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FULL LENGTH ARTICLE

The effects of cutting interval on agro-qualitative traits of different millet (*Pennisetum americanum* L.) cultivars

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Abstract A field experiment was conducted to study the forage yield and qualitative traits of different varieties of millet with different days of harvest during the summer, 2014 at Agronomic Research Area, University of Agriculture Faisalabad. Experiment was laid out in randomized complete block design (RCBD) under factorial arrangement having three replications. Pearl millet seeds of three varieties viz. BS-2011, Ghana White and MB-87 were grown in 30 cm apart rows. Net plot size was 3.6 m × 8.0 m. Three different harvesting times were adopted i.e. 55, 65 and 75 days after sowing (DAS). Maximum plant height of pearl millet was recorded for cultivar BS-2011 at harvest time of 75 DAS. Maximum leaf area per plant was observed for the cultivar BS-2011 when it was harvested 75 DAS. Maximum dry matter percentage was also attained in cultivar BS-2011 where plots were harvested at 75 DAS. The highest forage yield was obtained where variety BS-2011 was grown and harvested at 75 DAS. Similarly, maximum dry matter production of BS-2011 was recorded in plots harvested at 75 DAS followed by Ghana White and MB-87 harvested at 55 DAS. Higher crude protein content was recorded where plots were harvested at 55 DAS and cultivar BS-2011 was sown. Higher crude fiber and total ash percentage was also seen in BS-2011. Finally, cultivar BS-2011 proved best for cultivation with harvest time of 75 DAS under Faisalabad conditions to obtain higher forage yield and better quality.

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1. Introduction

In a country like Pakistan where subsistence farming is prevalent and landholding is small, livestock is an important segment of farming systems. However, due to increasing population and change in land use, livestock is facing severe

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competition for resources, especially land. Livestock provides food as well as offer draught services for farm processes. Furthermore, it can contribute to crop production in the form of farmyard manure. Livestock is one of the main sub-sectors of agriculture in Pakistan and plays a main role in the economy of the country particularly in rural economy. Livestock contributed approximately 56.3% of the agricultural value addition and 11.8% to the national gross domestic production during 2014–2015 (Government of Pakistan, 2015). In support of a more competent as well as prolific livestock industry, production of enormous amount as well as high-quality forage is the basic necessity. Area under fodder crops is about 2.35 million hectares in Pakistan which is 12% of the total cultivated area of Pakistan (Govt. of Pakistan, 2013). Fodder crops show essential part in the agricultural economy of emerging countries by providing low-priced means of feedstuff for livestock.

In Punjab fodder crops are grown on an area of 2.7 million hectares, with once a year forage production of 57 million tones, providing an average forage yield of 21.1 t ha^{-1} (Bhatti, 2001; Bilal et al., 2001). Due to less yield ha^{-1} and minimum area under fodder crops, the available fodder amount is one third less than required and shortage is increasing due to reduction in area under fodder crops by 2% after each decade (Sarwar et al., 2002).

Among choices to control the scarcity of forage, the most important are cultivation of high yielding crop varieties (Bilal et al., 2001) and efficient resource use crop production through better agronomic management practices. Many studies have evidenced cultivar variation in forage yield. Significant differences have been reported among the pearl millet cultivars for yield and quality traits (Ashraf and Harris, 2004). Every cultivar has its own set of optimal agronomic practices and management regimes, also subjected to prevailing agro ecological conditions, to yield maximum.

Modern trend of worldwide agriculture is to explore prolific, environment friendly and sustainable cropping pattern by adopting integrated methods of management including nutrition management of crop, proper sowing method and selecting appropriate stage for harvesting (Crew and Peoples, 2004). Horizontal rise in forage production is almost impossible because of rapid elevation in population as well as decline in cultivated area. So the feasible approach is now to improve its yield per unit area. The time of harvest is a major factor affecting the yield and quality of forage. There are studies that proved the effects of harvesting interval not only on yield but quality of forage produce, which ultimately is an important aspect of forage production. Ram and Singh (2007) reported that harvesting interval affects the chemical composition of forages and according to Joshi et al. (2004), yield mostly increases as the harvesting time is extended but quality is reduced. Selection of proper harvesting interval and usage of efficient planting pattern improve the total mixed green forage yield as well as crude protein (Iqbal et al., 2006).

Whether it is for livestock raised at family owned small farms or private sector led commercial livestock farms, supply of quality forage is essential to add to the net productivity of livestock farming. Hence, determining the optimal crop harvesting calendar to reap maximum gains in terms of yield, quality and efficiency of resources utilized is important. Current study was therefore, planned to determine the effect of harvest time on agro-qualitative traits and green forage yield of different Millet (*Pennisetum americanum* L.) cultivars under agro-ecological conditions of Faisalabad.

2. Materials and methods

2.1. Experimental

Field experiment was carried out at Agronomic Research Area, University of Agriculture Faisalabad, during the summer 2014. Bold and healthy seeds of millet crop were selected and obtained from Punjab Seed Corporation, Faisalabad. Seeds were sown on 27th June 2014 and three harvesting times were selected i.e. harvesting at 55, 65 and 75 days after sowing (DAS), respectively. Forage yield from each plot was recorded after sun drying and computed on hectare basis.

The crop was laid out in randomized complete block design with three replications, grown in 30 cm apart rows using three varieties of pearl millet viz. MB-87, BS-2011 and Ghana White, which were harvested at three different times. Physio-chemical analysis of experimental soil was conducted before sowing indicating that the experimental soil was clay loam with slight alkaline reaction (Table 1). Average climatic features for the whole crop season were also presented in Fig. 1. Previous crop in the experimental area was wheat, grown with recommended agronomic practices.

2.2. Treatments

V_1H_1 = Cultivar MB-87, harvested at 55 DAS.
V_1H_2 = Cultivar MB-87, harvested at 65 DAS.
V_1H_3 = Cultivar MB-87, harvested at 75 DAS.
V_2H_1 = Cultivar BS-2011, harvested at 55 DAS.
V_2H_2 = Cultivar BS-2011, harvested at 65 DAS.
V_2H_3 = Cultivar BS-2011, harvested at 75 DAS.
V_3H_1 = Cultivar Ghana white, harvested at 55 DAS.
V_3H_2 = Cultivar Ghana white, harvested at 65 DAS.
V_3H_3 = Cultivar Ghana white, harvested at 75 DAS.

2.3. Cultural operations

After harvesting previous crop, seed bed was prepared by cultivating the field for 3–4 times each followed by planking. Recommended dosage of Nitrogen and Phosphorus (60–60 kg ha^{-1}) was applied. Half dose of nitrogen was applied with 1st irrigation. Seed rate was 15 kg ha^{-1} with line sowing by single row hand drill, keeping row to row distance of 30 cm. Three irrigations were applied overall during the growing season. One hand weeding was done after about 20–30 days of sowing to eradicate weeds. All other agronomic practices were kept normal and uniform throughout the experiment.

2.4. Measurements

2.4.1. Phenology

Population of pearl millet from three randomly selected places of one square meter from each plot was counted and averaged. Leaves of ten randomly selected plants of pearl millet from each plot were counted and mean was calculated. Similarly,

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Table 1 Physio-chemical analysis of soil.

Determination	Unit	Value	Determination	Unit	Value	Status
Sand	%	33.80	pH	–	7.7	Alkaline
Silt	%	34.00	EC	dSm^{-1}	1.2	Normal
Clay	%	32.20	Organic matter	%	0.78	Low
Textural class	–	Clay loam	Total nitrogen	%	0.048	Low
Saturation	%	37	Available phosphorous	ppm	8.8	Very low
			Available potassium	ppm	130	Sufficient

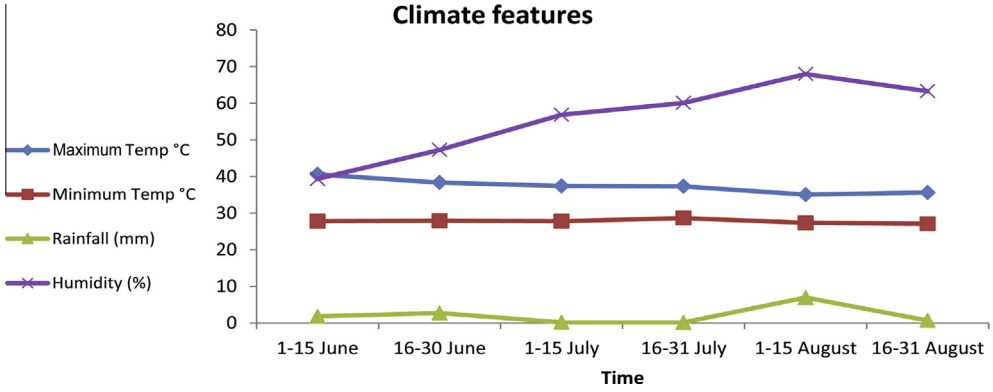

Figure 1 Monthly meteorological data for experimental year (2014) of Agronomic research area, University of Agriculture Faisalabad.

height (cm) of ten randomly selected plants was measured from the base to the tip of the highest leaf or apex. Stem diameter (cm) was also measured from the base, middle and top of the plant with the help of vernier caliper and average was computed. For leaf area per plant (cm^2), 10 g fresh leaf sample from each plot was taken and measured with the help of leaf area meter (Model: Li-3000 portable leaf area meter). Thereafter leaf area per plant was measured by multiplying the leaf area to the total weight of leaves per plant. For fresh forage yield ($t\ ha^{-1}$), manual harvesting with sickle was done at respective time of harvest for each treatment i.e. 55, 65 and 75 DAS, respectively, and bundles were then weighed immediately by spring balance in the field.

After recording the dry weight per plant, dry matter percentage was calculated as:

$$Dry\ matter\ percentage = \frac{Dry\ weight}{Fresh\ weight} \times 100 \quad (1)$$

Dry matter percentage calculated was used for converting the fresh fodder yield into dry matter yield ($t\ ha^{-1}$).

2.4.2. Quality

Grain protein content (%) was determined by using Micro Kjeldahl Method (AOAC, 1990). Similarly crude fiber (%) and total ash (%) were also determined by following Official methods of Analysis (AOAC, 1990).

2.5. Statistical analysis

Data collected on all parameters were analyzed statistically by using Fisher's analysis of variance technique and treatment's means were compared by contrast analysis at 5% probability level (Steel and Torrie, 2001).

3. Results

Almost all the treatments showed significant effects of harvest time in interaction as well as main effect; except for plant population, fresh weight per plant, dry matter percentage and total ash for interaction. Whereas, fresh weight per plant and dry matter percentage were insignificant for main effect of varieties (Table 2). Results showed that the cultivars vary significantly regarding plant population and maximum plant density which was observed in BS-2011 ($21\ m^{-2}$) followed by Ghana white ($19\ m^{-2}$). The minimum plant population was observed from cultivar MB-87 ($17\ m^{-2}$) (Table 3). For plant height, cultivar BS-2011 showed maximum plant height when harvested at 75 DAS followed by Ghana White as compared to all other treatments. Minimum plant height was displayed by MB-87 when harvested at 55 DAS (Table 3). Similarly, BS-2011 also produced maximum number of leaves per plant, leaf area and maximum stem diameter at harvest time of 75 DAS followed by Ghana White cultivar. MB-87 was recorded with minimum values for these three traits (Table 3).

Non-significant interaction was found for fresh weight per plant and dry matter percentage in millet crop. Among varieties, BS-2011 performed best for both of the mentioned parameters followed by Ghana White and MB-87. Harvest time of 75 DAS was quite effective in terms of producing maximum fresh weight per plant with higher dry matter percentage (Table 4). Ghana White cultivar was recorded with maximum dry weight per plant at 75 DAS harvest time as compared to BS-2011. MB-87 showed minimum value for this parameter at 55 DAS harvest as compared to all other treatments (Table 4). Regarding yield attributes, BS-2011 proved to be the best in producing maximum fresh forage and dry matter yield when harvested at 75 DAS, as well as at 65 and 55 DAS, followed by Ghana White and MB-87 (Table 4).

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Table 2 Analysis of variance result for cutting interval impact on agro-quality of millet genotypes.

SOV Observations	Varieties d.f. (2)	Harvests (2)	$V \times H$ (4)
Plant population	259.31**	265.38**	2.74 NS
Plant height	4819.7**	6290.8**	108.3**
Leaves per plant	185.32**	715.30**	10.24**
Leaf area	10358.45**	30224.74**	18.95**
Stem diameter	948.88**	1639.45**	50.63**
Fresh weight per plant	1.82 NS	220.88**	0.37 NS
Dry weight per plant (g)	163.39**	818.06**	113.91**
Dry matter percentage	1.01 NS	2068.06**	0.51 NS
Fresh forage yield	4104.11**	6659.74**	108.53**
Dry matter yield (t ha^{-1})	705.55**	5566.05**	50.77**
Crude protein	103.11**	14.52**	5.56**
Crude fiber	79.05**	43.32**	4.62*
Total ash	40.01**	12.94**	0.67 NS

SOV = source of variation, d.f. = degree of freedom, NS = nonsignificant.
** Significant at 0.01.
* Significant at 0.05.

Table 3 Effect of cutting intervals on growth and development of millet genotypes.

Varieties	Harvesting intervals (days after sowing)			Mean (V)
	55	65	75	
Plant population (m^{-2})				
BS-2011	19.58	21.75	24.50	21.94 A
Ghana white	16.65	18.46	22.30	19.13 B
MB-87	15.16	16.75	19.30	17.07 C
Mean (H)	17.13 C	18.98 B	22.03 A	
LSD at P 0.05 varieties (V) = 0.46, harvesting intervals (H) = 0.46				
Plant height (cm)				
BS-2011	155.8 f	206.6 c	257.9 a	206.8
Ghana white	144.7 g	129.9 d	243.6 b	193.7
MB-87	100.8 i	134.4 h	166.4 e	133.8
Mean (H)	133.8	178.0	222.6	
LSD at P 0.05 varieties (V) = 1.680, harvesting intervals (H) = 1.680, $V \times H$ = 2.909				
Number of leaves per plant				
BS-2011	9.09 f	12.05 c	14.10 a	11.75
Ghana white	9.18 f	11.22 d	13.12 b	11.17
MB-87	7.56 g	10.27 e	11.17 d	9.66
Mean (H)	8.61	11.18	12.80	
LSD at P 0.05 varieties (V) = 0.236, harvesting intervals (H) = 0.236, $V \times H$ = 0.409				
Leaf area (cm^2)				
BS-2011	161.5 f	214.5 c	242.2 a	206.1
Ghana white	141.9 h	193.4 e	228.3 b	187.9
MB-87	122.9 i	151.3 g	201.4 d	158.5
Mean (H)	142.1	186.4	224.0	
LSD at P 0.05 varieties (V) = 2.249, harvesting intervals (H) = 2.249, $V \times H$ = 3.895				
Stem diameter (cm)				
BS-2011	0.85 f	0.93 d	1.18 a	0.99
Ghana white	0.71 g	0.89 e	0.98 b	0.86
MB-87	0.58 i	0.67 h	0.96 c	0.74
Mean (H)	0.72	0.83	1.04	
LSD at P 0.05 varieties (V) = 0.003, harvesting intervals (H) = 0.003, $V \times H$ = 0.005				

Interaction and main effects sharing the same case letter, for a parameter, do not differ significantly at P 0.05.

Ghana white and MB-87 were significantly at par in terms of dry matter yield at harvest time of 55 DAS.

Quite different results were collected in regard to quality attributes. Millet cultivar BS-2011 was harvested with maximum crude protein content at 55 DAS followed by harvesting at 65 and 75 DAS, which then followed by the cultivars Ghana White (similar trend) and MB-87 with statistically similar values at all harvest times (Table 5). Oppositely, BS-2011 proved best in terms of maximum crude fiber content when harvested at 75 DAS and crude fiber content decreased with early harvesting, however, cultivars variation for crude fiber content followed same trend as for crude protein content (Table 5). Statistically non-significant interaction effect was found for total ash contents in three millet cultivars (Table 2). Regarding main effect, BS-2011 displayed maximum ash content followed by Ghana White and MB-87. Whereas, harvest time of 55 DAS proved best in yielding highest ash contents in millet cultivars as compared to harvesting at 65 and 75 DAS (Table 5).

4. Discussion

Better crop stand is reflected by the number of plants per unit area which is one of the most important yield components of forage crop (Afzal et al., 2015). Variable plant population in millet cultivars (Table 2) depicts their genetic makeup which might be attributed to differences in seed viability or thousand grain weight (Ayub et al., 2002). Overall, millet cultivar BS-2011 performed best in all the growth, yield and quality characters with maximum values for plant height, leaves per plant, leaf area, stem diameter, fresh forage and dry matter yield at 75 DAS harvest time (Tables 3–5). This was followed by the cultivar Ghana White for all these parameters and MB-87 resulted almost with minimum interaction effects for growth and yield attributes at harvesting time of 55 DAS. BS-2011 also gave similar better results for forage quality characters viz. crude fiber (%), crude protein (%) and total ash (%). Crude protein and total ash were maximum when harvested at 55 DAS, however interaction effect was not significant for total ash. Contrastingly, crude fiber was maximum when harvested at 75 DAS. Whereas, main effect for ash content was maximum for harvest time of 55 DAS and for BS-2011 cultivar followed by Ghana White (Table 5). Also BS-2011 cultivar resulted maximum for fresh and dry weight per plant and dry matter percentage under main effect as compared to Ghana White and MB-87 (Table 4).

Uniform and higher plant population is the key foundation, which ensures the efficient performance and overall crop growth (Afzal et al., 2015). An increase in plant height with delayed harvesting has also been reported by Ayub et al. (2002), Sharma and Gupta (2003) and Amodu et al. (2007) confirming our results. Secondly, number of leaves per plant holds basic role in overall growth and development because these are the food factories which synthesize food through photosynthesis. Leaves are also major source of total dry matter accumulation, which a plant accumulates during its development through various physiological processes. Moreover, leaves also

Table 4 Effect of cutting intervals on forage yield of millet genotypes.

Varieties	Harvesting intervals (days after sowing)			Mean (*V*)
	55	65	75	
Fresh weight per plant (g)				
BS-2011	144.67	152.33	163.33	153.44 A
Ghana white	141.65	151.33	161.67	151.45 B
MB-87	135.00	149.00	162.00	148.66 C
Mean (*H*)	140.44 C	150.88 B	162.33 A	
LSD at *P* 0.05 varieties (*V*) = 1.99, harvesting intervals (*H*) = 1.99				
Dry weight per plant (g)				
BS-2011	36.05 g	42.33 c	43.05 b	40.47
Ghana white	35.01 g	40.02 d	45.05 a	40.03
MB-87	35.06 h	37.93 f	38.88 e	37.29
Mean	35.86	40.14	42.38	
LSD at *P* 0.05 varieties (*V*) = 0.34, harvesting intervals (*H*) = 0.34, *V* × *H* = 0.60				
Dry matter percentage				
BS-2011	16.59	20.69	24.00	20.76 A
Ghana white	15.84	19.84	22.93	19.53 B
MB-87	15.08	18.24	22.10	18.47 C
Mean	15.83 C	19.59 B	23.04 A	
LSD at *P* 0.05 varieties (*V*) = 0.51, harvesting intervals (*H*) = 0.51				
Fresh forage yield (t ha^{-1})				
BS-2011	57.01 g	64.62 d	75.83 a	65.82
Ghana white	55.46 h	62.24 e	73.81 b	63.83
MB-87	53.76 i	60.83 f	70.16 c	61.58
Mean	55.41	62.56	73.26	
LSD at *P* 0.05 varieties (*V*) = 0.59, harvesting intervals (*H*) = 0.59, *V* × *H* = 1.023				
Dry matter yield (t ha^{-1})				
BS-2011	9.46 g	13.37 d	18.20 a	13.67
Ghana white	8.79 h	12.35 e	16.93 b	12.69
MB-87	8.11 h	11.10 f	15.51 c	11.57
Mean	8.78	12.27	16.88	
LSD at *P* 0.05 varieties (*V*) = 0.39, harvesting intervals (*H*) = 0.39, *V* × *H* = 0.67				

Interaction and main effects sharing the same case letter, for a parameter, do not differ significantly at *P* 0.05.

Table 5 Effect of cutting intervals on quality traits of millet genotypes.

Varieties	Harvesting intervals (days after sowing)			Mean (*V*)
	55	65	75	
Crude protein (%)				
BS-2011	9.05 a	8.06 b	7.33 c	8.15
Ghana white	7.07 c	6.88 cd	6.50 de	6.81
MB-87	6.14 e	6.05 e	5.96 e	6.05
Mean (*H*)	7.42	6.97	6.63	
LSD at *P* 0.05 varieties (*V*) = 0.392, harvesting intervals (*H*) = 0.312, *V* × *H* = 0.541				
Crude fiber (%)				
BS-2011	36.92 cd	38.99 b	41.03 a	38.98
Ghana white	35.59 ef	36.84 cd	37.82 c	36.75
MB-87	34.97 f	35.54 ef	36.27 de	35.59
Mean (*H*)	35.83	37.12	38.38	
LSD at *P* 0.05 varieties (*V*) = 0.392, harvesting intervals (*H*) = 0.5801, *V* × *H* = 1.005				
Total ash (%)				
BS-2011	10.77	9.79	9.05	9.87 A
Ghana white	9.72	8.66	8.74	9.04 B
MB-87	8.18	7.56	7.09	7.61 C
Mean (*H*)	9.56 A	8.67 B	8.29 B	
LSD at *P* 0.05 varieties (*V*) = 0.541, harvesting intervals (*H*) = 0.541				

Interaction and main effects sharing the same case letter, for a parameter, do not differ significantly at *P* 0.05.

play a vital role in the fodder quantity and quality. Therefore, higher number of leaves per plant (Table 3) for cultivar BS-2011 ultimately resulted in higher quantitative (Table 4) and qualitative returns (Table 5). Current findings were also supported by Naeem et al. (2007) and Amodu et al. (2007). Studies by Ayub et al. (2004) and Keerio and Singh (2000) also proved a significant effect of harvesting time on number of leaves per plant. Similarly, Singh and Jadhav (2003) also reported cultivar variation in these traits. Stem thickness in the cultivar BS-2011 also resulted in heavier fresh and dry matter yields confirming the results of Ayub and Shoaib (2009). Our quality trait results (Table 5) also confirmed previous study of Bukhari (2009) who observed a decrease in crude protein and ash contents with delayed harvest, whereas, crude fiber and dry matter percentage were increased with advanced maturity. Similarly Beck et al. (2007) also observed a linear decrease in crude protein and increase in dry matter percentage when harvesting is delayed. Subsequent decrease in crude protein contents may be due to dilution factor. Quality characteristics results indicate that cultivar BS-2011 is more efficient in nutrient uptake and this may be due to better root penetration into the soil than other cultivars.

5. Conclusion

Yield and quality parameters differed among the three millet cultivars under study. Regarding harvesting intervals, yield was increased with delaying the harvest but quality parameters were decreased. The plots harvested at 75 DAS produced the maximum forage yield (75.83 t ha^{-1}) with BS-2011 cultivar and the plots harvested at 55 DAS gave minimum forage yield (53.76 t ha^{-1}) from MB-87 cultivar. For getting higher forage yield of good quality, the pearl millet cultivar BS-2011 may be sown under Faisalabad conditions and suitable harvest time can be 75 DAS.

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