Effects of Maturity on Yield and Quality Traits in Tall Fescue (*Festuca arundinace* Schreb)

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**Abstract:** The objective of this study was to investigate the effects of phenological stages on yield and quality traits in tall fescues (*Festuca arundinace* Schreb). A split plot design was conducted using a complete randomized block with two replications in Research Institute of Forests and Rangelands, Karaj, Iran during 2004-2006. Eight genotypes 1610, 1269, A221, 1081, 1768, AB1, 1061 and Festorina were used as subplot and were cut in five maturity stages as vegetation, heading date, anthesis, milky development and dough seed stage as main plots. Data were collected and analyzed for DM yield, stem numbers, plant height and five quality traits as: dry matter digestibility (DMD), water soluble carbohydrate (WSC), crude protein (CP), acide detergent fibre (ADF) and total ash. The results showed significant differences among genotypes for DM yield, stem number and CP. The genotypes, 1269, 1768, 1061 and Festorina with average values of 4398 to 4972 Kgh⁻¹ had higher DM production. The effect of phenological stage was significant for all of traits. For DM yield, the lower and higher values of 3083 and 5089 Kgh⁻¹ were obtained, in vegetation and soft dough stages, respectively. In contrast, the average values of DMD% and CP% were high in both vegetation and heading stages and they dramatically decreased in mature hay by 18% and 44% lower than those of vegetation hay, respectively. It concluded that milky stage was the best stage for harvesting maximum DM yield couple with three quality traits DMD, WSC and CP yields in tall fescues under conservation management.

**Key words:** Tall fescues (*Festuca arundinace*) • Yield • Digestibility • Carbohydrates phenological stages

**INTRODUCTION**

Forage production from grassland is very important in Iran. The botanical composition of rangelands is very variable. Tall fescue (*Festuca arundinacea* Schreb) is one of the main perennial grasses that naturally grown in temperate pasture and rangelands in north and west of Iran. It is being used for grazing and hay production and consumed by livestock. Tall fescue is growing from the level of 1200m to 2900m areas having more than 300 mm annual participation [1].

The improvement of forage quality has a great effect on dairy production. Crude protein (CP) is one of the main factors of forage quality. Absorbable protein in rumen can be increased by decreasing the process of protein resolution in rumen. For livestock to absorb more protein, it is needed to increase soluble carbohydrates in order to provide the necessary energy for protein microbes (Hoffman *et al*, 2003). Animal performance depends on the intake of digestible and metabolizable nutrients. Digestibility accounts for up to 60% of intake variation (Van Vuuren, 1994). Walters (1984) reported that even a small change in digestibility could lead to a relatively large change in voluntary intake. Selection for improved digestibility is expected to cause a correlated improvement in intake characteristics (Hacker, 1982). Chemical composition of grasses changes with advancing maturity. As grass matures the proportion of the cell wall increases and the cell, content fraction decreases. Both non-structural and structural carbohydrates, depending on maturity stage, make up approximately 50 to 80% of dry matter of forages (Gill *et al*, 1989). Maturity and herbage age generally have a greater influence on forage quality than environmental factors. As plants advance in maturity, cell wall concentration within stems and leaves, increases and the proportion of cell soluble content decreases. The rate of decline in digestibility of forage is greatest during reproductive growth (Buxton *et al*,...
1996). Breese and Thomas (1967) showed that small differences in maturity of cocksfoot could greatly affect digestibility.

ADF percent will increase by growing the stem height and as plant matures, cellulose and other structural carbohydrates will be collected in cell wall. This process is called lignifications. One of the other factors that affect forage production is changing the ratio of leaf to stem. With the gradual growth of plant, the ratio of leaf to stem will change (more stem and less leaf) and by increasing of NDF, digestibility percent and plant energy will decrease and therefore the plant quality will reduce (Hoffman et al. 2003).

As in the case of other quality traits, CP in herbage is strongly influenced by environment and stage of growth. CP concentration declined linearly over time in cool season grasses and this was due to a decrease in CP concentration in both leaves and stems (Buxton et al., 1996). Today traditionally, farmers know that the beginning of ear emergence time for forage harvest. However, the reduction of quality with plant growth and their relationships with dry matter yield is greatly important in forage harvest and grazing management. Being aware of forage quality and its changes in different phenological stages is one of the fundamental items for estimating of accurate amount of daily feed requirement for livestock and estimating grazing capacity in pastures to determine suitable time that livestock enter into pasture.

For establishment of new pastures and rangelands improvement and rehabilitation, this research was carried out as a part of a project for breeding improved grass varieties. The aim of study was to determine the effect of phenological stages on forage quality traits as: dry matter digestibility (DMD), water soluble carbohydrate (WSC) and crude protein (CP), Acid detergent fiber (ADF) and total ash in eight accessions of tall fescue.

**MATERIALS AND METHODS**

Three foreign varieties (A221, Festurina, AB1) from Ireland and five domestic and/or unknown origin accessions (1610, 1269, 1081, 1768 and 1061) of tall fescue were provide from Iranian natural resources gene bank. They were sown as spaced plants using a split plot design with two replications under irrigated condition in Research Institute of Forests and Rangelands, Karaj, Iran in 2004. Eight genotypes were used as subplot and five phenological stages (vegetative, heading, pollination, milky and dough seed stage) as main plot. Each plot containing four spaced plants rows in 50 cm apart, with 40 cm spacing within rows. Fertilizer application rates were 50 and 100 kg/ha⁻¹ nitrogen (N) and phosphorus (P) at sowing time, respectively. Application of nitrogen was continued at 50 kg/ha⁻¹ for the second and third years. No measurements were taken in the establishment year. In spring 2005 and 2006, genotypes were harvested at five phenological stages for the following traits.

- DM yield: the plants of each plot was harvested, allowed to air dry and dry weight was expressed in Kgh⁻¹. Thus, this represented the aboveground biological yield.
- To obtain total annual (TDM) yield, plots were also cuts by 45 days interval from the last phenological stage.
- Stem length (cm): from the soil surface to the tip of tallest stem was recorded
- Stem numbers: was recorded as the stem number of five individual plants per plots.
- Quality traits: A sub sample was taken, dried at 70°C for 12h and reweighed to determine DM yield, then ground with 1 mm screen mill. Five quality traits (DMD, WSC, CP, ADF and total ash) were estimated in the first cuts for two subsequent years using near infrared spectroscopy (NIR). Details of the methodology and calibrations of NIR are given by Jafari et al. (2003b).
- Total digestible yield, CP-yield and WSC-yield were also estimated by the product of quality traits percent by DM yield.

Phenological stages and genotype effects was determined by analysis of variance (SAS Inst. 2004). Both phenological stages and genotypes and their induction effects mean were compared by DMRT method.

**RESULTS AND DISCUSSION**

The results of analysis of variance showed significant effect of phenological stages for all of traits (Table 1). For DM yield, the lower and higher values of 3083 and 5089 Kgh⁻¹ were obtained, in vegetation and seed soft dough stage, respectively (Table 2 and Fig. 1). In vegetative stage, DM yield values were 40% lower than soft dough. Therefore, as a general rule one can estimate about half the yield at vegetative than what would be expected at soft dough in tall fescue.
Table 1: Results of analysis of variances for yield and quality traits in 8 tall fescue accessions in 5 maturity stages over two years.

<table>
<thead>
<tr>
<th>S.O.V</th>
<th>DM Yield tonh⁻¹</th>
<th>Stem No.</th>
<th>Plant height (cm)</th>
<th>DMD%</th>
<th>CP%</th>
<th>WSC%</th>
<th>Ash%</th>
<th>ADF%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Block</td>
<td>0.036</td>
<td>4402</td>
<td>31</td>
<td>2.92</td>
<td>3.28</td>
<td>8.45</td>
<td>0.16</td>
<td>3.15</td>
</tr>
<tr>
<td>Stage (S)</td>
<td>9.76**</td>
<td>7993*</td>
<td>2115*</td>
<td>335.3**</td>
<td>186.2**</td>
<td>53**</td>
<td>20.1**</td>
<td>87.8**</td>
</tr>
<tr>
<td>Error1</td>
<td>0.214</td>
<td>1142</td>
<td>22</td>
<td>4.95</td>
<td>4.92</td>
<td>0.23</td>
<td>5.26</td>
<td>1.13</td>
</tr>
<tr>
<td>Genotype (G)</td>
<td>5.26**</td>
<td>3911**</td>
<td>276</td>
<td>6.11</td>
<td>2.26**</td>
<td>0.48</td>
<td>1.51</td>
<td>2.5</td>
</tr>
<tr>
<td>G x S</td>
<td>1.06**</td>
<td>1545*</td>
<td>60*</td>
<td>3.00*</td>
<td>1.67*</td>
<td>1.45</td>
<td>0.66</td>
<td>0.78*</td>
</tr>
<tr>
<td>Error1</td>
<td>0.453</td>
<td>821</td>
<td>50</td>
<td>2.97</td>
<td>0.80</td>
<td>1.15</td>
<td>0.16</td>
<td>3.15</td>
</tr>
</tbody>
</table>

*, ** = Means of squares are significant at 5%, 1%, respectively.

Table 2: Mean comparison for yield and quality traits in 8 tall fescue genotypes in 5 maturity stages over two years (2005 and 2006 averaged).

<table>
<thead>
<tr>
<th>Phenological Stages</th>
<th>DM Yield Kgh⁻¹</th>
<th>Stem No.</th>
<th>Plant height (cm)</th>
<th>DMD%</th>
<th>CP%</th>
<th>WSC%</th>
<th>Ash%</th>
<th>ADF%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vegetation</td>
<td>3083 c</td>
<td>107.9 b</td>
<td>56.29 c</td>
<td>57.23 a</td>
<td>17.82</td>
<td>8.38 c</td>
<td>6.78 a</td>
<td>40.35 c</td>
</tr>
<tr>
<td>Heading</td>
<td>3517 c</td>
<td>141.4 a</td>
<td>75.78 c</td>
<td>58.20 a</td>
<td>15.67</td>
<td>10.19 b</td>
<td>6.90 a</td>
<td>39.68 c</td>
</tr>
<tr>
<td>Anthesis</td>
<td>4024 b</td>
<td>160.7 a</td>
<td>70.65 b</td>
<td>55.07 b</td>
<td>12.57</td>
<td>10.92 b</td>
<td>6.82 a</td>
<td>43.13 b</td>
</tr>
<tr>
<td>Seed milky</td>
<td>4430 b</td>
<td>161.4 a</td>
<td>81.66 a</td>
<td>50.99 c</td>
<td>10.42</td>
<td>12.73 a</td>
<td>5.60 b</td>
<td>43.17 b</td>
</tr>
<tr>
<td>Seed ripening</td>
<td>5089 a</td>
<td>154.8 a</td>
<td>77.87 a</td>
<td>46.75 d</td>
<td>9.84 d</td>
<td>12.69 a</td>
<td>4.94 c</td>
<td>48.27 a</td>
</tr>
</tbody>
</table>

Means with the same letter are not significantly different (p<0.01).

Percent of DMD and CP were the highest when the plants were immature (Table 2 and Fig 1, 2, 5 and 6). CP tends to drop sharply as the plants go to milky stage and then its value was consistent from milky to soft dough stage (Figs. 1 and 6). DMD values were declined from 57.23 to 46.75 for vegetative and soft dough stage, respectively. The average values of DMD and CP concentration were trend to be high from vegetation to heading stages and they dramatically decreased to soft dough stage by 19% and 45% lower than those of vegetation hay, respectively. DMD declines were slower than did for CP by advancing maturity from vegetative to milky stages. But, CP values was dropped off sharply from milky to soft dough stage (Fig. 1, 2 and 5). Such results are in agreement with the published data for reduction of forage digestibility with plant phenological growth (Hoffman et al. 2003 and Marten, 1989). It seems the reduction of DMD and CP with advancing maturity is due to the reduction of leaf to stem ratio (Buxton et al. 1996, Wilkins and Lovatt, 1989). Berdahl et al. (1994) reported that protein content in leaves of Agropyron intermedian is two times larger than its stems. For WSC, The average values were increased from vegetation to milky stages and then its value was consistent from milky to soft dough stage. Such result is expected because with plant maturity and reducing the ratio of leaf to stem, the WSC density will increase in stem. McGrath (1988) reported that the percent of WSC in stems is 50% more than leaves.

The results showed significant differences among genotypes for DM yield, stem number and CP. The effect of phenological stages was significant for all of traits (Table 1). The genotypes, 1269, 1768, 1061 and Festorina had higher DM yield than other genotypes (Table 2). For stem number, the genotypes 1269 and 1061 had the highest values over growing stages and for plant height. The genotypes, 1269 with average values of 78.9 cm had higher stem length (Table 2). For DMD, 1061 and 1768 with average values of 54.6 and 52.46 had the higher and lower DMD, respectively. This result indicating that the range of DMD among genotypes was small.
Fig. 1: The effects of maturity stages on both DM yield and CP% in tall fescue

Fig. 2: The effects of maturity stages on DM yield and DMD% in tall fescue

Fig. 3: The effects of maturity on CP yield, WSC yield and CP% in tall fescue

Fig. 4: Mean comparison for TDM yield (sum of 2 Cuts) in 8 tall fescue genotypes over two years (2005 and 2006 averaged).

The genotype × phenological stage interaction was significant for all of traits except WSC and total Ash (Table 1). Similarly, Humphreys (1989) and Burner et al. (1983) reported that interaction between tall fescue genotypes and environments for WSC concentration were minor. Buxton and Casler (1993), in a review, concluded that most environment stresses have a greater effect on DM yield than on quality traits and GE interactions should be smaller for forage quality than for yield.
Means of DM yields and three quality traits (DMD, CP and WSC) over five phenological stages were overlaid in the same graph (Fig. 3). The higher values for DMD-yield, CP-yield and WSC-yield were obtained in milky stage. Since, DM yield had almost the same values in both milky and soft dough stage; therefore, it concluded that milky stage is the best time of harvesting for both yield and quality traits in tall fescue under conservation management.

For ADF As it can be considered the concentration of ADF, increased by maturity. Such result is usually expectable in forage plants (Hoffman, et al. 2003). The trend of total ash was similar as that of CP and it was decrease, as advancing plant maturity.
Part of the aim of this study was to compare several introduced genotypes with several local ones native to Iran. The genotypes were compared at two levels. The first comparison were made among genotypes in the first cuts (Table 2) and later among TDM yield (Cut1+Cut2) as shown in fig. 4 and 7. The genotypes, 1168, 1061 and Festorina with average values of 8052 to 8466 Kgh⁻¹ had higher TDM production (Table 2). The genotype by stage of growth interaction was significant for all but two of the attributes measured. This means that the variation in the majority of the attributes measured changed over time in a different way in at least some of the genotypes. In similar results Jafari and Naseri (2007) in cocksfoot grown in Iran, found significant genotype × year interactions for DM yield, morphological and quality traits. The published data for interaction of variety × harvest stage are different. Rhodes (1971) and Wilkins (1989) found significant variety × harvest interaction for DM yield in some grass species. In contrast, Camlin and Stewart (1975) and Jafari et al (2003a) in ryegrass under frequent cutting management and grazing did not find significant variety × harvest frequency interaction for DM yield.

When population × environment interactions are significant then evaluation prior to selection is more difficult. Ideally, more than one environment (e.g. years, harvesting frequency, locations etc.) should be used to assess the breeding material. Similar to current study Wilkins (1997) in perennial ryegrass and Marum et al (1979) in reed canary grass found significant variety × harvesting stages interaction for DMD. For WSC Jafari et al (2003a) found significant variety × harvest frequency interaction, while in perennial ryegrass Humphreys (1989) for WSC and Jafari et al (2003a) for DMD and CP did not find genotype × management interaction under two cutting management. It seems in grasses, quality traits are more stable than DM yield under various cutting management in rainy European country, but for steppe or semi steppe region as Iran, due to low and irregular precipitation and other environmental stress, the genotype × environment interactions are present for quality traits. Part of the aim of current study, was to describe differences among genotypes. Some genotypes had less reduction with maturity than others genotypes.

Summary of genotype x stage of maturity interaction effects for DMD, CP and TDM yield are shown in Fig. 5 - 7, respectively. For DMD, the genotypes A2210 and 1081 had higher DMD% for many stages than other genotypes (Fig. 3). For CP 1081 and AB1 had higher CP than other genotypes in pollination stages. For TDM yield, 1269, 1768, 1061 and Festorina had higher values for both heading and anthesis date (Fig. 7). However, the latter genotypes had lower quality values. Such negative relationships among DM yield with both DMD and CP, has also been reported (Jafari and Naseri, 2007; Jafari et al. 2003a).

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**Fig. 7:** Means of DM yield in 8 tall fescue genotypes for each phenological stages. ($V_1$=1610, $V_2$=1269, $V_3$=A2210, $V_4$=1081, $V_5$=1768, $V_6$=FESTORINA, $V_7$=AB1, $V_8$=1061)
This negative correlation between both DMD and CP with TDM yield indicates that combined selection for both traits is necessary in order to prevent loss in DM yield that might occur if selection for quality traits alone was employed.

REFERENCES

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