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Full Length Research Paper

Forage yield and some quality attributes of millet (*Pennisetum americannum* L.) hybrid under various regimes of nitrogen fertilization and harvesting dates

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The current cultivation practices have made the soils deficient in nitrogen and therefore, artificial application of nitrogen is critical to obtain substantial biomass production. A field trial to evaluate the effect of nitrogen levels viz., 75, 100 and 125 kg ha^{-1} and harvesting times i.e. 45, 60 and 75 days after sowing (DAS) on forage production and quality of millet hybrid (FH-50) was conducted at Agronomic Research Farm, University of Agriculture, Faisalabad, Pakistan during 2009. The treatments were laid out in randomized complete block design (RCBD) with factorial arrangements in four replications. Both the forage yield and quality were significantly differed among the nitrogen rates and harvesting times. The nitrogen application has positive impact on the agronomic and forage quality components and also remained helpful to off set the negative impact of maturity. Plant received low rates of nitrogen were deficient in crude protein (CP), crude fibre (CF), ash and fat contents than plant received higher nitrogen rates. The protein, fat and ash contents were decreased with the advancement in crop growth period and this decreased was associated with increase in CF concentration. Moreover, late harvesting resulted a great loss in leaves which reduces the forage quality. The harvesting at 60 DAS produce fresh and dry matter yield with 8.72% CP, 29.72% CF, 11.21% ash, 1.37% fat and 48.99% nitrogen free extract (NFE) contents. One day delay in harvesting resulted to a loss of 0.072%, 0.081%, 0.008% CP, ash and fat, respectively in 45 days old plants. The nitrogen application at the rate of 125 kg ha^{-1} and harvesting at 60 DAS seems to be the best compromise between forage yield and quality for millet hybrid FH-50.

Key words: Nitrogen levels, harvesting dates, dry matter, nutritional value, millet hybrid.

INTRODUCTION

Millet is erect, leafy and drought resistant plant, widely used for grain production in semi arid regions of African and Asian countries (Nithya et al., 2006). The millet has been traditionally used as forage but forage was obtained after removing the heads for grains production. The crop associated characters like more tillers production capacity (Van et al., 1996), drought tolerant (Pandey, 2001), rapid growth rate and higher crude protein (CP) contents (Amodu et al., 2001) and short growth period (Lorenz, 1983) make the millet as strong candidate for forage (Dahiya et al., 2000). The millet has great potential to supply nutritious fodder in areas characterized by moisture deficient and have comparatively higher temperature. The chemical analysis showed that millet contains dry matter (15.2 to 28.5%), CP (3.5 to 6%),

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Abbreviations: DAS, Days after sowing; **RCBD,** randomized complete block design; **CP,** crude protein; **CF**, crude fibre; **NFE,** nitrogen free extract; **LSD,** least significant difference.

neutral detergent fibre (60.3 to 64.5%), acid detergents fibre (37.1 to 41%) and having 53.9 to 68.7% dry matter in-vitro digestibility (Arora et al., 1977). Due to its good quality fodder farmers of dry areas have shifted its cultivation for fodder rather to grains production.

Although millet has adequate nutritional value but the increase is essential to meet the nutritional standards of forage for livestock. The nutritional quality of live stock feeds stuff is assessed by its dry matter, CP, fat, ash contents and crude fibre (CF) contents. The required concentration of these attributes in dry matter can be achieved with the use of genetically improved cultivars, harvesting at optimal time (Cecelia et al., 2007) and growth factors such as nitrogen rates (Almodares et al., 2009).

The earlier studies regarding the nitrogen fertilization in millet were mostly conducted for grains production and showed that millet crop responds positively to the additional nitrogen supply (Lemaire et al., 1982; Fribourg, 1995). In most forage crops, the nitrogen fertilization resulted higher dry matter production (Ayub et al., 2007, Karasu et al., 2009), with higher protein (Keskin et al., 2005). The additional nitrogen supply enhances the CF concentrations (Harumoto et al., 1986) in sorghum. While limited supply of nitrogen keeps the crops greenish for longer time (Russel et al., 1992) and reduces synthesis of organic nitrogen (Karic et al., 2005) in plants. Therefore, judicious rates of nitrogen application must be ensured for obtaining higher dry matter with good quality.

The harvesting management is based on more biomass production in the field with high nutritional value that ultimately affects the animal performance. The differences in feeding quality obtained among the harvesting times surpass the varietals differences (Firdous et al., 1996). The most common variations associated with harvesting time are forage yield (Gul et al., 2008; Ayub et al., 2003), dry matter % age, neutral and acid detergent fibre, water soluble carbohydrates, total digestible nutrients, metabolize energy and CP (Khan et al., 2007) and in-vitro organic matter digestibility (Bayble et al., 1995). The previous studies reflected that the quality of forages can be regulated by just selecting the harvest time at which plants are rich in nutrients concentration. The proper harvest management is not crucial only for forage yield and quality but it also has impacts on sowing of subsequent crops. Besides deteriorating quality, the late harvesting also increases the post harvest losses due to rejection of stems by the animals (Man and Wiktorsson, 2003). The proper fertilization and harvesting times have been found very effective to improve the quality and quantity of forage (Bartle and Klopfenstein, 1988; Reddy et al., 2003). These treatments will in turn improve the animal performance. The previous work on integrated effect of nitrogen and proper harvest time is not sufficient with special reference to hybrid millet. The present study was therefore planned to refine the optimal nitrogen level and harvest dates for harvesting more nutritive forage from millet.

MATERIALS AND METHODS

Local soil and climatic characteristics

A field experiment to evaluate the effect of different nitrogen levels and harvesting intervals was conducted at Agronomic Research Area, University of Agriculture, Faisalabad (31°.40'' N, 73°.11'' E), Pakistan during the growing year 2009. The soil used was sandy clay loam, higher pH value (7.90), calcareous and was deficient in organic matter (0.70%). For soil analysis, sample was taken from 0-30 cm depth and a composite sample was formed for analysis. The average value for total N, available P and extractable K of soil were as 0.39 g kg^{-1}, 12 and 160 mg kg^{-1}, respectively. The climate of the experimental area was semi arid receiving a total rainfall of 150 mm during the course of study.

Crop husbandry and treatments

The field was prepared by ploughing twice at 15 cm depth with cultivator and was planked to crush the clods resulted from the ploughing. The crop was given nitrogen represented as 75 (N_1), 100 (N_2) and 125 (N_3) kg ha^{-1} and was harvested at 45 (H_1), 60 (H_2) and 75 (H_3) days after sowing (DAS). The experiment was quadruplicated in randomized complete block design with factorial arrangements in plots measuring a net plot size of 1.8 x 6m. In this way, the complete experiment was comprised of 36 plots and individual plots have 6 rows of crop. The seeds of commercially available pearl millet hybrid FH-50 were sown on 18th July in 30 cm spaced rows with single row hand drill by using seed rate of 13 kg ha^{-1}. Initially, 7.5 cm of irrigation water was applied to ensure uniform germination and the subsequent two irrigations were applied at the same depth of water. Full dose of phosphorus was broadcasted at time of seed bed preparation in the form of single super phosphate [$Ca(H_2PO_4)_2 + CaSO_4$] having 18% P and half of the prescribed levels of nitrogen were applied as basal dose at sowing and the remaining half of nitrogen was top dressed with first irrigation in the form of urea (46 % N). All the plots were treated alike except for treatments.

Measurement of agronomic parameters and yield

The plant samples were taken by harvesting ten plants randomly at ground level from each plot. The response variables include plant height, stem diameter and leaf to stem ratio and were measured at each harvest. The plant height of ten randomly selected plants was measured from ground level to highest leaf tip with the help of measuring tape. The leaf to shoot ratio was also calculated from these plants on fresh weight basis. The stem diameter of individual plant was measured at bottom, middle and top portions of plant with the help of vernier caliper and average was taken. The total yield was calculated by harvesting the complete plot and was converted on hectare basis. The dry matter yield was calculated from dry matter % age of respective plot. The green plants were chopped manually and were weighed on digital weight balance. The whole mass of chopped sample was placed in shade for drying and was shifted to electric oven at 70℃ for the period till a constant weight was achieved.

Chemical analysis

The forage nutritive value was recorded in term of CP, CF, fat, ash and nitrogen free extract (NFE) contents of dry matter. The sub sample of dry matter was well grind and passed through 0.5 mm sieve and was preserved for chemical analysis. The dry matter and ash contents were determined by method 942.05, AOAC (1999). The ash contents were calculated by incineration the well grind samples at 550℃ for three hours (ISO 5984). For CP, the nitrogen contents of feed sample was determined by Kjeldahl N (method 954.01; AOAC, 1999) and the value recorded for nitrogen was then multiplied with 6.25 (Jones, 1931) to determine CP of the sample. The CF contents were recorded by methods recommended by Van Soest et al. (1991). The fat contents were recorded by using Soxelt method (GOST 1349.15–85). The NFE in plant material was determined by using formula as:

NFE (%) = 100-[CP (%) + CF (%) + EE (%) +Total ash (%)].

Statistical analysis

The recorded data was statistically analyzed by using statistical programme (Statistix 8.1). The significance of each nitrogen rates and harvesting schedule was determined by using factorial plot ANOVA and the treatment means were compared at 5% probability level by using least significant difference (LSD) test (Steel et al., 1997).

RESULTS

Agronomic traits and forage yield

The effect of nitrogen was proved to be significant in case of plant height, stem diameter, leaf to stem ratio, fresh and dry matter yield (Table 1). The plant height was increased with each successive increase in nitrogen rate. The differences between N2 and N3, and N1 and N2 for plant height were not significant in 45 and 75 days old plants, respectively. The highest value for plant height was observed in plots fertilized with N3 in 75 days old plants. The fertilizing with N3 level was equally effective both at H2 and H3 which suggested that plant height does not increase after 60 days. The non significant interactions (N x H) were found for stem diameter, forage and dry matter yield (Table 1). Therefore, only main effects are being presented. These were generally increased with increase in nitrogen rates but the difference between N1 and N2 were not significant for stem diameter, fresh forage and dry matter yield and the highest values for these attributes were recorded with N3 at all harvestings (Table 1). The role of nitrogen in improving the leaf to stem proportion was stronger in immature plants than mature ones (Table 1).

The data presented in Table 2 pointed out that harvesting times have striking effect on plant height, stem diameter, leaf to stem ratio, green forage and dry matter yield (Table 1) and the highest mean values for these were observed at 75 DAS. The plant height and fresh forage yield showed a significant increase with lengthening the harvesting time up to 60 DAS and further delay in harvesting did not account a significant increase. The maturation increased the dry matter yield considerably at all nitrogen rates and among the harvesting times, the maximum dry matter production was recorded between H2 and H3.

Forage quality attributes

The significant differences (Table 2) existed among nitrogen levels for CP, CF, fat, ash and NFE in dry matter. The interactive effect of N x H can be considered only for CP, ash and NFE (Table 2). The millet respond positively to additional nitrogen supply with special reference to CP but the differences among nitrogen levels for CP was more visible at 45 DAS. The low rates of nitrogen application produced the less CP contents and the lowest value was recorded with N1 in 75 days old plants. The highest values for CF and fat contents were observed with N3 and least with N1 (Table 2). The inverse relation between nitrogen rates and NFE was observed and therefore, the minimum value was obtained with N3.

The effect of lengthening the harvesting time was associated with decrease in CP, ash and fat, accompanying with higher CF concentration in dry matter. Considering the CP, ash and fat contents as indicator of forage quality, the quality is deteriorated. The CF in plant material showed a progressive increase with longer harvesting intervals which underscore the deposition of lignin in cell wall with passage of time. The harvesting at 75 DAS produced a hard and low quality fodder due to more fibre contents in dry matter. The absence of N x H effect for fat concentration in plant biomass suggested that adverse effects of maturity on fat cannot be compensated by nitrogen application rates. The data regarding the ash showed that 45 days old plants produced the maximum ash contents with N2. While, all the other combinations were not differed significantly for ash contents

DISCUSSION

Forage yield

The lower plant height, fresh and dry matter yield with reduced nitrogen rates is the result of more dependence of plants for nitrogen on soil resources. The higher plant

Table 1. Effect of nitrogen levels (N) and harvesting times (H) on plant height, stem diameter, leaf to stem ratio, fresh and dry matter yield.

Nitrogen level (kg ha^{-1})	Harvesting time (DAS)			Mean
	H_1	H_2	H3	
Plant height (cm)		**LSD=12.214**		
N1	136.03 e **(LSD=21.155)**	224.53 c	256.90 b	205.82 c
N2	184.32 d	260.30 b	260.27 b	234.97 b
N3	192.03 d	283.13 a	285.65 a	253.60 a
Mean (LSD=12.214)	170.79 b	255.98 a	267.61 a	
Stem diameter (cm)		**LSD= 0.1037**		
N1	1.45 ns	1.52	1.77	1.58 b
N2	1.42	1.50	1.84	1.59 b
N3	1.55	1.60	2.05	1.73 a
Mean (LSD= 0.1037)	1.47 b	1.54 b	1.89 a	
Leaf to stem ratio		**LSD=0.0388**		
N1	0.57 b (LSD=0.0673)	0.41 c	0.25 d	0.41 b
N2	0.70 a	0.42 c	0.27 d	0.46 a
N3	0.76 a	0.44 c	0.25 d	0.48 a
Mean (LSD=0.0388)	0.68 a	0.42 b	0.26 c	
Fresh forage yield (t ha^{-1})		**LSD= 12.245**		
N1	74.97 ns	99.32	96.05	90.12 b
N2	87.47	92.17	115.10	98.25 ab
N3	92.50	115.53	122.88	110.30 a
Mean(LSD= 12.245)	84.98 b	102.34 a	111.34 a	
Dry matter yield (t ha^{-1})		**LSD=2.5874**		
N1	8.20 ns	16.94	28.87	18.00 b
N2	9.69	15.50	28.77	17.99 b
N3	9.63	18.95	35.31	21.30 a
Mean (LSD=2.5874)	9.17 c	17.13 b	30.98 a	

The values in rows and columns represented by lower case letters and means in both rows and columns are significantly different from each other at (P<.005).

height with surplus nitrogen is mainly reflected by increase in inter nodal distance which results stem elongation (Eltelib et al., 2006). The similar results have also been obtained from previous studies conducted by Ayub et al. (2007) and Khalid et al. (2003) on millet and sorghum, respectively. The phenomenon is of great importance as plant height is major contributor in dry matter per unit area. The beneficial effect of nitrogen on stem diameter has also been confirmed by Saruhan and Sireli (2005). The role of nitrogen with respect to leaf to stem ratio was significant and is mainly attributed by more leaf mass production per plant. It showed that among the aerial plant parts, the leaves are more responsive to additional nitrogen supply than stems. In this study, the leaf mass of plant species is further a function of more leaf length and width rather by leaf numbers. The results confirmed the findings of Assaeed (1994) who have also reported positive response of oat to additional nitrogen supply with respect to leaf to stem ratio. The nitrogen influenced the total biomass production of crops (Karasu et al., 2009; Khalid et al., 2003). The similar findings have also been presented in this study (Table 1). The nitrogen rates increased fresh and dry matter yield from 90.12 to 110.30 and 18.00 to 21.30 t ha^{-1}, respectively (Table 1). The enhancement of forage material is contributed for variations in agronomic

Table 2. Effect of nitrogen levels (N) and harvesting times (H) on CP, CF, fat, ash and NFE contents (dry matter basis) of millet.

Nitrogen level (kg ha^{-1})	Harvesting time (DAS)			mean
	H1	H2	H3	
CP (%)		**LSD= 0.4077**		
N1	8.15 ^{de} **(**LSD=0.7062)	8.06 ^{de}	6.89 ^{g}	7.70 ^{c}
N2	9.56 ^{b}	8.72 ^{cd}	7.27 ^{fg}	8.52 ^{b}
N3	10.57 ^{a}	9.38 ^{bc}	7.65 ^{ef}	9.20 ^{a}
Mean (LSD= 0.4077)	9.43 ^{a}	8.72 ^{b}	7.27 ^{c}	
CF (%)		**LSD= 2.0154**		
N1	24.63 ^{ns}	27.51	29.83	27.32 ^{c}
N2	26.78	29.75	31.50	29.34 ^{b}
N3	29.05	31.89	34.74	31.89 ^{a}
Mean (LSD= 2.0154)	26.82 ^{c}	29.72 ^{b}	32.02 ^{a}	
Fat contents (%)		**LSD= 0.0978**		
N1	1.26 ^{ns}	1.19	1.10	1.18 ^{c}
N2	1.52	1.34	1.23	1.36 ^{b}
N3	1.79	1.58	1.48	1.61 ^{a}
Mean (LSD= 0.0978)	1.52 ^{a}	1.37 ^{b}	1.27 ^{c}	
Ash contents (%)		**LSD= 1.3514**		
N1	11.50 ^{cde} (LSD=2.3407)	9.63 ^{e}	10.75 ^{de}	10.63 ^{b}
N2	16.50 ^{a}	10.38 ^{de}	12.00 ^{cd}	12.96 ^{a}
N3	14.50 ^{ab}	13.63 ^{bc}	12.50 ^{bcd}	10.63 ^{b}
Mean (LSD= 1.3514)	14.18 ^{a}	11.21 ^{b}	11.75 ^{b}	
NFE (% age)		**LSD=2.7433**		
N1	54.47 ^{a} (LSD=4.7515)	53.64 ^{a}	51.43 ^{ab}	53.18 ^{a}
N2	45.64 ^{cd}	49.81 ^{abc}	48.00 ^{bcd}	47.82 ^{b}
N3	44.09 ^{d}	43.52 ^{d}	43.63 ^{d}	43.75 ^{c}
Mean	48.07 ^{ns}	48.99	47.69	

The values in rows and columns represented by lower case letters and means in both rows and columns are significantly different from each other at (P<.005).

attributes at varying nitrogen fertilization. The yield increase was obviously the result of higher plant height, stem diameter and more dry matter production per plant. The two possible mechanisms involved for higher yield might be the regulatory role of nitrogen in production of amino acids and plant hormones responsible for cell division and enlargement (Siam et al., 2008). Secondly, higher nitrogen facilitates the optimum development of photosynthetic apparatus which capture the incident light more efficiently. This can be reevaluated by the data present in Table 1 for leaf to stem ratio.

The plant height was increased with delay in harvesting up to 60 DAS and further delay in harvesting did not account a significant increase in plant height due to termination of stem elongation. The results are comparable to those of Amodu et al. (2001) who have reported a significant increase in plant height of millet. The decrease in leaf to stem ratio with advancement in growth period suggested that leaf mass of plants does not increase in same ratio as stems do. Therefore, higher dry matter production is the result of contribution from stems. The above trend of growth is one of the major causes of declining the forage quality resulted from decreased proportion of leaves in plant total biomass. The decline in leaf to stem ratio with delayed harvesting has also been confirmed by Assaeed (1994) for forage oat.

The dry matter production was positively associated with maturity (Table 1). Ram et al. (2007) and Hussain et al. (2002) also found the same trend in mixed pasture and oat, respectively. The lower dry matter production at earlier harvesting can be supported with classic model suggested by Adjei and Fianu (1985). According to the model, nutrients uptake is more at early growth stages accompanied with low dry matter production and then dry biomass production outstrips the nutrient uptake, then nutrients contents decline due to natural dilution processes. The studies conducted by Butler and Bailey (1973) showed that the accuracy of this model is limited by nature of element, crops and soil moisture contents. This theory can be supported by higher ash contents at early harvesting (Table 2). The Table 1 also pointed out that the highest dry matter accumulation occurs between H2 and H3. According to Mut et al. (2006), total dry matter accumulation in cereals occurs during later growth stages.

Forage quality

As studies conducted by Almodares et al. (2009) and Galdamez-Cabrera et al. (2003) showed a positive association between nitrogen rates and protein values. The more CP contents with elevated nitrogen levels are connected with the build up of amino acids as result of nitrogen being a structural component. The reduced production of CP at lower doses of nitrogen is due to reduced use of carbon chains in synthesis of protein. Although CP contents respond to nitrogen fertilization but the above levels could not achieve the concentration that forage should have. According to Yildiz (2001), the plants dry matter containing 12.5% CP are taken as high quality forages and the highest value of CP (9.20%) achieved in this study with N3 is far less than standard value for animal nutrition.

The results regarding the CF are in consistency with those obtained by Ali et al. (1999), Ayub et al. (2007), Ayub et al. (2003) and Harumoto et al. (1986) in previous studies. The results are however, in contrast to previous data obtained from Patel et al. (1994) in sorghum forage under various nitrogen supplies. Such contradiction may arise from the species differences for nitrogen redistribution within the plants (Smith et al., 1990) and soil residual nitrogen (Maranville and Sirifi, 1995). The phenomenon of increasing CF contents with higher nitrogen supply is however not valuable from animal nutrition point of view. The fat concentration in the plants also showed a positive association with nitrogen rates which can be explained by the involvement of nitrogen in the synthesis of photosynthates which are further used in the synthesis of fatty acid. The improvement in fat contents in dry matter has already been found in studies conducted by Bumane (2010). The peak value for ash was observed at N2 which showed that the optimum production of inorganic minerals at N2. While, the plots fertilized with N1 and N2 did not differed significantly at all harvestings. Our findings regarding the ash in phytomass are quite comparable to those of Khalid et al. (2003). The lower NFE at higher rate of nitrogen is the result of positive association of nitrogen with CP, CF, fat and ash contents. Although, increasing nitrogen decreased the NFE at all harvesting dates but the rate of reduction for N1 and N2, and N2 and N3 was strong at 45 and 60 DAS, respectively.

The protein would be lower in later harvesting as confirmed by Amodu et al. (2001) and Shehu et al. (2008). The decreased CP might be result that nutrient contents do not match the dry matter production at later growth stage and thus CP concentration is diluted. On the other hand, the lower CP concentration in plant material might be the result of loss of leaves as they are thought to contribute twice in term of CP than stems (Buxton, 1996). Therefore, the decreased CP is the result of loss of leaves mass coupled with higher proportion of stems in total biomass which are deficient in CP. The CP was higher in immature plants than aged plants. Over the growth stage, the proportion of CF fractions in the plant dry matter was enhanced which might be function of lignin deposition in plant dry mass. The results are in harmony with Amodu et al. (2001) and Hussain et al. (2002) who have also reported increased CF proportion in millet and oat. The adverse effect of CF on forage nutritional value therefore can be avoided with proper harvest management.

The ash is total mineral nutrients calcium, phosphorus, potassium, magnesium (Ca, P, K, Mg) in the dry matter and the ash contents were reduced with delayed harvesting due to loss of leaves and translocation of inorganic nutrients from vegetative to reproductive plant parts. The significant differences among the mean values of ash contents at various growth stages have also been reported by Kitaba and Tamir (2007). The significant differences in mean values of fat at various growth stages have also been reported by Hussain and Durrani, (2009). The differences in NFE among growth stages were non significant and our findings are supported by the previous studies conducted by Hussain and Durrani, (2009) for grasses.

Conclusion

Throughout the growth period the additional nitrogen was beneficial for maintaining and improving the yield and dry matter chemical composition. The plants having sufficient supply of nitrogen and harvested at earlier stages were higher in forage quality. The selection of particular time of harvesting will be on the basis whether quality or quantity is more important. The millet can efficiently serve as forage but the future research work must quantify the exact value along with other supplement for dairy animals. The harvesting at 60 DAS seems to be good when taken CP, fat and ash as standard quality attributes. This shows that protein value in millet can be enhanced and complete reliance on protein supplements can be reduced.

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