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EFFECT OF STAGE OF GROWTH AND CULTIVARS ON CHEMICAL COMPOSITION OF WHOLE MAIZE PLANT AND ITS MORPHOLOGICAL FRACTIONS

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Samples of whole plant, leaf and stem of Akbar, Neelum, U.M-XI and LZ-31 cultivars of maize fodder harvested at weekly intervals/growth stages were drawn and analysed for dry matter contents and various cell wall constituents such as neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose. cellulose, lignin, cutin and silica. The dry matter contents of whole maize plant, leaf and stem increased significantly with advancing plant age. Maximum dry matter was found in the leaf fraction of the plant. The cell wall components continued to increase significantly 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 fractions. 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 digestibility and dry matter contents and lower lignin concentration.

Key **words:** chemical composition. cultivars, maize plant, stage of growth

INTRODUCTION

In recent years the 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 (Singh and Pradhan, 1981). Poor digestibility and lower intake are usually associated with high lignin contents which increase with advancing stage of maturity. As the plant matures, dry matter and cell wall constituents increase and erude protein and cell contents decrease (Gupta *et al., 1976).*

Maize *(Zea mavs)* has for centuries been used as a forage crop in the ludo - Pak subcontinent. Generally. the whole plant, when cobs are at the milking 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. The yield per hectare of maize fodder is [4.80 tonnes (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. The information on local maize fodder is 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, U.M - 81 and LZ-31 were cultivated from March to June, 1991 in experimental fields of the University of Agriculture, Faisalabad. Urea (125 kg / hectare) was applied as fertilizer. TIle experimental fields were irrigated six times during the experimental period. The representative samples of maize fodder were harvested from different parts of the experimental fields at weekly intervals (1st to 14th week). The morphological fractions such as leaves and stem were also collected at various harvest stages. The leaves (blade + sheath) were separated manually from stem and saved for further analysis. All fodder samples were chaffed into 2 - 3 cm pieces and dried at 60"C to constant weight (AOAC, 1984). The dried fodder samples were ground in a laboratory mill and passed through lrnm screen (Harris, 1970). Various structural components such as neutral detergent fibre (NDF), acid detergent fibre (ADF), hemicellulose, cellulose, lignin, cutin and silica were determined by the method of Van Soest and Robertson (1985). A brief description of the methods is as under:

Neutral Detergent Fibre (NDF): One gram of fodder sample was refluxed with 100 ml neutral detergent solution (pH 7) for 60 minutes. The insoluble residue so obtained was filtered. dried at 105 "C and weighed. The loss in weight was recorded as NDF.

Acid Detergent Fibre (ADF) and Silica: One gram of fodder sample was refluxed for 60 minutes in 1 N sulphuric acid containing 2 % cetyl trimethyl ammonium bromide (CTAB) as the detergent. The residue was filtered. dried at !O5 C and weighed. The loss in weight was taken as ADF. The residue left after ADF extraction was ashcd at 600 C in a muffle furnace and silica so obtained was measured.

Hemicellulose: The hemicellulose contents of the fodders were determined by difference between the NDF and ADF.

Cellulose, Lignin and Cutin: The fodder samples were first digested with neutral detergent and then with acid detergent to dissolve all detergent soluble fractions. The residue was further digested by 72 % sulphuric acid. The loss in weight was considered as cellulose. The remaining residue after elimination of cellulose was oxidized by potassium permanganate (KM nO.) solution to separate the plant cuticle which was resistant to KMnO. The loss in weight was taken as lignin. The residue left after KMnO treatment was cutin and acid insoluble ash (silica). The residue was ashed and loss in weight was determined as cutin.

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

RESUL TS 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 I. Average dry matter contents and structural components of different cultivars of maize plant are given in Table 2.

Dry Matter: A significant increase in DM contents of maize fodder and its morphological fractions was observed with advancing stage of maturity. The highest OM contents were found in leaf fraction (l3.60± 0.23 to 3699±0.66%) followed by whole plant (l2.26±0.18 to 33.80±0.63%). whereas the lowest DM contents (9.87±0.09 to 26.93±1.37%) were observed in stem fraction. This was probably due to increased photo-synthetic 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 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

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±0.41. to 69.67±I.I6% in stem fraction, being higher than that of whole plant (38.80±0.32 to 66.31 ±0.47%), whereas NDF contents were lower in case of leaves (38.21 ±0.92 to 65.27±0.63%). 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. U. M-81 cultivar had significantly higher NDF contents than other cultivars. The differences in NDF between Akbar and I . Z - 3 I were non -significanr. 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.

ADF: The values for ADF also showed similar trend as by 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. 15 to 43.75 ±0.45 %) in stem than that of whole plant (22.71 ±0.25 to 38.52±0.36%). whereas the leaf fraction of the plant had lower (20.74 ±O. 17 to 36.20±0.22%) ADF contents. Azim *et at.* (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.

Hemicellulose: A significant increase in hemicellulose

Table 1. Average chemical composition of whole maize plant and its morphological fractions at different stages of growth

Chemical composition	Growth stages (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±0.18' ,	15.02 ±0.19 d	18.34 ±0.35 c	26.88 ±0.32 h	33.80 ±0.63·'
NDF	38.80±0.32 r	48.41 ±0.43 d	59.85 ±0.36 c	62.14 ±0.39 h	66.31 ±0.47 "
ADF	22.71 ±0.25 ;	28.60 ±0.49 d	34.75 ±o.n '	36.15 ±0.17 h	38.52 ±0.36 .,
Hemicellulose	16.09 ±0.17 '	19.81 ±0.15 d	25.10 ±0.16'	25.99 ±0.12 h	n.91 ±0.32 "
Cellulose	18.90 ±0.18 d	23.45 ±0.41 '	n.08 ±0.37 h	n.61 ±0.06 h	28.75 ±0.17 "
Permanganate lignin	1.95 ±0.19'	2.69 ±O.06 d	4.05 ±0.21 c	4.58 ±0.18 h	5.n ±0.23 a
Cutin	0.37 ±O.02 '	0.71 ±O.04 d	1.14 ±0.02 r	1.29 ±0.03 h	1.44 ±0.02 "
Silica	I.49 ± (Ul7 c	1.75 ±O.03 d	2.49 ±0.02 :	2.67 ±0.01 h	3.05 ±0.04 u
Leaf					
DM	13.60 ±0.23 c	19.08±O.55 d	25.0 I ±0.62 c	33.42±0.12 h	36.99 ±0.66 "
NDF	38.21 ±0.92 "	47.17±O.28 d	58.33 ±0.47 c	61.16 ±0.41 b	65.27 ±0.63 a
ADF	20.74 ±0.17'	26.17 ±0.26 d	32.57 ±0.42'	34.03 ±0.18 h	36.20 ±0.22 a
Hemicellulose	17.38 ±O.25 '	21.01 ±0.22 d	25.76 ±0.09 c	n.lO ±0.40 h	29.32 ±0.35 u
Cellulose	17.31 ±O.10 d	21.67 ±0.07 c	25.59 ±0.17 ' h	25.81 ±0.16 h	27.08 ±O.22 "
Permanganate lignin	1.47 ±0.05 '	2.05 ±O.18 d	3.19 ±0.19 c	14.12 ±0.21 h	4.66 ±O.II "
Cutin	0.42 ±(U)I c	0.76 ±0.03 d	1.27 ± 0.04'	1.35 ±0.02 h	1.50 ±0.02"
Silica	1.55 ±O.O3'	1.82 ±0.04 d	2.52 ±0.04 r	2.76 ±0.02 h	3.13 ±0.03 "
Stem					
OM	9.87 ±0.09 d	12.25 ±0.09 d	14.55 ±o.n '	23.21 ±0.39 h	26.93 ± 1.37 "
NOF	40.55 ±0.41 r	52.48 ±0.77 d	63.80 ±(l.]O '	66.19 ±0.39 h	69.67 ±1.16" '
ADF	24.79 ±0.15 r	33.20 ±0.97 d	40.74 ±O.19'	41.95 ±(UI h	43.75 ±0.45 "
Hemicellulose	15.74 ±O.24 r	18.90 ±0.43 d	23.06 ±0.79 r	24.24 ±0.32 h	25.93 ±0.16 "
Cellulose	20.M ±0.25 d	27.75 ±0.68 '	31.47 ±O.32 h	31.96 ±o.n ;ll.	32.64 ±O.26 "
Pcrmanganate lignin	2.41 ±0.07'	3.21 ±0.29 d	5.63 ±0.21 '	6.19 ±0.22 h	6.98 ±0.17"
Cutin	0.29 ±0.01 <	0.57 ±O.03 d	1.07 ±O.02 c	1.22 ±O.02 h	1.35 ±O.OI a
Silica	1.45 ±O.06 !	1.68 ±O.03 d	2.42 ±O.02 !	2.57 ±0.01 h	2.76 ±0.02 "

Different superscripts on means in the same row show significant (P< 0.(1) differences.

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±0.25 to 29.32±0.35%. heing higher than that of whole plant (l6.09±0.17 to 27.91±0.32 %l, whereas the stem fraction of the plant had the lowest hemicellulose (l5.74±0.24 to 25.93±0.16%) concentration. Azim *er al.* (1989) also reponed that maximum hemicellulose values were observed in leaves and the minimum in the bottom fraction of tl1e stem or maize plant. However. the values reported by them were slightly lower than those of lie present study.

'111e effect of cultivar was found to be significant only in case or whole plant and stem. whereas the differences were non - significant in leaf fraction. Significantly higher hemicellulose contents were observed in U.M - 81 cultivar, followed by Akbar. However. Neelum and I.Z - 31 cultivars had almost similar hemicellulose contents. In case of stem fractions, significantly higher hemicellulose contents were observed in Akbar and lJ.M - 81 than those or Neelurn and I.Z - 31 cultivars. HU1 *Ir al.* (1993) reponed 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.

Cellulose: A significant increase in cellulose contents was

Tahk 2, Awrage chemical composition of various cultivars of maize fodder and its mOlphological fractions

Chemical composition	Cultivars			
	Akbar	Ncclurn	U, M-!H	I, Z-3!
		Whole plant		
DM	2\,92 ±4,21	21,22 ±3,92	20,99 ±4,08	20,92 ±3,71
NDF	55,16 ±4,98	54,33 ±5,OO'	55,87 ±5,17	55.05 ± 5.02"
ADF	32.18 ±2.80	31.70 ±2.85	32.43 ±2.94	32.27 ±2.95
Hemicellulose	23.07 ±2.26	22.63 ±2,16	23,44 ±2.24	22.78 ±208
Cellulosc	25.23 ± 1,80	25.22 ± 1.81	25 . 12 ±181	25.08 ± 1.82
Pcnuang.uuue lignin	3.54 ±O.52 "	3,42 ±0.58	3.69 ±O.67	3,91 ±ON
Cutin	IOI ±0.20'	0.95 ±0.21	1.04 ±0.19'	096 ±0.21 "
Silica	230 ±0.26	2.21 ±0.32	2.31 ±O.29	2.32 ±O.28
		Leaf		
DM	26.41 ±4.33	25.50 ±4.57	25.07 ±4.20	25.21 ±4.19
NDf~	53.69 ±4.68	53,43 ±4.88	54.72 ±5.31	5425 ±5.65
ADF	29.76 ±4:73	29,56 ±2.88	30.33 ±2.91	30.11 ±288
Hemicc llulose	24.14 ±2.10	23.87 ±2.01	24.39 ±2,42	2405 ;1:2.22
Cellulose	23.26 ±1.74	23,49 ± 1.83	23.59 ±1.83	23.63 ± I,M
Permanganate lignin	2.97 ±0.56	2.88 ±(165	3,38 ±(1.63	3,16 ±O()()
Cutin	1.08 ±0.20	1.03 ±O.20	\,09 ±0.21	1.04 ±0.20
Silica	*2.36 ±(U6*	2.30 ±0.32	2.38 ±(UO	2.37 ±0.37
		Stem		
DM	18.03 ±3.93	16.66 ±2.74	17.52 ±3.55	17.24 ±3.25
NDF	58.24 ±4.82	59.08 ±4.91	58.71 ±5,46	58.10 ±5,58
ADF	36.26 ±334	37.7X ±3,42	36.81 ±3.66	36.67 ±3.81
Hemicellulose	22.02 ±1.76	21.07 ±1.93	21.88 ±1.93	21 .33 ± l .86
Cellulose	28.29 ± 1.98	29,46 ±2.09	28.94 ±2.39	28.88 ±2.38
Permanganate lignin	4.75 ±O.83	5.29 ±O.91	4.77 ±O.89	4.74 ±O.93
Cutin	0.90 ±O.19	0.91 ±O.20	0.92 ±0.21	0.87 ±0.21
Silica	\.01 ±0.24'	0.95 ±0.28	1.04±0.24"	0.96 ±0.2e

Different superscripts on means in the same row show significant (P < 0.0 I) differences.

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,M±(l.25 to 32.M±O.26%) was observed in stem fraction than whole plant (18.90±0,18 to 28.75 ±(L17 'X). However. the leaf fraction had the lowest cellulose (17.31±0.1O to 27.08±0.22%) 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 he non-significant in whole plant as well as its leaf and stem fractions.

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±O, 17%) than that of whole plant (l,95±O.19 to 5.27±O,23%) and were minimum (1,47 ±(Ul5 10 4.66±O.11 %) in leaf fraction of the maize plant. Gupta and Sugar (1987) reported an increase in the lignin contents of some non-legume (including maize) forages with advancing harvest stages, 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 U.M-81 and I.Z - 31. Weller *et al.* (1984) reported that maize cultivar brown midrib-J gene significantly reduced lignin synthesis in whole plant and plant components at all harvests,

Cutin: Cutin contents of whole maize plant and its morphological fractions such as leaf and stem continued to increase signiticantly with advancing stage of growth. Cutin contents in leaf fraction of the plant ranged from (042±O.OI to 1,50±O.02%1. , being higher than those of whole maize plant (O.37±O.02 to I 44±0.02%) and stem fraction (O.29±O.OI to I.35±(H)1 %). Cultivar effects on cutin content were found to be SIgnificant only in case of whole maize plant. Akbar and U.M-81 cultivars had significantl~ higher cutin contents than those of Neclum and 17-1. I

Silica: Silica contents of whole maize plant and its leaf and stern tractions were significantly affected by ,ulv.mccmcut in stage of growth. Higher silica concentration (I.S5±:O.03 to 3.13 ± .O.03'Yt) was observed in leaf fraction followed by whole maize plant (149±O.07 to 3.0S±O.04';{}. whereas these values were minimum in case of stem fraction of the planu 1.54±O.06 to 2.76ttU)2'1t). 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 Krisunaruoorthy (19!Q) also reported a higher silica content in leaf than whole plant and stem. Variations in silica contents due to cultivars were found to be sigriilic.uu only in case of stem fraction of the maize plant. Stem fractions of Akbar and U. M-81 cultivars had signilicantly higher silica contents than those of Ncelum and 1.7-31.

REFERENCES

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

Azim. A.. Z. Nasecr and A. Ali. 1989. Nutritional evaluation of maize fodder at two different vegetative stages. AJAS. 2 (I): 27-34.

Bhalti. M.B. and S. Khan. 1996. Fodder production in Pakistan. Proc, National Conference on 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. Agri., Faisalabad, Pakistan.

Gupta, P.C .. S. Randhir and K. Pradhan. 1976. Availability in protein. cell wall constituents and *in yitro* nutrient digestibility in some important strains of fodder oat harvested at different stagcs of growth Indian J Agr: Sci. 46 (8): 359-36'

Guptu. P.C. and V. Sagar 1987. Assessmg the teeding value of tropical forages by direct and indirect methods. Tech. Bull.. Department of Animal Nutrition. Haryaua Agricultural University, Hisar. India.

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

Hunt. C.W .. W. Kezar., D.D. Hinman and J.J. Combs. 1993. Effects of hybrids and cnsiling with or without microbial inoculant and on the nutritional characteristics of whole corn plant.. J. Anim. Sci. 71 (I): 38-43 (Maize Abst. 9 (6): 3785. 1(93).

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): S23-528 (Nutr. Abst. Rev. 5S:29. 1985).

Singh, R. and K. Pradhan. 1981. Forage Evaluation. 1st cd. Allied Publishers. New Delhi

Steel. R G. D. and J. H. Tonic. 19114. Principles and Procedures of Statistics. International Student Ed. McGraw Hill Book Co. lnc.. New York.

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

Wcller , R.F .. R.H. Phipps ami E.S. Griftith. 1984. The nutritive value of normal and brown midrib-J maize. J. Agri. Sci. 103 (I): 223-227 (Nutr. Abst. Rcv. S4 (12): SOlO, 1984).