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EFFECT OF STAGE OF HARVEST ON NUTRITIONAL COMPOSITION AND MINERAL PROFILE OF MAIZE CROP, GRAIN, MAIZE TOP SILAGE AND HAY

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SUMMARY

The study was conducted to determine nutritional evaluation of maize top silage and maize top hay and maize grains. The maize plant growth which can be classified as vegetative growth and reproductive growth, the reproductive growth is divided into different stages; silk stage (R-1), blister stage (R-2), dough stage (R-3), dent stage (R-4) and physiological maturity stage (R-6). From this experiment it was concluded that, Among R-1 to R-3 stages of maize plant growth, CP was significantly higher at R-3 stage in maize tops whereas in cobs, CP was significantly higher in R-2 and R-3 stages. Fiber fractions increased in the maize tops as the maturity increased and vice-versa in grains. The dry matter yield from the maize tops was higher in R-4 stage onwards. The proximate principles and fiber fractions of MTS and MTH were comparable on dry matter basis. Nutritionally, MTS and MTH were more beneficial to support milk production when compared to any other cereal straw/stovers. Therefore, the benefit of highly nutritious part of the maize plant like tops can be harvested at physiological stage of maturity (R6-96th day of plant growth) without allowing for higher lignification till the harvest of the cob. So that it can fill gap of 8% to the existing green fodder deficit in India.

Key words: Maize top hay, Maize top silage, Green fodder yield, Dry fodder yield

Indian livestock farming system faces shortage of crop residues and green fodder to the tune of 23.4 and 11.2 percent respectively (Roy et al., 2019b) due to shrinkage of arable land and interest of farmers' preference towards commercial crop production (Agarwal *et al*., 2016). The farmers in Karnataka commonly cultivate cereals like maize, sorghum, rice and ragi for grain production and residues of these crops are utilized as roughage for ruminant feeding except maize because of its hard and thick stem which render it unpalatable. In addition, higher labor cost in harvesting and collection, maize stover is burnt in the field. However, highly lignified maize crop residue production can be reduced by better utilization of the plant part above the cob level, at 55-65 days after silking stage at which plant reaches the physiological maturity where the grain formation process is almost completed (Nielsen, 2013). As the top is not required for the plant for rest of life it can better be utilized either as fresh green fodder or converted to silage or hay (Methu *et al*., 2006) instead of keeping the top till the harvest of the cob which renders the portion of the plant unutilizable by the livestock due to higher lignification. In addition, de-tasselling of maize after pollination and topping after physiological maturity provide fodder and also increase the grain yield. Therefore, the study is undertaken to assess the effect of harvest at different phases of the growth of maize crop on nutritional composition.

MATERIALS AND METHODS

Maize crop (variety; CP-818, rate; 6kg/acre, spacing; 60 cm x 30 cm) was cultivated during *kharif* season (June to October) in farm section of Department of Livestock Farm Complex Veterinary College, Shivamogga. Farm yard manure (2500 kg/ha) was incorporated into the soil 30 days before sowing. The recommended dose of NPK fertilizers (150:75:50 kg/ha) was applied by using urea, Diammonium phosphate (DAP) and Muriate of potash (MOP). Basal dose of NPK fertilizers (50% N and 100% P and K) were applied at the time of sowing. Remaining 50% of nitrogen fertilizer (urea) was applied at 30 and 50 days after sowing as top dressing. Agricultural operations like gap filling, thinning and weed management were taken up to get maximum yield.

The maize plant growth which can be classified as vegetative growth and reproductive growth, the reproductive growth is divided into different stages; silk stage (R-1), blister stage (R-2), dough stage (R-3), dent stage (R-4) and physiological maturity stage (R-6). Arial part of the plant, leaving one inter node above the cob is called maize top. The tops and cobs from five maize plants from R-1 to R-6 stages from corner and middle part of the plot were harvested in one square meter area at five different spots in crop production plots and labeled for estimating dry matter (DM). The DM of the maize tops was determined at 70 ^{0} C for 72 h and for cobs 96 h in hot air oven (AOAC, 2016) and the samples were stored in airtight polythene bags for further analysis.

The maize tops were harvested at the physiological maturity stage (R-6) of growth where the grains attained the maximum (65-70%) DM accumulation and was conserved as hay and as silage to assess the suitable conservation method of maize tops at field level. The maze top hay was prepared by chopping to about 1-2 inches' length using electrical chaff cutter (M/s Fortune Ltd.) and sun dried for 4 to 5 days around 27 to 30 ^{0}C with raking for every one hour. Some portion of maize tops were ensiled without any additives and silos were opened after 45 days. The samples of maize top hay and maize top silage were subjected for proximate composition (AOAC, 2016), fiber fractions (Van Soest, *et al.,* 1991) and mineral profile (AAS, M/S Perkin Elmer, Analyst 400). The DM of silage was determined by toluene distillation method (AOAC, 2016), pH by using pH meter (M/S Systronics, μ pH system 362) and NH_3-N by AOAC (2016). The Metabolisable energy (ME) content of maize top hay and silage was estimated by rumen in vitro gas production technique (RIVGPT) using chemical composition, net gas production at 24 hour incubation by the following equations proposed by Manke and Steingass (1988). Where the rumen contents were collected from nearby slaughter house in male cattle soon after evisceration with sufficient care to avoid any contamination and brought in a thermos flask previously filled with warm water. Rumen content was brought to the laboratory with a minimum lapse of time and filtered through four layers of muslin cloth with continuous bubbling with carbon dioxide to maintain anaerobic condition. Buffered rumen inoculum was prepared by mixing strained rumen contents with medium in the standard proportions.

For Roughages: ME=2.20+0.1357GP*+0.0057CP+ 0.0002859(EE)^2
For Concentrate feed mixture: ME=1.06+0.157GP+ 0.0084CP+0.022EE-0.081TA
Where,
GP = Gas production in ml/200mg of DM.
CP= Crude Protein g/kg of DM.
EE= Ether Extract g/kg of DM.
TA= Total Ash g/kg of DM.
ME= Metabolisable energy, MJ/kg DM.
*For silage, corrected gas volume = 4.7+0.089 gas production.

RESULTS AND DISCUSSION

The proximate principles, fiber fractions and mineral composition of maize tops harvested at different stages of plant growth from R-1 to R-6 stages are presented in Table 1. The chemical composition of maize tops (% on DMB) from R-1 to R-6 stages ranged; CP 6.81 to 10.06, CF 21.98 to 27.96, EE 0.95 to 1.82, NFE 51.83 to 64.80, TA 4.69 to 11.49, NDF 60.44 to 64.01, ADF 28.67 to 34.46, ADL 2.75 to 3.47, HC 29.56 to 33.26 and Cellulose 25.88 to 30.98, respectively. The chemical components except hemicellulose differed significantly (P<0.01) across different stages. The CF, NDF, ADF and ADL contents increased as the maturity of the plant increased therefore NFE content was significantly (P?0.01) decreased. Similar values were reported by Azim *et al*., (1989) and Giridhar *et al*., (2016). The major mineral composition (g/kg) of maize tops from R-1 to R-6 stages ranged; Ca 1.13 to 3.41, P 2.99 to 3.16, K 1.96 to 2.13 and the micro mineral (mg/kg) ranged Fe 0.29 to 0.80, Cu 6.0 to 8.88, Zn 26.8 to 41.80 and Mn 62.83 to 53.43 respectively. Except phosphorous and zinc differed significantly (P<0.01) in different stages. The variation in the mineral composition when compared to other studies was due to difference in the verities of maize grain used, spacing, soil type, quantity of fertilizers applied and stages of growth.

The proximate principles, fiber fractions and mineral composition of grains harvested at different stages of growth from R-1 to R-6 are presented in Table 2. The chemical composition of grains (% on DMB) from R-1 to R-6 stages ranged CP 8.97 to 14.15, CF 1.59 to 14.66, EE 0.96 to 3.44, NFE 64.50 to 84.70, TA 1.29 to 5.07, ADL 0.96 to 7.71,

TABLE 1
Chemical, fiber fraction and mineral composition (% on DMB) of maize crop at different stages of plant growth

Parameter	R1	R2	R3	R4	R5	R6	SEM	P
OM**	95.31[a]	94.51[b]	93.73[c]	92.47[d]	92.12[e]	88.51[f]	0.535	0.001
CP**	7.37[b]	6.81[b]	10.06[a]	7.05[b]	7.65[b]	7.40[b]	0.300	0.001
CF**	21.98[b]	22.19[b]	22.29[b]	25.61[a]	27.14[a]	27.96[a]	0.676	0.001
EE**	1.16[bcd]	1.82[a]	1.21[b]	0.95[d]	1.15[bcd]	1.33[b]	0.069	0.001
NFE**	64.80[a]	63.70[ab]	60.18[bc]	58.85[c]	58.73[c]	51.83[d]	1.125	0.001
TA**	4.69[f]	5.49[e]	6.27[d]	7.53[c]	7.88[b]	11.49[a]	0.535	0.001
AIA**	1.06[c]	2.20[b]	2.34[b]	2.84[c]	3.59[b]	6.77[a]	0.437	0.001
NDF**	61.06[cd]	61.93[bc]	60.44[d]	62.65[b]	61.77[bc]	64.01[a]	0.294	0.001
ADF*	29.78[b]	28.67[b]	30.82[b]	30.75[b]	29.93[b]	34.46[a]	0.547	0.017
ADL**	2.75[b]	2.78[b]	3.11[ab]	3.20[a]	3.38[a]	3.47[a]	0.080	0.008
HC	31.28	33.26	29.62	31.9	31.85	29.56	0.483	0.181
Cellulose*	27.04[b]	25.88[b]	27.71[b]	27.54[b]	26.55[b]	30.98[a]	0.504	0.027
Macro mineral composition (g/kg)								
Ca**	1.13[b]	1.35[b]	1.48[b]	2.18[c]	2.70[b]	3.41[a]	0.201	0.001
P	3.15	3.08	3	3.3	2.99	3.16	0.058	0.714
K**	2.13[a]	2.13[a]	2.09[a]	1.96[b]	1.99[b]	2.13[a]	0.020	0.002
Micro mineral composition (mg/kg)								
Fe**	0.29[d]	0.80[a]	0.59[b]	0.57[b]	0.32[c]	0.43[cd]	0.044	0.001
Cu**	8.88[a]	7.02[bc]	7.15[b]	6.00[cd]	6.13[d]	8.07[a]	0.266	0.001
Zn	29.32	31.07	35.59	41.8	29.49	26.80	2.029	0.317
Mn**	62.83[f]	87.64[e]	90.93[d]	106.09[c]	109.25[b]	153.4[a]	6.702	0.001

**P ≤ 0.01, *P ≤ 0.05, Means bearing different superscripts in a row differ significantly.
R1-Silks stage, R2-Blister stage, R3- Milk stage, R4-Dough stage, R5- Dent stage and R6-Physiological maturity stage.

respectively. The chemical composition of maize gain differed significantly (P<0.01) across different stages. The CP content gradually decreased to 8.97% because of increased gain fill (NFE) as the maturity of the plant increased. The CF, NDF, ADF and ADL were higher at R-1 and R-2 stage because grains were inseparable at these stages. The major mineral composition (g/kg) of grains form R-1 to R-6 stages ranged Ca 0.43 to 0.53, P 2.35 to 3.17, K 1.21 to 2.13 and the micro minerals (mg/kg) ranged Fe 0.20 to 1.13, Cu 1.05 to 9.09, Zn 4.87 to 39.41 and Mn 7.35 to 29.15, respectively. Among the macro and micro minerals, except for phosphorous and iron others differed significantly (P<0.001) across different stages.

Green matter, per cent dry matter and DM yield of maize tops and grain yield at different stages of plant growth from R-1 to R-6 stages are presented in Table 3. Green yield (tons/ha), DM (%) and DM yield (tons/ha) of maize tops were 5.50, 22.69 and 1.27; 6.40, 23.43 and 1.50; 7.20, 26.01 and 1.87; 7.67, 27.74 and 2.13; 6.70, 30.90 and 2.07, and 6.73, 32.14 and 2.20, respectively in R-1 to R-6 stages of plant growth. There was a significant (P<0.01) difference between the stages in green yield, DM (%) and DM yield. The DM (%) and grain yield (tons/ha) in the corresponding stages were 10.82 and 2.76; 12.38 and 3.47; 25.06 and 4.23; 37.71 and 5.13; 49.02 and 5.29 and 66.90 and 6.13, respectively. There was significant (P<0.01) difference between R-1 to R-6 stages in DM % of grains and grain yield. The maize tops yield in this study was comparable to the values reported by Methu *et al*., (2006). However, fodder yield observed in this study was lesser because the maize variety used was grain variety and not the fodder variety and the seed rate used per hector was also lesser when compared to the fodder variety maize. There was no significant difference in grain yield at R-6 stage between the plants with tops and without tops. The results were corroborated to the values reported by Subedi *et al*. (1996).

Physical and chemical properties of maize top silage and maize top hay are presented in Table 4. The color of maize top silage was greenish yellow and smell was of fruity. The chemical properties like moisture, pH and NH3-N of maize top silage were 69 %, 4.7 and 9%, respectively whereas the moisture level of maize top hay was 6% and the color was light green. The silage properties were comparable to silage prepared by Giridhar *et al*., (2012) and Haque (2018).

The proximate composition, fiber fractions, ME and mineral profile of maize top silage (MTS) and maize top hay (MTH) are presented in Table 5. The chemical composition of MTS and MTH (% on DMB) were CP 8.06 and 7.46, CF 27.69 and 28.08, NDF 58.33 and 65.39, ADF 32.60 and 34.86, ADL 2.78

TABLE 2

Chemical, fiber fractions and mineral composition (% on DMB) of maize grains at different stages of plant growth

Parameter	R1#	R2#	R3	R4	R5	R6	SEM	P
OM**	96.25	94.93	97.02^{a}	98.12^{b}	98.55^{c}	98.71^{d}	0.690	0.001
CP**	11.71	14.15	13.03^{a}	12.10^{b}	10.14^{c}	8.97^{d}	1.688	0.001
CF**	5.81	14.66	3.44^{a}	2.87^{a}	1.88^{bc}	1.59^{c}	0.800	0.001
EE*	0.96	1.61	1.85^{a}	2.12^{a}	2.40^{ab}	3.44^{b}	0.746	0.014
NFE**	77.77	64.5	78.70^{a}	81.03^{b}	84.14^{c}	84.70^{cd}	2.573	0.001
TA**	3.75	5.07	2.98^{a}	1.88^{b}	1.45^{c}	1.29^{d}	0.690	0.001
AIA	0.25	0.40	0.10	0.10	0.10	0.15	0.039	0.293
NDF**	28.3	38.11	24.21^{a}	20.49^{a}	19.63^{a}	12.01^{b}	5.134	0.003
ADF**	10.19	16.63	4.13^{a}	2.68^{b}	2.45^{bc}	2.10^{cbd}	0.864	0.001
ADL**	3.98	7.71	1.41^{a}	1.80^{b}	1.27^{ac}	0.96^{cd}	0.335	0.001
HC**	18.11	21.48	20.08^{a}	17.81^{a}	17.17^{a}	9.91^{b}	4.512	0.001
Cellulose**	6.20	8.92	2.72^{a}	1.89^{b}	1.18^{bc}	1.14^{cbd}	0.820	0.001
Macro mineral composition (gm/kg)								
Ca**	0.47	0.51	0.47^{a}	0.43^{ab}	0.46^{ac}	0.53^{d}	0.040	0.004
P	3.16	2.49	3.14	3.17	2.35	2.63	0.452	0.051
K**	2.04	2.13	2.05^{a}	1.29^{b}	1.41^{bc}	1.21^{bcd}	0.349	0.001
Micro mineral composition (mg/kg)								
Fe	0.24	0.20	0.28	1.13	0.30	0.32	0.018	0.444
Cu**	5.04	9.09	3.96^{a}	1.49^{b}	1.05^{c}	1.18^{c}	1.245	0.001
Zn**	39.41	37.59	11.17^{a}	9.37^{b}	7.27^{c}	4.87^{d}	2.494	0.001
Mn**	24.79	29.15	14.13^{a}	8.88^{b}	9.60^{c}	7.35^{d}	2.636	0.001

**$P \leq 0.01$, *$P \leq 0.05$, Means bearing different superscripts in a row differ significantly.

Cobs along with grains was sampled and analyzed as grains could not be separated from the cob and excluded for statistical analysis, only stages R3 to R6 were compared statistically.

R1-Silks stage, R2-Blister stage, R3- Milk stage, R4-Dough stage, R5- Dent stage and R6-Physiological maturity stage.

and 3.65, respectively. The CP and ADL levels MTS were comparable to whole plant maize silage reported in other studies (Bal *et al.*, 2000; Gouri, 2012; Sarubbi, 2014; Petrovska, 2015). The NDF and ADF were slightly higher but lower than values reported for maize stover silage and sorghum stover silage (Gouri, 2012; Ningaraju, 2014). The CP level MTH was higher and NDF and ADL were lower than the values reported for cereal stovers like maize stover, maize stover dry, sorghum stover, sorghum stover dry and finger millet straw (Krishnamoorthy *et al.,* 1996; Gouri 2012; Babu, 2014; Ningaraju 2014).

The ME (MJ/kg DM) of MTS and MTH were 7.77 and 6.65, respectively. The ME (MJ/kg DM) reported in this study were similar to the values reported for sorghum stover silage (7.45) and sorghum stover dry (6.96) in the study conducted by Ningaraju (2014). The macro mineral (g/kg) profile of MTS and MTH was Ca 3.49 and 3.11, P 2.26 and 2.69, K 3.13 and 5.53 and micro minerals (mg/kg) content were Zn 45.19 and 25.83, Mn 153.23 and 132.63, Cu 8.86 and 7.76, respectively. The Ca and P levels of both MTS and MTH were far higher than the values reported for maize silage (Petrovska *et al.*, 2015).

TABLE 3

Maize crop yield (green and DM) and grain yield at different stages of plant growth

	Maize tops			Grains	
Stage	Green yield**	% DM**	DM yield**	% of DM**	Grain yield**
R-1	5.50^{d}	22.69^{c}	1.27^{d}	10.82^{e}	2.76^{e}
R-2	6.40^{ec}	23.43^{c}	1.50^{c}	12.38^{e}	3.47^{d}
R-3	7.20^{ab}	26.01^{b}	1.87^{b}	25.06^{d}	4.23^{c}
R-4	7.67^{a}	27.74^{b}	2.13^{a}	37.71^{c}	5.13^{b}
R-5	6.70^{bc}	30.90^{a}	2.07^{a}	49.02^{b}	5.29^{b}
R-6	6.73^{bc}	32.14^{a}	2.20^{a}	66.90^{a}	6.13^{a}
SEM	0.18	0.894	0.09	4.866	0.281
P	0.001	0.001	0.001	0.001	0.001

**$P \leq 0.01$, *$P \leq 0.05$, Means bearing different superscripts in a column differ significantly

Yield, tones/ha

R1-Silks stage, R2-Blister stage, R3- Milk stage, R4-Dough stage, R5- Dent stage and R6-Physiological maturity stage.

TABLE 4
Physical and chemical properties of maize top silage and hay

Parameters	Maize top silage	Maize top hay
Smell	Fruity odor	-
Colour	Greenish yellow	Light green
Moisture	69%	6%
pH	4.7	-
NH_3^- N	9%	-

TABLE 5
Chemical, fiber fractions, mineral composition (% on DMB) and ME of MTS and MTH

Parameter	MTS	MTH
Proximate composition		
Organic matter	87.17	87.46
Crude protein	8.06	7.46
Crude fiber	27.69	28.08
Ether extract	2.77	1.00
Nitrogen free extract	48.65	50.92
Total ash	12.83	12.54
Acid insoluble ash	7.41	7.71
Fiber fractions		
Neutral detergent fiber	58.33	65.39
Acid detergent fiber	32.60	34.86
Hemicellulose	30.53	25.74
Cellulose	28.84	26.31
Acid detergent lignin	2.78	3.65
Energy value		
ME, MJ/kg	7.77	6.65
Minerals		
Calcium, g/kg	3.49	3.11
Phosphorus, g/kg	2.26	2.69
Potassium, g/kg	3.13	5.53
Zinc, mg/kg	45.19	25.83
Manganese, mg/kg	153.23	132.63
Copper, mg/kg	8.86	7.76

MTS= Mize top silage, MTH = Maize top hay.

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