Effect of Stage of Growth and Cultivar on Chemical Composition of Whole Maize Plant and Its Morphological Fractions

R. Firdous* and A. H. Gilani

Department of Animal Nutrition, University of Agriculture, Faisalabad, Pakistan

ABSTRACT : Samples of whole plant, leaf and stem of Akbar, Neelum, UM-81 and IZ-31 cultivars of maize fodder harvested up to 14 weeks at different growth stages were drawn and analysed for dry matter contents and various cell wall constituents such as NDF, ADF, hemicellulose, cellulose, lignin, cutin and silica. The dry matter contents of whole maize plant, leaf and stem increased significantly ($p<0.01$) with advancing plant age. Maximum dry matter was found in the leaf fraction of the plant. The cell wall components continued to increase significantly ($p<0.01$) in whole maize plant and its morphological fractions as the age advanced. Maximum values for NDF, ADF, cellulose and lignin were observed in stem followed by whole plant and leaf, whereas hemicellulose, cutin and silica contents were higher in leaf fraction of the plant. The cultivars were observed to have some effects on chemical composition of all plant fraction. The results indicated that maturity had a much greater effect on the concentration of all the structural components than did the cultivars. It was concluded that maize fodder should be cut preferably between 8th to 9th week of age (flowering stage) to obtain more nutritious and digestible feed for livestock. Among the maize cultivars, Neelum proved to be the best, due to its higher dry matter contents and lower lignin concentration. (*Asian-Aus. J. Anim. Sci. 1999. Vol. 12, No. 3 : 366-370*)

Key Words : Cell Wall Constituents, Growth Stages, Maize Cultivars, Morphological Fractions

INTRODUCTION

In recent years plant breeders have paid much attention to varietal development to increase the production of good quality fodders since this is a key to increase livestock production. The value of green fodder for animal production depends upon its nutrient concentration as well as intake by an animal. Generally, the chemical composition of fodders varies between regions due to variation in soil, plant species, climatic conditions and agronomic practices. The fibre level in the forages is not constant rather it varies widely according to the stage of maturity of the plant when harvested and the environmental conditions. Poor digestibility and lower intake are usually associated with high lignin contents which increase with advancing maturity. As the plant matures, dry matter and cell wall constituents increase and crude protein and cell contents decrease (Gupta et al., 1976).

Maize (*Zea mays*) has for centuries been used as a forage crop in India and Pakistan. Generally, the whole plant, when cobs are at the milky stage is cut and fed to animals. Maize fodder provides adequate energy and protein for physical growth and milk production of buffaloes and cattle (Choudhry, 1983). Maize is an important summer (Kharif) crop grown basically for grain and at the same time is a popular fodder for livestock, with yield per hectare of maize fodder of 14.80 tonnes recorded by Bhatti (1996). Commonly three crops of maize per year are grown in Pakistan. Maize is also a major crop of the northern areas and a part of the Punjab province. Data on local maize fodder are scanty, particularly with reference to plant parts, effects of harvesting stages and varietal differences. The study under report was therefore conducted to determine the changes in chemical composition of different varieties and morphological fractions of maize plant at various growth stages.

MATERIALS AND METHODS

Four maize cultivars, Akbar, Neelum, UM-81 and IZ-31 were cultivated from March to June, 1991 in experimental fields of the University of Agriculture, Faisalabad. Fodder cultivation and harvesting/sampling procedures used are given as under:

A. Agronomic practices

Each maize cultivar was grown in three replicates using randomized complete block design. Plot size was 5 m × 7 m and row spacing was 30 cm. The plots were fertilized by urea at the rate of 57 kg N/hectare. The fertilizer application was done about 20 days after sowing at the time of first irrigation. Six irrigations of canal water were given to the experimental fields during a period of fourteen weeks.

B. Harvesting / sampling

First sample was obtained at first week after the germination of seed. The subsequent samples were collected up to 14 weeks at various growth stages. For sampling, method of Harris (1970) was followed. Ten or more sample sites were selected for random sampling. The aerial parts of the plants were clipped and saved in plastic bags. At the same time leaves (blade+sheath) were separated manually from the stem. Samples of whole maize plant and its morphological fractions were saved for further analysis.

C. Sample preparation

The samples of whole plant, leaf and stem were run

through a fodder cutter to cut in to 2 to 3 cm pieces and dried at 60 °C in hot air oven to constant weight (AOAC, 1984). All fodder samples were ground in a laboratory mill and were passed through 4 mm screen. Sub-samples were obtained which were further ground to pass through one mm screen (Harris, 1970; Van Soest Robertson, 1985). Dried fodder samples from three replicates were mixed to make one composite sample and were analysed in duplicate for various cell wall components. For the determination of neutral detergent fibre (NDF), method of Van Soest and Wine (1967) was used. Acid detergent fibre (ADF) and silica were determined by the method of Van Soest (1963). Hemicellulose contents of the fodders were calculated by difference between NDF and ADF. Cellulose, lignin and cutin contents of fodder samples were estimated by the method of Van Soest and Robertson (1985).

D. Statistical analysis

The data were subjected to statistical analysis by using analysis of variance technique. Duncan's new multiple range test was used to compare treatment means (Steel and Torrie, 1984).

RESULTS AND DISCUSSION

Average dry matter (DM) contents and various cell wall constituents such as NDF, ADF, hemicellulose, cellulose, lignin, cutin, and silica of different fractions of maize plant at various growth stages have been presented in table 1. Average dry matter contents and structural components of different cultivars of maize plant are given in table 2

A. Dry matter

A significant increase in DM contents of maize fodder and its morphological fractions was observed with advancing stage of maturity. Highest DM contents were found in leaf fraction (13.60 ± 0.16 to $36.99 \pm 0.40\%$) followed by whole plant (12.26 ± 0.13 to $33.80 \pm 0.37\%$), whereas the lowest DM contents (9.87 ± 0.15 to $26.93 \pm 0.66\%$) were observed in stem fraction. This was probably due to increased photosynthetic activity in leaves than in stem leading to higher DM production. Azim et al. (1989) reported that dry matter contents of whole maize plant, leaf and portions of stem increased significantly with the stage of maturity. They further

Table 1. Chemical composition of whole maize plant and its morphological fractions at different stages of growth (mean ± SE)

Chemical composition	Growth stage (age in weeks)				
	Seedling (1st week)	Early growth (5th week)	Flowering (9th week)	Milk/dough (11th week)	Mature (14th week)
Whole plant					
DM	12.26 ± 0.13^c	15.02 ± 0.15^d	18.34 ± 0.26^c	26.88 ± 0.27^b	33.80 ± 0.37^a
NDF	38.80 ± 0.25^c	48.41 ± 0.41^d	59.85 ± 0.38^c	62.14 ± 0.30^b	66.31 ± 0.34^a
ADF	22.71 ± 0.19^c	28.60 ± 0.33^d	34.75 ± 0.18^c	36.15 ± 0.18^b	38.52 ± 0.26^a
Hemicellulose	16.09 ± 0.12^c	19.81 ± 0.25^d	25.10 ± 0.17^c	25.99 ± 0.19^b	27.91 ± 0.25^a
Cellulose	18.90 ± 0.14^d	23.45 ± 0.29^c	27.08 ± 0.05^b	27.61 ± 0.11^b	28.75 ± 0.15^a
Permanganate lignin	1.95 ± 0.07^c	2.69 ± 0.05^d	4.05 ± 0.12^c	4.58 ± 0.13^b	5.27 ± 0.16^a
Cutin	0.37 ± 0.02^c	0.71 ± 0.03^d	1.14 ± 0.02^c	1.29 ± 0.02^b	1.44 ± 0.03^a
Silica	1.49 ± 0.05^c	1.75 ± 0.02^d	2.49 ± 0.02^c	2.67 ± 0.02^b	3.05 ± 0.04^a
Leaf					
DM	13.60 ± 0.16^c	19.08 ± 0.35^d	25.01 ± 0.38^c	33.42 ± 0.22^b	36.99 ± 0.40^a
NDF	38.21 ± 0.22^c	47.17 ± 0.25^d	58.33 ± 0.36^c	61.16 ± 0.34^b	65.27 ± 0.48^a
ADF	20.74 ± 0.17^c	26.17 ± 0.20^d	32.57 ± 0.31^c	34.03 ± 0.19^b	36.20 ± 0.24^a
Hemicellulose	17.38 ± 0.20^c	21.01 ± 0.25^d	25.76 ± 0.22^c	27.10 ± 0.29^b	29.32 ± 0.26^a
Cellulose	17.31 ± 0.14^d	21.67 ± 0.10^c	25.59 ± 0.26^b	25.81 ± 0.21^b	27.08 ± 0.24^a
Permanganate lignin	1.47 ± 0.05^c	2.05 ± 0.15^d	3.19 ± 0.18^c	4.12 ± 0.11^b	4.66 ± 0.08^a
Cutin	0.42 ± 0.02^c	0.76 ± 0.02^d	1.27 ± 0.03^c	1.35 ± 0.02^b	1.50 ± 0.02^a
Silica	1.55 ± 0.04^c	1.82 ± 0.03^d	2.52 ± 0.03^c	2.76 ± 0.03^b	3.13 ± 0.02^a
Stem					
DM	9.87 ± 0.15^d	12.25 ± 0.17^{cd}	14.55 ± 0.20^c	23.21 ± 0.29^b	26.93 ± 0.66^a
NDF	40.55 ± 0.17^c	52.48 ± 0.51^d	63.80 ± 0.13^c	66.19 ± 0.29^b	69.67 ± 0.36^a
ADF	24.79 ± 0.19^c	33.20 ± 0.69^d	40.74 ± 0.29^c	41.95 ± 0.29^b	43.75 ± 0.36^a
Hemicellulose	15.74 ± 0.19^c	18.90 ± 0.33^d	23.06 ± 0.24^c	24.24 ± 0.26^b	25.93 ± 0.15^a
Cellulose	20.64 ± 0.21^d	27.75 ± 0.52^c	31.47 ± 0.27^b	31.96 ± 0.25^{ab}	32.64 ± 0.24^a
Permanganate lignin	2.41 ± 0.07^c	3.21 ± 0.19^d	5.63 ± 0.15^c	6.19 ± 0.15^b	6.98 ± 0.12^a
Cutin	0.29 ± 0.01^c	0.57 ± 0.02^d	1.07 ± 0.02^c	1.22 ± 0.02^b	1.35 ± 0.02^a
Silica	1.45 ± 0.04^c	1.68 ± 0.02^d	2.42 ± 0.02^c	2.57 ± 0.01^b	2.76 ± 0.02^a

Different superscripts on means in the same row show significant (p<0.01) differences.

reported that the maximum dry matter content was found in top portion of stem followed by leaves. However, their values were comparable with values obtained in the present study. The variations due to cultivars were found to be non-significant in whole plant and its fractions.

B. Cell wall constituents

1. NDF

The results showed that NDF contents in whole plant, leaf and stem fractions continued to increase significantly with advancing stage of growth. NDF contents ranged from 40.55 ± 0.17 to 69.67 ± 0.36 in stem fraction, being higher than that of whole plant (38.80 ± 0.25 to $66.31 \pm 0.34\%$), whereas NDF contents were lower in case of leaves (38.21 ± 0.22 to $65.27 \pm 0.48\%$). Gupta and Sagar (1987) also reported an increase in NDF contents of some non-legume fodders, harvested at pre-flowering, flowering and post-flowering stages. Azim et al. (1989) reported that maximum values for NDF were found in the bottom portion of the stem followed by those of whole maize plant. The results reported by these workers are quite comparable with those of the present study.

The changes due to cultivars were also significant in whole maize plant, however, the effect of cultivars was non-significant in case of leaf and stem fractions. UM-81 cultivar had significantly higher NDF contents than other cultivars. The differences in NDF between Akbar and IZ-31 were non-significant. Significantly lower NDF content was recorded in Neelum cultivar. Hunt et al. (1993) also reported some varietal differences in maize hybrid. They observed that whole plant samples of maize hybrid Pioneer 3377 had a lower (p<0.01) NDF than 3389 hybrid.

2. ADF

The values for ADF also showed similar trend as of NDF. A significant increase in ADF content was observed in whole plant, leaf and stem fractions with advancing stages of maturity. ADF concentration was higher (24.79 ± 0.19 to $43.75 \pm 0.36\%$) in stem than that of whole plant (22.71 ± 0.19 to $38.52 \pm 0.26\%$), whereas the leaf fraction of the plant had lower (20.74 ± 0.17 to $36.20 \pm 0.24\%$) ADF contents. Azim et al. (1989) reported that the values for ADF also showed similar trend as NDF and were maximum in bottom portion of stem followed by whole maize plant. Variations due to cultivars were non-significant in whole plant and its morphological fractions.

Table 2. Chemical composition of various cultivars of maize fodder and its morphological fractions (mean ± SE)

Chemical composition	Cultivars			
	Akbar	Neelum	UM-81	IZ-31
Whole plant				
DM	21.92 ± 2.26	21.22 ± 2.10	20.99 ± 2.20	20.92 ± 1.99
NDF	55.16 ± 3.34^b	54.33 ± 3.32^c	55.87 ± 3.45^a	55.05 ± 3.35^b
ADF	32.18 ± 1.87	31.70 ± 1.90	32.43 ± 1.96	32.27 ± 1.97
Hemicellulose	23.07 ± 1.55^b	22.63 ± 1.45^c	23.44 ± 1.50^a	22.78 ± 1.39^c
Cellulose	25.23 ± 1.20	25.22 ± 1.20	25.12 ± 1.21	25.08 ± 1.21
Permanganate lignin	3.54 ± 0.35^b	3.42 ± 0.39^b	3.69 ± 0.45^a	3.91 ± 0.45^a
Cutin	1.01 ± 0.14^a	0.95 ± 0.14^b	1.04 ± 0.13^a	0.96 ± 0.13^b
Silica	2.30 ± 0.18	2.21 ± 0.22	2.31 ± 0.20	2.32 ± 0.19
Leaf				
DM	26.41 ± 2.32	25.50 ± 2.45	25.07 ± 2.32	25.21 ± 2.24
NDF	53.69 ± 3.25	53.43 ± 3.26	54.72 ± 3.55	54.25 ± 3.33
ADF	29.76 ± 1.82	29.56 ± 1.93	30.33 ± 1.94	30.11 ± 1.92
Hemicellulose	24.14 ± 1.36	23.87 ± 1.35	24.39 ± 1.62	24.05 ± 1.48
Cellulose	23.26 ± 1.17	23.49 ± 1.24	23.59 ± 1.22	23.63 ± 1.19
Permanganate lignin	2.97 ± 0.38	2.88 ± 0.43	3.38 ± 0.42	3.16 ± 0.41
Cutin	1.08 ± 0.13	1.03 ± 0.14	1.09 ± 0.14	1.04 ± 0.14
Silica	2.36 ± 0.18	2.30 ± 0.22	2.38 ± 0.20	2.37 ± 0.20
Stem				
DM	18.03 ± 1.70	16.66 ± 1.48	17.52 ± 1.74	17.24 ± 1.74
NDF	58.24 ± 3.39	59.08 ± 3.47	58.71 ± 3.71	58.10 ± 3.68
ADF	36.26 ± 2.23	37.78 ± 2.29	36.81 ± 2.45	36.67 ± 2.49
Hemicellulose	22.02 ± 1.18^a	21.07 ± 1.30^b	21.88 ± 1.29^a	21.33 ± 1.25^b
Cellulose	28.29 ± 1.40	29.46 ± 1.41	28.94 ± 1.58	28.88 ± 1.60
Permanganate lignin	4.75 ± 0.13	5.29 ± 0.13	4.77 ± 0.14	4.74 ± 0.14
Cutin	0.90 ± 0.19	0.91 ± 0.20	0.92 ± 0.21	0.87 ± 0.21
Silica	1.01 ± 0.16^a	0.95 ± 0.19^b	1.04 ± 0.18^a	0.96 ± 0.17

Different superscripts on means in the same row show significant (p<0.01) differences.

3. Hemicellulose

A significant increase in hemicellulose contents of whole maize plant, leaf and stem was observed with advancement in stage of maturity. Hemicellulose contents of leaf fraction ranged from 17.38 ± 0.20 to $29.32 \pm 0.26\%$, being higher than that of whole plant (16.09 ± 0.12 to $27.91 \pm 0.25\%$), whereas the stem fraction of the plant had the lowest hemicellulose (15.74 ± 0.19 to $25.93 \pm 0.15\%$) concentration. Azim et al. (1989) also reported that maximum hemicellulose values were observed in leaves and the minimum in the bottom fraction of the stem of maize plant. However, the values reported by them were slightly lower than those of the present study.

The effect of cultivar was found to be significant only in case of whole plant and stem, whereas the differences were non-significant in leaf fraction. Significantly higher hemicellulose contents were observed in UM-81 cultivar, followed by Akbar. However, Neelum and IZ-31 cultivars had almost similar hemicellulose contents. In case of stem fractions, significantly higher hemicellulose contents were observed in Akbar and UM-81 than those of Neelum and IZ-31 cultivars. Hunt et al. (1993) reported that whole plant samples of maize hybrid Pioneer 3377 had a lower ($p<0.01$) percentage of hemicellulose (16.2 vs 18.2) than hybrid 3389. However, the values reported by these workers are slightly less than those of the present study.

4. Cellulose

A significant increase in cellulose contents was observed in whole plant and its fractions with advancing maturity. A rapid increase in cellulose contents was observed up to the flowering stage. However, a slight increase was recorded at milk/dough stage. Higher cellulose (20.64 ± 0.21 to $32.64 \pm 0.24\%$) content was observed in stem fraction than whole plant (18.90 ± 0.14 to $28.75 \pm 0.15\%$). However, the leaf fraction had the lowest cellulose (17.31 ± 0.14 to $27.08 \pm 0.24\%$) contents. The cellulose contents have been reported to be maximum in the bottom portion of the stem followed by whole mixed plant (Azim et al., 1989). Their values for leaf fraction are close to the values observed in the present study, whereas the values for whole plant and stem are slightly higher than those of this study. The effect of cultivars on cellulose contents was found to be non-significant in whole plant as well as its leaf and stem fractions.

5. Lignin

Concentrations of lignin significantly increased with advancing age in whole maize plant and its leaf and stem fractions. Lignin contents of stem fraction were higher (2.41 ± 0.07 to $6.98 \pm 0.12\%$) than that of whole plant (1.95 ± 0.07 to $5.27 \pm 0.16\%$) and minimum (1.47 ± 0.05 to $4.66 \pm 0.08\%$) in leaf fraction of the maize plant. Gupta and Sagar (1987) reported an increase in the lignin contents of some non-legume (including maize) forages with advancing harvest stage. Variations in lignin

concentration due to cultivars were significant only in case of whole plant. Akbar and Neelum cultivars had a significantly lower lignin content than those of UM-81 and IZ-31. Weller et al. (1984) reported that maize cultivar brown midrib-3 gene significantly reduced lignin synthesis in whole plant and plant components at all harvests

6. Cutin

Cutin contents of whole maize plant and its morphological fractions such as leaf and stem continued to increase significantly with advancing stage of growth. Cutin contents in leaf fraction of the plant ranged from (0.42 ± 0.02 to $1.50 \pm 0.02\%$), being higher than those of whole maize plant (0.37 ± 0.02 to $1.44 \pm 0.03\%$) and stem fraction (0.29 ± 0.01 to $1.35 \pm 0.02\%$). Cultivar effects on cutin content were found to be significant only in case of whole maize plant. Akbar and UM-81 cultivars had significantly higher cutin contents than those of Neelum and IZ-31.

7. Silica

Silica contents of whole maize plant and its leaf and stem fractions were significantly affected by advancement in stage of growth. Higher silica concentration (1.55 ± 0.04 to $3.13 \pm 0.02\%$) was observed in leaf fraction followed by whole maize plant (1.49 ± 0.05 to $3.05 \pm 0.04\%$), whereas these values were minimum in case of stem fraction of the plant (1.45 ± 0.04 to $2.76 \pm 0.02\%$). This may be due to the reason that whatever silica is absorbed from the soil, gets deposited in leaves after being transported to that site. Rakkiyappan and Krishnamoorthy (1982) also reported a higher silica content in leaf than whole plant and stem. Variations in silica contents due to cultivars were found to be significant only in case of stem fraction of the maize plant. Stem fractions of Akbar and UM-81 cultivars had significantly higher silica contents than those of Neelum and IZ-31.

ACKNOWLEDGEMENTS

REFERENCES

AOAC. 1984. Official Methods of Analysis of the Association of Official Analytical Chemists. 14th Ed. Arlington, Virginia, USA.

Azim, A., Z. Naseer and A. Ali 1989. Nutritional evaluation of maize fodder at two different vegetative stages. Asian-Aus. J. Anim. Sci. 2(1):27-34.

Bhatti, M. B. and S. Khan. 1996. Fodder production in

Pakistan. Proceed. of Nutritional Coference on the Improvement. Production and Utilisation of Fodder Crops in Pakistan, held at NARC, Islamabad, March 25 to 27.

Choudhry, A. R. 1983. Maize in Pakistan. Punjab, Agri. Res. Coordination Board, Univ. of Agri., Faisalabad, Pakistan.

Gupta, P. C., S. Randahir and K. Pradhan. 1976. Availability in protein, cell wall constituents and *in vitro* nutrient digestibility in some important strains of fodder oat harvested at different stages of growth. Indian J. Agri. Sci. 46(8):359-363.

Gupta, P. C. and V. Sagar. 1987. Assessing the feeding value of tropical forages by direct and indirect methods. Technical Bulletin, Department of Animal Nutrition, Haryana Agriculture University, Hisar, India.

Harris, L. E. 1970. Nutrition Research Techniques for Domestic and Wild Animals, Vol. 1. Anim. Sci Department, Utah State University, Logan, Utah, USA.

Hunt, C. W., W. Kezar, D. D. Hinman and J. J. Cors. 1993. Effects of hybrids and ensiling with or without microbial inoculant on the nutritional characteristic of whole corn plant. J. Anim Sci. 71(1):38-43 (Maize Abstr. 9(6):3785, 1993).

Rakkiyappan, P. and K. K. Krishnamoorthy. 1982. Evaluation of hybrid napier (NB-21) for its forage quality by cell wall component analysis. Madras Agri. J. 69(8):523-528 (Nutr. Abst. Rev. 55:29, 1985).

Steel, R. G. D. and J. H. Torrie. 1984. Principles and Procedures of Statistics. International Student Ed. McGraw Hill Book Co. Inc., New York.

Van Soest, P. J. 1963. Use of detergents in the analysis of fibrous feed. 11. A rapid method for the determination of fibre and lignin. J. Ass. Official Anal. Chem. 46(5):829-835.

Van Soest, P. J. and R H. Wine. 1967. Use of detergents in the analysis of fibrous feed. IV. Determination of plant cell wall constituents. J Assn. Official Anal Chem. 50, 50-55.

Van Soest, P. J. and J. B. Robertson. 1985. Analysis of forage and fibrous feeds. A Laboratory Manual for Animal Science 613, Cornell University, New York.

Weller, R. F., R. H. Phipps and E. S. Griffith. 1984. The nutritive value of normal and brown midrib-3 maize. J. Agri. Sci. 103(1):223-227 (Nutr. Abst. Rev. 54(12):5010, 1984).