The Study and Comparison of 3 Foxtail Millet (Setaria italica L.) Cultivars in Different Phenological Stages in Karaj Region

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ABSTRACT: The determination of forage quality is one of the most important factors essential to appropriate field management. The most important factor, effective on forage quality, is the growth stage; by studying on phenological stages of the forage, we can determine the suitable grazing time. Since different cultivars of forage crops have different feed qualities in each of their growth stages, for the purpose of investigation of genetic diversity of forage yields and their quantitative characters, we studied three foxtail millet cultivars, namely KFM1, KFM6 and KFM9 in three phenological stages including vegetative growth stage, flowering stage and seeding stage by use of a factorial experimental design with a complete block basic design with 3 replications in Karaj, Iran. Except for ADF and crude fiber percentage, the difference between the other feed quality indices as well as wet and dry yields, among the different cultivars and the three growth phases of the cultivars, was not significant (P<0.01). Further, the interaction effect between different cultivars and also the phenological growth stages was statistically significant only in connection with wet and dry yield. Proportional to the development of growth stages, approximately in all cultivars, the crude protein percentage and digestive dry material percentage are decreased and the fiber content increased. In general, according to the measured indices, KFM1 has had the highest feed quality and, taking into account its appropriate feed quality, was selected as the outstanding cultivar. The vegetative growth stage (1st phenological stage), from the point of view of feed quality indices, was higher than the two other stages (except for water soluble carbohydrates); but, considering relatively small forage energy difference between stages 1st and 2nd phenological stages, and also higher production and readiness of the fields (ranges) for grazing, the 2nd phenological stage (flowering stage) was selected as the best time for grazing (by use of grazing systems).

Keywords: Foxtail millet, forage yield, forage digestibility percent, crude protein percent, growth stage

INTRODUCTION

The food shortage and increasing trend of global population, more especially in the developing countries, has caused serious concerns in connection with future food production. The role of forage crops in animal feed and, consequently, supply of human's food requirements, is an outstanding role. In line with development of milk and meat products plan in the country, the extension of forage production and access to the new resources of feeds are among priorities of the Office of Forage Crops of Division of Forage Crop Researches Center. The importance of appropriate and adequate feed of the ruminants, necessities that the feed quality of each of feed items and their ingredient to be determined by use of correct and standard systems. Foxtail millet has been among feed grasses which could draw more attention and focus of the researchers in the recent years. Foxtail millet is mainly used as a feed crop. In addition, foxtail millet is a qualitative forage crop and has appropriate palatability 5,11.

Foxtail millet has rapid growth rate in tropical climates and is among the plant with high water efficiency 8. This crop is produced in poor and low efficiency soils of Europe and tropical and sub-tropical regions of Asia. As foxtail millet has high growth rate, it could be used as second crop in crop rotation program 13. Meanwhile, the production of this crop is common in areas with low precipitation up to 2000 m altitude 9.

Foxtail millet is produced in Northern Iran (Mazandaran Province) and its seeds are used for preparation of a kind of local food and birds feed 4 and its advantage is the lack of inhibitors (such as prussic acid) in its
composition. The high growth rate of foxtail millet in poor soils in comparison with other forage crops and its high crude protein content (16% w/w) is among its other advantages 12,16.

John's investigations (2004) showed that the best time for harvesting of foxtail millet is the flowering stage up to booting stage and it will contain a crude protein (CP) content of 10 to 14 percent and 57 to 60 percent of total digestible nutrient if it is harvested at beginning of flowering stage. Through a test. Neville et al., (2006) concluded that the delay in foxtail millet harvesting results in rapid decrease of CP percent hence ADF and NDF are increased. Weichenthal et al., (2008) showed that foxtail millet has 12.1 percent crude protein, 62 percent NDF, and its ADF content is 36 percent and has digestible dry material in the laboratory equal to 70 percent (w/w).

Nleya and Jeranyama (2005) have concluded through an experiment that foxtail millet has 8 to 13 percent crude protein, 32 percent ADF, 61% NDF and 53 to 73 percent digestible dry material. Mehrani et al.,(2004) have studied 10 cultivars of foxtail millet in Karaj, Iran and concluded that they have significant difference with each other and the treatments 1, 3 and 9 with 5.5, 5 and 5 t/hac yields, respectively, have the highest dry feed production rate 10.

**MATERIALS AND METHODS**

For the purpose of study and comparison of genetic diversity and the qualitative characters of three foxtail millet cultivars (KFM6, KFM1, KFM9) in three phenological stages: vegetative growth, flowering, and seeding stages by use of a factorial experimental design using a complete block design with 3 replication. For the purpose of implementation of the experiment, a land with 800 m² in a farm located in Karaj, Iran with longitude and latitude of 51°, 6' E & 35°, 59' N respectively and 1321 m altitude which had been prepared for the experiment. The field was tilled, disk applied, and leveled by leveler and 200 to 250 kg/hect ammonium phosphate and 100 to 150 kg/hect urea fertilizer was applied. The seeds of each cultivar, were sown in each plot with 60 cm row distance. The sowing took place on May 26th, as per the plan. The plots were irrigated with 7 to 10 days intervals using corrugation irrigation method. The hoeing of the furrows and weeding took place after germination. Since the harvesting took place in three stages, the border lines and 0.5 m of both ends of plots were removed first in each stage and the harvesting took place in 12 m² area of the plots. The harvested plants were weighed immediately after harvesting and the wet yield was calculated. A 1 kg sample was prepared from each treatment and was dried at 80°C for one week. The dried samples were weighed first and the dry yield was calculated; then it was milled well and dispatched to the laboratory for determination of nutrient value. Near Infrared (NIR) spectrometer, belonging to Research Laboratory of State Forests and Ranges Organization, was used for determination of protein percentage, crude fiber, ash percentage, Acid Detergent Fiber (ADF) and dry material percentage.

After calibration of the NIR instrument, the measurement of qualitative characters took place using the instructions given by Jafari et al., (2003). The gathered data were analyzed by use of MSTATC and SAS9 software.

**RESULTS**

The statistical parameters including maximum, minimum, mean, standard error, and coefficient of variations (cv) of means of the 3 cultivars of foxtail millet in its three growth stages have been included in Table 1. The results of analysis of variance (ANOVA) of the characters and the significance level of the MS’s of the cultivars in the growth stages and the interaction effects have been included in Table 2. Table 3 contains the results of means comparison between the cultivars and the growth stages. The interaction effect of the cultivars and growth stages in different characters are shown in Figures 1 through 8.

**Wet and Dry Mater Yield**

The wet yield and dry yield are among most important study parameters in foxtail millet. There is significant difference between the wet and dry yields of the three cultivars (P<0.01); which KFM6 with 7.74 and 27.04 t/hect had the highest wet and dry yield respectively. Also the ANOVA of wet and dry yield in three phenological stages (vegetative growth, flowering and seeding) shows that there is significant difference between these three stages of growth (P<0.01); where the highest dry and wet yield with 8.23 and 29.43 t/hect, respectively, belongs to flowering stage. The interaction effect at P<0.01 was significant for dry and wet yield; where KFM9 had has highest dry yield in seeding stage with 10.8 t/hect yield and the lowest in vegetative growth stage with 5.3 t/hect (Figure 1). KFM6 cultivar had the highest wet yield in its flowering stage with 34.7 t/hect yield.

**Crude Protein Percentage and Digestibility**

The quality and nutrition value of the plant have direct relationship with their crude protein content and digestibility and reverse relationship with ADF and crude fiber 1. The statistical results showed that there is significant difference between the cultivars from the points of view of protein percentage and digestibility.
percentage (P<0.01). KFM1 with 11.26 and 64.69 percent had the highest protein and digestibility respectively. There was significant difference between different growth stages at P<0.01; where the vegetative growth stage showed 10.52 and 64.20 percent protein and digestibility among other stages respectively. The results of studies carried out in USA, which correspond with our obtained results at the early flowering stage. Despite non-significance of the interactive effect, the highest protein percent and digestibility belongs to KFM1 at vegetative growth stage (Figures 3 & 4).

**ADF & Crude Fiber Percentage**

The results of ANOVA of ADF and crude fiber percentage showed that there is no significant difference between the cultivars and the difference between the growth stages is only significant for ADF percentage at P<0.05. Nevertheless, KFM1 had the lowest ADF and crude fiber content (highest digestibility). The mean comparison between different growth stages showed that the flowering stage had the lowest ADF and crude fiber percentage. The interactive effect between two characters was not significant although KFM1 had the lowest crude fiber and ADF except for hemi cellulose (Figures 5 & 6).

**Ash and Water Soluble Carbohydrate Percentage**

There was no significant difference between the cultivars and also the growth stages when the two above characters are concerned (P<0.01). KFM9 with 7.30 percent and KFM1 with 4.39 had the highest and lowest water soluble carbohydrate content respectively. Also, the seeding stage with 6.53 percent water soluble carbohydrate had the highest level. Despite non-significance of the interaction effect, KFM9 had higher carbohydrate content in seeding stage (Figure 7). KFM1 and also the vegetative growth stage showed the highest ash content.

**DISCUSSION**

In general, the results of the research showed the highest wet and dry yield in seeding stage and this is because of timely establishment of the plant and its better utilization of the environmental conditions. As we pointed out earlier, the majority of qualitative parameters of the plant are decreased with progress of growth and phenological stages of the plant. Stodart *et al.*, (1975) pointed out that the nutrition quality of the forages show considerable differences depending on different places and times. The majority of forage plants have the highest nutrition value and quality at the beginning of their vegetative stage, where, due to decrease in nutrition value of the plant at their maturity stage, the plants have not appropriate quality. As the plant reaches to its maturity stage the structural carbohydrate content is increased hence the protein concentration and digestibility of the plant and the value of metabolic energy is decreased. In our study, we found that the crude protein content and digestibility of the plant is decreased as the plant reaches to its maturity stage.

The water soluble carbohydrates (WSC) had its lowest level at flowering stage and the its highest value at seeding stage and this is due to the fact that as the plant goes to be matured the need to structural and reinforcement textures is increased these textures have been mainly made of cellulose, hemi cellulose and lignin. Therefore, at the end of growth period, the water soluble carbohydrates are transformed into structural carbohydrates. The minimum value of carbohydrates at the beginning of the first growth stage is due to lower ratio of the stem textures to the leaf. Since the young cells form the majority of young plant structure, has thin cell wall and a little ADF and fiber content; but simultaneous with aging, the cell wall becomes thicker and harder and the fiber and ADF contents are increased. As we found in this study, the ADF and fiber content increased proportional to increase in growth stage and the highest ADF content (the lowest digestibility) belongs to seeding stage.

The date of introduction and exit of livestock to the field (or range) depends on both soil and plant conditions. As we told earlier, the forage quality is in its highest level at the beginning of the season (spring). But, due to high precipitation at this stage and wet land, the soil will be compacted and this leads to rapid soil erosion and, on the other hand, in case of heavy grazing, the plant will have little time for recovery. On the other hand, the early harvesting of the plant may decrease the yield and stem stability and these two factors should be considered in any decisions making process. The harvesting at the early growth stage will have the highest loss and is the worst time for harvesting, because the TAC content is in its lowest level.

We should combine these factors with another important fact that the plant yield and its resistance to the grazing in the second growth stage (flowering) is higher than the first stage and this is an important fact for animal husbandry. Therefore, we can conclude that the more appropriate time for grazing is the second phenological stage (flowering), which seems to be better than all other stages provided, however, that the appropriate grazing system to be implemented to allow the filed (range) to reproduce and recover and the number of the livestock should be in harmony with the real capacity and capability of the range (field).
Table 1. Summary of statistical data of each of studied characters of 3 foxtail millet cultivars in three growth stages

<table>
<thead>
<tr>
<th>Statistical Factor</th>
<th>Dry Matter Yield</th>
<th>Wet Matter Yield</th>
<th>Protein Percentage</th>
<th>Digestibility</th>
<th>ADF</th>
<th>WSC</th>
<th>Crude Fiber</th>
<th>Ash Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mean</td>
<td>7.3</td>
<td>25.6</td>
<td>9.7</td>
<td>63.0</td>
<td>31.4</td>
<td>5.5</td>
<td>40.3</td>
<td>8.7</td>
</tr>
<tr>
<td>Minimum</td>
<td>4.8</td>
<td>19.3</td>
<td>5.3</td>
<td>56.2</td>
<td>26.2</td>
<td>2.2</td>
<td>37.1</td>
<td>6.7</td>
</tr>
<tr>
<td>Maximum</td>
<td>11.8</td>
<td>37.0</td>
<td>13.3</td>
<td>69.7</td>
<td>35.3</td>
<td>8.8</td>
<td>44.7</td>
<td>10.5</td>
</tr>
<tr>
<td>Standard Error</td>
<td>0.4</td>
<td>0.9</td>
<td>0.4</td>
<td>0.5</td>
<td>0.4</td>
<td>0.4</td>
<td>0.3</td>
<td>0.2</td>
</tr>
<tr>
<td>SD</td>
<td>2.0</td>
<td>4.8</td>
<td>2.0</td>
<td>2.8</td>
<td>2.1</td>
<td>2.1</td>
<td>1.8</td>
<td>1.0</td>
</tr>
<tr>
<td>CV</td>
<td>28.0</td>
<td>18.7</td>
<td>21.0</td>
<td>4.5</td>
<td>6.8</td>
<td>38.1</td>
<td>4.4</td>
<td>11.7</td>
</tr>
</tbody>
</table>

Table 2. ANOVA of 3 foxtail millet cultivars in three phenological stages

<table>
<thead>
<tr>
<th>Variation Source</th>
<th>DF</th>
<th>Dry Matter Yield</th>
<th>Wet Matter Yield</th>
<th>Protein Percentage</th>
<th>Digestibility</th>
<th>ADF</th>
<th>WSC</th>
<th>Crude Fiber</th>
<th>Ash Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rep.</td>
<td>2</td>
<td>1.9*</td>
<td>5.2 ns</td>
<td>2.4*</td>
<td>7.2 ns</td>
<td>1.9 ns</td>
<td>0.1 ns</td>
<td>0.1 ns</td>
<td>0.4 ns</td>
</tr>
<tr>
<td>Cultivar</td>
<td>2</td>
<td>3.2**</td>
<td>37.5**</td>
<td>18.1**</td>
<td>21.6**</td>
<td>2.1 ns</td>
<td>21.8**</td>
<td>0.7 ns</td>
<td>6.7**</td>
</tr>
<tr>
<td>Phenological Stage</td>
<td>2</td>
<td>11.6**</td>
<td>102.7**</td>
<td>13.2**</td>
<td>23.8**</td>
<td>10.2 *</td>
<td>17.1**</td>
<td>5.3 ns</td>
<td>3.1**</td>
</tr>
<tr>
<td>Cultivar x Phenological Stage</td>
<td>2</td>
<td>15.5**</td>
<td>53.4**</td>
<td>1.3 ns</td>
<td>6.9 ns</td>
<td>7.3 ns</td>
<td>1.3 ns</td>
<td>0.3 ns</td>
<td>0.2 ns</td>
</tr>
<tr>
<td>Error</td>
<td>16</td>
<td>0.7</td>
<td>5.9</td>
<td>0.8</td>
<td>4.6</td>
<td>3.8</td>
<td>1.9</td>
<td>4.2</td>
<td>0.3</td>
</tr>
</tbody>
</table>

* Significant at P<0.05, ** Significant at P<0.01, Non significant

Table 3. Means comparison of yield and qualitative characters of 3 foxtail millet cultivars in three phenological stages

<table>
<thead>
<tr>
<th>Treatments</th>
<th>Dry Yield</th>
<th>Wet Yield</th>
<th>Protein Percentage</th>
<th>Digestibility</th>
<th>ADF</th>
<th>WSC</th>
<th>Crude Fiber</th>
<th>Ash Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Cultivar</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>KFM1</td>
<td>6.58 b</td>
<td>26.55 a</td>
<td>11.26 a</td>
<td>64.69 a</td>
<td>31.09 a</td>
<td>4.39 b</td>
<td>39.96 a</td>
<td>9.23 a</td>
</tr>
<tr>
<td>KFM6</td>
<td>7.74 a</td>
<td>27.04 a</td>
<td>9.94 b</td>
<td>62.73 ab</td>
<td>31.96 a</td>
<td>4.88 b</td>
<td>40.28 a</td>
<td>9.06 a</td>
</tr>
<tr>
<td>KFM9</td>
<td>7.46 a</td>
<td>23.28 b</td>
<td>7.75 c</td>
<td>61.63 b</td>
<td>31.16 a</td>
<td>7.30 a</td>
<td>40.54 a</td>
<td>7.65 b</td>
</tr>
<tr>
<td>Phenological Stage</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Vegetative Growth</td>
<td>6.01 b</td>
<td>24.47 b</td>
<td>10.52 a</td>
<td>64.20 a</td>
<td>31.02 a</td>
<td>3.95 b</td>
<td>40.13 a</td>
<td>9.29</td>
</tr>
<tr>
<td>Flowering</td>
<td>8.23 a</td>
<td>29.43 a</td>
<td>10.17 a</td>
<td>63.69 a</td>
<td>30.59 a</td>
<td>6.09 a</td>
<td>39.56 a</td>
<td>8.51 b</td>
</tr>
<tr>
<td>Seeding</td>
<td>7.55 a</td>
<td>22.97 b</td>
<td>8.26 b</td>
<td>61.16 b</td>
<td>32.62 a</td>
<td>6.53 a</td>
<td>41.09 a</td>
<td>8.14 b</td>
</tr>
</tbody>
</table>

The means of the treatments with same connotations have not significant difference as per Duncan's multi-range test at P<0.05

![Figure 1. Interaction effect between cultivars and phenological stage on dry mater yield](image-url)
Figure 2. Interaction effect between cultivars and phenological stage on wet matter yield

Figure 3. Interaction effect between cultivars and phenological stage on protein percentage

Figure 4. Interaction effect between cultivars and phenological stage digestibility percentage

Figure 5. Interaction effect between cultivars and phenological stage on crude fiber percentage
Figure 6. Interaction effect between cultivars and phenological stage on ADF percentage

Figure 7. Interaction effect between cultivars and phenological stage on WSC percentage

Figure 8. Interaction effect between cultivars and phenological stage on ash percentage

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