Scientific Research and Essays Vol. 7(34), pp. 3020-3025, 30 August, 2012
Available online at http://www.academicjournals.org/SRE
DOI: 10.5897/SRE11.852
ISSN 1992-2248 ©2012 Academic Journals

Full Length Research Paper

Effect of different harvest time on yield and forage quality of three varieties of common millet (*Panicum miliaceum*)

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Accepted 11 June, 2012

Monitoring forage quality is one of the most important factors of essential and good management of a farm. The most important factor about plants and forage quality is growing stage which can help to identify the optimum time of harvest. As different varieties of plants have different harvest times and quality, in order to search the variety effect on forage yield and quality traits, three varieties of common millet (*Panicum miliaceum*), namely, KCM2, KCM7, and KCM9 in three phenological growth stages, including booting, milky, and seed maturity stages were studied. Experiments in factorial form were surveyed in Karaj district, Iran with three replications in the form of randomize complete blocks design in 2009. Except ash percentage, there were significant differences among three growth stages in other quality traits and forage yield (P < 0.01). Significant differences among varieties for dry and wet forage yield, dry matter digestibility (DMD), water soluble carbohydrates, and acid detergent fiber percentage were also observed. However, interaction effect of variety and phenological growth stage were not significantly different on acid detergent fiber, crude fiber (CF), and ash percentages. Almost in all varieties, the amount of crude protein (CP) and DMD decreased during developing growth stages, while the amount of CP increased. KCM2 variety had the highest forage quality based on measurement indices and it was chosen as the best variety with regard to the most desirable forage yield. Booting stage (first phenological stage) was the most desirable in quality traits among the three growth stages. However, considering the little difference between the first and second stages in dietary energy, the second stage (milky stage) was recommended as the most suitable time for harvesting, because of high yield and compatibility of farm to plant.

Key words: Quality traits, forage yield, dry matter digestibility, crude protein, growth stage, crude fiber.

INTRODUCTION

Food shortage and day by day increasing population especially in developing countries create serious problem about the future of food. Meanwhile, the role of forage plants in animal feeding and subsequently providing human needs in live stocks products has an important and enormous role. The amount of animal products is related highly to animal feed provided. Forage plants do not only solve the feed problems of animals, but also has important role in soil protection in regional conditions and preventing undesirable events like destructive floods. The amount of live stocks products are directly related to forage plants and their production, and it is necessary to make exact basic plan for forage production and it is possible with increasing the amount of cultivations and modern plant breeding methods (Karimi, 1988).

One of the forage plants which get more attention in recent years is common millet. Common millet is often used for forage production. In fact, common millet is one of the world's oldest cultivated crops. Its cultivation is

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estimated to have started over 400 years ago (Chang, 1987). It is one of the most important food crops of the Neolithic culture in China. In India, common millet is grown primarily in the hot drought zones and used mostly for food purposes especially by people with low income (Marathee et al., 1993). Common millet is an important cereal and nutritious food in traditional diets, especially for people in the Europe, Asia, and Africa continents. The main components of millet include starch, protein, liquid, vitamins, and minerals (Usha et al., 1996). This kind of millet survives hot weather better than other millets. It has coarse, woody, hollow stems from 30 to 120 cm. Stems are round or flattened, 6 to 8 mm thick at the base, covered with hairs. It needs full sunlight for growth (Holmes, 1996). Proso millet is called common millets or real ones, they are resistant to dryness and because of short period of growth season, they use less water while they are sensitive to temperature below 0°C (Arbat, 1999). The forage of common millet has good quality and is desirable for live stocks, and the absence of deterrent material (such as prosaic acid) is their advantage. Some other advantages of common millet are better growth in poor soils in comparison with other forage plants and having high crude protein (CP) in forage (up to 16% based on dry material) (Oelke et al., 1990).

Proso millet is a short-season (45 to 90 days) summer cereal with low water requirements and high water-use efficiencies for both grain and dry matter yield. Proso millet grows slowly at first and is a relatively poor competitor with weeds during the first few weeks of growth (Hanna et al., 2004). The cultivation of this plant is common in low rain areas and 2000 m higher than sea level (Marathee et al., 1993). Johns (2004) stated that the best time of harvesting of common millet is during booting stage, and if common millet is harvested in booting stage, forage will have 10 to 14% of CP and 57 to 60% dry matter digestibility (DMD) and nutritional values. Neville et al. (2006) in their experiment achieved this result that in late harvesting of Foxtail millet, percentage of CP decreased strongly and the amount of acid detergent fiber (ADF) increased. Weichenthal et al. (2008) in their experiment showed that forage of common millet had 12.1% CF, 36% ADF and 70% DMD. Nleya and Jeranyama (2005) in their experiments observed that foxtail millet has 8 to 13% CP, 32% ADF and 53 to 73% DMD. Marten (1989) declared that water soluble carbohydrates (WSC) changes of forage plants are different in phenological stages and are dependent on types of plants. Increasing the rate of plant growth also decreases carbohydrate storages. Wilkins and Lovatt (1989) showed that CP in grasses and forage plants is usually more than 12% and the remained protein increases the live stocks products.

So, it can be suggested that it is better to prevent the decreasing CP percentage less than 12%, because it decreases milk and meat products of animal feeding. The aims of the present work are (1) evaluation of genetic variation for DM yield, (2) investigation on quality traits during growth, and (3) identification and introduction of the best varieties of common millet.

MATERIALS AND METHODS

In order to search and compare genetic diversity of forage yield and quality traits, three varieties of common millet (KCM2, KCM7 and KCM9) were examined in three phenological growth stages: booting stage, milky stage, and seed maturity stage in the form of factorial experimental design with a complete block basic design with three replications in Karaj, Iran in 2009. For this research, a plot of about 800 m^2 in a farm field, about 400 ha in the Seed and Plant Improvement Institute was chosen and prepared. Geographical situation was in length 51° and 6 min Eastern and 35° and 59 min North latitude and the height of 1321 m from sea level. For preparation of plot, 200 to 250 kg/ha ammonium phosphate and 100 to 150 kg/ha urea fertilizers were used during ploughing and disk. All the seeds were cultivated in small plots with 6 lines about 6 m length and 60 cm width. Seeds of each variety were cultivated as specially planed on May 26th, 2009. During the growth period, irrigation was done by gravity method. After growing, hoeing in the furrows and weeding were done. As the harvest was done in three growth stages, harvesting was done in three different times in 12 m^2. The harvested forage was at once weighed and the yield of wet forage was calculated. From each variety, some samples (1 kg) were dried about 24 h in oven at 80°C. The samples were weighed at first and the yield of dry forage was calculated. Subsequently, they were ground and in order to identify the quality traits, they were sent to laboratory. In the laboratory of Research Institute of Forest and Rangelands, percentage of the CP, crude fiber (CF), Ash, ADF, and DMD were determined by near infrared radiation (NIR) spectroscopy device. After calibration, percentage of quality traits was calculated by following the method of Jafari et al. (2003). The resulted information and inputs were analyzed statistically by the help of SAS 9 and Minitab14 software.

RESULTS

Statistical parameters including maximum, minimum, average, standard error, and coefficient variations of the 3 varieties are shown in Table 1 in the three growth stages. The result of analysis of variance (ANOVA) and significant level of the mean sum squares of varieties, growth stages and interaction effects are shown in Table 2. Also, the means comparison among varieties and growth stages are compared in Table 3. Interaction effects of varieties and growth stages in different traits are identified in Figures 1 and 2.

Wet and dry matter yield

Yield of forage is studied as the most important parameter of common millet. There were significant differences for wet and dry matter yield among the three studied varieties ($P < 0.01$). The KCM2 variety with 15.14 and 36.81 ton/ha had the most yield of dry and wet matter, respectively. The statistical analysis of wet and dry yield in three phenological growth stages (booting stage, milky stage, and maturity stage) showed significant differences among the 3 stages, as the most

Table 1. Summary of statistical data in each character of 3 common millet varieties in three growth stages.

Statistical factor	Wet yield	DM	CP	CF	WSC	ADF	DMD	Ash
Mean	32.95	13.47	8.87	43.38	6.8	29.45	6.77	7.35
Minimum	25.0	8.60	4.98	40.10	2.89	26.75	2.89	6.03
Maximum	43.58	18.76	11.56	46.45	10.99	33.72	10.99	9.0
SE	1.02	0.51	0.29	0.31	0.32	0.34	0.32	0.11
SD	5.29	2.66	1.51	1.61	1.66	1.80	1.65	0.58
CV (%)	16.06	19.78	17.05	3.72	24.40	6.11	24.38	7.93

DMD, Dry matter digestibility; WSC, water soluble carbohydrates; ADF, acid detergent fiber; CF, crude fiber; CP, crude protein; SE, standard error.

Table 2. ANOVA of 3 common millet varieties in three phenological stages.

Variation source	df	Wet yield	DM	DMD	CP	CF	WSC	ADF	Ash
Block	2	32.03^{ns}	11.35^{ns}	0.59^{ns}	4.06*	2.61^{ns}	8.31*	1.55^{ns}	0.25^{ns}
Variety (A)	2	116.2**	31.42**	6.04*	1.68^{ns}	0.58^{ns}	0.83*	7.95**	0.04^{ns}
Phenological stage (B)	2	64.0**	3.89*	26.4**	4.24**	11.7**	12.9**	16.1**	0.03^{ns}
A*B	4	36.72**	11.94**	5.42*	6.03**	3.34^{ns}	3.07*	3.11^{ns}	0.62^{ns}
Error	16	15.83	2.16	1.83	0.96	1.51	0.95	1.29	0.36

DMD, Dry matter digestibility; WSC, water soluble carbohydrates; ADF, acid detergent fiber; CF, crude fiber; CP, crude protein. *Significant at $P < 0.05$; **Significant at $P < 0.01$.

Table 3. Means comparison of yield and quality traits of 3 common millet varieties in three phenological stages.

Treatment	Wet yield	DM	DMD	CP	CF	WSC	ADF	Ash
Variety								
KCM2	36.81^{a}	15.14^{a}	65.10^{a}	8.47^{a}	43.67^{a}	6.86^{a}	28.48^{b}	7.29^{a}
KCM7	29.71^{b}	11.45^{b}	64.14^{ab}	8.81^{a}	43.22^{a}	7.07^{a}	29.53^{ab}	7.33^{a}
KCM9	32.3^{b}	13.82^{a}	63.47^{b}	9.33^{a}	43.24^{a}	6.48^{b}	30.36^{a}	7.43^{a}
Total mean	32.95	13.48	64.24	8.88	43.38	6.81	29.46	7.35
Growth stage								
Booting	31.35^{b}	12.44^{b}	64.95^{a}	8.70^{ab}	42.10^{b}	8.09^{a}	28.95^{b}	7.37^{a}
Milky stage	36.26^{a}	14.36^{a}	65.48^{a}	9.63^{a}	44.30^{a}	6.62^{b}	28.44^{b}	7.28^{a}
Maturity	31.46^{b}	13.61^{ab}	62.28^{b}	8.29^{b}	43.73^{a}	5.71^{b}	30.97^{a}	7.41^{a}
Total mean	32.95	13.48	64.24	8.88	43.38	6.81	29.46	7.35

The means of the treatments with same small letters were not significantly different as per Duncan's multi-range test at $P < 0.05$. DMD, Dry matter digestibility; WSC, water soluble carbohydrates; ADF, acid detergent fiber; CF, crude fiber; CP, crude protein.

yield of wet and dry was observed with 14.36 and 36.26 ton/ha in milky stage. The interaction effect of dry and wet matter yield in the level of 1% was significant and KCM2 in milky stage with 18.07 ton/ha for DM (Figure 1A) and 40.91 ton/ha for wet matter yield (Figure 1B) had the most yields, while KCM7 at booting stage with 10.6 ton/ha had the least yield of dry matter.

Crude protein (CP) and dry matter digestibility (DMD)

The quality and nutritional values of plants have direct relation with CP and DMD, while they have opposite relation with ADF and CF (Arzani, 1994). The statistical analysis showed significant difference among varieties for DMD ($P < 0.05$), but there was no significant difference for CP. The KCM9 variety with 9.33% and KCM2 with 65.10% had the most percentage of CP and DMD, respectively. Among the different growth stages, significant difference ($P < 0.01$) was observed for both traits that booting stage had the highest percentage of CP and DMD. Similar to these results, some researches in America confirmed these results in the booting stage (Johns, 2004). With regard to significant difference of

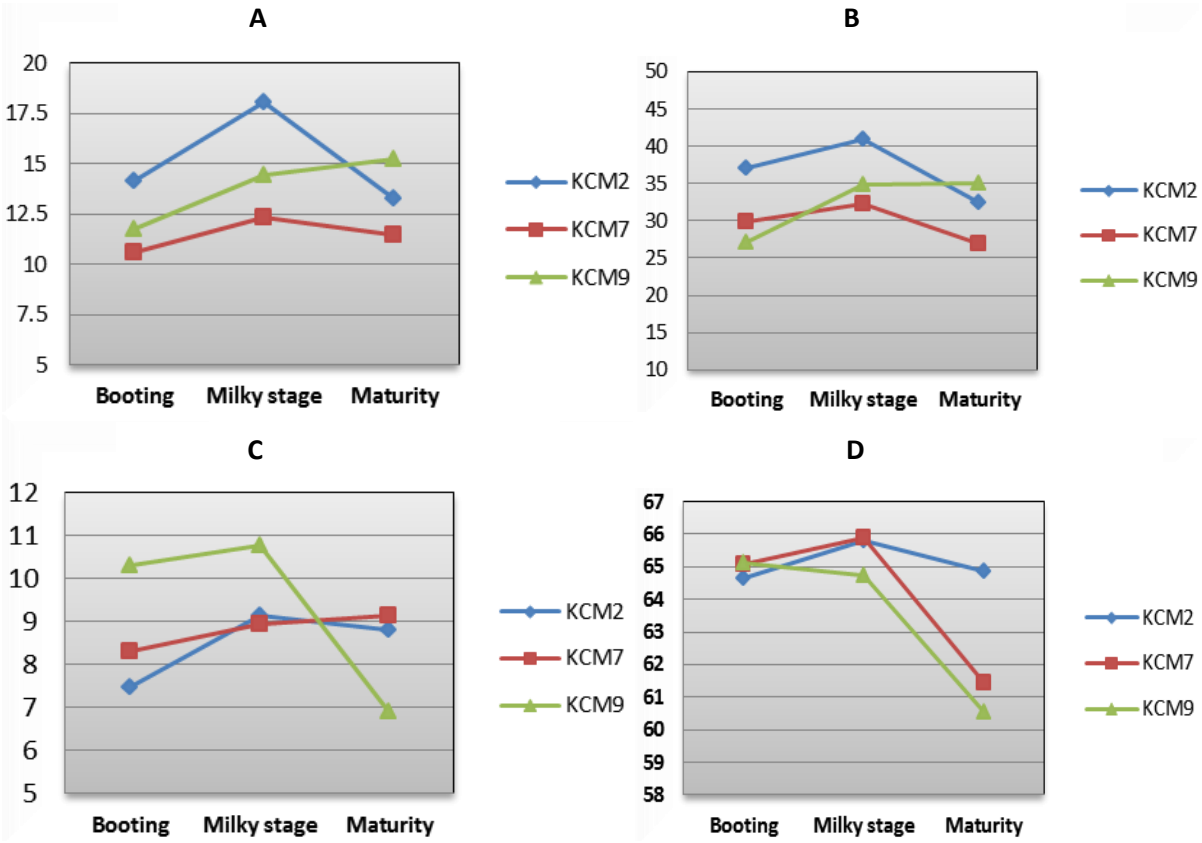

Figure 1. Interaction effect among varieties and phenological stages of *Panicum miliaceum*: (A) I dry matter yield (DM, ton/ha), (B) wet matter yield (ton/ha), (C) crude protein (CP, %), and (D) dry matter digestibility (DMD, %).

interaction effect, the highest percentage of CP and DMD were observed in KCM9 and KCM2 varieties at milky stage (Figure 1C and D).

Acid detergent fiber (ADF) and crude fiber (CF)

The results of ADF and CF showed that there were significant differences ($P < 0.01$) between different growth stages for both traits. KCM2 variety had the least percentage of ADF (actually the most DMD). The means comparison among different growth stages showed that milky stage had the least percentage ADF and booting stage had the least percentage of CF. The interaction effect for both of them were not significant, although totally the KCM9 variety in booting stage had the least percentage of CF and KCM7 in milky stage had the least amount of ADF (Figure 2A and B).

Ash percentage and water soluble carbohydrates (WSC)

For these two traits, ash percentage and WSC, the significant difference was only found for WSC among varieties, growth stages and interaction effect. KCM7 variety with 7.07% had the most and the KCM9 variety with 6.48% had the least amount of WSC. The booting stage had also the highest percentage of WSC with 8.09%. Based on statistical analysis for interaction effect ($P < 0.05$), the KCM9 variety at booting stage had the most amount of the WSC (Figure 2C). KCM 9 variety at maturity stage had the most percentage of the ash and despite no significance difference of the interaction effect, KCM9 had most of the ash value in the booting stage (Figure 2D).

DISCUSSION

Generally, the results of this research and previous works show that the optimum forage yield is in milky stage, but maturity stage is more suitable for harvesting, because of solidification of plants and the better adaptation to climate (Nleya and Jeranyama, 2005; Neville et al., 2006). In the present work, it was found that most indices of the forage quality decrease with advancement of growing stages and plant phenology. Stodart et al. (1975) considered that forage quality can change depending on time and place

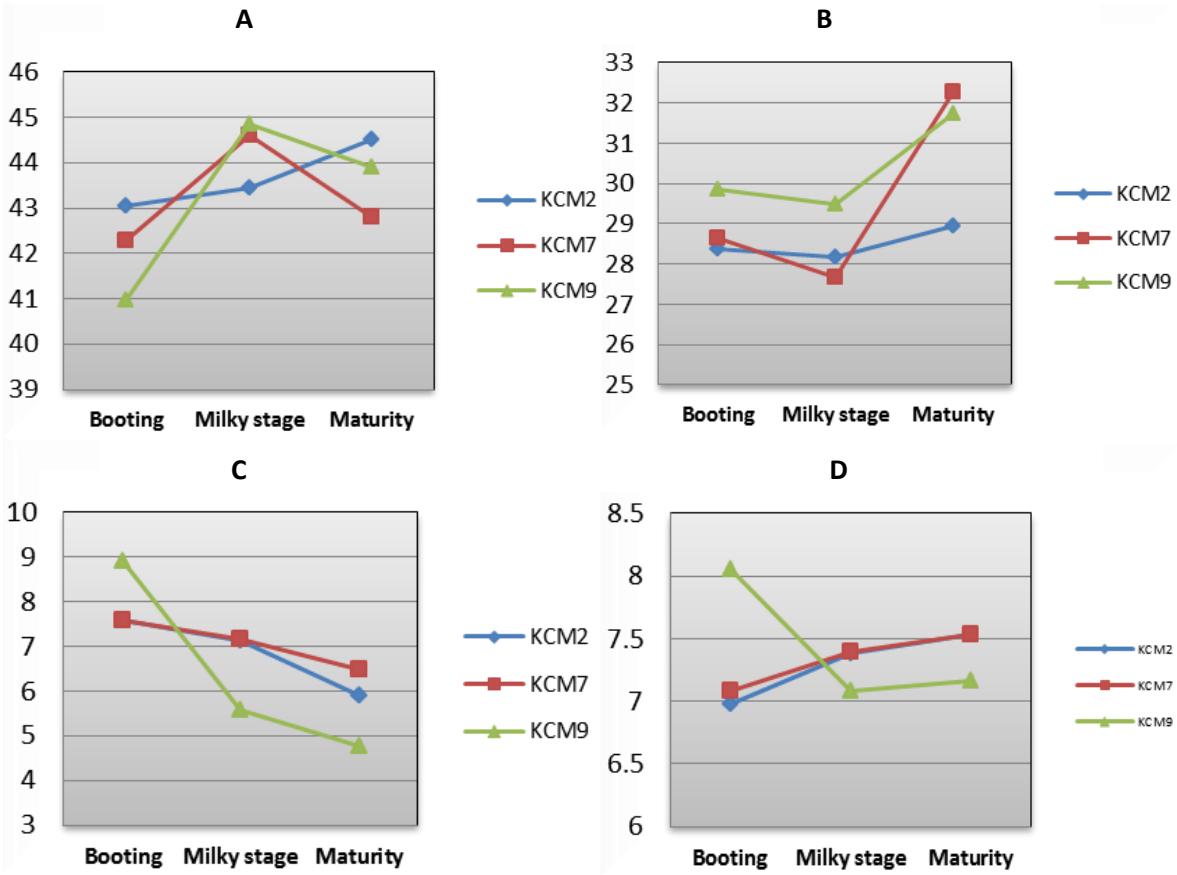

Figure 2. Interaction effect among varieties and phenological stages of *Panicum miliaceum* in percentage: (A) I crude fiber (CF, %), (B) acid detergent fiber (ADF, %), (C) water soluble carbohydrates (WSC, %), and (D) ash (%).

of growth.

Usually, in the beginning of growing season, common millets have the most nutritional value and forage quality, while they do not have high forage quality in the maturity period, because of decrease in food nutrition. The amount of carbohydrates increases with completion of the plant growing stages, while density of protein, percentage of the DMD and amount of the forage metabolism energy become less by the advancement of the growing period (Arzani et al., 1999). In the present research, the amount of CP and DMD of the varieties also decreased during the process of the phenological growth stages. Based on the results obtained, the amount of WSC was the highest in the booting stage and it was the least in maturity stage. This could be due to it needs to increase strength and protective tissues which are made of cellulose, hemicelluloses and lignin while the plant is growing. However, at the end of growing period, WSC change to carbohydrates structure. Minimizing the amount of carbohydrate in the first growing stage is because of low relation of stem to leaf. Sufficient photosynthetic tissues must remain on plants for production of carbohydrates to meet growth and respiration demands of the plant. With regard to this matter, young plants have more young cells, they have thin and elegant cellular walls and also less ADF and CFs, while with increase of the plant age, cellular wall become stronger and thicker and CFs and ADF percentage increase (Fahey, 1994). We also proved in this research that the amount of the ADF and CF increased with development of growing stage, and maturity stage had the most ADF percentage (the least DMD).

Harvesting time is dependent on farms' plants and soil. As shown in this research, forage yield is the most desirable at the beginning of the growth stage. However, early harvesting decrease yield and stem resistance, so it has to be taken into account in making decisions. The most damage time of harvesting is in spring, because the total carbohydrate is the least (Vallentine, 2001). These factors should be considered with other important points and it should be noted that forage yield and plant resistance are more in the second stage than the first stage, which is important for live stocks husbandry. So, we suggest that the precise time of harvesting is the second phonological growth stage (milky stage) which is

the most suitable as compared to the other growth stages.

Conclusion

The results in this study establish a general framework for the domestication history of common millet. The results obtained confirmed that there were significant differences among phenological growth stages for forage yield, and also, important quality traits such as DMD and CP. This research proved that forage quality decrease, while forage yield increase from vegetative stage to flowering stage. The best stage for harvesting is flowering due to high forage yield and plant resistance. Varieties of KCM2 and KCM9 are recommended for future plant breeding research since they can give high yield and good quality of forage.

ACKNOWLEDGEMENTS

The authors thank Seed and Plant Improvement Institute, Iran (SPII) and University of Malaya for providing samples and financial support.

Abbreviations: DMD, Dry matter digestibility; **WSC,** water soluble carbohydrates; **ADF,** acid detergent fiber; **CF,** crude fiber; **CP,** crude protein; **ANOVA,** analysis of variance; **DM,** dry matter yield; **NIR,** near infrared reflectance spectroscopy.

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