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Yield and nutritive value of vetch (*Vicia sativa*) — barley (*Hordeum vulgare*) forage under different harvesting regimens

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Abstract

A field experiment was carried out in 2 consecutive years to study the changes in the values of cell wall constituents and the digestibility of some nutrients in forages subjected to 2 harvest regimens. Vetch (*Vicia sativa*) and barley (*Hordeum vulgare*) were grown in a mixed culture and a monoculture system under rainfed conditions in a semi-arid region. Plants were either harvested at 3 sequential times (H1, H2 and H3; 115, 146 and 167 d after planting), or harvested once (H0; 167 d after planting), at physiological maturity. The results indicated that the quality of harvested material declined from the first to the second of the sequential harvests for all cropping systems, with minimal change between the second and third harvests. Material harvested only once at physiological maturity consistently had higher levels of crude fibre and cell wall constituents than material from any of the sequential harvests. *In vitro* organic matter digestibility and digestible energy values were lower in later harvests than in the first of the sequential harvests. *In vitro* digestible crude protein (IVDCP) values were consistently higher for vetch than for barley, declining progressively from H1 to H2, H3 and H0 in the case of vetch. With barley, IVDCP values for H3 were significantly higher than for other harvests. A single cut at physiological maturity yielded more digestible energy and protein/ha than serial cuts. The mixed cropping of vetch and barley produced much more forage than barley alone and the quality of the material was much higher than that from barley alone.

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Introduction

The inclusion of winter legumes, *e.g.* vetch, with winter cereals, *e.g.* barley, has the potential to improve the quality of forage. Vetch (*Vicia sativa*) has high concentrations of crude protein (Ebelhar *et al.* 1984) compared with barley. In the Middle East, vetch is used widely for forage production in a mixed cropping system with oats (Papastylianou and Danso 1989; 1991) or barley (Kurdali *et al.* 1996). Mixtures could provide an alternative source of feed for animals during winter and early spring when hay supply is limited. Forage quality of a vetch-barley mixture is influenced by harvest management (Trevino *et al.* 1983; Depeters *et al.* 1989). In a previous paper, Kurdali *et al.* (1996) reported nitrogen accumulation, N_2 fixation by the vetch and soil N balance in vetch, barley, and vetch-barley systems at several successive harvests throughout the growing season. However, the quality of the forage has not been investigated. This paper reports on the nutritive value of vetch and barley forages from monocultures or mixed sowings under 2 harvesting regimens.

Materials and methods

A field experiment with 6 treatments and 4 replicates (3 × 2 × 4) was conducted in 1991–1992 (S1) and 1992–1993 (S2) at Gillin (32° 42′ N, 35° 59′ E; 339 m altitude) in south-west Syria. The forage treatments were: vetch monoculture (Vp) at a sowing rate of 150 kg/ha; barley monoculture (Bp) at a sowing rate of 150 kg/ha; and vetch-barley mixed culture (VBm) at sowing rates of 25% and 75% of the vetch and barley rates, respectively. Two harvesting systems were compared: 3 successive harvests (H1, H2 and H3); and a single harvest (H0) at physiological maturity. Three main plots each 9 m^2 were randomised in a split-plot design with the forages (Vp, Bp and VBm) as the main treatments, and each one was divided into 2 subplots (4.5 m^2, with 3 m^2 to harvest) for the cutting systems

[3 successive cuts (H1, H2 and H3) and a single cutting (H0)] as the auxiliary treatments. These main plots were repeated 4 times in a split-plot design. In both seasons, seed was sown on November 19, and harvests were made on March 13 (H1), April 13 (H2) and May 4 (H3 and H0, which corresponded with physiological maturity of the barley). These dates coincided with 115, 146 and 167 d after planting (DAP). Inter-row distance was 15 cm. Triple superphosphate was applied pre-planting at a rate of 8.89 kg/ha P. After seed germination or before the re-growth of plants after each harvest, 20 kg/ha N was added. Wheat was the previous crop for both growing seasons. The total precipitation in S1 and S2 was 567 and 356 mm, respectively. Further management details are reported in Kurdali *et al*. (1996).

The soil is a Vertisol with alty texture in the top 15 cm and a silty clay below that depth. Total soil N was: 0.1, 0.09, 0.06 and 0.05% in S1; and 0.09, 0.08, 0.05 and 0.04% in S2 in successive 15 cm layers from the surface. A detailed soil description is reported by Arslan and Kurdali (1996).

The crops were cut by a forage chopper 2–3 cm above ground level when plants were approximately 15–20, 20–25, 25–30 and 45–50 cm high for H1, H2, H3 and H0, respectively. These harvesting dates corresponded to early stem elongation (H1), late stem elongation (H2), flowering stage (H3) and physiological maturity (H0). Plants from the mixed stand were separated by hand in the laboratory into component species (barley and vetch). All harvested plants were dried at 60 °C in the oven for 3 days, ground to pass a 1 mm sieve and kept for analysis.

Neutral-detergent fibre (NDF), acid-detergent fibre (ADF) and acid-detergent lignin (ADL) were determined by the method of Goering and van Soest (1970). Crude fibre (CF) concentration and *in vitro* digestible crude protein (IVDCP) (HCL-pepsin-crude protein solubility) were measured according to Naumann and Bassler (1976). *In vitro* organic matter digestibility (IVOMD) was determined by the pepsin-cellulase method of Jones and Hayward (1973). Gross energy (GE) was determined by calorimeter (HC 10; HAAKE, Germany), and the *in vitro* digestible energy (IVDE) was calculated by multiplying GE values by IVOMD. Data were subjected to analysis of variance (ANOVA) using [512]Statview program and Fisher's protected Least Significant Difference (LSD) at P<0.05.

Results and discussion

In both seasons, quality of harvested material declined (P<0.05) from the first to the second of the sequential harvests for all cropping systems, with minimal change between the second and third harvests. This was reflected in increases in CF, NDF, ADF and ADL (Table 1), which is attributed to increases in lignocellulosic materials in the cell walls (Kirchgessner 1982). Kung *et al*. (1990) indicated that nitrogen and water-soluble carbohydrates in forage from vetch-barley mixtures decreased with maturity while NDF, ADF and ADL increased. Digestibility and crude protein content of forages decreased and the concentration of lignin and cell wall increased with advancing maturity (Depeters *et al*. 1989). However, chronological ages of the harvested material from H1, H2 and H3 were 115, 31 and 21 days, respectively, so the decline in quality was not necessarily a function of increased age of material. Daylength, light intensity for photosynthesis, temperature, amount of carbohydrates reserved in rootstocks and soil water could have influenced the increases in the proportion of cell wall and the decreases in digestibility of material from successive harvests. Catchpoole (1968) indicated that the composition of tropical grasses changed between the growing periods. In addition, Bathurst and Mitchell (1958) reported that light intensities and temperature affect the water-soluble carbohydrate levels in pasture plants. Plants of the first sequential cuts (H1) were very leafy and the subsequent cuts (H2 and H3) had more stems as temperatures rose and daylength increased. Al-Rabat (1975) reported that serial cuts of pasture plants may decrease the quality and the yield of forages, especially in dry areas. The sequential cuts may also decrease carbohydrate supply in the roots and delay flowering and maturity of the crop, which may reduce the quality of the forage material.

Material harvested only once at physiological maturity consistently had higher CF and ADL levels than material from any of the sequential harvests (Table 1). There was no consistency in differences in gross energy (GE) values for material from the various harvests but *in vitro* digestible energy (IVDE) was lower in material

Table 1. Crude fibre (CF) and cell-wall constituents of vetch (V) and barley (B) grown in pure (p) or mixed (m) stands and harvested on 3 successive occasions (H1, H2 and H3) or once at physiological maturity (H0) in 1991–1992 and 1992–1993 growing seasons.

Cropping system	Harvest	1991–1992				1992–1993			
		CF	NDF[1]	ADF	ADL	CF	NDF	ADF	ADL
Pure vetch		(g/kg DM)				(g/kg DM)			
Vp	H1	138.7	304.9	250.1	35.1	128.2	306.1	254.3	31.7
	H2	184.7	398.5	277.9	48.0	163.1	367.2	276.7	49.3
	H3	181.3	392.1	276.9	48.7	163.8	370.5	275.4	48.8
	H0	218.8	434.6	276.9	51.1	195.4	425.3	276.4	57.5
	LSD (P<0.05)	**7.0**	**8.2**	**6.0**	**2.4**	**1.8**	**2.8**	**3.7**	**2.7**
Pure barley									
Bp	H1	179.1	461.0	235.2	22.6	157.2	422.2	222.6	22.6
	H2	190.6	550.7	299.2	26.2	165.0	533.3	286.6	26.4
	H3	155.8	547.5	293.1	26.5	164.3	530.6	286.2	27.2
	H0	198.5	550.6	295.6	31.7	178.1	532.4	284.9	35.5
	LSD (P<0.05)	**4.8**	**8.5**	**5.3**	**2.3**	**2.4**	**2.9**	**3.5**	**1.7**
Mixture									
VBm	H1	150.2	372.1	214.0	26.2	144.0	356.6	208.0	27.0
	H2	200.8	459.4	268.3	30.1	164.4	413.7	269.7	32.3
	H3	193.4	496.9	271.9	35.6	170.4	452.3	270.2	34.0
	H0	203.7	497.9	280.0	46.1	187.0	452.3	272.2	49.4
	LSD (P<0.05)	**6.0**	**9.4**	**7.2**	**1.8**	**3.2**	**4.3**	**3.8**	**2.0**
Vetch from mixture									
Vm	H1	148.2	307.1	210.2	34.1	130.7	303.6	205.3	31.0
	H2	184.4	362.4	262.8	45.3	163.1	339.7	262.7	46.4
	H3	188.7	447.8	260.3	47.7	170.3	433.4	263.5	46.0
	H0	198.3	450.7	265.7	47.9	190.7	434.5	264.1	51.0
	LSD (P<0.05)	**5.8**	**9.0**	**9.7**	**2.6**	**2.4**	**3.5**	**4.0**	**3.2**
Barley from mixture									
Bm	H1	160.2	453.2	216.1	19.2	154.4	420.9	216.7	20.1
	H2	195.8	519.3	280.3	23.1	167.2	497.0	271.9	27.2
	H3	197.3	522.7	293.8	24.9	167.9	498.5	271.9	25.8
	H0	227.1	591.8	307.7	40.2	180.9	546.3	298.6	42.4
	LSD (P<0.05)	**5.5**	**7.8**	**7.9**	**2.1**	**2.7**	**2.9**	**4.1**	**2.0**

[1]NDF: neutral-detergent fibre; ADF: acid-detergent fibre; ADL: acid-detergent lignin.

from later harvests than from the first of the sequential harvests (Table 2). *In vitro* organic matter digestibility (IVOMD) was lower in later harvests than in the first of the sequential harvests. Differences between material from H2, H3 and H0 were small in the case of vetch but, for barley, material from H0 was much less digestible (P<0.05) than that from H2 and H3. The decreases in IVOMD and IVDE values in the later harvests are attributed to a combination of increased crude fibre levels and the presence of lignocellulosic materials in the cell walls (Al-Masri and Guenther 1995).

In vitro digestible crude protein (IVDCP) values were consistently higher for vetch than for barley, declining progressively (P<0.05) from H1 to H2, H3 and H0 in the case of vetch. With barley, IVDCP values for H3 were significantly (P<0.05) higher than for other harvests. Differences in crude protein and *in vitro* digestibility values were also reported between legume and grass forages (Hadjipanayiotou and Economides 1985).

Our results indicate that IVOMD and IVDE values are related to the CF concentration and cell wall components in the vetch-barley mixture. Average correlation coefficients (r) between CF, NDF, ADF and ADL and IVOMD and IVDE were 0.93, 0.95, 0.93 and 0.89 and 0.90, 0.95, 0.93 and 0.88, respectively. Similar results were obtained by Al-Masri (1995).

Dry matter yields of harvested material (Table 3) were significantly (P<0.05) greater for the single harvest at physiological maturity than

Table 2. Energy and digestibility of some nutrients[1] of vetch (V) and barley (B) grown in pure (p) or mixed (m) stands, and harvested on 3 successive occasions (H1, H2 and H3) or once at physiological maturity (H0) in 1991–1992 and 1992–1993 growing seasons.

Cropping system	Harvest	1991–1992				1992–1993			
		GE	IVDE	IVOMD	IVDCP	GE	IVDE	IVOMD	IVDCP
Pure vetch		(MJ/kg DM)		(g/kg DM)		(MJ/kg DM)		(g/kg DM)	
Vp	H1	16.8	14.0	830.8	197.7	16.5	13.9	840.2	212.5
	H2	16.7	13.1	784.3	172.9	16.9	13.5	800.8	196.0
	H3	16.7	13.1	787.3	155.1	16.6	13.3	799.5	167.8
	H0	16.8	13.2	786.7	134.6	16.6	13.3	800.2	146.9
	LSD (P<0.05)	**N.S.**	**0.33**	**6.4**	**2.3**	**0.29**	**0.22**	**3.8**	**2.9**
Pure barley									
Bp	H1	17.0	13.9	813.8	124.4	17.4	14.4	826.4	116.8
	H2	16.9	12.3	728.8	91.1	17.0	12.6	741.2	107.0
	H3	16.7	12.2	729.3	134.2	16.7	12.4	742.7	146.4
	H0	17.2	10.7	625.2	54.9	16.7	10.7	641.2	54.7
	LSD (P<0.05)	**0.26**	**0.19**	**7.6**	**1.8**	**0.33**	**0.22**	**4.6**	**2.2**
Mixture									
VBm	H1	17.1	14.0	818.1	172.2	16.9	14.0	828.4	166.8
	H2	17.2	13.3	770.3	125.8	17.0	13.3	783.2	145.2
	H3	17.1	13.1	765.2	131.9	16.6	13.1	787.1	152.7
	H0	17.2	13.2	767.7	105.2	17.1	13.3	780.9	117.7
	LSD (P<0.05)	**N.S.**	**0.32**	**9.5**	**2.0**	**0.24**	**0.21**	**4.4**	**2.2**
Vetch from mixture									
Vm	H1	17.3	14.3	825.8	202.5	16.7	14.1	841.3	216.8
	H2	17.3	13.6	783.2	172.5	17.0	13.5	792.0	195.8
	H3	17.0	13.3	781.7	145.4	16.8	13.3	793.9	163.9
	H0	17.6	13.7	778.3	123.0	17.3	13.7	792.0	145.7
	LSD (P<0.05)	**0.23**	**0.23**	**6.5**	**2.4**	**0.28**	**0.25**	**6.0**	**2.5**
Barley from mixture									
Bm	H1	17.2	14.1	822.2	133.7	17.4	14.6	835.2	126.1
	H2	16.8	12.7	754.3	79.3	16.7	12.8	769.6	86.5
	H3	17.0	12.8	753.1	108.5	16.9	13.0	770.4	116.5
	H0	17.1	10.8	633.7	63.4	17.0	11.1	651.1	64.7
	LSD (P<0.05)	**0.26**	**0.19**	**6.3**	**2.1**	**0.23**	**0.19**	**3.4**	**1.8**

[1]GE: gross energy; IVDE: *in vitro* digestible energy; IVOMD: *in vitro* organic matter digestibility; IVDCP: *in vitro* digestible crude protein.

for the sum of the yields from the 3 sequential harvests. Over both seasons, the magnitude of the increase in yield was 155% for vetch, 141% for barley and 288% for the vetch-barley mixture. Differences were much greater in the first season than in the second season. Yield from the mixed crop was similar to the sum of the two monoculture yields.

When the data on dry matter yields and digestible energy and protein concentrations are combined (Table 3), the total feed value of material from the different systems becomes obvious. In all cases, a single harvest at physiological maturity produced more digestible energy and protein/ha than did the sequential harvests. The mixed crop of vetch and barley produced substantially more digestible energy and protein/ha than either of these crops in monoculture. Most of the harvested material would provide above maintenance diets for stock, the only material which would require supplements to be fed being barley harvested for the first time at physiological maturity.

This study has shown that mixed cropping of vetch and barley has distinct advantages over a barley monoculture for livestock feeding. The mixed crop produces much more forage than a barley monoculture and the quality is improved through improved nutritive value. In addition, soil nitrogen levels could be expected to be higher with the mixed crop. If the crop is to be used for hay, a single harvest at physiological maturity of the barley would provide more

Table 3. Dry matter (DM), digestible protein (DP) and digestible energy (DE) yields of vetch (V) and barley (B) grown in pure (p) or mixed (m) stands, and harvested on 3 successive occasions (H1, H2 and H3) or once at physiological maturity (H0) in 1991–1992 and 1992–1993 growing seasons.

Cropping system	Harvest	1991–1992			1992–1993		
		DM	DP	DE	DM	DP	DE
Pure vetch		(kg/ha DM)		(MJ/ha)	(kg/ha DM)		(MJ/ha)
Vp	H1	565	112	7886	1547	329	21448
	H2	908	157	11925	1091	214	14744
	H3	249	39	3269	213	36	2830
	LSD (P<0.05)	**101**	**18**	**1403**	**94**	**19**	**1158**
	Total of 3 harvests	1722	307	23080	2851	395	39022
	H0	6452	869	84972	5218	578	69466
	LSD (P<0.05)	**713**	**98**	**9014**	**468**	**238**	**6954**
Pure barley							
Bp	H1	932	116	12924	2026	236	29143
	H2	1318	120	16240	838	90	1056
	H3	372	50	4521	214	31	2646
	LSD (P<0.05)	**178**	**20**	**2244**	**166**	**17**	**2480**
	Total of 3 harvests	2621	286	33684	3078	357	42350
	H0	8133	447	88566	5596	307	57363
	LSD (P<0.05)	**736**	**57**	**5609**	**508**	**29**	**8395**
Mixture							
VBm	H1	658	113	9209	2611	435	36622
	H2	1185	149	15735	1071	155	14270
	H3	234	31	3238	231	35	3025
	LSD (P<0.05)	**65**	**10**	**840**	**147**	**26**	**2361**
	Total of 3 harvests	2077	294	28180	3913	626	53917
	H0	14882	1566	196573	8378	987	111787
	LSD (P<0.05)	**949**	**84**	**10978**	**640**	**95**	**9156**
Vetch from mixture							
Vm	H1	3148	64	4481	944	205	1327
	H2	532	92	7212	453	121	5952
	H3	151	22	2004	95	16	1268
	LSD (P<0.05)	**83**	**15**	**1125**	**93**	**21**	**1310**
	Total of 3 harvests	996	177	13697	1482	342	20494
	H0	5088	626	69770	3041	443	41717
	LSD (P<0.05)	**798**	**106**	**11967**	**504**	**75**	**7452**
Barley from mixture							
Bm	H1	344	46	4859	1667	210	24281
	H2	653	52	8272	619	38	7935
	H3	84	9	1072	156	18	2031
	LSD (P<0.05)	**34**	**4**	**414**	**72**	**8**	**1184**
	Total of 3 harvests	1081	107	14202	2442	267	34222
	H0	9794	621	106025	5337	345	59252
	LSD (P<0.05)	**556**	**49**	**6158**	**258**	**17**	**3097**

digestible nutrients/ha than sequential harvests during the growing season. Landholders in the region could well consider a vetch-barley mixture as an alternative source of fodder for their livestock during winter and spring.

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