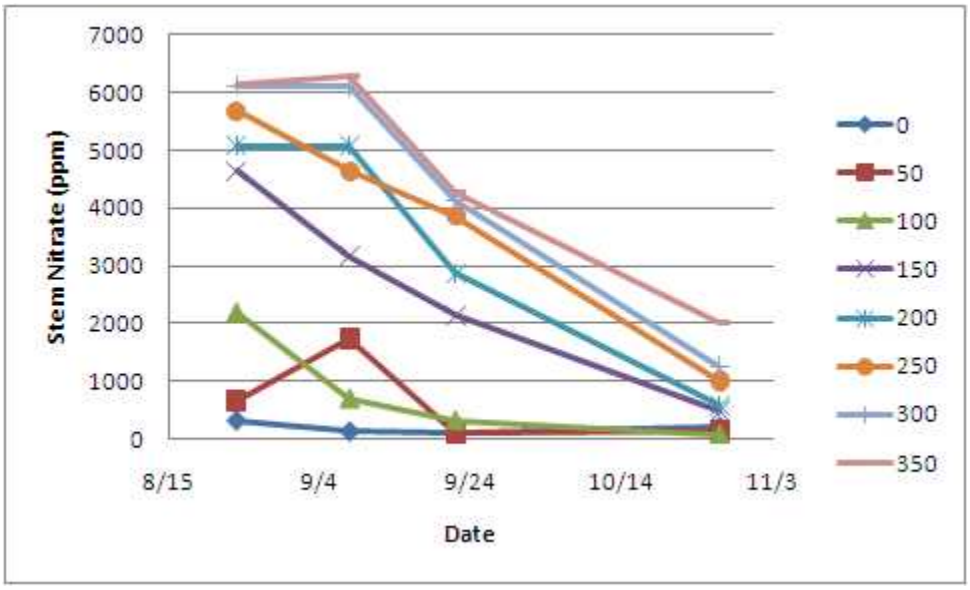

Fig. 6. Stem nitrate over time for the various N application rates.

Acknowledgments

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Doerge, T. A., R. L. Roth, and B. R. Gardner. 1991. Nitrogen fertilizer management in Arizona. College of Agriculture, Univ. of Arizona, Tucson.

Table 1. Irrigation and fertilizer schedule for a forage sorghum fertilization experiment conducted at Maricopa, AZ in 2009. A total of 1.52 inches of rainfall was recorded during the growing season.

			Seasonal N rate (lbs N/acre)							
Date	Stage	Irrigation	0	50	100	150	200	250	300	350
		inches	---------- lbs N/acre ----------							
07/08	Planting	4.55	0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
07/15	2-leaf	1.89	---	---	---	---	---	---	---	---
07/30	6-leaf	2.50	0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
08/12	10-leaf	2.93	---	---	---	---	---	---	---	---
08/25	14- leaf	3.26	0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
09/04	17- leaf	3.25	---	---	---	---	---	---	---	---
09/17	21-leaf	4.65	0	12.5	25.0	37.5	50.0	62.5	75.0	87.5
10/01	Boot	3.71	---	---	---	---	---	---	---	---
Sum		26.74	0	50	100	150	200	250	300	350

Tablel 2. Nitrogen (N) rate effect on forage yield adjusted to 70% moisture, forage moisture, stem density at harvest, date of 50% bloom, and number of leaves at various dates.

	Forage	Forage	Stem	Bloom	Leaf Number			
N Rate	Yield	Moisture	Density	Date	8/19	9/11	9/28	10/10
lbs N/A	T/A	%	Stems/A					
0	12.5	68.4	77,200	10/19	11.5	18.1	21.4	22.1
50	17.1	68.5	85,600	10/16	12.0	19.0	22.0	22.8
100	22.3	70.0	82,600	10/10	11.9	19.8	24.1	24.3
150	24.2	73.3	81,700	10/09	11.9	20.3	23.7	24.5
200	22.7	73.8	84,100	10/09	12.0	20.2	23.6	24.3
250	23.5	72.7	79,700	10/08	11.8	20.8	22.9	23.3
300	21.8	72.2	86,600	10/08	11.5	19.2	22.4	23.1
350	22.2	73.2	84,642	10/08	11.4	19.4	22.4	22.9
Average	20.8	71.5	82,800	10/11	11.8	19.6	22.8	23.4
CV (%)	11.1	2.0	8.6	0.0	4.1	6.9	5.2	4.3
Linear	**	**	ns	**	ns	ns	ns	ns
Quadratic	**	**	ns	**	*	*	**	**
Cubic	*	ns	ns	+	ns	ns	ns	ns

Table 3. Nitrogen fertilizer rate effect on forage yield adjusted to 70% moisture, nitrogen uptake, stem nitrate and total N, leaf nitrogen on a percentage and leaf area basis, and plant nitrogen at various growth stages.

Date	Growth Stage	N Rate lbs N/a	Forage Yield T/A	Nitrogen Uptake lbs/A	Stem Nitrate ppm NO_3-N	Stem Nitrogen %	Leaf Nitrogen %	Leaf Specific Nitrogen g N m^{-2} leaf	Plant Nitrogen %
07/29	6-leaf	0	0.036	0.74	---	2.79	4.00	---	3.29
		50	0.042	0.87	---	2.81	4.04	---	3.33
		100	0.044	0.93	---	2.82	4.20	---	3.36
		150	0.047	0.97	---	2.77	4.08	---	3.31
		200	0.051	1.05	---	2.90	4.07	---	3.29
		250	0.052	1.10	---	2.83	4.12	---	3.37
		300	0.050	1.08	---	2.89	4.15	---	3.43
		350	0.054	1.19	---	2.86	4.10	---	3.59
		Average	0.047	0.99	---	2.83	4.09	---	3.37
		CV (%)	17	17	---	4	3	---	5
		Linear	**	**	---	ns	ns	---	*
		Quadratic	ns	ns	---	ns	ns	---	ns
		Cubic	ns	ns	---	ns	ns	---	ns
08/10	9-leaf	0	0.139	2.95	---	2.66	3.98	1.79	3.50
		50	0.214	4.72	---	2.91	3.97	2.07	3.69
		100	0.212	4.74	---	2.92	4.10	1.98	3.74
		150	0.232	5.40	---	3.00	4.15	1.89	3.89
		200	0.257	6.06	---	3.04	4.14	1.89	3.92
		250	0.337	7.64	---	2.94	4.09	2.07	3.75
		300	0.246	5.76	---	3.06	4.12	2.06	3.94
		350	0.338	7.86	---	2.98	4.07	2.01	3.87
		Average	0.247	5.64	---	2.94	4.08	1.97	3.79
		CV (%)	24	23	---	5	3	7	5
		Linear	**	**	---	**	+	+	**
		Quadratic	ns	ns	---	*	*	ns	*
		Cubic	ns	ns	---	ns	ns	ns	ns
08/24	13-leaf	0	1.95	21.0	315	1.36	2.38	1.24	1.87
		50	3.05	35.0	655	1.52	2.46	1.34	1.91
		100	3.22	44.1	2199	1.97	2.78	1.57	2.29
		150	3.75	59.3	4640	2.56	3.02	1.69	2.61
		200	3.73	58.8	5073	2.73	3.03	1.80	2.60
		250	3.65	58.2	5683	2.75	3.05	1.31	2.62
		300	3.61	62.9	6117	2.95	3.12	1.50	2.87
		350	3.60	59.5	6138	2.82	2.98	1.42	2.72
		Average	3.32	49.8	3852	2.33	2.85	1.48	2.44
		CV (%)	13	17	19	14	8	21	9
		Linear	**	**	**	**	**	ns	**
		Quadratic	**	**	**	**	**	*	**
		Cubic	ns	ns	*	ns	ns	ns	ns

Table 3 (con'd). Nitrogen fertilizer rate effect on forage yield adjusted to 70% moisture, nitrogen uptake, stem nitrate and total N, leaf nitrogen on a percentage and leaf area basis, and plant nitrogen at various growth stages.

Date	Growth Stage	N Rate lbs N/a	Forage Yield T/A	Nitrogen Uptake lbs/A	Stem Nitrate ppm NO_3-N	Stem Nitrogen %	Leaf Nitrogen %	Leaf Specific Nitrogen g N m^{-2} leaf	Plant Nitrogen %
09/08	18-leaf	0	5.42	37.7	131	0.70	1.27	0.69	1.25
		50	6.81	56.5	123	0.98	1.54	0.87	1.46
		100	7.80	73.2	695	0.86	1.49	0.82	1.68
		150	7.99	89.3	3174	1.25	1.76	0.92	1.97
		200	9.08	112.6	5075	1.60	1.96	1.08	2.14
		250	8.83	111.8	4636	1.41	2.08	1.10	2.22
		300	7.21	96.5	6295	1.94	2.16	1.11	2.29
		350	8.48	108.1	6104	1.77	2.00	1.07	2.18
		Average	7.70	85.7	3279	1.31	1.78	0.96	1.90
		CV (%)	10	11	32	23	13	15	8
		Linear	**	**	**	**	**	**	**
		Quadratic	**	**	ns	ns	+	ns	**
		Cubic	ns	ns	*	ns	ns	ns	ns
09/22	Pre-boot	0	11.2	78	98	0.32	0.72	0.10	1.23
		50	15.0	100	107	0.36	0.78	0.26	1.22
		100	19.4	165	314	0.42	1.10	0.38	1.50
		150	21.7	204	2137	0.75	1.31	0.52	1.65
		200	21.4	191	2868	0.88	1.36	0.44	1.55
		250	21.8	216	3860	0.97	1.45	0.48	1.71
		300	20.1	191	4118	1.14	1.66	0.56	1.62
		350	21.0	213	4276	1.16	1.55	0.50	1.74
		Average	19.0	170	2222	0.75	1.24	0.40	1.53
		CV (%)	15	18	25	13	14	32	12
		Linear	**	**	**	**	**	**	**
		Quadratic	**	**	ns	ns	*	**	ns
		Cubic	ns	ns	**	*	ns	ns	ns
10/27	Harvest	0	13.0	37	212	0.22	0.35	0.20	0.44
		50	17.7	52	130	0.21	0.37	0.23	0.46
		100	23.2	77	75	0.26	0.47	0.33	0.52
		150	25.1	148	479	0.36	0.65	0.55	0.93
		200	23.5	138	573	0.40	0.72	0.47	0.92
		250	24.4	142	1001	0.42	0.87	0.56	0.90
		300	22.6	154	1256	0.56	0.80	0.52	1.06
		350	23.0	142	2019	0.57	0.80	0.62	0.96
		Average	21.6	111	718	0.38	0.63	0.44	0.77
		CV (%)	11	23	52	19	23	37	19
		Linear	**	**	**	**	**	**	**
		Quadratic	**	**	**	ns	+	ns	*
		Cubic	*	ns	ns	ns	+	ns	ns

Table 4. Coefficient of determination (R^2) for the relationship between forage yield (dependent variable) and nitrogen content of various plant tissues (independent variable) using a third degree polynomial as the model.

		Coefficient of Determination (R^2)				
		Stem	Stem	Leaf	Leaf Specific	Plant
	Growth	Nitrate	Nitrogen	Nitrogen	Nitrogen	Nitrogen
Date	Stage	ppm NO_3-N	%	%	g N m^{-2} leaf	%
07/29	6-leaf	---	0.19	0.02	---	0.06
08/10	9-leaf	---	0.20	0.06	0.29	0.13
08/24	13-leaf	0.61	0.56	0.54	0.28	0.52
09/08	18-leaf	0.55	0.54	0.60	0.50	0.69
09/22	Pre-boot	0.52	0.43	0.49	0.51	0.34
10/27	Harvest	0.11	0.39	0.61	0.68	0.45
8/24-09/22		0.56	0.51	0.54	0.43	0.52