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Short communication. Harvest stage effects on forage yield and quality for rape and turnip genotypes

M. Sincik, U. Bilgili, A. Uzun and E. Acikgoz*

Department of Field Crops. Faculty of Agriculture. Uludag University. 16059 Bursa. Turkey

Abstract

The effects of two different harvest stages (full flowering and full podding) on forage yield and quality of ten forage rape (*Brassica napus* L. var. *oleifera)* and three turnip (*Brassica rapa* L. var. *rapa)* cultivars were evaluated under rainfed conditions in a Mediterranean type climate at Bursa, Turkey, during the 2002/2003 and 2003/2004 growing seasons. Plant height, branches per plant, leaf length and width, plant part components, and dry matter (DM) and crude protein (CP) yield were measured. Significant differences were observed for the main effects cultivar and harvest stage on DM and protein yields. The CP content of the whole plant and vegetative parts of the *Brassica* genotypes decreased as plant maturity progressed. In general, turnip cultivars showed better performance in DM yield. Fall sown turnip produced 9.10 and 12.1 Mg ha^{-1} DM yield, with 15.1 and 9.10% CP concentrations, at full flowering and at podding stage, respectively. Significant differences were noted among cultivars for these two parameters. Protein content decreased dramatically in stem parts when maturity advanced from full flower to full pod stages. High leaf percentage and high protein content at full flowering suggest that this should be the preferred forage harvest stage for rape and turnip cultivars.

Additional key words: *Brassica napus* L. var. *oleifera, Brassica rapa* L. var. *rapa,* crude protein, dry matter yield, plant proportions.

Resumen

Comunicación corta. Efecto del momento de la recolección sobre la producción y la calidad del forraje en genotipos de colza y nabo

Se evaluaron los efectos de dos momentos diferentes de la recolección (en flor o vaina completada) sobre la producción y calidad del forraje en 10 cultivares forrajeros de nabo (*Brassica napus* L. var. *oleifera)* y tres de colza (*Brassica rapa* L. var. *rapa)* en Bursa, Turquía, una zona de clima mediterráneo con precipitaciones, durante las campañas 2002/2003 y 2003/2004. Se midió la altura de las plantas, ramas por planta, longitud y anchura de hoja, componentes de partes de las plantas, y producción de materia seca (MS) y proteínas crudas (PC). Se observaros diferencias significativas para los principales efectos cultivar y momento de la recolección sobre el rendimiento en MS y PC. El contenido en PC de la planta completa y partes vegetativas de los genotipos de *Brassica* estudiados disminuyeron al avanzar la maduración de la planta. En general, los cultivares de nabo dieron mejor producción de MS. Nabos sembrados en otoño produjeron 9,10 y 12,1 Mg ha^{-1} de MS, con concentraciones de PC de 15,1 y 9,10%, en los momentos de flor o vaina completas, respectivamente. Para estos dos parámetros se observaron diferencias significativas entre cultivares. El contenido en proteínas disminuyó dramáticamente en partes del tallo cuando la planta pasó del estado de flor completa a vaina completa. La detección de un alto porcentaje de hojas y de contenido en proteínas en cultivares de colza y nabo en el estadío de flores completas sugieren que éste debe ser el momento preferido para la recolección.

Palabras clave adicionales: *Brassica napus* L. var. *oleifera, Brassica rapa* L. var. *rapa,* proteína cruda, rendimiento de materia seca, proporciones de plantas.

Forage *Brassica* crops produce high yield of leaves and roots of high nutritive value at two critical periods in the year, the first in mid-summer and the second in late fall to early winter when most warm and cool-season grasses are unproductive (Wiedenhoeft, 1993; Reid *et al*., 1994; Wiedenhoeft and Barton, 1994). *Brassica* forage has high quality and digestibility and retains its nutritive value longer than a traditional grass-legume pasture, as well as after frost (Kay, 1975;

* Corresponding author: esvet@uludag.edu.tr
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Koch and Mitchell, 1985; Guillard and Allinson, 1988). Therefore, forage *Brassicas* are often used in cool regions for livestock production (Claridge, 1972; Macfarlane Smith *et al*., 1984).

Jung *et al*. (1986) reported yields of more than 7.01 Mg ha^{-1} roots and leaves, 90 d after planting in the majority of 19 cultivars of forage *Brassica* spp. Guillard and Allison (1988) reported total plant yields of 5.10 to 8.30 Mg ha^{-1} for several *Brassica* species planted in mid-June and harvested 100 d after planting in Connecticut, USA conditions. The authors concluded that decreasing temperature and light intensity reduced herbage production of rape (*Brassica napus* L. var. *oleifera*), but not that of turnip (*Brassica rapa* L. var. *rapa*) or turnip hybrids. Wiedenhoeft (1993) reported that the amount of forage produced by *Brassica* plants averaged 3.10 Mg ha^{-1} during summer and 3.60 Mg h^{-1} during fall and early winter. To maximize total dry matter (DM) yield and maintain good protein and energy levels, these crops should be cut any time from early podding stage (just after the flowers have dropped) up to the stage where the lower leaves are starting to drop. When *Brassica* species were cut at the early to mid-podded stage of development, protein content averaged 14-15% and total digestible nutrients (TDN) were 58-60% in a DM basis (Anonymous, 2004).

In general, fall sowing result in higher yields than spring sowing in the Mediterranean basin. Fall sown pea (*Pisum sativum* L.) and common vetch (*Vicia sativa* L.) produced a greater forage and seed yield than when these species were sown in the spring (Cousin, 1976; Aydogdu and Acikgoz, 1995; Uzun and Acikgoz, 1998). Similarly, forage turnip seed was successfully produced in fall seeded plots under rainfed conditions in a Mediterranean-type environment (Bilgili *et al*., 2003). Forage *Brassica* cultivars are widely grown in the northern European countries. Sometimes oil cultivars of *Brassica napus* var. *oleifera* are seeded for forage production in Turkey and forage yield performance of different *Brassica* species has not been well documented. The aim of this study was to determine the effect of different harvest stages on forage yield and quality of cultivars of two *Brassica* species, in a region with Mediterranean climate, under fall seeding conditions.

A field study was carried out at Uludag University, Faculty of Agriculture, in Bursa, Turkey (40° 11' North, 29° 04' East, 70 m above sea level) during 2002/2003 and 2003/2004 growing seasons. The soil was clay loam, classified as vertisol typic habloxrert, slightly alkaline (pH 7.21) clay loam, with 180 kg ha^{-1} potassium and 71.3 kg ha^{-1} phosphorous, and low (1.42%) organic matter. The climatic zone is characterized by a Mediterranean-type climate with long-term (1928-2001) total annual precipitation of 700 mm yr^{-1}, pan evaporation 1,048 mm yr^{-1}, annual mean temperature 14.6°C and average relative humidity 68%. Temperature, rainfall and relative humidity values during growing season (November-June) are shown in Table 1. The minimum temperatures were –11.7ºC on 23 February 2003 and –15.8ºC on 15 February 2004.

Factorial arrangements of two harvest stages (full flowering and full podding) of 13 cultivars from two *Brassica* species were evaluated in a randomized complete block design with three replications. *B. napus* var. *oleifera* cultivars Bristol (Monsanto Seeds Ltd., Turkey); Campari, Caramba, Jumbo, Tapir, and Torero

Table 1. Monthly rainfall, mean temperature and relative humidity in 2002/2003, and 2003/2004 growing seasons, and long term (1928-2001) averages

Months	2002/2003			2003/2004			Long-term		
	Monthly rainfall (mm)	Mean temp. (°C)	Relative humidity (%)	Monthly rainfall (mm)	Mean temp. (°C)	Relative humidity (%)	Monthly rainfall (mm)	Mean temp. (°C)	Relative humidity (%)
November	67.9	10.7	72.6	64.5	10.1	74.4	76.3	9.30	74.6
December	28.8	5.01	67.0	91.0	6.20	74.2	99.9	6.10	70.2
January	65.3	8.60	74.8	154.8	5.01	58.4	88.8	6.20	75.2
February	106.2	2.70	72.5	72.6	5.10	68.3	77.5	6.60	65.2
March	33.1	4.40	71.7	62.1	9.40	64.8	69.8	8.50	67.4
April	112.1	9.90	69.9	50.4	13.1	67.5	62.9	14.0	59.8
May	45.7	18.8	69.2	22.8	17.6	62.4	50.0	17.9	67.9
June	2.40	23.8	61.1	37.5	22.6	62.0	30.4	21.6	58.3
Total/Mean	461.5	10.5	69.8	555.7	11.1	66.5	555.6	11.3	67.3

(Hans-Georg Lembke KG, Germany); Emerald, English Giant, Hobson, and Interval (Advanta Seeds Ltd., UK); *B. rapa* var. *rapa* cultivars Lenox and Malvira (Hans-Georg Lembke KG, Germany), and Polybra (Mommersteeg International, The Netherlands) were used. Each plot consisted of 8 rows, 10 m long, with 17.5 cm row spacing. Seeding rate was 5 kg ha^{-1} for all cultivars. The experiments were sown with an oyjort experimental drill on 5 November 2002 and 24 October 2003.

Trifluralin was sprayed at 1.0 kg ha^{-1} after sowing for weed control. Hand-hoeing was carried out when necessary. Nitrogen fertilization of 100 kg ha^{-1} after sowing and 50 kg ha^{-1} in spring was uniformly applied to all plots as ammonium nitrate. There were no significant problems with pests, diseases or weeds during the course of the study.

Ten plants were removed at random from each plot at full flowering stage (early May) and full podding stage (early June) for morphological measurements. Plant height, branches per plant, leaf length and width (8th leaf on plant) were measured, as well as morphologic proportional determinations and crude protein (CP) analysis on separate part constituents (leaf, stem and flower/pod). All plant components were dried and weighed. The forage yield was determined from 2.8 m^2 of each plot and 200 g sub-samples were dried in ovens at 70ºC for 48 h for DM yield determination (Martin *et al*., 1990). Dried samples were ground and nitrogen content determined using the Kjeldahl method. The nitrogen content from each sample was then multiplied by factor 6.25 to calculate CP content.

Analysis of variance was performed on morphological measurements and dry matter yield using MINITAB (Release 14 for Windows, University of Texas at Austin, TX) and MSTAT-C (Version 2.1, Michigan State University, East Lansing, MI) programs. The significance of treatment, main effects, and interactions were determined at the 0.05 and 0.01 probability levels, using the F-test. The F-protected least significant difference (LSD) was calculated at the 0.05 probability level. Mean comparisons of *B. napus* var. *oleifera* and *B. rapa* var. *rapa* were carried out by orthogonal contrasts using JMP 5.0 program (SAS Inst., 2002).

There were significant effects from most sources of variation on the measured parameters at both full flowering and full podding harvest stages of the *Brassica* cultivars in individual and combined years. Cultivars × year interactions were not significant for DM and protein yield, as well as for most other measured components. Therefore results for the two growing seasons were combined (Table 2).

Plant height, leaf width and leaf length at full flowering and podding stages were significantly influenced by cultivar. In general, plant height differences between rape and turnip cultivars were negligible at both harvest stages. At full podding stage, Emerald and English Giant were the tallest (157 cm), while Bristol was the shortest (109 cm) among the rape cultivars. Polybra was the shortest (122 cm) turnip cultivar. Turnip cultivars, in average, had more branches per plant than rape cultivars at both full flowering (4.87 *vs* 6.59, respectively), and full podding stages (6.03 *vs* 7.15, respectively). Turnip cultivars also had longer leaves than rape cultivars at both full flowering (16.0 *vs* 15.0 cm, respectively), and full podding stages (18.0 *vs* 15.9 cm, respectively). However, turnip cultivars had narrower leaves than rape cultivars at both full flowering (6.12 *vs* 6.98 cm, respectively), and full podding stages (6.99 *vs* 7.87 cm, respectively). Plant height and leaf dimensions of both species increased at the later growing stage, as plants developed (Table 2).

Overall, the average DM yield of turnip cultivars (7.78 and 10.3 Mg ha^{-1}) was higher than that of rape cultivars (5.78 and 6.32 Mg ha^{-1}) at both full flowering and full podding stages, respectively (Table 2). Although significant difference between turnip and rape cultivars was not found for DM yield at both harvest stages in orthogonal contrast tests, Malvira turnip cultivar was consistently superior at both harvesting stages, with average DM yield of 9.12 and 12.1 Mg ha^{-1}, respectively. On the other hand, Emerald was the most productive rape cultivar at both harvest stages, with DM yield of 7.35 and 8.91 Mg ha^{-1}, respectively. Crude protein content of *Brassica* cultivars decreased as plant maturity advanced, with average values for rape and turnip cultivars of 12.6 and 14.2%, respectively, at full flowering, compared to 7.77 and 9.17% when harvest was performed at full podding stage (Table 2). These values indicate that turnip cultivars had significantly higher protein content than rape cultivars. The orthogonal contrast test also confirmed that the difference in CP content between rape and turnip cultivars was significant at both harvest stage.

Total CP yield also decreased as plant maturity advanced, with average values for rape and turnip cultivars of 716 and 1,099 kg ha^{-1}, respectively, at full flowering, compared to 492 and 914 kg ha^{-1} when harvesting at full podding stage (Table 2). Orthogonal contrast tests showed that total CP yield difference between

Table 2. Effect of harvesting at two growth stages on the forage yield and quality of several cultivars of two *Brassica* species (average of two growing seasons, 2002/03 and 2003/04)

Cultivars	Plant height (cm)	Branches/ plant	Leaf length (cm)	Leaf width (cm)	Dry matter yield (Mg ha^{-1})	Crude protein (%)	Crude protein yield (kg ha^{-1})
Full flowering harvest stage							
B. napus var. *oleifera* cultivars							
Bristol	99	3.51	11.3	4.92	4.92	12.5	607
Campari	114	6.23	16.7	6.28	6.03	11.6	688
Caramba	104	3.50	16.5	6.30	6.32	12.5	781
Emerald	117	3.22	17.8	6.32	7.35	12.4	901
English Giant	119	3.81	18.0	6.11	6.48	12.5	802
Hopson	119	3.42	16.2	7.22	6.76	12.9	847
Interval	121	6.75	16.7	5.75	5.50	12.7	698
Jumbo	104	5.80	13.8	4.90	3.61	13.4	466
Tapir	110	6.71	14.9	5.82	5.38	12.2	645
Torero	123	5.76	18.5	7.63	5.52	13.5	730
B. rapa var. *rapa* cultivars							
Lenox	111	5.62	15.6	7.71	7.60	14.5	1,087
Malvira	111	6.01	16.8	7.93	9.12	15.1	1,357
Polybra	109	8.15	12.7	5.30	6.64	13.2	854
$LSD_{0.05}$	8.93	0.84	1.81	0.86	1.10	0.71	129
CV(%)	6.2	13.2	10.1	10.8	15.1	5.0	4.4
Contrast[a]	*	**	**	ns	ns	**	ns
Full podding harvest stage							
B. napus var. *oleifera* cultivars							
Bristol	109	4.71	14.7	6.55	5.42	7.92	430
Campari	138	6.62	18.0	6.71	6.15	7.20	435
Caramba	147	5.48	18.3	6.83	6.96	7.61	528
Emerald	157	6.30	20.8	7.56	8.91	7.63	687
English Giant	157	5.31	18.9	6.88	6.93	7.88	552
Hopson	146	5.92	16.2	7.32	7.05	8.04	568
Interval	127	6.53	18.2	6.80	6.18	7.92	496
Jumbo	121	6.26	16.9	6.01	3.66	7.91	283
Tapir	135	7.28	17.8	6.52	5.74	7.42	425
Torero	150	5.92	20.6	8.73	6.22	8.20	515
B. rapa var. *rapa* cultivars							
Lenox	151	6.20	16.8	8.15	10.1	9.13	897
Malvira	150	6.71	16.5	8.83	12.1	9.17	1,080
Polybra	122	8.54	14.3	6.64	8.82	9.21	764
$LSD_{0.05}$	8.61	0.68	1.41	0.51	1.22	0.64	109
CV(%)	5.3	9.9	7.1	5.9	14.6	6.9	15.9
Contrast[a]	ns	ns	ns	*	ns	**	ns

[a] Orthogonal contrast *B. napus* var. *oleifera* vs *B. rapa* var. *rapa*. *, ** Significant at the 0.05 and 0.01 level. ns: not significant.

rape and turnip cultivars was not significant. However, among the rape cultivars, Emerald consistently had the highest CP yield and Jumbo the lowest at both harvest stages. Among the turnip cultivars, Malvira had the highest CP yield and also consistently out-yielded all other rape cultivars (Table 2).

Dry matter yields of *Brassica* crops in the present study were similar to those of earlier reports. Harper and Compton (1980) reported that harvest date significantly affected DM yield and leaf-stem ratio of *Brassica* crops. Jung *et al*. (1986) found that DM yields for 13 of 19 *Brassica* cultivars exceeded 7.01 Mg ha^{-1}. Reid *et al*. (1994) examined the yield potential of five *Brassica* cultivars in USA. They found that DM yield ranged from 5.60 to 10.5 Mg ha^{-1}, which were generally similar to values of 7.01 and 9.01 Mg ha^{-1} reported by Jung *et al*. (1984) for forage turnip and rape, respectively, grown with minimum tillage, and high N and P fertilization levels in Pennsylvania, USA. Rao and Horn (1986) obtained a DM yield of rape near 7.01 Mg ha^{-1} at El Reno, OK, in the southern US Plains. Altinok and Karakaya (2003) found that the rape cultivar Emerald was the most productive in Turkey, with a DM yield of 5.50 Mg ha^{-1}.

Since turnip plants developed more quickly in early spring and flowered 12-15 d earlier than rape (mid April *vs*. beginning of May), turnip cultivars generally produced higher DM yield than rape cultivars in Mediterranean-type environments. In this study, climatic conditions of early spring (average temperature of 6.90°C and rainfall 47.6 mm in March and 11.5°C and 81.2 mm in April) were very suitable for vegetative development of turnip plants. However, rapid onset of high temperatures and water deficit in late spring depressed the vegetative development of the rape cultivars. The mean temperature in May (flowering period of rape) increased to 18.2°C and rainfall decreased to 34.2 mm. Similar to what has been indicated by several other researchers (Guillard and Allison, 1988; Undersander *et al*., 1991; Rao and Horn, 1995), in the present study fall sown turnip plants developed quickly and produced high DM yield with high protein content under the cool and moist conditions of early spring.

The DM proportions, and CP content and yield for the different plant components, at both harvest stages, are shown in Table 3. Harvest stage had a significant effect on the DM partitioning of plant parts. Even though the leaf component of *Brassica* cultivars decreased from full flowering to full podding, the flower + pod portion increased. However, the stem component was not affected by the stage at which plants were harvested. The average leaf component of the total plant mass decreased from flowering to podding stage, from 26.5% to 6.81% in the rape cultivars and from 29.1% to 7.84% in the turnip cultivars, respectively. The flower + pod fraction increased from flowering to podding stage, as expected. The general average proportion of flower + pod was 15.6% at flowering stage, and rapidly increased to 38.9% at podding stage. Crude protein content varied significantly between plant parts. The flower + pod component had the highest CP content while the stem component had the lowest at both harvest stages. Particularly at podding stage, stems had very low CP content (3.11%), which was a 31.0% decrease from the flowering stage. Leaf and flower + pod contributed to CP yield almost equally at flowering stage (36.4 and 35.4%, respectively). Contrarily, flower + pod parts produced 68.2% of the CP yield at podding stage, while the contribution of leaves and stems to CP yield dropped to 8.80 and 23.0%, respectively (Table 3).

The CP results obtained in the present study were supported by reports from several researchers. For example, Rao and Horn (1995) found CP content values of 16.0% in 1983 and 23.0% in 1984, 95 d after seeding rape. They stated that CP content of rape ranged from 20.0-25.0% in leaves and averaged 10.0% in the stems. They also indicated that the CP content of all plants parts declined with maturity and that this decline was more rapid for the stem component. These authors attributed this rapid decline of CP to increasing DM accumulation rate and N dilution during this growth period. Other researchers concluded that the CP concentrations in the leaves of kale (*B. oleracea* L.) and turnips also declined with time (Pelletier *et al*., 1976; Reid *et al*., 1994).

In conclusion, fall sown *Brassica* genotypes, particularly turnip cultivars, have the potential to provide additional or supplemental forage with high DM and CP yield in the early summer of a region with quite mild winters. According to our results, DM yield of most *Brassica* genotypes was slightly increased by later harvest. However, full flowering stage with high leaf percentage and high CP content must be the preferred harvest stage of *Brassica* forage production.

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Table 3. Effect of harvesting at two growth stages on the crude protein content and yield in different plant components of several cultivars of two *Brassica* species (averages of 2 yr)

Cultivars	Plant part proportions (%)			Crude protein (%)			Crude protein yield (kg ha^{-1})		
	Leaf	Stem	Flower/ pod	Leaf	Stem	Flower/ pod	Leaf	Stem	Flower/ pod
Full flowering harvest stage									
B. napus var. *oleifera* cultivars									
Bristol	24.3	56.3	19.3	11.3	3.61	17.5	142	98	150
Campari	27.8	57.7	14.5	10.5	3.42	17.5	147	113	180
Caramba	30.2	58.0	11.8	12.4	3.83	17.4	189	138	180
Emerald	29.7	58.8	11.5	11.3	4.15	19.3	202	177	232
English Giant	29.2	59.2	11.7	11.2	3.70	18.9	175	139	189
Hopson	28.2	60.0	11.8	13.2	5.11	20.5	211	201	212
Interval	20.3	58.3	21.3	12.5	4.95	19.3	162	159	192
Jumbo	25.3	54.5	20.2	13.1	5.01	20.8	124	94	131
Tapir	21.8	56.8	21.0	11.6	3.83	17.5	144	115	184
Torero	28.3	58.5	13.2	13.0	4.98	21.2	177	156	184
B. rapa var. *rapa* cultivars									
Lenox	30.3	55.7	14.0	15.5	5.12	24.7	325	215	307
Malvira	32.2	53.0	14.8	16.0	6.38	22.4	431	318	343
Polybra	25.0	55.0	20.0	14.1	4.31	19.5	241	151	226
$LSD_{0.05}$	3.34	3.30	2.86	1.15	0.58	1.98	49.7	51.6	64.1
CV(%)	10.4	4.95	11.0	7.29	9.46	8.34	6.63	8.76	7.84
Contrast[a]	**	*	**	ns	ns	**	ns	ns	ns
Full podding harvest stage									
B. napus var. *oleifera* cultivars									
Bristol	6.22	56.3	37.5	7.98	2.55	12.2	28.2	86.2	247
Campari	8.35	52.8	38.8	7.35	2.42	12.3	36.5	84.7	288
Caramba	5.78	55.3	39.0	8.71	2.74	12.2	34.1	105	336
Emerald	7.51	51.2	41.3	7.96	2.92	13.5	50.4	142	504
English Giant	8.26	55.0	36.8	7.94	2.61	13.2	44.5	103	346
Hopson	6.02	52.7	41.3	9.20	3.66	15.3	39.3	137	410
Interval	5.80	54.3	39.8	8.72	3.40	14.4	31.1	121	336
Jumbo	5.82	60.2	34.0	9.26	3.54	15.3	20.2	75.2	186
Tapir	6.59	52.5	41.0	8.22	2.78	12.3	30.8	83.1	286
Torero	7.71	52.7	39.5	9.14	3.51	14.9	42.1	117	365
B. rapa var. *rapa* cultivars									
Lenox	8.32	57.8	33.8	11.7	3.62	16.5	100	208	546
Malvira	7.88	54.0	38.2	11.8	3.96	14.7	112	254	671
Polybra	7.34	56.0	36.7	11.0	3.34	14.4	72.1	155	457
$LSD_{0.05}$	1.73	2.92	2.81	0.72	0.33	1.35	20.2	26.4	87.1
CV(%)	18.1	4.66	6.27	6.57	9.35	8.35	11.2	5.58	6.21
Contrast[a]	ns	**	**	ns	ns	**	*	**	ns

[a] Orthogonal contrast *B. napus* var. *oleifera* vs *B. rapa* var. *rapa*. *,** significant at the 0.05 and 0.01 level. ns: not significant.

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