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Research article

Yield and nutritive value of local races of grasses and legumes to rejuvenate pastures for sustaining livestock productivity in sub-Himalayan region of India

Sultan Singh[2]*, S. Ahmad[1], S. S. Bhat[1], Tejveer Singh[2] and N.H. Mir[1]

[1]Regional Research Station, ICAR-IGFRI, Srinagar-191132, India
[2]ICAR-Indian Grassland and Fodder Research Institute, Jhansi-284003, India
*Corresponding author e-mail: sultansingh64@gmail.com

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Abstract

Improved local races of 8 grasses and 5 legumes were evaluated for forage yield and nutritional characteristics for introduction in sub-Himalayan pastures. Forage yield was higher for *Phalaris aquatic-PA* in grasses and *Onobrychis viciifolia-OV* in legumes. Grasses had low ($P<0.05$) CP and more NDF, ADF and cellulose than legumes. Grasses had higher ($P<0.05$) tCHO except *Trifolium pretense*-TP, while legumes had higher non structural carbohydrates-NSC. Lignin bound carbohydrate fraction (C_C) was higher in legumes except *Phleum pretense*-PP and *Festuca rubra-FR*. Protein fraction P_A (NPN) was lower ($P<0.05$) in grasses. Grasses and legumes had lowest contents of rapidly degradable protein fraction (P_{B1}). Grasses and legumes differed ($P<0.05$) in gross energy and digestible energy and legumes had higher total digestible nutrients (TDN) except *Bromus unioloides-BU*. Truly digestible non fibrous carbohydrates (tdNFC) and tdCP of legumes were higher ($P<0.05$) than grasses. Legumes *TR, Medicago sativa-MS* and *Coronilla varia-CV* had higher ($P<0.05$) digestible DM (DDM) except *Festuca arundinacea-FA* (59.38) and *BU* (60.78%). Dry matter intake (DMI) and relative feed value (RFV) were higher ($P<0.05$) for legumes. Neutral detergent fiber and cellulose were negatively correlated ($P<0.01$) with TDN, energy and DDM, RFV, DMI, tdNFC and tdCP. P_{B1} and moderately degradable protein fraction (P_{B2}) were positively correlated ($P<0.01$) with RDP, while lignin bound protein fraction (P_C) was negatively associated with TDN, energy and DDM. The NSC was positively associated with TDN, energy, DDM, RFV, DMI and tdCP. Variability in nutritional characteristics of grasses and legumes signify their potential to rejuvenate pastures to improve livestock production.

Keywords: Himalaya, Livestock, Quality, Temperate grasses/legumes, Yield

Introduction

Grasses and legumes either sole or mixed with tree foliages constitute the major component of both intensive (stall fed) and extensive (pasture) feeding system for livestock in sub-Himalayan region of India (Ahmad *et al.,* 2017). These forage resources are of prime relevance for cost effective and sustainable animal production (Chaudhry, 2008; Mahanta *et al.,* 2020). Legumes provide more protein and grasses may be more readily digestible (King *et al.,* 2012). Under grazing, mixed swards of ryegrass and white clover were beneficial due to their persistence, palatability and digestibility (Tedstone, 1997). Intake and digestibility accounted for 70% and 30% of the differences in nutritive value index or digestible energy intake among forages (Crampton *et al.,* 1960). Quality and palatability of forage affect animal intake, growth rate and reproductive performance (Herrero *et al.,* 2015). The N forms in forages influence its availability to animal resulting in differences in animal productivity. In livestock feeding estimation of forages nutritive value is essential to know amount of nutrients present to sustain a particular level of livestock production (Schut *et al.,* 2010). Concentration of total digestible nutrient (TDN), crude protein (CP) and metabolism energy (ME) frequently used to assess forage quality. Carbohydrate and protein fractions of forages could be reliable indicator to precisely predict their nutritive value and performance in ruminants (Russel *et al.,* 1992).

Yield and quality of forages are economically relevant production aspects (Schaub *et al.,* 2020). Information on nutritive value of forages is important for appropriate selection of forages and supplement to meet ruminant's nutrient requirements for their cost effective production under intensive (stall fed) and extensive system (pastures) of feeding (Shinde and Mahanta, 2020). One of the basic needs in the planning and utilization of pastures and achieving optimum performance of livestock is determining the nutritional needs (energy, protein, minerals and vitamins) of livestock. This is only possible when the quality of pastures forage plants for each region in terms of chemical composition is known (Amiri and Shariff, 2012). The paucity of data quantifying the nutritive value of different forage plants grown across different locations means that nutrition is rarely considered as a part of ecological or conservation studies (Pontes *et al.,* 2007). The extent by which forage plants vary in their nutritive value and palatability has not been comprehensively assessed at the global scale. Likewise local races of grasses and legumes having higher biomass yield selected from Sub-Himalayan region have not been evaluated for their nutritional and palatability attributes. Therefore, the present study intended to evaluate improved races of grass and legume species for yield and nutritive value to improve pastures productivity and nutritional quality.

Materials and Methods

Experimental site: Local races of grasses and legumes (Table 1) were grown in a randomized block design with 3 replications in 5 x 4 m plots spaced at 30 cm between rows and 15 cm between plants within rows at Regional Research Station, ICAR-Indian Grassland and Fodder Research Institute, Srinagar, India (34°46' N latitude and 74°47' E longitude and 1640 m above mean sea level) during 2017-20. Uniform dose of N, P_2O_5 and K_2O (80, 50, 40 kg ha^{-1}) was applied in March every year and 30 kg ha^{-1} N was applied additionally after each cut. Nitrogen was applied in two split doses as 40 kg at basal and remaining 40 kg at just prior to flowering. Maximum temperature 35°C was recorded during July-August, while as sub-freezing temperatures and frost were common during December to February. The soil was a silt clay loam with 6.75 pH, 0.685% soil organic carbon, 282.76 kg ha^{-1} available N, 10.4 kg ha^{-1} available P and 384.65 kg ha^{-1} available K (Ahmad *et al.,* 2021).

Forage sampling and processing: For forage yield estimation two cuts of grasses/legume were taken per year at 50% heading stage randomly from 1m x 1m plot using hand sickle and intercrops were separated and weighed for green forage weight.

Table 1. Details of grasses and legumes

Forages	Common name	Cultivar/accession
Grasses		
Dactylis glomerata (DG)	Orchard grass	IC-0622333
Festuca arundinacea (FA)	Tall fescue	IC-0622332
Phalaris aquatica (PA)	Harding grass	IC-634850
Phleum pratense (PP)	Timothy	IC-0622346
Lolium multiflorum (LM)	Ryegrass	IC-635997
Bromus unioloides (BU)	Prairie grass	IC-0622334
Chrysopogon gryllus (CG)	Smooth brome grass	Non-specific
Festuca rubra (FR)	Red fescue grass	IC-636004
Legumes		
Trifolium pratense (TP)	Red clover	IC-0622335
Trifolium repens (TR)	White clover	IC-0622338
Onobrychis viciifolia (OV)	Sainfoin	IC-636011
Medicago sativa (MS)	Alfalfa (Lucerne)	IC-622399
Coronilla varia (CV)	Crown vetch	IC-636009

About 500 g representative sample of each grass and legume was used for dry matter and nutritional analysis. Samples were dried at 55-60 ^{0}C for 96 h to achieve constant weight and dried samples were then grind using 1 mm sieve in a Wiley mill.

Chemical analysis: Dry matter (DM), crude protein (CP), ether extracts (EE) and ash were estimated following AOAC (2000). Neutral detergent fiber (NDF), acid detergent fiber (ADF), cellulose and lignin were determined using Van Soest *et al.* (1991). Lignin was determined by treating cellulose with 72% H_2SO_4 in the ADF residue (Van Soest *et al.,* 1991). Cellulose and lignin were estimated as the difference between ADF and lignin in sequential analysis and hemicellulose was calculated as NDF minus ADF.

Carbohydrate and protein fractions: Total carbohydrates (tCHO) were calculated as 100 - (CP + EE + ash). Structural carbohydrates (SC) were calculated as NDF minus neutral detergent insoluble protein (NDIP), while non-structural carbohydrates (NSC) were estimated as the difference between tCHO and SC (Caballero *et al.,* 2001). Slowly degradable (C_{B2}); and unavailable/lignin-bound cell wall (C_C) carbohydrate fractions were calculated according to Cornell net carbohydrate and protein system (CNCPS) (Sniffen *et al.,* 1992). CP was partitioned into 5 fractions as per CNCPS modified by Licitra *et al.* (1996). The NDIP, ADIP and NPN were estimated using the standard method. For soluble protein (SP) estimation, method of Krishnamoorthy *et al.* (1982) was followed.

Intake, digestibility, energy, feed value: Dry matter intake (DMI), digestible dry matter (DDM), relative feed value (RFV), total digestible nutrients (TDN) and net energy (NE) for lactation (NE_L), growth (NE_G) and maintenance (NE_M) were calculated using different equations (Undersander *et al.,* 1993). Digestible energy (DE) and net energy (NE) values were calculated using equations of earlier workers (Fonnesbeck *et al.,* 1984; Khalil *et al.,* 1986). For gross energy (GE) (Son and Kim, 2018), truly digestible non fibrous carbohydrates (tdNFC) and truly digestible crude protein (tdCP) (NRC 2000), truly digestible neutral detergent fiber (tdNDF) and truly digestible fat (tdFA) and rumen degradable protein (RDP) calculation different equations were used.

Statistical analysis: The data was analyzed using SPSS version 20 and means were compared with one way ANOVA keeping grasses and legumes (1-13) as fixed factor and variables as dependent. Post hoc multiple comparisons were performed using Duncan test at P<0.05 level of significance.

Results and Discussion

Forage yield: Grass *PA* and legume *OV* had maximum green (48.38 and 41.50 t/ha) and dry fodder yield (12.58 and 10.79 t/ha; Table 2). Higher green and dry fodder yield in *PA* might be ascribed to its long-term persistence, deep root system and drought tolerance (Ahmad *et al.,* 2021). Legumes had higher crude protein yield (1435.6) than grasses (988.1 kg/ha) which might be due to their more CP than grasses. Further highest crude protein yield for *OV* and *BU* (1145.7 kg/ha), might be attributed to their both more dry matter yield and CP content.

Chemical composition: Legumes had CP (17.84-21.76%; Table 3) higher than minimum of 150 g/kg CP recommended for optimum growth and milk production (NRC, 2001), while CP content (8.44-15.14% DM) of grasses was more than 7.0%, required for maintenance and rumen microbial growth (Minson, 1990). Grasses had higher (P<0.05) NDF, ADF and cellulose, while lignin was higher (P<0.05) in legumes except *TR* and *MS* than grasses. The CP of *LM*, *DG, FA, PA, BU* grasses (Fulkerson *et al.,* 2007) was higher, while NDF and ADF were lower than evaluated grasses values. Grass EE values except *PP* (4.17%) were within the range of 2.4-3.4%, reported earlier for grasses in different seasons (Fulkerson *et al.,* 2007). CP for *MS, TP* and *TR* across growth seasons were relatively higher than our legumes CP, while our NDF and ADF were within range except *OV* (51.60 and 42.17%). Protein, EE, NDF, ADF, cellulose and lignin contents in grasses and legumes had been reported earlier (Kirchhof *et al.,* 2010; Homolka *et al.,* 2012; Sahoo *et al.,* 2014; Zhang *et al.,* 2021). The CP, NDF and ADF for *MS, CG, FA, DG* and *LM* reported (Sayar *et al.,* 2014) partially confirmed our values. Our CP, ash, NDF, ADF and lignin of *MS* and *PP* were within the range values of two varieties each of *MS* (Pioneer and Beaver) and *PP* (Climax and Joliette) reported (Yu *et al.,* 2003). Our NDIN, ADIN, SP and NPN %DM of *MS* and *PP* were also within the range of values reported for *MS* and *PP* by Yu *et al.* (2003).

Carbohydrate and protein fractions: Grasses had higher (P<0.05) total carbohydrates (tCHO) than legumes except *TP* (65.44% DM), while legumes had higher (P<0.05) non-structural carbohydrates (NSC; Table 4). The tCHO and NSC of *MS* (Yu *et al.,* 2003)

Table 2. Fodder and crude protein yield of grasses and legumes

Parameters	Grasses								Legumes					SEM	CD ($P<0.05$)
	FA	*DG*	*PA*	*PP*	*LM*	*BU*	*CG*	*FR*	*TP*	*TR*	*OV*	*MS*	*CV*		
GFY (t/ha)	37.4	33.4	48.3	29.7	37.4	31.0	21.3	26.8	30.5	21.4	41.5	29.4	17.4	0.09	0.3
DMY (t/ha)	9.72	8.67	12.6	7.73	9.78	8.06	5.53	6.97	7.94	5.55	10.8	7.65	4.52	0.03	0.09
CP yield (kg/ha)*	885	987	1065	1039	1501	1147	417	865	1632	1079	1931	1670	865	4.21	11.95

*1000 kg = 1 ton (t)

Table 3. Chemical composition (% DM basis) of grasses and legumes

Parameters	Grasses								Legumes					SEM
	DG	*FA*	*PA*	*PP*	*LM*	*BU*	*CG*	*FR*	*TP*	*TR*	*OV*	*MS*	*CV*	
OM	90.5	89.9	90.1	89.9	89.7	89.5	90.9	91.6	87.2	85.9	90.0	89.9	91.4	0.269
EE	3.21	2.81	2.82	4.17	2.06	2.66	2.49	2.48	1.27	2.48	1.86	2.17	1.74	0.12
CP	11.3	9.08	8.4	13.4	15.1	14.2	7.51	12.4	20.5	19.4	17.8	21.7	19.1	0.75
NDF	72.5	66.6	74.1	64.8	65.8	66.4	75.5	72.0	46.7	41.0	51.6	50.2	53.3	1.81
ADF	45.6	37.9	40.0	41.3	40.2	36.1	39.9	39.1	37.3	36.4	42.2	33.5	37.1	0.50
Cellulose	35.9	30.4	33.5	32.6	30.8	28.5	32.9	28.5	25.1	27.1	25.7	25.7	21.6	0.63
Lignin	8.15	5.89	5.26	8.51	6.65	5.73	4.87	10.5	12.0	8.49	16.7	7.75	16.2	0.61
NDIN	0.95	0.82	0.88	1.07	0.73	1.08	0.65	0.95	1.64	1.01	1.62	0.80	1.45	0.05
ADIN	0.47	0.32	0.196	0.462	0.196	0.330	0.268	0.471	1.16	0.662	1.09	0.277	0.672	0.05
SN	0.483	0.149	0.104	0.480	1.281	0.622	0.250	0.430	0.735	1.14	0.813	1.85	0.997	0.08

Values bearing different superscripts in different columns within a row differed significantly ($P<0.05$)

Table 4. Carbohydrates and protein fractions (CNCP) of grasses and legumes

Parameters	Grasses							Legumes					SEM
	DG	*FA*	*PA*	*PP*	*LM*	*BU*	*CG*	*FR*	*TP*	*TR*	*OV*	*MS*	*CV*	
tCHO %DM	75.9^{e}	78.0^{fg}	78.5^{c}	72.3^{a}	72.5^{c}	72.7^{c}	80.9^{f}	76.8^{de}	65.4^{b}	64.0^{a}	70.4^{c}	66.0^{b}	70.6^{c}	0.83
NSC %DM	9.30^{a}	16.5^{c}	9.83^{a}	14.2^{cd}	11.3^{ab}	13.0^{bc}	9.45^{a}	10.8^{ab}	28.9^{c}	29.3^{c}	28.9^{c}	20.8^{e}	26.4^{f}	1.28
SC %DM	66.6^{f}	61.5^{c}	68.7^{g}	58.1^{e}	61.2^{fg}	59.7^{de}	71.4^{g}	66.0^{f}	36.5^{b}	34.7^{a}	41.5^{c}	45.2^{c}	44.3^{c}	2.00
C_{B2} %tCHO	62.0	60.7	71.4	52.11	62.4	63.2	73.9	53.1	11.8	22.4	5.30	40.3	7.74	
C_{C} %tCHO	25.7^{e}	18.1^{c}	16.1^{b}	28.2^{f}	22.0^{c}	18.9^{c}	14.5^{a}	32.9^{c}	43.9^{f}	31.8^{c}	57.1^{g}	28.2^{f}	54.9^{g}	2.18
P_{A} %CP	18.5^{bc}	3.4^{a}	4.47^{a}	18.0^{bc}	33.9^{e}	23.0^{cd}	15.6^{b}	17.7^{bc}	17.4^{bc}	22.3^{cd}	22.2^{cd}	47.4^{f}	25.2^{c}	1.81
P_{B1} %CP	8.08^{b}	6.89^{ab}	3.22^{a}	4.33^{ab}	19.0^{c}	4.39^{ab}	5.33^{ab}	3.86^{ab}	4.97^{ab}	14.5^{c}	6.30^{ab}	5.8^{ab}	7.42^{ab}	0.77
P_{B2} %CP	21.1^{bc}	33.3^{f}	27.4^{cd}	27.9^{cd}	16.9^{ab}	24.8^{cde}	24.9^{cde}	30.2^{de}	27.6^{cd}	30.6^{de}	14.8^{a}	23.7^{cd}	19.7^{ab}	0.95
P_{B3} %CP	26.1^{ce}	34.4^{c}	50.4^{f}	28.2^{de}	22.0^{cd}	33.2^{c}	31.9^{fc}	24.3^{ce}	14.5^{ab}	11.2^{a}	18.4^{bc}	15.1^{ab}	25.6^{ce}	1.66
Pc %CP	26.2^{e}	22.1^{c}	14.5^{b}	21.6^{c}	8.10^{a}	14.6^{b}	22.3^{cd}	23.8^{c}	35.5^{f}	21.3^{c}	38.3^{c}	8.00^{a}	22.0^{c}	1.40

Values bearing different superscripts in different columns within a row differed significantly ($P<0.05$)

Table 5. Energy (Mcal/kg DM) and TDN (%) contents of grasses and legumes

Parameters	Grasses							Legumes					SEM
	DG	*FA*	*PA*	*PP*	*LM*	*BU*	*CG*	*FR*	*TP*	*TR*	*OV*	*MS*	*CV*	
GE	4.55^{c}	4.51^{b}	4.51^{b}	4.61^{f}	4.51^{b}	4.54^{cd}	4.48^{a}	4.52^{bc}	4.51^{b}	4.57^{e}	4.52^{bc}	4.57^{e}	4.52^{bc}	0.005
DE	2.01^{a}	2.45^{de}	2.33^{cd}	2.26^{bc}	2.32^{cd}	2.56^{f}	2.33^{cd}	2.39^{ce}	2.49^{ef}	2.54^{ef}	2.21^{b}	2.70^{g}	2.50^{ef}	0.028
ME	1.65^{a}	2.01^{de}	1.91^{cd}	1.85^{bc}	1.91^{cd}	2.10^{f}	1.92^{cd}	1.96^{ce}	2.04^{ef}	2.08^{ef}	1.81^{b}	2.22^{g}	2.05^{ef}	0.023
NE_{l}	1.00^{a}	1.24^{de}	1.17^{cd}	1.13^{bc}	1.17^{cd}	1.30^{f}	1.18^{cd}	1.21^{ce}	1.26^{ef}	1.29^{ef}	1.11^{b}	1.38^{g}	1.27^{ef}	0.016
NE_{M}	1.03^{a}	1.32^{de}	1.24^{cd}	1.19^{bc}	1.24^{cd}	1.39^{f}	1.25^{cd}	1.28^{ce}	1.35^{ef}	1.38^{ef}	1.16^{b}	1.49^{g}	1.35^{ef}	0.019
NE_{G}	0.31^{a}	0.60^{de}	0.52^{cd}	0.47^{bc}	0.52^{cd}	0.67^{f}	0.53^{cd}	0.56^{ce}	0.63^{ef}	0.66^{ef}	0.44^{b}	0.77^{g}	0.63^{ef}	0.019
TDN	45.69^{a}	55.6^{de}	52.8^{cd}	51.2^{bc}	52.6^{cd}	57.9^{f}	52.9^{cd}	54.1^{ce}	56.4^{ef}	57.5^{ef}	50.1^{b}	61.3^{g}	56.7^{ef}	0.647

Values bearing different superscripts in different columns within a row differed significantly ($P<0.05$)

Table 6. Digestible nutrients, intake and feed values of temperate grasses and legumes

Parameters	Grasses								Legumes					SEM
	DG	*FA*	*PA*	*PP*	*LM*	*BU*	*CG*	*FR*	*TP*	*TR*	*OV*	*MS*	*CV*	
tdNFC%DM	9.11^{a}	16.2^{c}	9.63^{a}	13.9^{cd}	11.1^{ab}	12.7^{bc}	9.26^{a}	10.5^{ab}	28.4^{e}	28.7^{e}	28.3^{e}	20.4^{d}	25.8^{f}	1.26
tdCP%DM	8.28^{c}	6.97^{b}	7.09^{b}	10.3^{d}	13.7^{e}	11.9^{f}	5.75^{a}	9.30^{c}	13.4^{e}	15.0^{h}	11.3^{f}	19.8^{i}	14.6^{h}	0.62
tdFA%DM	2.21^{f}	1.81^{d}	1.82^{d}	3.17^{g}	1.06^{bc}	1.66^{d}	1.49^{de}	0.27^{a}	1.48^{de}	0.86^{bc}	1.17^{cd}	0.74^{b}	1.48^{de}	0.12
tdNDF	33.1^{i}	33.0^{hi}	39.0^{j}	26.9^{d}	31.6^{e}	32.0^{eh}	41.6	9.64^{b}	12.0^{c}	8.46^{a}	19.4^{e}	10.3^{b}	29.4^{f}	1.82
RDP%CP	31.7^{bcd}	43.6^{ef}	35.7^{bcd}	35.1^{bcd}	38.1^{cd}	32.5^{bcd}	33.4^{bcd}	36.5^{cd}	34.0^{bcd}	46.2^{f}	23.0^{a}	31.1^{bc}	29.6^{b}	1.02
DDM%	53.4^{a}	59.4^{ef}	57.7^{cd}	56.7^{bc}	57.6^{cd}	60.8^{f}	57.8^{cd}	58.5^{de}	59.8^{ef}	60.5^{ef}	56.0^{b}	62.8^{g}	60.0^{ef}	0.39
DMI%	1.65^{ab}	1.80^{c}	1.62^{ab}	1.85^{c}	1.82^{c}	1.81^{c}	1.59^{a}	1.67^{b}	2.57^{f}	2.92^{g}	2.33^{d}	2.39e	2.25^{d}	0.07
RFV%	68.4^{a}	82.9^{cd}	72.4^{bc}	81.4^{c}	81.4^{c}	85.1^{d}	71.2^{ab}	75.5^{b}	119^{h}	137^{i}	101^{f}	116^{h}	104^{g}	3.38

Values bearing different superscripts in different columns within a row differed significantly (P<0.05)

were more or less similar to our values of *MS* (66.04 and 20.81%), while for *PP,* these values were higher. Unavailable carbohydrate fraction (C_C) was higher in legumes than grasses except *PP* and *FR* (28.23 and 32.90% tCHO). The C_C fraction for *MS (*31.7-41.2% tCHO) observed by Yu *et al.* (2003) was higher than present (28.17%), while for *PP* grass (13.8-18. %) were lower than our values (28.23% tCHO) which might be attributed to differences in their lignin contents.

Protein fraction P_A (NPN) for *TR* and *TP* (Kirchhof *et al.,* 2010) was similar, while for *MS* much lower (17.6-18.3%) than our values (47.39%). Rapidly degradable protein fraction (P_{B1}) and moderately degradable protein fraction (P_{B2}) of these workers for *TR, TP* and *MS* were higher than our values which might be due to higher NDF and ADF. Higher slowly degradable protein fraction (P_{B3}) and unavailable protein fraction (P_C) in present study might be attributed to higher NDF, ADF and lignin. Legumes in general had higher (P<0.05) P_A than grass (Solati *et al.,* 2017), which substantiated our higher P_A in legumes than grasses except *LM* and *BU*. Yu *et al.* (2003) also reported more P_A in alfalfa (41.5%) than timothy grass (16.5% CP). Higher P_{B3} in grasses than legumes was consistent to reported values (Solati *et al.,* 2017). Our higher P_C in legumes (22.03-38.27% CP) except *MS* than grasses (8.10-26.22%) was consistent to earlier workers (Solati *et al.,* 2017; Sanderson and Wedin, 1989). Protein fractions P_A, P_{B1} and P_C recorded for *MS* were similar to Yu *et al. (*2003), while P_{B2} and P_{B3} were inconsistent. Our values of P_A for *PP* were similar to Yu *et al. (*2003), while P_C was higher (21.56%) than these workers (3.5-6.6% CP).

Energy value and its efficiency for different animal functions: Primary factors in conversion of forage to animal product are intake of energy, digestibility of energy, and efficiency of converting digested energy to animal products. Lower ME for *DG* (1.65) and higher for *BU* grass (2.01 M cal/kg DM; Table 5) were similar to earlier findings (Fulkerson *et al.,* 2007). Legumes *MS, TP, TR* and *LC* ME ranged between 9.0-10.0 Mj/kg DM across seasons (Fulkerson *et al.,* 2007). The GE, DE, ME, NE_L and NE_G of *TP* and *MS* evaluated at 12 stages of growth (Homolka *et al.,* 2012) corroborated with our energy values of *TP* and *MS* except NE_L which were higher than our values. Legumes TDN (50.07-61.33) were higher than grasses (45.59-55.62) except *BU*

Table 7. Pearson correlation of chemical constituents with energy, intake and digestible nutrients in grasses and legumes

Parameters	RDP	TDN	DE	ME	DDM	RFV	DMI	tdNFC	tdCP	tdNDF
CP	-0.197	.488**	.491**	.487**	.488**	.863**	.860**	.795**	.926**	-.886**
NDF	0.007	-.491**	-.494**	-.492**	-.491**	-.977**	-.988**	-.944**	-.772**	.922**
ADF	-0.175	-1.000**	-1.000**	-1.000**	-1.000**	-.605**	-.476**	-.379*	-.605**	0.297
Cellulose	0.215	-.641**	-.643**	-.639**	-.641**	-.744**	-.710**	-.804**	-.688**	.830**
lignin	-.487**	-0.068	-0.065	-0.071	-0.068	.417**	.487**	.695**	.332*	-.823**
P_A%CP	-.338*	.375*	.374*	.373*	.375*	.419**	.385*	0.229	.838**	-.364*
P_{B1}%CP	.426**	-0.036	-0.039	-0.038	-0.036	0.232	0.26	0.124	0.311	-0.12
P_{B2}%CP	.735**	0.256	0.255	0.257	0.256	0.045	-0.007	-0.112	-0.238	0.211
P_{B3}%CP	-0.013	-0.22	-0.221	-0.219	-0.22	-.723**	-.754**	-.641**	-.687**	.728**
P_C%CP	-0.281	-.379*	-.373*	-.377*	-.379*	0.155	0.255	.468**	-0.28	-.468**
NSC%DM	-0.115	.380*	.384*	.381*	.380*	.896**	.925**	1.000**	.582**	-.948**
SC%DM	0.082	-.443**	-.447**	-.444**	-.443**	-.953**	-.972**	-.966**	-.735**	.956**
NDIN%N	-0.223	-.480**	-.477**	-.477**	-.480**	-.526**	-.478**	-0.217	-.820**	0.295
ADIN%N	-0.281	-.379*	-.373*	-.377*	-.379*	0.155	0.255	.468**	-0.28	-.468**
SN%N	-0.139	.481**	.480**	.479**	.481**	.657**	.628**	.464**	.949**	-.555**

*(P<0.05); **(P<0.01)

(57.96%). The TDN, NE_L NE_G and NE_M for *TP* reported by Markovic *et al.* (2011) at different stages of growth and cut were higher than our values of *TP* and *TR*. TDN of birdfoot trefoil and medow broom grasses (82.2 and 68.6%) and *MS* and *OV* legumes (70.0 and 76.0%; Zhang *et al.,* 2021) were higher than our values. Ashoori *et al.* (2021) reported higher TDN (62.9%) than recorded values of *TP* and *TR*. The TDN for *MS, CG, FA, DG* and *LM* reported earlier (Sayar *et al.,* 2014) were identical to our TDN values. The TDN, DE, ME, NE_G and NE_L values of *MS* and *PP* cultivars at three growth stages (Yu *et al.,* 2003) were similar to our energy values of *MS* and lower for *PP*.

Digestible nutrients, intake and feed value: The truly digestible non fibrous carbohydrates (tdNFC) of legumes (20.39-28.74%) were higher (P<0.05) than grasses (9.11-16.18%; Table 6), which might be due to higher NSC and DDM in legumes. The truly digestible CP (tdCP) of grasses and legumes varied (P<0.05) between 5.75- 13.74 and 11.27- 19.78%, respectively. Grasses lower DMI might be attributed to their higher NDF contents (64.79-75.15%) as NDF above 65% affects animal intake and production (Van Soest, 1994). Bruineberg *et al.* (2002) reported DMD of *LM, DG, P pretense* and *TR* between 0.66-0.84, 0.54-0.78, 0.67-0.82 and 0.75-0.80 during three cuttings. The IVOMD of *DG, LM* and *CG* grasses reported (Sahoo *et al.,* 2014) were higher than our values. The IVDMD of *MS* (60.53-61.93) and *OV* (55.20-62.71%) in different growth periods (Naydenova and Vasileva, 2015) was at par with our DMD values of *MS* and *OV*. The DDM and DOM of *MS*, birdfoot trefoil, *OV* and medow broom grass (83.3 & 91.7, 83.1 & 91.6, 84.8 &90.8 and 73.8 & 79.6%; Marković *et al.,* 2011) were higher than our values. The DMD of *TP* (0.598-0.729) and *MS* (0.573-0.690) in sheep at vegetative to late flower stage (Marković *et al.,* 2011) confirmed our DMD values. The DDM (65.7%) for clover (Ashoori *et al.,* 2021) was higher than *TP* and *TR* present values, while DMI and RFV (2.39% and 122.2%) were close to our values. DMI, DDM and RFV for *TP* recorded (Sanderson and Wedin, 1989) were higher than values recorded for *TP* and *TR*. This might be due to higher NDF and ADF recorded for these clovers. The DMI, DDM and RFV for *MS, CG, FA, DG* and *LM* for three years (Sayar *et al.,* 2014) were higher than evaluated grasses and legumes values. Similarly, DMD, DMI and RFV for *TR, Vicia sativa, MS, Trifolium incarnatium, Medicago lupilina* and *Lathyrus sativa* legumes (60.54-65.56, 2.92-3.11 and 138.81-

155.07%) were marginally higher (Kiraz, 2011) than our values.

Correlation studies: Temperate forages (grasses/legumes) CP was positively correlated ($P<0.01$) with TDN, DE, ME, DDM, RFV, DMI, tdNFC and tdCP and negatively correlated with tdNDF (Table 7). The NDF, ADF and cellulose were negatively correlated ($P<0.01$) with TDN, energy, DDM, DMI, RFV, tdNFC and tdCP. Uslu *et al.* (2018) reported negative correlation of NDF and ADF with ME and OMD, while CP was positively associated with ME and OMD of 13 legume species hays, which was consistent to our negative correlation of NDF and ADF with ME and DMD and positive correlation of CP with DMD of grasses and legumes. Abd El-Naby *et al.* (2016) recorded that ADL had high significant negative correlation with TDN (-0.721) and RFV% (-0.654). Increasing ADF decreased TDN% and RFV. NDF had a high significant and negative correlation with TDN% and RFV (-0.721** and -0.992**) substantiated our negative correlation of NDF with TDN and RFV. Sahin (2020) also recorded highly significant negative correlations between NDF and TDN, NDF and RFV, and NDF and RFQ (r=0.71, r=0.95, r=0.92, $P < 0.001$, respectively). Negative correlation of CP, NDF, ADF and lignin with TDN, RFQ and DMI of rye and tall fescue grasses monocultures (Qin, 2014) was consistent to our observations. Studies on correlation of protein fractions with TDN, DMI, RFV, energy and truly digestible nutrients were negligible. Homolika *et al.* (2012) reported positive correlation ($P<0.05$) of CP with CP digestibility in *MS* and non significant in *TP*. These workers further reported that NDF, ADF and lignin had negative correlation with DM and CP digestibility of *MS* and *TP, which* substantiated our correlation observations.

The NSC was positively correlated with TDN, DE, ME, DDM, DMI, RFV and tdCP. The NDIN and ADIN%CP were negatively associated with TDN, DE, ME, DDM, DMI, RFV, tdNFC and tdCP, while soluble-N was positively associated with these parameters. NSC contents of *MS* and *TP* were positively related with DM digestibility in sheep (Marković *et al.,* 2011), which substantiated present findings. Protein fractions P_{B1} and P_{B2} were positively correlated ($P<0.01$) with RDP, while P_{B3} was negatively associated with RFV, DMI, tdNFC and tdCP and positively with tdNDF. Lignin bound protein fraction P_C was negatively correlated ($P<0.05$) with TDN, DE, ME and tdNDF ($P<0.01$).

Conclusion

Significant variability exists in grasses and legumes for forage yield and nutritional characteristics. Legumes had higher protein, non-structural carbohydrates, total digestible nutrients, palatability attributes (dry matter intake, DM digestibility) and relative feed value than grasses. Evaluated grasses and legumes had adequate protein and energy to meet ruminant requirement for maintenance and moderate level of production. Animal studies would provide more realistic results on predicted intake and nutrients digestibility. Yield and nutritional characteristics could be used appropriately to identify grass/legume mixtures for pastures rejuvenation for enhancing livestock productivity.

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