CHAPTER I

Tall Fescue Seedling Response for Root and Shoot Growth.

ABSTRACT

A series of controlled environment experiments were conducted in order to determine root and shoot growth of mowed and unmowed tall fescue germplasm. Seedlings from seven distinct tall fescue seed sources having turf-type, forage or undetermined growth habits were evaluated. Seedlings were grown for 5 weeks in plastic cylinders and were evaluated for: numbers of leaves, tillers and roots per plant, fresh shoot and root weight, root volume, deep roots and leaf area.

Broad sense heritabilty (BSH) and genetic coefficient of variation (GCV) for seedlings mowed at 33 mm ranged from 1.2 to 34.1, and 1.5 to 17.2, respectively. Unmowed seedlings had BSH and CGV values ranging from 1.0 to 10.7, and 2.8 to 9.4, respectively.

Mowing reduced root numbers (20%), rooting depth (23%), fresh root weight (61%), fresh top weight (60%) and leaf area (64%) when compared to unmowed plants. Certain sources had less severe growth reductions when compared to their unmowed counterparts. Changes in source rank occurred. Seed source x cut interactions were observed for number of roots

($p \geq 0.01$), deep roots ($p \geq 0.05$) and root volume ($p \geq 0.10$). These results indicate that it may be possible to alter the shoot and root systems of mowed tall fescue by selection and hybridization. Further testing of individual plants under replicated field conditions appears warranted.

Introduction

Tall fescue (*Festuca arundinacea* Schreb.) is a cool season grass used for both forage and turf. Over 35 million acres have been planted in the United States (Buckner, 1979). The species is comprised of many ecotypes with different growth habits. Tall fescue has been regarded as a low maintenance turfgrass, having a coarse, leaf-texture and low shoot density. Tall fescue is ranked among turfgrass species as having good drought tolerance (Beard, 1973; Turgeon, 1980). Reference is made to its coarse and deep root system when compared to different turf species (Youngner et al., 1981; Sheffer and Dunn, 1981), but intraspecific data concerning root systems are limited to forage studies (Williams et al., 1982; Elkins et al., 1979). Being a cross-pollinated species, variability should be expected for root growth within tall fescue (Buckner, 1979; Williams, 1982; Elkins et al., 1979). It would be valuable to estimate the genetic variation associated with both the root and shoot system of tall fescue if selection schemes are to be formulated for germplasm development of ideotypes based on root or shoot growth.

Root systems of forage tall fescues have been found to exhibit variation in root size (Williams, 1982; Elkins et al., 1979) and distribution patterns (Williams, 1982). Forage management practices have an impact on the plant's root system since sudden and severe defoliation causes a halt in root activity and decreased root growth (Crider,1954). Mowing at more frequent intervals and removing one third or less of the topgrowth per mowing is believed to be less detrimental to turfgrass root growth, and has become a commonly recommended turfgrass cultural practice (Beard, 1973).

Turf-type tall fescues have only recently been developed (Funk et al., 1980; Funk,et al., 1982). Therefore, it is important to study their root and shoot systems to allow a better understanding of the genetic response to turf-related mowing stress. Information of this nature would allow identification of tall fescue germplasm which may have improved drought avoidance characteristics. This approach has been undertaken in other crop species. Successful wheat ideotypes have been developed with certain root parameters under genetic control and were moderately heritable (Hurd, 1974; Murphy et al., 1982). Mean root number was a stable characteristic in diploid wheat accessions (Robertson et al., 1979). Root depth, total numbers of seminal and nodal roots were genetically controlled (Dereda et al., 1969). 1969). Genetic variation was moderate in alfalfa for root diameter, number of lateral roots, root dry weight, and degree of branching (Pederson et al., 1984).

The objectives of this study were to determine the genetic response associated with root and shoot growth for both mowed and unmowed tall fescue seedlings, and to determine the effects of mowing on root and shoot growth of tall fescue seedlings having diverse growth habits. This information would be of benefit to plant breeders for selection of mowed seedlings for field testing.

Materials and Methods

Seedlings from five cultivars, one experimental synthetic, and one F1 experimental hybrid accession were included in each test. These seven distinct germplasms will hereafter be referred to collectively as "sources". The sources `Rebel',`Mustang' and experimental Syn-Ga have turf-type growth characteristics. `Pastuca' and `Kenhy' were forage types having long lax leaves, longer internodes and more robust tillers than the turf-types. DT-294 was a F1 population from the cross of a single clone from PI 2609921 X Rebel. The female was selected for leaf turgor maintenance as a mowed space plant during an extended period of drought in Adelphia, New Jersey in 1980. The source Kentucky 31 was selected because it has been used in turf, even though it has forage characteristics.

Seeds were germinated in washed vermiculite on a greenhouse bench. In each test, 28 randomly selected seedlings per source were transplanted into 38 mm diameter x 210 mm deep plastic tubes filled with washed silica sand. Fourteen seedlings per source were mowed every three days at 33 mm with the other 14 being unmowed. Seedlings were grown in a controlled environment chamber with a 14 hr photoperiod at 175 W m^{-2}, and exposed to constant temperatures of 14.0, 16.5, and 18.0 $\pm$ 2.0 ^{0} C in each respective test. Plants were watered every other day to profile saturation with a 1/3 strength Hoaglands solution until the profile was saturated (Hoagland and Arnon, 1950). Profiles were leached every 6 days with distilled water to prevent salt accumulation. Experiments were terminated 5 weeks after transplanting, when approximately one-half of the unmowed plants had two or more roots at the bottom of the tube. Plants were removed from their tubes and roots were washed.

Seedling root variables measured included single deepest root (mm), depth of the third deepest root (mm), fresh root weight (mg), and root volume (m^3) Fresh root weight was determined after blotting excess moisture from the root system with paper towels followed by uniform bursts of compressed air. Root volume was determined by displacement using the formula:

$$\text{Root volume} = \frac{\text{fresh root weight}}{1 + (P1-P2)}$$

where P1 = weight of pycnometer, water and roots

P2 = weight of pycnometer and water.

To substantiate the technique, biological root densities were determined by dividing the fresh root weight by root volume. Seedling root distribution was not quantified but studied indirectly by analyzing the divisor of the third deepest root/deepest root. Seedling shoot parameters measured included number of tillers with at least one fully expanded leaf, leaf number, fresh shoot weight (g) and leaf area (m^2). Root/shoot ratios were also determined for each seedling by fresh wweight.

Experimental design was a split plot with mowing as the whole plot and sources as sub-plots. Whole plots were replicated twice in each test. Seven seedlings per source were randomly assigned to both for a total of 14 seedlings per mowing treatment. Twenty eight seedlings were used to evaluate all effects in each environment. A combined analysis of variance was performed with experiments treated as environments (Table 1). A combined analysis was performed for each mowing regime to determine source responses to mowing and to determine genetic effects (Table 2). Variance components were estimated from mean square expectations to determine broad sense heritability (Comstock and Moll, 1963) and the genetic coefficient of variation (GCV) (Burton and Devane, 1953). Variance components for source, source x environment, source x replication / environment, and observations /source x replication / environment were used as estimates of the genetic, genetic x environment, experimental error and sampling error variances, respectively.

Results and Discussion

Techniques for determining root volume proved successful since there were no significant effects due to mowing or source in any analysis for the biological density of roots which ranged from 0.97 to 1.01 (g/cm^3). Partial correlation coefficients for fresh and dry root weights, and fresh root weight and root volume were $r = 0.94$ and $r = 0.98$, respectively. These data indicate that the root washing technique worked, and that root volume can be estimated using the pycnometer bottle and blotting method. Other researchers have successfully used the displacement technique in oats and computed a correlation of $r = 0.84$ for fresh root weight and volume (Murphy et al., 1982).

Seedlings of mowed sources exhibited significant differences for leaf number and deep root ($p \geq 0.05$). The number of roots was significant at the 0.10 probability level (Table 3).

DT-294 was unique in that it produced the shallowest root system when unmowed, but always the deepest when mowed. DT-294 also produced the largest root volume of mowed sources, (ranking fifth unmowed). These facts strongly suggest that this source has the ability to respond with favorable root growth when mowed as a seedling.

Interestingly, root volume was not consistent with root/shoot ratio. The partial correlation coefficient for root volume and root/shoot ratio was r= 0.20. This was because root growth was accumulated during the entire experiment while plants were clipped twice weekly. Inducing mowing stress to large seedling numbers was more important than collecting clipping yields in these experiments.

Syn-Ga produced the largest number of roots, was second in root volume and produced a robust root system when mowed. Both Syn-Ga and DT-294 originated as accessions which had superior summer performance as clones in Georgia and New Jersey (C.R. Funk, personal communication). These sources had the greatest root volumes when mowed, leading to speculation that drought avoidance due to more extensive root systems may have contributed to their empirical selection.

Kenhy and Pastuca reacted differently to mowing. Pastuca had the deepest roots when unmowed, but the shallowest when mowed (Table 4). Kenhy produced poor root growth and was stable in rank whether mowed or unmowed. It produced the fewest and the shallowest roots of the sources tested. Pastuca and Kenhy remained stable in rank for root/shoot ratio whether mowed or unmowed (Table 4).

Kentucky 31 ranked intermediate for most shoot and root parameters when mowed. This may be a factor contributing to it's acceptable performance as a utility turf. It had the second lowest root/shoot ratio when mowed (Table 4).

It is believed that the root/shoot ratio is a constant value, and that alterations in any one will cause growth adjustments in the other (Brouer and DeWit, 1979). Results of this study are in partial agreement with their theory since root/shoot ratios were never significantly different in any analysis due to source or mowing. This is further substantiated by the lack of relationship between root/shoot ratio and leaf area (partial correlation coefficient r= -0.05). This may be important if the time dependency of the experiment has equal affects on shoot and root development. If so, then it would be valid to formulate a selection index in order to develop germplasm which has a large root volume and large root/shoot ratio when mowed.

Broad sense heritability (BSH) indicates percentage of overall variation which is genetic, while the genetic coefficient of variation (GCV) is a measure of genetic variation about the mean on a percentage basis (Burton 1953). The BSH and GCV values for shoot and root growth response variables wrer low (Table 5). Factors leading to these results are large sampling errors due to analysis on a single plant basis (not on plot means) and the highly heterozygous nature of the sources. These factors would increased the denominator in heritability estimates, and increased the total variation about the mean. GCV values for shoot related forage response variables ranged from 8.3 to 31.0% for 77 tall fescue accessions when analyzed on plot mean basis (De Arujo et al.,1984). GCV and BSH values obtained in this research were reasonable with those of De Arujo's study, based on the different types of analysis used.

Unmowed sources had decreased genetic estimates for tiller and leaf numbers. This was probably due to the experiment's short duration. Rooting decreased with clipping treatment, but the expression of genetic variation was not greatly suppressed, suggesting that genetic progress could be made in root growth improvement of mowed tall fescue plants.

Root parameters and leaf area were affected by mowing (Table 6). Leaf number, tiller number and root/shoot ratio were not affected by mowing. Shoot density has been reported to increase with mowing (Beard, 1973; Madison and Hagan, 1962). This was not the case in this study. This again was probably due to the short study duration (i.e. 5 weeks) and the differences in light intensity between field and controlled environment.

Mowing reduced root numbers by 20%, rooting depth by 23%, fresh top growth weight by 60%, and fresh root weight by 61% (Table 3). Root growth reduction was expected since root growth had been reported to be closely associated with mowing height and frequency (Beard, 1973; Madison and Hagan, 1962).

Significant mowing height x source interactions were realized for root numbers ($p \geq 0.01$), while interactions were significant at the 0.10 probability level for deep root, third root and root volume (Table 7). Certain sources changed rank when mowed while others maintained more growth both in relation to other sources and their unmowed counterparts. The latter case was indicated by the growth comparison index (GCI) which was calculated by the equation: (mowed mean $\div$ unmowed mean) x 100. A large value indicated that a mowed source closely approached its unmowed performance (Table 8). Rebel tall fescue produced the greatest root volume when mowed, but had the lowest GCI when compared on a mowed to unmowed basis (31%). Rebel had the greatest reduction in shoot fresh weight, and ranked next to the lowest in root volume. Rebel had the largest root/shoot ratio when mowed, but next to the lowest leaf area which paralleled its root volume. Rebel's leaf area was the second lowest. It was important to study root volumes and weights with root/shoot ratios, since turfs with a high root/shoot ratio and a extensive root system would be desirable from a drought avoidance standpoint (Burton, 1959).

Estimates of the additive genetic variance and narrow sense heritabilities can be calculated with an appropriate mating scheme (Gardner, 1963). This would allow predicted gains from selection and choice of a suitable mating scheme for developing tall fescue germplasm with superior root characteristics when screened under mowing stress. There are many environmental (Robertson et al, 1979; Bierhauzen, 1981) and cultural factors (Crider, 1955; Whitehead, 1983; Willard ,1932; Madison and Hagan, 1962) which influence root and shoot growth. These experiments were conducted at temperatures within an acceptable range for root growth of cool season grasses and water was not a limiting factor from an excess or deficient standpoint.

Genetic variation was evident for mowed tall fescue seedlings for the growth parameters studied. Current investigations are underway to determine the relationship between seedling and mature plant shoot and root growth at the University of Nebraska Research and Development Center located near Mead, Nebraska.

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Table I.1. Combined analysis of varaiance for mowed and unmowed tall fescue seedlings.

Source of variation		df
Total		587
Environment		2
Replication/Environment		3
Cut		1
Cut x Environment		1
Cut x Replication/Environment	(error a)	3
Seed Source		6
Seed Source x Environment		12
Seed Source x Cut		6
Seed Source x Cut x Environment		12
Seed Source x Cut x Replication/Environment	(error b)	36
Plants within plots		504

Table I.2. Combined analysis of variance, showing df, mean square expectations and variance components for mowed and unmowed tall fescue seedlings.

Source of variation	df	EMS	Variance Component
Total	293		
Environment	2	@2 + @2 re + @2e	-
Rep/Environment	3	@2 + @2 re	-
Source	6	7@2 sr/e + 14@2 se + 42@2 s	@2 g
Source x Environment	12	7@2 sr/e + 14@2 se	@2 ge
Source x Rep/Env.	18	7@2 sr/e	@2 e
Plants within plots	252	@2[†]	@2 w

[†]@2 = σ^2, the estimate of the population variance.

Table I.3. Tall fescue seedling germplasm responses for root and shoot variables when mowed or unmowed.

	Unmowed		Mowed		
Response	Mean	Significance of effect	Mean	Significance of effect	Mean%† Change
Tillers	4.0	**	4.1	ns	0
Leaves	9.7	**	10.3	*	+6
Deep root (mm)	174.8	ns	134.2	**	-23
Third root (mm)	148.1	ns	100.4	ns	-49
No. Roots	7.8	*	6.3	ns	-20
Fresh root (g)	0.5	ns	0.2	ns	-62
Fresh shoot (g)	0.7	ns	0.2	ns	-61
Root vol (m^3)	0.5	ns	0.2	ns	-62
Root:shoot	0.7	ns	0.7	ns	-2
Leaf area (m^2)	17.1	ns	6.1	ns	-64

†Mean% change = (grandmean mowed / grandmean unmowed) X 100

*,**, and ns indicate significance at the 0.05, 0.01 probabilty levels, respectively.

Table I.4. Plant growth responses for mowed and unmowed tall fescue seedlings.

Deepest root (mm)			Root volume (10 m)			Leaf area (10 m)		
Source	Mowed	Unmowed	Source	Mowed	Unmowed	Source	Mowed	Unmowed
DI294	150 a	164 a	DI-294	2.4 a	5.2 a	DI-294	7.0 a	17.3 ab
Syn-Ga	139 b	178 a	Syn-Ga	2.23 b	5.9 a	Mustang	6.6 b	18.0 ab
Mustang	137 b	177 a	Mustang	2.1 b	6.3 ab	Syn-Ga	6.4 b	18.7 a
K-31	132 b	173 a	K-31	2.0 b	5.3 ac	Festuca	6.3 b	16.0 ab
Kenhy	131 bc	178 a	Festuca	2.0 b	5.0 bc	K-31	6.0 b	16.9 ab
Rebel	130 bc	170 a	Rebel	1.9 b	6.4 a	Rebel	6.0 b	18.2 a
Festuca	118 c	179 a	Kenhy	1.8 b	4.6 c	Kenhy	4.9 b	15.2 b

Root/Shoot ratio			Number of Roots		
Source	Mowed	Unmowed	Source	Mowed	Unmowed
Rebel	0.81 a	0.81 a	Syn-Ga	7.1 a	8.6 a
Syn-Ga	0.79 b	0.71 b	DI-294	6.9 ab	7.4 c
Festuca	0.71 b	0.73 ab	Festuca	6.5 ab	7.7 bc
Mustang	0.71 b	0.77 ab	Mustang	6.2 ac	8.5 ab
DI-294	0.71 b	0.70 b	K-31	6.1 ac	7.8 ac
K-31	0.69 b	0.74 ab	Rebel	5.9 bc	7.9 ac
Kenhy	0.68 b	0.69 b	Kenhy	5.2 c	6.5 d

Values are means of 42 observations each for mowed and unmowed tall fescue seedlings.
Values in a column followed by the same letter are not significantly different at the 0.10 probability level Duncan's multiple range test.

Table I.5. Broad sense heritability (BSH) and genetic coefficient of variation (GCV) values for mowed and unmowed tall fescue seedlings.

	Unmowed		Mowed	
Response	BSH	GCV	BSH	GCV
Tillers	17.4	15.2	4.9	7.5
Leaves	34.1	17.2	10.7	9.4
Deep root (mm)	0.2	0.9	5.6	6.1
Third root (mm)	1.2	1.5	2.2	4.2
No. roots	7.4	6.5	6.9	6.5
Root volume (m^3)	34.9	8.0	0.3	6.8
Root:shoot	28.3	7.7	5.5	2.8
Leaf area (m^2)	–[+]	–	1.0	4.0

+ Nonestimable due to negative variance component.

Table I.6. Overall significance of mowing on tall fescue seedlings.

Response	F Value	Significance
Tillers	0.01	NS
Leaves	0.03	NS
Deep root (mm)	22.0	NS
Third root (mm)	14.0	*
No. Roots	15.0	*
Fresh root wt (g)	63.0	*
Fresh shoot wt (g)	370.0	**
Root volume (cm^3)	898.0	**
Root:shoot	0.1	NS
Leaf area (m^2)	733.0	**

*,**, and ns indicate significance at the 0.05, 0.01 probability levels and nonsignificance, respectively.

Table I.7. Mowing and mowing x source interaction affects for tall fescue seedlings.

	Mowing		Mowing x source	
Response	F Value	Significance	F Value	Significance
Tillers	0.01	ns	1.16	ns
Leaves	0.03	ns	1.82	ns
Deep root (mm)	22.00	**	2.16	*
Third root (mm)	14.00	**	2.24	*
No. roots	15.00	**	2.51	**
Fresh root wt (g)	63.00	***	1.88	ns
Root vol. (cm^3)	898.00	***	2.15	*
Root:shoot	0.10	ns	0.20	ns
Leaf area (cm^2)	733.00	***	0.89	ns

*,**, and ns indicate significance at the 0.05, 0.01 and probability levels, and nonsignificance, respectively.

Table I.8. Growth comparison index (GCI)[†] values for 7 tall fescue seed sources.

Source	Deepest root	Third deepest root	Root volume	Leaf area	Fresh shoot	Root/shoot ratio	Number of roots
Rebel	72	63	31	31	42	99	74
Pastuca	66	61	40	38	40	97	85
K-31	76	68	38	35	40	94	78
Syn-Ga	77	68	38	34	38	102	81
DT-294	91	82	47	40	43	100	93
Kenhy	77	66	39	33	40	93	79
Mustang	77	82	33	37	37	102	93

[†]Values are % performance of mowed and unmowed counterparts.