Agronomic traits in tall fescue populations under irrigated and rain-fed conditions

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Abstract. Grasslands and native rangelands are the predominant land-use all over the world. Tall fescue [*Schedonorus arundinaceus* (Schreb.) Dumort] is a cool-season perennial grass widely grown throughout the temperate regions of the world and an important component of the grasslands. Drought can have serious consequences on performance of agriculture, soil and plant health, and economics. Developing drought tolerant plants that can maintain productivity during drought, will have great environmental and economic benefits to farmers. A tall fescue population was developed by crossing a drought tolerant genotype to a susceptible genotype. The population was evaluated for different morphological and yield traits under irrigated and rain-fed conditions at the University of Wyoming, USA. Large variations among the 252 tall fescue genotypes for several traits of interest have been observed. Plants under irrigated conditions were about 1.5 times more vigorous and 1.9 times taller than those grown in rain-fed conditions. Rain-fed conditions greatly reduced the tillering ability (<2.6 fold) of tall fescue plants. Plants under irrigated conditions were 2.9 times more productive than those grown in rain-fed condition. The largest difference in a year for water content (WC) between the plants grown in the two conditions was 8.06%. Genotypes with better tolerance to drought have been identified in the population which could be useful to develop drought tolerant tall fescue cultivars.

Keywords: Biomass, visual vigor, water content, rain-fed, irrigated.

Introduction

Drought stress is one of the most important constraints on agricultural profitability and sustainability worldwide. Grasslands and native rangelands are the predominant land-use all over the world. In the USA, improved pastures and rangeland cover nearly 99 million hectares, representing 27% of total land uses (Nickerson *et al.* 2011). Unfortunately, the yield and quality of many of these grasslands are low and have declined over time. This declining trend has been further accelerated by soil degradation and poor management practices (Islam *et al.* 2011).

Plant improvement programs are very important for agricultural profitability and sustainability. Crops with high-use efficiency of limiting resources including water are critical to producer's success (Islam *et al.* 2011). Grasses allow producers to harvest important commodities, like fibre and animal feed, and even biomass for biofuel, from marginal lands that would otherwise be incapable of high productivity. Tall fescue is considered to be one of the important cool‐season grass species in the USA that can grow on a wide range of soils, has high winter hardiness, and can be used for pasture, hay, stockpiling, silage, soil conservation, and turf grass (Ball *et al.* 2007; Bohlen *et al.* 2009; Islam *et al.* 2011).

Demand for new and suitable plant materials is a long-term issue and is increasing continuously. Major limitations are lack of appropriate cultivars or selections, limited growth response to added resources (*e.g.* fertilizers, irrigation, rain-fed conditions), and poor adaptation. Identification of drought tolerant genotypes and their utilization in breeding programs can have huge impacts (such as increasing productivity, sustainability, and profitability) on tall fescue cultivation in the temperate regions of the world. The objective of this study is to measure the production potential of tall fescue genotypes and identify agronomic traits relating to growth under marginal environments.

Methods

A total of 252 genotypes of the tall fescue population were planted at the University of Wyoming (41°19' N latitude and 105°33' W longitude, elevation 2195 m) under irrigated and rain-fed conditions. This was a F1 population which was developed from a cross between a drought tolerant genotype (B348) and a drought susceptible genotype (W947). Each genotype was planted 1 m apart in August 2008 and replicated three times. The experimental design of the study was a randomized complete block design. The total number of genotypes in each treatment was 756.

The plants were clipped three times (June, August, and October) in 2009 but two times (June and August) in 2010, 2011 and 2012. Frequency of harvest depended on the crop growth which was largely influenced by the weather conditions. Plant vigor was visually scored in a 0-10 scale, where 0 = dead and 10 = most vigorous. To determine water content (WC), fresh weight (FW) and dry weight (DW) of each harvest were determined using a 4-digit balance. WC was calculated according to Barrs (1968) as:

$$WC = (FW - DW/FW) \times 100.$$

This method was determined for each plant at each harvest. The plant height was measured as average height of whole plant. The leaf width was measured at the middle of randomly selected 10 leaves per plant and average was used. The tiller number was recorded by counting tillers of a section of whole plant and then multiplying by the number of sections. For DW estimate, the whole plant was harvested at 5 cm height and oven dried at 60°C for 24 hours.

Results

Forage yield and drought tolerance are difficult traits to select because of the low heritability occasioned by non-uniform testing conditions and large environment-by-genotype interactions (Izaurralde *et al.* 2011). It is difficult to obtain uniform drought stress conditions in the field where variation exists due to differences in soils, past practice, and microclimates (Islam *et al.* 2011; Izaurralde *et al.* 2011). Initial analysis of the data indicated wide variations among the 252 tall fescue genotypes for vigor, plant height, tiller number, and DW for evaluated genotypes under both irrigated and rain-fed conditions (Table 1). Average visual vigor scores were much higher in irrigated conditions compared to the rain-fed conditions. In general, plants were more vigorous at the beginning of all years and the growth diminished at later harvests.

Wide variations were observed in plant height under both conditions; however, variations were wider in drought conditions compared to the irrigated plots. The tallest plant under irrigation measured 164.0 cm but it was only 133.3 cm in drought conditions (Table 1). Number of tillers per plant was one of the most affected traits due to drought stresses. In irrigated fields even the poorest plant produced at least four tillers in 2009. Tillers per plant significantly increased each year from 2009 to 2012 and the highest number of tillers (583/plant) was recorded in irrigated plots

Table 1. Agronomic traits of tall fescue genotypes under irrigated and rain-fed conditions at different harvests during 2009-2012. Standard deviation (SD) was used to compare the means.

		Irrigated						Rain-fed					
Year/ harvest		Vigor*	Plant height (cm)	Tiller/ plant	Leaf width (cm)	DW/ plant (g)	WC (%)	Vigor	Plant height (cm)	Tiller/ plant	Leaf width (cm)	DW/ plant (g)	WC (%)
2009													
1st	Range	0.5-9.3	4.0-25.7	4.0-88.7	0.3-0.9	0.9-93.1	31.5-75.1	2.0-8.0	3.0-27.0	11.7-81.7	0.3-0.8	0.9-70.4	49.6-83.3
	Mean	6.3	14.6	44.7	0.6	35.1	66.2	5.4	12.9	43.9	0.6	22.5	68.9
	SD	1.4	3.9	13.7	0.1	17.0	6.9	1.1	4.1	11.8	0.1	12.0	3.9
2nd	Range	4.0-9.3	16.0-47.0	11.5-125.0	0.6-1.1	2.8-124.0	60.8-79.5	2.0-6.3	7-27.3	8.0-57.3	0.5-1.0	1.0-40.6	47.2-83.7
	Mean	7.0	28.2	67.1	0.8	54.2	69.0	4.2	17.2	38.2	0.7	12.6	66.3
	SD	0.9	4.4	14.9	0.1	18.3	2.3	0.7	3.3	7.3	0.1	5.7	4.8
3rd	Range	3.7-7.7	11.3-25.3	22.5-90.0	0.6-1.1	4.9-116.8	36.4-71.9	1.5-6.0	4.5-20.3	12.5-56.5	0.4-0.9	1.0-21.6	37.9-87.5
	Mean	6.0	17.4	61.3	0.8	31.4	52.7	3.5	10.6	32.1	0.7	7.7	64.2
	SD	0.6	2.4	10.1	0.1	11.1	6.1	0.6	2.3	6.7	0.1	3.6	5.1
2010													
1st	Range	4.0-10.0	30.0-60.0	25.0-126.7	0.5-0.7	14.3-157.7	65.5-85.7	0.0-9.3	0.0-55.7	0.0-100.0	0.0-0.7	0.0-129.5	56.3-80.8
	Mean	8.7	48.9	85.3	0.5	103.2	78.1	6.3	44.0	61.3	0.6	61.1	72.1
	SD	1.1	4.8	16.5	0.0	24.3	2.2	1.2	5.9	15.3	0.1	21.7	5.4
2nd	Range	4.0-9.7	23.7-45.0	40.0-113.3	0.6-1.0	26.5-174.8	29.7-82.9	0.0-6.5	0.0-27.7	0.0-60.0	0.0-0.6	0.0-54.7	0.0-78.0
	Mean	7.3	34.3	75.1	0.7	90.6	74.4	4.6	19.5	42.7	0.5	28.5	66.7
	SD	0.9	3.8	11.3	0.1	25.1	4.5	0.7	2.9	6.7	0.1	8.2	6.7
2011													
1st	Range	2.3-7.3	66.0-164.0	30.0-275.0	0.5-0.7	22.5-444.5	54.1-87.4	0.0-7.0	0.0-133.3	0.0-163.3	0.0-0.8	0.0-361.2	0.0-85.8
	Mean	5.8	116.0	243.9	0.6	227.6	74.1	4.4	31.1	90.7	0.6	91.3	77.0
	SD	0.7	13.1	54.9	0.0	65.7	2.8	1.1	8.8	34.5	0.1	45.2	7.3
2nd	Range	1.7-7.3	13.0-37.0	51.7-44.0	0.5-1.0	20-337.9	67.8-84.0	0.0-6.7	14.0-29.7	0.0-110.0	0.0-1.6	0.0-76.4	0.0-87.5
	Mean	5.2	28.2	193.1	0.7	163.1	74.4	4.0	23.8	59.1	0.6	35.7	66.0
	SD	0.9	4.0	47.7	0.1	44.7	1.9	1.0	2.8	18.8	0.1	14.0	7.0
2012													
1st	Range	1.0-6.7	7.0-15.3	26.0-583.3	0.4-0.7	2.0-83.33	34.6-75.0	0.0-6.0	0.0-11.0	0.0-222.3	0.0-0.7	0.0-34.0	0.0-87.5
	Mean	4.6	12.4	314.5	0.6	39.5	66.5	3.2	7.8	89.5	0.5	11.1	66.3
	SD	0.9	1.3	87.3	0.1	13.8	3.7	0.9	1.4	44.6	0.1	6.8	9.5
2nd	Range	1.7-6.3	9.3-29.0	33.3-411.7	0.5-0.8	2.67-126.0	56.7-78.5	0.0-4.5	0.0-21.0	0.0-80.0	0.0-0.8	0.0-18.0	0.0-84.3
	Mean	4.0	21.1	208.8	0.6	37.3	64.8	2.3	12.9	32.3	0.6	5.3	48.9
	SD	0.8	3.1	62.0	0.1	16.7	3.4	0.6	2.9	12.0	0.1	2.8	9.9

*Vigor score (0-10 scales, where 0 = dead and 10 = most vigorous), DW=dry weight, WC=Water content

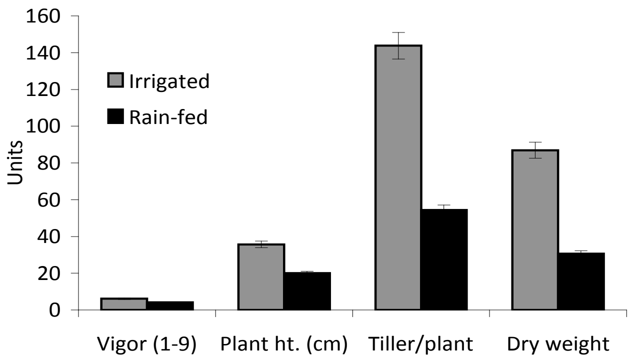

Figure 1. Performance of the tall fescue populations under irrigated and rain-fed conditions. Data are averaged across four years (2009-2012) and multiple harvests (2-3) in each year. Error bars for each data series are presented using standard error.

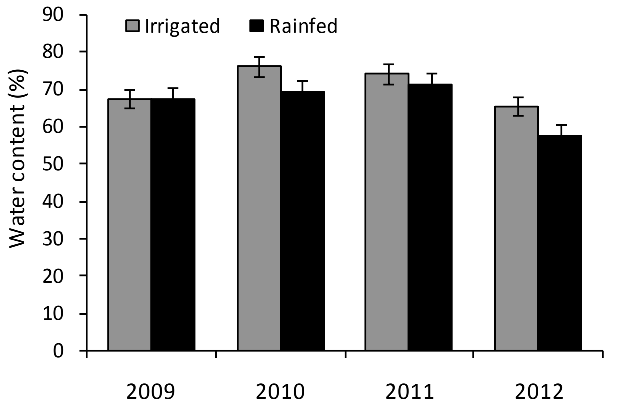

Figure 2. Water contents of the tall fescue population under irrigated and rain-fed conditions. Data are averaged across four years (2009-2012) and multiple harvests in each years. Error bars for each data series are displayed using standard error.

in 2012. In the same year, the highest number of tillers recorded in rain-fed plots was 222/plant. Little variations were noticed in leaf width. Dry weight ranged from 1-445 g/plant in irrigated plots while this range was 0-361 g/plant in rain-fed plots (Table 1).

A genotype effect was observed for WC. It is possible that this genotype effect was due to difference in osmotic adjustment (Blum 1999). Wide variability was observed among the genotypes for WC in different harvests and years (Table 1). In general, the WC was higher in 2011 compared to other years in both irrigated and rain-fed conditions. It is interesting to mention that the WC of some of the highly productive genotypes in rain-fed conditions was similar to some of the highly productive genotypes under irrigation. The genotypes with high WC in drought conditions might have the mechanisms to retain more water (high water retention capacity), hence may have high drought tolerance.

Plants under irrigated conditions were about 1.5 times more vigorous than those grown in rain-fed conditions (Fig. 1). Although plants in both irrigated and rain-fed conditions obtained moisture from melting snow at the early growing seasons in each year, the wide variation in the population was mainly due to inherent differences among the genotypes. Plants in irrigated conditions were 1.9 fold taller than those in rain-fed conditions (Figure 1). It is evident that water is very critical for tillering of the tall fescue plants. Tillering ability was badly affected by water limitations and plants under rain-fed conditions produced 2.6 fold less tillers than those in irrigated condition (Fig. 1). Plants under irrigated treatment were 2.9 times more productive than those grown in rain-fed treatments as demonstrated by 87 vs. 30 g average DW (irrigated vs. rain-fed) per plant (Fig. 1). Several classes of plants have been observed: for example – (1) plants performing well in both irrigated and rain-fed treatments; (2) plants performing well only in irrigated treatments; (3) plants performing well only in rain-fed treatments; and (4) plants performing poorly under both water treatments.

The WC of the population is summarized for each year from 2009-2012 (Fig. 2). The WC of the population in both treatments was similar in 2009 and 2011 but differed in 2010 and 2012. The largest difference in a year for WC between the plants grown in the irrigated and rain-fed treatments was 8.06% in 2012 and this may be because of extreme dry conditions in 2012 compared to other years (http://www.hprcc.unl.edu/data/).

Conclusions

Many of the tall fescue genotypes showed promise in respect to their growth and productivity. It is anticipated that selecting highly productive genotypes will help in developing new cultivars that will be specifically suitable for marginal environments. These genotypes will help to translate the genetic effects on complex traits such as drought tolerance, biomass production, and forage quality. These results could increase the effectiveness of future breeding programs and cultivar development.

References

Ball DM, Hoveland CS, Lacefield GD (2007) Southern forages, modern concept for forage crop management. (IPIN: Norcross).

Barrs HD (1968) Determination of water deficits in plant tissues. In 'Water Deficits and Plant Growth'. pp. 236-368. (Academic Press: New York)

Blum A (1999) Towards standard assays of drought resistance in crop plants. p. 3–35. *In*: Proceedings of the Workshop on Molecular Approaches for the Genetic Improvement of Cereals for Stable Production in Water-limited Environments (Mexico: CIMMYT).

Bohlen PJ, Lynch S, Shabman L, Clark M, Shukla S, Swain H (2009) Paying for ecosystems services on agricultural lands: an example from the Northern Everglades. *Frontiers in Ecology and the Environment* **7**, 46-55.

Islam MA, Biermacher JT, Interrante SM, Reuter RR, Hopkins AA, Cook BJ, Bouton JH, Butler TJ (2011) Production and economics of grazing rye–annual ryegrass and tall fescue systems. *Agronomy Journal* **103**, 558-564.

Izaurralde RC, Thomson AM, Morgan JA, Fay PA, Polley HW, Hatfield JL (2011) Climate impacts on agriculture: Implications for forage and rangeland production. *Agronomy Journal* **103**, 371-381.

Nickerson C, Ebel R, Borchers A, Carriazo F (2011) Major uses of land in the United States: 2007. EIB-89 US Department of Agriculture, Economic Research Services