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Cell-Constituents, Tannin Levels by Chemical and Biological Assays and Nutritional Value of Some Legume Foliage and Straws

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Abstract: Twenty six straw and 15 foliage samples of *Lathyrus sativus*, *Vicia narbonensis*, *V sativa* and *V ervilia* were analysed for ash, crude protein (CP), neutral detergent fibre (NDF), acid detergent fibre (ADF), extractable phenols (Pe), extractable tannins (Te), extractable condensed tannins (CTe), protein precipitation capacity (PPC) and *in vitro* characteristics predicted from Hohenheim gas test. The content of crude protein in the foliage was significantly higher than that of the straws (152·6 vs 64·5 g kg^{-1}), while ash (82·8 vs 116·8 g kg^{-1}), NDF (332·7 vs 523·5 g kg^{-1}) and ADF (205·2 vs 369·9 g kg^{-1}) were significantly lower. For straws of *L sativus*, *V narbonensis* and *V sativa*, there was no significant difference in the protein and ADF contents, whereas ash and NDF contents were significantly lower and higher respectively in *L sativus* as compared to *V narbonensis* or *V sativa*. Predicted from gas volumes, the organic matter digestibility (OMD: 70 vs 56%) and metabolisable energy (ME: 9·7 vs 7·3 MJ kg^{-1}) were significantly higher for the foliage compared to straws. The OMD of *L sativus* straws was significantly lower compared to the straws of *V narbonensis* and *V sativa*. The OMD and ME of the straws of second year was significantly lower than those of the first year. The CP, OMD and ME of *V sativa* foliage were higher than that of *V narbonensis*. There was no difference in the cell constituents, OMD and ME of foliage samples of *V sativa* harvested in May 1992 and June 1992. The contents of Pe, Te and CTe of straws were 1·08%, 0·43% and 0·33%, respectively, and those of foliage were 2·27%, 1·30% and 1·63%, respectively. PPC was not detected for any of the foliage and straw samples. The results suggested that the tannin levels of legume straws investigated are negligible and those of the legume foliage are very low. This does not appear to adversely affect their nutritive value since the maximum decrease in OMD by the tannins was about 3% units.

Key words: cell constituents, tannins, condensed tannins, protein precipitation capacity, organic matter digestibility, metabolisable energy.

INTRODUCTION

Tannins are polyphenolic compounds which form complexes with proteins, carbohydrates, alkaloids, vitamins and minerals. They adversely affect palatability, rate of digestion and nutritional value of the diet and may have a direct toxic effect on animals (see the reviews of McLeod 1974; Singleton 1981; Kumar and Singh 1984; Mangan 1988; Makkar 1993). The presence of moderate levels of tannins in forage legumes may have beneficial effects on animal production by reducing the risk of bloat (McLeod 1974; Mangan 1988). They can also increase protein outflow from the rumen and amino acid absorption in the small intestine (Barry *et al* 1986). Tannins have been found in legume seeds as well as their foliage. Aletor *et al* (1994) found that extractable

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condensed tannin content (as catechin equivalents) by vanillin–HCl method in the seeds of four species of *Vicia* and in two species of *Lathyrus* varied between undetectable and 6·1 mg g^{-1} dry matter (DM). In *L ochrus* the level was higher, between 14·1 and 28·5 mg g^{-1} DM. It appears that tannins are distributed throughout the foliage and in the seed coat, but there is usually little in the endosperm (Mangan 1988). In comparison with seeds, there is little information on tannins in the straws of forage legumes. It would be valuable to record the level of tannin in forage legume foliage and straw, so that it can be related to any beneficial or detrimental effects.

In the present study, tannin levels were determined by various methods based on chemical (oxidation–reduction, anthocyanidin formation) and functional (protein precipitation) properties. Physiological activities of tannins are attributed to their capacity to bind and precipitate proteins. Therefore, protein precipitation methods are considered to correlate better with the biological value of tannin-rich feeds and food (Makkar 1989; Scalbert 1989). The biological value of tannins was also measured using an approach (Makkar *et al* 1995) in which the tannin-containing feeds are incubated in an *in vitro* gas procedure (Menke *et al* 1979; Menke and Steingass 1988) in the presence and absence of a tannin-complexing agent, polyethylene glycol 6000 (PEG 6000). The PEG 6000 binds to tannins making them inert, which leads to higher gas production. The percent increase in gas production is positively correlated with the potential adverse effects of tannins on digestion in the rumen. The nutritive value (OMD and ME) calculated by the *in vitro* gas method (Menke and Steingass 1988) is also presented.

MATERIALS AND METHODS

Samples

Twenty six straws and 15 foliage samples were used for the studies and are described in Table 1. The foliage samples were whole plants containing leaves, stems and seeds in pods at the dough stage. The plants were grown at the Tel Hadya farm of the International Center for Agricultural Research in the Dry Areas (ICARDA), having 330 mm annual rainfall and a mediterranean type climate. The samples were freeze-dried. For determination of ash, nitrogen and cell-wall constituents and *in vitro* nutritional studies, the samples were ground to pass through a 1 mm screen. For tannin determination, samples were finely ground through an 80-mesh (0·18 mm) screen. Foliage samples were taken from the same stand on either 11 April or 13 May 1992; straw samples were taken from different crops in July 1992 or July 1993. All data are on a dry matter basis.

Nutritional evaluation using *in vitro* gas method

Samples (200 mg) were weighed into 100 ml calibrated syringes and inoculated with diluted rumen fluid according to the method of Menke and Steingass (1988). Parallel incubations for measurement of gas production without substrate (blank) or with 200 mg of hay reference standard (obtained from Institute for Animal Nutrition, Hohenheim, Germany) were also carried out. Incubations were stopped at 24 h. Using chemical composition and net gas production at 24 h (corrected for the blank and the hay standard; Menke), organic matter digestibility (OMD, %) and metabolisable energy (ME, MJ kg^{-1} DM) were calculated using the equations proposed by Menke and Steingass (1988).

Tannin determination

Extractable phenols (Pe) and extractable tannins (Te) were determined using the Folin–Ciocalteau reagent by the method of Makkar *et al* (1993). Extractable condensed tannins (CTe) were determined by the method of Porter *et al* (1986). The protein precipitation capacity (PPC) was determined by two methods: the dye-binding method of Asquith and Butler (1985) and the bovine serum albumin (BSA) precipitation assay of Makkar *et*

TABLE 1
Samples studied of selection of *Lathyrus* and *Vicia* spp

Species	*Foliage*		*Straw after harvest*	
	May 1992	*June 1992*	*July 1992*	*July 1993*
Lathyrus sativus	—	—	510, 530, 587	510, 530
Vicia ervilia	—	—	—	2511
Vicia narbonensis	2561	—	—	2380, 2390, 2391, 2392, 2462, 2464, 2475, 2561, 2601
Vicia sativa	1448, 1448, 2037, 2065, 2556, 2557, 2558, 2559	2037, 2065, 2556, 2557, 2558, 2559	1448, 2037, 2065, 2556, 2557, 2558, 2559	1448, 2557, 2558, 2559
Number of samples	9	6	10	16

al (1988). The details of these methods are available in Makkar (1995).

Biological value of tannins using the *in vitro* gas method

The method was according to Makkar *et al* (1995) which is based on the *in vitro* gas method of Menke and Steingass (1988). In brief, samples (500 mg) ground to pass a 1 mm screen were incubated in 100 ml glass syringes with and without a tannin-complexing agent, polyethylene glycol 6000 (1 g) and in the presence of 40 ml of an *in vitro* medium containing rumen microbes (Makkar *et al* 1995). Gas produced is recorded at 24 h, corrected for blank (gas produced in the blank containing the tannin-complexing agent is similar to that in the blank without this agent), and the percent increase in the gas production was calculated. The higher the percent increase in gas production, the higher are the potential adverse effects of tannins on rumen digestion.

Other analyses

The samples were analysed for ash, nitrogen and cell-wall constituents according to AOAC (1975) and Goering and Van Soest (1970). Each analysis was done in duplicate.

Statistical analysis

The significance of the difference between means of three or more groups was compared using the Duncan Multiple range test after ANOVA for one way classified data with the aid of SAS/STAT software (SAS 1988). For comparison of means of two groups, Student's *t*-test was used. The values reported in tables are the average of two values. The deviation of each value from the mean was not more than 5% in 80% of cases, and never more than 8%.

RESULTS AND DISCUSSION

Chemical composition

The chemical composition is presented in Table 2. The overall mean of crude protein (CP) content of the foliage samples was significantly higher than that of the straws. On the other hand, ash, ADF and NDF contents were lower in the foliage. Similar pattern was observed for the *Vicia sativa* foliage and its straw samples (Table 2). For straws of different species (*Lathyrus sativus*, *Vicia narbonensis* and *V sativa*), there was no significant difference in the CP and ADF contents, whereas ash and NDF contents were significantly lower and higher respectively in *Lathyrus sativus* as compared to both species of *Vicia*. These species of *Vicia* did not differ significantly in ash or NDF contents. Different chemical compositions of two foliage samples collected at the same time of the year (for example, *V sativa*, selection 1448) could be due to different proportions of leaves, stems and seeds in the two samples. The overall mean of *V sativa* foliage was higher than that of *V narbonensis*. However, the CP content of a selection (2037, May 1992) of *V sativa* had a lower CP content and the other two selections (2065, May and June 1992) had CP almost similar to *V narbonensis*. These information on individual selection numbers are generally of immense interest to plant breeders. The foliage of *V narbonensis* was more fibrous compared to *V sativa* foliage, as both NDF and ADF contents of *V narbonensis* were higher compared to the overall mean of *V sativa* foliage as well as of individual selection of *V sativa* foliage (Table 2). Unfortunately, samples of *L sativus* foliage were not available which would have allowed comparison of foliages of *L sativus* and *V sativa*. The foliage at the 100% flowering stage of *V sativa*, *V ervilia* and *V villosa* ssp *dasycarpa* had CP contents of 195, 215 and 165 g kg^{-1}, respectively, and the values for NDF and ADF were 310, 280, 400 g kg^{-1} and 220, 200, 310 g kg^{-1}, respectively (Abd El Moneim 1993). The CP contents observed for legume straws were higher than those of cereal straws and were comparable to other legume straws, for example, gram, mung and guar (Theander and Aman 1984; Rees *et al* 1991; Prasad *et al* 1993). On the other hand, the CP of foliage 152·6 g kg^{-1}, Table 2) was lower than those of fresh forages of alfalfa, berseeem and white clover (CP about 200·0 g kg^{-1}) (see Close and Menke 1988).

Table 3 presents cell constituents and *in vitro* characteristics of straw samples of only those selection numbers of *L sativus* and *V sativa* which were harvested in the month of July of both 1992 and 1993, and of foliage samples of only those selection numbers of *V sativa* which were harvested in both May and June of 1992 (see Table 1). For straw samples, the content of CP was significantly lower for 1992 as compared to 1993, and the contents of NDF and ADF were significantly higher. For foliage samples, no difference was noticed in the contents of CP, NDF and ADF between May 1992 and June 1992 samples (Table 3). The contents of cell solubles of legume straws (Table 2) was higher than those of cereal straws (Gebrehiwot and Mohammed 1989; Becker and Einfeldt 1995).

Nutritional value

The gas produced *in vitro* (Menke and Steingass 1988) by the foliage samples was significantly higher than that produced by the straw samples (49 ml vs 35 ml). The OMD (70% vs 56%) and ME (9·7 MJ kg^{-1} vs 7·3 MJ kg^{-1}) also had the similar pattern (Table 2).

TABLE 2

Cell constituents and *in vitro* characteristics of some leguminous samples[a]

Species	Selection number/data	CP ($g\ kg^{-1}$)	ASH ($g\ kg^{-1}$)	ADF[b] ($g\ kg^{-1}$)	NDF[b] ($g\ kg^{-1}$)	Gas[c] (ml)	OMD $g\ kg^{-1}$	ME ($MJ\ kg^{-1}$)
Straw samples								
Lathyrus sativus	510/July 1992	77·8	99·9	367·8	541·5	34·5	554	7·2
Lathyrus sativus	510/July 1993	54·1	88·5	451·8	607·9	31·8	513	7·6
Lathyrus sativus	530/July 1992	79·5	104·9	337·0	512·1	30·8	523	7·5
Lathyrus sativus	530/July 1993	60·2	83·1	413·5	583·0	34·9	542	8·1
Lathyrus sativus	587/July 1992	74·2	101·7	361·2	509·1	39·4	597	8·0
Mean		69·2	95·6a	386·3	550·7a	34·3	546a	7·7
SD		11·3	9·3	45·9	43·6	3·4	33	0·4
Vicia narbonensis	2380/July 1993	75·2	124·1	336·3	492·9	36·1	576	9·6
Vicia narbonensis	2390/July 1993	93·1	119·0	295·8	445·4	37·8	598	7·5
Vicia narbonensis	2391/July 1993	47·4	114·5	404·1	548·6	35·0	549	7·0
Vicia narbonensis	2392/July 1993	84·4	128·1	337·5	451·1	36·2	583	10·6
Vicia narbonensis	2462/July 1993	72·6	136·8	303·7	447·0	36·3	582	9·6
Vicia narbonensis	2464/July 1993	90·3	121·2	277·7	412·7	39·5	613	7·7
Vicia narbonensis	2475/July 1993	43·2	116·0	443·6	556·1	34·4	542	6·8
Vicia narbonensis	2561/July 1993	55·4	117·5	361·9	514·9	37·0	572	9·5
Vicia narbonensis	2501/July 1993	42·9	123·4	430·9	566·6	33·6	537	7·6
Mean		67·2	126·7b	354·6	492·8b,c	36·2	573b,c	7·5
SD		20·3	15·6	60·0	56·4	1·8	26	0·4
Vicia sativa	1448/July 1992	73·5	127·0	342·2	498·9	37·6	590	7·7
Vicia sativa	1448/July 1993	66·6	131·1	401·8	529·0	30·9	528	6·8
Vicia sativa	2037/July 1992	75·4	137·1	332·8	483·0	36·4	584	7·6
Vicia sativa	2065/July 1992	58·8	135·1	327·3	504·7	35·7	569	7·4
Vicia sativa	2556/July 1992	77·2	121·2	324·8	485·6	39·3	605	8·0
Vicia sativa	2557/July 1992	67·6	138·8	341·6	504·0	35·2	570	7·4
Vicia sativa	2557/July 1993	61·3	123·7	409·0	578·2	30·8	521	6·7
Vicia sativa	2558/July 1992	61·5	117·8	340·7	531·5	36·4	570	7·5
Vicia sativa	2558/July 1993	44·3	111·5	349·0	546·9	34·4	541	7·1
Vicia sativa	2559/July 1992	51·0	120·9	365·9	517·9	36·8	569	7·5
Vicia sativa	2559/July 1993	45·5	106·0	439·3	556·6	30·2	501	6·6
Mean		62·1	124·6b	361·3	521·5a,c	34·9	559a,c	7·3
SD		11·5	10·5	38·3	30·2	3·0	32	0·44
Vice ervilia	2511/July 1993	43·5	87·2	519·0	686·3	31·6	506	6·7
Overall mean		64·5	116·8	369·9	523·5	35·1	559	7·3
SD		15·2	15·3	56·0	57·0	2·8	32	0·4
Foliage samples								
Vicia sativa	1448/May 1992	188·2	77·0	170·1	304·2	53·8	773	10·6
Vicia sativa	1448/May 1992	143·7	111·9	220·1	348·0	48·3	715	9·6
Vicia sativa	2037/May 1992	66·6	92·6	213·9	336·3	47·4	662	9·0
Vicia sativa	2037/June 1992	144·4	82·8	212·7	349·6	48·0	702	9·5
Vicia sativa	2065/May 1992	139·7	85·7	215·2	343·0	48·2	702	9·5
Vicia sativa	2065/June 1992	134·7	104·3	222·3	336·6	46·3	690	9·3
Vicia sativa	2556/May 1992	170·2	84·2	175·6	298·9	50·8	740	10·1
Vicia sativa	2556/June 1992	180·4	75·3	185·0	313·5	49·4	729	9·9
Vicia sativa	2557/May 1992	151·2	92·5	193·7	312·5	47·8	707	9·6
Vicia sativa	2557/June 1992	162·3	79·7	209·8	333·0	48·0	709	9·6
Vicia sativa	2558/May 1992	170·8	66·5	202·3	316·3	48·5	713	9·8
Vicia sativa	2558/June 1992	166·7	57·6	168·6	325·7	51·7	736	10·2
Vicia sativa	2559/May 1992	157·3	64·6	218·5	368·2	47·2	694	9·5
Vicia sativa	2559/June 1992	170·9	76·9	195·2	310·0	49·0	722	9·8
Mean[d]		153·4	82·3	200·2	328·3	48·9	714	9·7
SD		29·6	14·9	19·0	19·8	2·0	26	0·41
Vicia narbonensis	2561/May 1992	137·5	80·5	274·5	395·0	48·4	701	9·6
Overall mean		152·6*	82·8*	205·2*	332·7*	48·9*	713*	9·7*
SD		27·7	13·8	25·6	25·0	1·86	25	0·37

[a] For the straw samples, means with dissimilar following letters in the same vertical column differ significantly ($P < 0·05$).

* Significantly different ($P < 0·05$) from the corresponding value for the straw samples.

[b] 1, on ash free basis.

[c] ml per 24 h from 200 mg sample.

[d] all means for vegetative samples of *Vicia sativa* differ significantly ($P < 0·05$) from the corresponding means for straw samples of *V sativa*.

TABLE 3

Cell constituents and *in vitro* characteristics of some leguminous samples collected at different periods (mean ± SD, $n = 6$)[a]

	CP ($g\ kg^{-1}$)	*ASH* ($g\ kg^{-1}$)	*ADF*[b] ($g\ kg^{-1}$)	*NDF*[b] ($g\ kg^{-1}$)	*Gas*[c] (*ml*)	*OMD* ($g\ kg^{-1}$)	*ME* ($MJ\ kg^{-1}$)
Straw samples[d]							
July 1992	68·5 ± 10·9	118·2 ± 14·3	349·2 ± 13·8	517·7 ± 16·3	35·2 ± 2·4	563 ± 23	7·4 ± 0·31
July 1993	55·3 ± 9·0*	107·5 ± 18·9 (NS)	410·7 ± 35·8*	566·9 ± 28·3*	32·2 ± 2·0*	524 ± 16*	6·9 ± 0·27*
Foliage (May 1992 and June 1992) samples of Vicia sativa[e]							
May 1992	142·6 ± 39·1	81·0 ± 12·5	203·2 ± 37·9	366·7 ± 35·1	48·3 ± 1·3	703 ± 25·5	9·6 ± 0·3
June 1992	159·5 ± 17·1 (NS)	79·4 ± 15·0 (NS)	211·8 ± 24·8 (NS)	354·9 ± 26·5 (NS)	48·7 ± 1·8 (NS)	715 ± 17·5 (NS)	9·7 ± 0·3 (NS)

[a] Means with dissimilar following letters in the same vertical column differ significantly ($P < 0·05$).
* Means significantly ($P < 0·05$) different from corresponding values for July 1992; NS, not significant ($P > 0·05$) from corresponding value for July 1992.
[b] On an ash-free basis.
[c] ml per 24 h from 200 mg sample.
[d] straw samples include: *Lathyrus sativus* (510 and 530) and *Vicia sativa* (1448, 2557, 2558, 2559); species and selection numbers present in July of both 1992 and 1993.
[e] Samples include: *Vicia sativa* (2037, 2065, 2556, 2557, 2558, 2559); selection numbers harvested in both May and June of 1992 (see Table 1). The numbers following the species name are selection numbers.

There was no significant difference in the gas production and ME of straw samples of different species. However, the OMD of *L sativus* straw was significantly lower compared to the straws of the two strains of *Vicia* (Table 2). The gas production, OMD and ME of the straws of *L sativus* and *V sativa* collected in 1993 was significantly lower compared to those cut in 1992. On the other hand the CP was lower and fibre content higher for straws cut in July 1993 (see above). These observations suggest that the quality of straw harvested in July 1993 was lower than that of July 1992, which could be due to differences in weather between the years. The OMD and ME of *V sativa* foliage were slightly higher than those of *V narbonensis* (OMD: 71·4 vs 68·6%; ME; 9·7 vs 9·4 MJ kg^{-1}, Table 2). These results together with higher CP and lower NDF and ADF of *V sativa* foliage suggest that this foliage is of better quality compared to *V narbonensis* foliage. Abd El Moneim (1993) has reported *in vitro* dry matter digestibilities of 69, 72 and 46% for the foliage samples of *V sativa*, *V ervilia* and *V villosa* ssp *dasycarpa*, respectively. The CP, ME and OMD were statistically similar for foliage samples of *V sativa* cut in May 1992 and June 1992. In addition, there was no significant difference in the ash, crude protein or cell-wall constituents of these samples (Table 3). These results show that the nutritive values of the foliage did not change over a period of one month, ie from May to June 1992. It is evident from the above results that OMD and ME of *L sativus*, *V narbonensis* and *V sativa* straws were also higher than those of cereal straws, and that of foliage of *V sativa* and *V narbonensis* comparable to those of fresh forages of alfalfa, berseeem and white clover (Rexen and Knudsen 1984; Sundstol and Coxworth 1984; Wilkinson 1984; Close and Menke 1988).

Tannin levels

Tannin levels by various methods are given in Table 4. The contents of Pe, Te and CTe of the foliage were significantly higher than those of the straws. There was no significant difference in the contents of total Pe, Te and CTe among the straws of different species. The Pe and Te contents (as mg g^{-1}) of straws were less than 20 average 10·8) and 10 (average 4·3) respectively and those of the foliage were respectively less than 35 (average 22·7) and 25 (average 13). The CTe content had a similar pattern—higher in foliage samples (Table 4). The contents of Pe, Te and CTe did not differ significantly between straws cut in July 1992 and those cut in July 1993. Similarly there was no significant difference in the increase in gas production using PEG 6000 in the gas method between these two group of samples (Table 5). The contents of Pe, Te and CTe in *V sativa* foliage were about 1·7-, 2·3- and 4-fold higher compared to in *V narbonensis* foliage (Table 4). The foliage of *V sativa* cut in May 1992 and June 1992 also did not differ significantly in the contents of Pe, Te and CTe and in increase in gas production on addition of PEG 6000. Protein precipitation capacity, measured by both the dye-binding (Asquith and Butler 1985) and bovine serum albumin precipitation methods (Makkar *et al* 1988) was not detectable in the foliage samples (results not shown). In addition, a maximum of 6% increase in the gas production (average 3·9%) in the foliage

TABLE 4

Extractable phenols (Pe), extractable tannins (Te), extractable condensed tannins (CTe) ($g\ kg^{-1}$ dry matter), and percent increase in gas production by polyethylene glycol 6000 (a tannin-complexing agent)[a]

Selection	*Number/date*	*Pe*[b]	*Te*[b]	*CTe*[c]	*Increase in gas species* (%)
Straw samples					
Lathyrus sativus	510/July 1992	12·3	4·4	1·9	0·5
Lathyrus sativus	510/July 1993	11·0	3·7	1·1	0·6
Lathyrus sativus	530/July 1992	11·6	4·0	6·4	3·1
Lathyrus sativus	530/July 1993	15·6	5·4	1·9	0·9
Lathyrus sativus	587/July 1992	10·0	3·7	1·5	0·5
Mean		12·1a	4·2a	2·6a	1·1a
SD		2·1	0·7	2·2	1·1
Vicia narbonensis	2380/July 1993	9·8	3·2	1·3	0
Vicia narbonensis	2390/July 1993	10·1	3·3	2·1	0
Vicia narbonensis	2391/July 1993	8·7	3·3	0·7	0
Vicia narbonensis	2392/July 1993	10·0	3·7	1·5	0
Vicia narbonensis	2462/July 1993	11·8	5·0	1·2	4·1
Vicia narbonensis	2464/July 1993	12·4	5·3	1·7	0·7
Vicia narbonensis	2475/July 1993	8·2	3·0	0·9	0
Vicia narbonensis	2561/July 1993	9·2	3·4	1·5	2·6
Vicia narbonensis	2501/July 1993	8·0	2·8	0·5	0
Mean		9·8a	3·7a	1·3a	0·82a
SD		1·5	0·9	0·5	1·50
Vicia sativa	1448/July 1992	13·1	9·3	8·4	1·5
Vicia sativa	1448/July 1993	9·5	6·4	3·1	0·6
Vicia sativa	2037/July 1992	14·7	6·9	15·7	6·9
Vicia sativa	2065/July 1992	19·1	9·4	12·6	2·1
Vicia sativa	2556/July 1992	10·5	2·9	1·2	2·8
Vicia sativa	2557/July 1992	15·7	5·9	9·2	1·4
Vicia sativa	2557/July 1993	11·0	4·9	2·4	0·5
Vicia sativa	2558/July 1993	11·4	4·2	1·6	0
Vicia sativa	2559/July 1992	7·5	2·9	0·6	4·2
Vicia sativa	2559/July 1993	4·6	1·3	0·5	0
Mean		11·4a	5·2a	5·1a	1·82a
SD		4·0	2·7	5·3	2·14
Vicia ervilia	2511/July 1993	6·5	1·8	4·7	1·1
Overall mean		10·8	4·3	3·3	1·31
SD		3·0	2·0	3·9	1·72
Foliage samples					
Vicia sativa	1448/May 1992	17·3	8·3	7·8	4·5
Vicia sativa	1448/May 1992	24·1	13·5	21·1	3·5
Vicia sativa	2037/May 1992	29·6	23·1	24·5	5·6
Vicia sativa	2037/June 1992	29·5	22·8	26·7	6·1
Vicia sativa	2065/May 1992	29·9	18·7	25·0	5·6
Vicia sativa	2065/June 1992	34·1	21·0	30·3	3·1
Vicia sativa	2556/May 1992	18·1	7·8	8·8	4·1
Vicia sativa	2556/June 1992	15·5	5·9	5·7	4·5
Vicia sativa	2557/May 1992	29·3	16·8	20·7	3·8
Vicia sativa	2557/June 1992	31·2	16·8	26·2	5·2
Vicia sativa	2558/May 1992	18·8	9·6	9·2	0
Vicia sativa	2558/June 1992	15·0	7·2	9·4	2·3
Vicia sativa	2559/May 1992	20·7	10·0	13·1	5·9
Vicia sativa	2559/June 1992	14·4	7·5	11·8	4·1
Mean[e]		23·4	13·5	17·2	4·16
SD		7·0	6·2	8·5	1·63
Vicia narbonensis	2561/May 1992	13·7	6·0	4·3	0
Overall mean		22·7*	13·0*	16·3*	3·89*
Mean		7·1	6·0	8·0	1·90

[a] For the straw samples, means with dissimilar following letters in the same vertical column differ significantly ($P < 0.05$). The numbers following the species name are selection numbers.
* Significantly different ($P < 0.05$) from the corresponding value for the straw samples.
[b] As tannic acid equivalent.
[c] As leucocyanidin equivalent.
[d] Protein precipitation capacity by the methods of Asquith and Butler (1986) and Makkar *et al* (1988) was not detected for any of the above samples.
[e] All means for vegetative samples of *V sativa* differ significantly ($P < 0.05$) from the corresponding means for straw samples of *V sativa*.

TABLE 5
Extractable phenols (Pe), extractable tannins (Te) and extractable condensed tannins (CTe) (g kg^{-1}) of some leguminous samples (mean ± SD, $n = 6$)[a]

	Pe[b]	*Te*[b]	*CTe*[c]	*Increase in gas* (%)
Straw samples[d]				
July 1992	11·5 ± 2·9	4·9 ± 2·4	4·6 ± 3·9	1·9 ± 1·5
July 1993	10·5 ± 3·6 (NS)	4·3 ± 1·7 (NS)	1·7 ± 0·9 (NS)	1·1 ± 1·6 (NS)
Foliage (May 1992 and June 1992) samples of Vicia sativa[e]				
May 1992	24·4 ± 5·8	14·3 ± 6·1	16·9 ± 7·4	4·2 ± 2·2
June 1992	23·3 ± 9·2 (NS)	13·5 ± 7·6 (NS)	18·4 ± 10·6 (NS)	4·2 ± 1·4 (NS)

[a] Means with dissimilar following letters in the same vertical column differ significantly ($P < 0·05$). NS, not significant ($P > 0·05$) from corresponding value for July 1992.
[b] as tannic acid equivalent.
[c] As leucocyanidin equivalent.
[d] straw samples include: *Lathyrus sativus* (510 and 530) and *Vicia sativa* (1448, 2557, 2558, 2559); species and selection numbers present in July of both 1992 and 1993 (see Table 1).
[e] Samples include *Vicia sativa* (2037, 2065, 2556, 2557, 2558, 2559); selection numbers harvested in both May and June of 1992 (see Table 1). The numbers following the species name are selection numbers.

samples (for straws the increase was virtually nil) was observed in the presence of PEG 6000. For tannin-rich samples of *Acacia saligna*, *Acioa barteri* and *Quercus incana*, etc, up to 200% increase in the gas production has been observed (Makkar *et al* 1995). In the present study, the tannins present in foliage decrease the gas production by a maximum of 6%, which translates to a maximum decrease in OMD of about 3% units according to the equation used for calculation of OMD (Menke and Steingass 1988). The results suggest that (i) the legume straws have negligible tannins, and (ii) low levels of tannins are present in the foliage samples, which do not adversely affect their nutritive value to a significant extent.

The results of the present study demonstrated that legume foliages (*Vicia narbonensis*, *V sativa*) with pods sampled in the dough stage have higher protein, organic matter digestibility and metabolisable energy compared to their straws, and that the legume straws (*Vicia narbonensis*, *V sativa* and *Lathyrus sativus*) have higher protein, organic matter digestibility and metabolisable energy compared to cereal straws. The legume foliages are lower in crude protein content compared to fresh forages of alfalfa, white clover and berseeem, but have comparable organic matter digestibility and metabolisable energy. The legume straws have negligible tannins whereas the legume foliages have a low level of tannins, some of which probably lies in the seeds present in these foliages. However, these tannins do not adversely affect the nutritive value of the legume foliages. This study clearly indicates the high potential of legume foliages and straws for incorporation into livestock diets, especially in West Asia and North Africa where the major limiting factor to livestock production is the inadequate feed supply. Shortages can be alleviated by the introduction of leguminous forage species in the existing fallow lands.

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