Turkish Journal of
Field Crops
2014, 19(2), 197-202

DRY MATTER YIELD AND SILAGE QUALITY OF SOME WINTER CEREALS HARVESTED AT DIFFERENT STAGES UNDER MEDITERRANEAN CLIMATE CONDITIONS

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Received: 28.03.2014

ABSTRACT

Winter cereals can provide feed earlier than annual grasses since they are generally more adaptable to early sowing due to their higher tolerance of dry conditions. Cereals are also better suited to single-cut silage-making, whereas annual grasses require multiple cuts or grazings to be fully utilised. A field and laboratory experiments were conducted to evaluate the effect of different harvest stages on the dry matter yield and silage quality of some winter cereals, during 2009-2011 growing season. Effects of three different harvest stages (early heading, milky stage, mid-dough stage) on five cereals (*Hordeum vulgare*, *Triticum aestivum*, *Secale cereale*, *Triticosecale*, *Avena sativa*) were tested. The experiment was arranged in split block with four replications. Results indicated that, it was possible to produce an average of 10.9 t ha^{-1} dry matter yield and an average of 9.2% crude protein content at mid-dough stage in regions with Mediterranean-type climates. It was also concluded that *Avena sativa* should be preferred for high biomass yield and should be cut at the beginning of mid-dough maturity stages for higher quality silage.

Key words: winter cereals, harvest stages, dry matter yield, silage quality, CP, ADF

INTRODUCTION

Producers have some problems in meeting the required feed for livestock in some regions of the world. Winter cereals, to overcome these obstacles, supply an important alternative. In addition to using the grain feed, the entire plant can be used as ensiled roughage when harvested at the milk-dough stage (Delogu et al., 2002). Harvesting small grain cereals for forage has several advantages: i) land might be double cropped, ii) the risk of crop loss from rain, wind or hail is decreased, iii) circumstances sometimes make it desirable, even, necessary, to use these crops for forage even though they were planted for another purpose, e.g., weather stressed wheat with a low level of grain production might be more profitable if harvested as forage.

Such silage is best exploited in environments with low rainfall. On the other hand, harvesting the entire crop at the milk-dough stage in an environment marked by high fertility and good water supply makes it possible to maximize yields per unit area via double-cropping such as winter cereal + summer crop (Siefers and Bolsen, 1997).

Many of studies that have focused on the yield and quality potential of various cereal species ear-marked for whole-plant silage production (Bocchi et al., 1996) have found that their high variability in yield and nutritive value are linked to year and environment. Indeed, it is a known fact that the nutritional value of forages is dependent largely on seasonal temperature, light and rainfall trends, soil type, energy inputs applied over the growing cycle and, to a lesser extent, to the cultivar within the species.

If winter cereal crops are to be harvested for silage, management recommendations are needed to obtain the best compromise between forage yield and quality for a given farm situation or weather conditions. On the other hand, stage of maturity at harvest has a major effect on yield and quality of cereals (Cherney and Martin, 1982; Bergen et al., 1991). Although Schneider et al. (1991) found little effect of stage of maturity at harvest on triticale silage quality, Ben-Ghedalia et al. (1995) found that the quality of silage made from cereals declined with maturity at harvest. Yield increases and quality declines as the crop matures, although in cereals, quality may keep improve as grain development takes place (Khorasani et al., 1997; Budaklı Çarpıcı et al. 2010). The optimal stage of harvest for barley and oat to maximize yield and quality traits is the soft-dough stage (Bergen et al., 1991; Juskiw et al., 2000); while for triticale and rye it ranges from the boot to early milk stages (Twidwell et al., 1987; Schneider et al., 1991). Research in other areas has shown little difference in forage yield among oats (*Avena sativa*), barley (*Hordeum vulgare*) and triticale (*x Triticosecale*) when harvested for silage (McCartney and Vaage, 1994).

Barley was shown to have better forage quality as compared to oats due to its greater proportion of highly-digestible inflorescence during development (Cherney and Martin, 1982). Brink and Martin (1986) also found higher digestibility in barley as compared to oats, but this did not translate to higher yields of digestible dry matter. In this sense it is important to know the relations of production and quality as the crop proceeds phenology to determine the right time to cut, especially for animals with high requirements for winter cereals.

The objective of this experiment was to evaluate the agronomic performance and optimum cutting time for silage making in different winter cereals under Mediterranean climatic conditions.

MATERIALS AND METHODS

Location of Experiment

The experiment was carried out during 2009 and 2011 growing season (Table 1) on a silty-clay loam soil with 7.8 pH (Table 2) at Bornova experimental area (38°27.236 N, 27°13.576 E) in Agricultural Faculty of Ege University, Izmir, Turkey, at about 20 m a.s.l. with typical Mediterranean climate characteristics.

Table 1: Monthly average temperatures and total precipitations recorded at Bornova-Turkey location during the 2009 and 2011 growing seasons

	------- Temperature (°C) -------			------- Total precipitation (mm) -------		
	2009-10	**2010-11**	**LA**	**2009-10**	**2010-11**	**LA**
November	14.6	18.1	13.2	160.3	32.4	80.3
December	13.1	13.3	9.9	151.8	155.7	122.3
January	10.6	9.0	8.1	143.2	100.9	109.7
February	12.6	10.3	8.6	301.3	107.3	89.8
March	13.3	12.0	10.8	16.1	18.8	72.3
April	17.4	14.5	15.0	20.4	65.3	48.9
May	21.8	20.1	20.2	27.1	29.0	32.2
Mean or total	14.8	13.9	12.3	820.2	509.4	555.5

LA: Long-term average

Table 2: Soil characteristics of the experiment area

Soil (0-30 cm)			
Sand (%)	32.7	pH	7.8
Clay (%)	30.6	OM (%)	1.1
Silt (%)	36.7	N (%)	0.1
$CaCO_3$ (%)	18.6	P (ppm)	0.4
Salt (%)	0.07	K (ppm)	400

Field applications and experimental design

Five winter cereals (*Hordeum vulgare* [Akhisar-98], *Triticum aestivum* [Cumhuriyet-75], *Secale cereale* [Aslim-95], *Triticale* [Ege yıldızı], *Avena sativa* [Faikbey]) and three harvest stages (*i*: early heading, *ii*: milky stage, *iii*: mid-dough) were tested. The experimental design was a split plot arrangement of a randomized complete block with four replications. The harvesting stages were main plots, and cereals were sub-plots. Each sub-plot was consisted of 10 rows with 20 cm apart and 5 m length (10 m^2).

All cultivars were sown by hand on 15th November in both years (2009-2010), at a density of 350 viable seeds m^{-2}, in to the field which pioneer crop was forage turnip. The basic pre-sowing fertilization rates for all plots were 30 kg N ha^{-1}, 35 kg P ha^{-1}, 35 kg K ha^{-1}; a top dressing of 120 kg N ha^{-1} was applied as follows; 50% of total N at the 3-4 leaf stage and the remainder at the early stem elongation stage.

Measurements, silage making and chemical analysis

Plots were harvested at 3 different stages of cereals, cutting mid 6 rows of plots in order to avoid border effects (net 4.8 m^2), by cutting the plants leaving a 3-5 cm stubble height. Harvested fresh forage were weighed and dried to a constant weight at 65ºC during 48 h. In each plot 5-6 kg of fresh mixture samples were taken at the stage and were chopped mechanically then wilted for 24 h. The samples without additives were pressed using a special apparatus (Petterson, 1988) into glass jars of 3 litres capacity. The jars were then tightly sealed and kept in storage without light for app. 70 days for fermentation.

pH value of matured silage samples was also determined (Alcicek and Ozkan, 1996). Matured silage samples of each component were dried at 65ºC for 48 h. The dried samples were reassembled and ground in a mill passed through a 1 mm screen. The crude protein (CP) was calculated by multiplying the Kjeldahl N concentration by 6.25. The neutral detergent fibre (NDF) and acid detergent fibre (ADF) concentrations were measured to Ankom Technology.

Statistical analysis

All data were statistically analyzed using analysis of variance (ANOVA) with the Statistical Analysis System (SAS, 1998). Probabilities equal to or less than 0.05 were considered significant. If ANOVA indicated differences between treatment means a LSD test was performed to separate them (Stell et al., 1997).

RESULTS AND DISCUSSION

Experimental area is located in the Mediterranean zone of the country with quite mild winters and hot summers. Field studies were started in late autumn with low air temperature and satisfactory moisture levels were experienced in the germination and emergence period of relatively small seeds. Therefore, stands were excellent in both years. The results are summarized in Table 3 and 4. The year effect was the main source of variation in all characters tested, while the Year x Cereal x Harvest Stages (YxCxHS) interactions for all traits were not significant but for dry biomass yield and CP content.

Table 3: Effect of different harvest stages on the plant height, dry matter yield and silage pH values of some winter cereals.

	---------- 2010 ----------				---------- 2011 ----------				--------- 2 yrs average ---------			
Cereals	I	II	III	Mean	I	II	III	Mean	I	II	III	Mean
	---- Plant height (cm) ----											
Barley	96.4	100.4	101.1	99.3	89.6	92.1	90.1	90.6	93.0	96.3	95.6	95.0
Wheat	86.8	97.9	100.5	95.1	92.4	97.8	91.8	94.0	89.6	97.8	96.2	94.5
Rye	86.8	102.3	104.7	97.9	74.7	85.4	88.3	82.8	80.7	93.9	96.5	90.3
Triticale	120.4	124.4	126.1	123.6	117.9	120.3	140.1	126.1	119.2	122.4	133.1	124.9
Oat	134.5	182.1	185.3	167.3	106.2	111.7	122.0	113.3	120.4	146.9	153.7	140.3
Mean	105.0	121.4	123.6	116.7	96.2	101.5	106.5	101.4	100.6	111.4	115.0	109.0
LSD (.05)	Year (Y):4.6 Cereal (C):7.3 Harvest Stage (HS):5.6											
	YxC:10.3 YxHS:ns CxHS:12.6 YxCxHS:ns CV(%):10.1											
	---- Dry matter yield (kg ha^{-1}) ----											
Barley	6062	8167	10588	8272	5430	6897	10097	7474	5746	7532	10342	7873
Wheat	5931	7208	9494	7544	5993	6622	9153	7256	5962	6915	9323	7400
Rye	5244	6774	9541	7186	3214	5767	8131	5704	4229	6270	8836	6445
Triticale	7480	9147	12517	9715	7913	9795	13707	10472	7697	9471	13112	10093
Oat	7667	9102	13096	9955	6858	9989	12935	9927	7263	9546	13016	9941
Mean	6477	8079	11047	8535	5882	7814	10804	8167	6179	7947	10926	8351
LSD (.05)	Y:134 C:211 HS:164 YxC:298 YxHS:ns CxHS:366 YxCxHS:517 CV(%):3.82											
	---- Silage pH ----											
Barley	4.68	4.41	4.01	4.37	4.47	4.33	4.27	4.36	4.58	4.37	4.14	4.36
Wheat	5.53	4.87	4.69	5.03	4.35	4.24	4.05	4.21	4.94	4.56	4.37	4.62
Rye	4.48	4.45	4.34	4.42	5.02	4.42	4.14	4.53	4.75	4.44	4.24	4.48
Triticale	4.28	4.26	4.16	4.23	4.46	4.14	3.97	4.19	4.37	4.20	4.06	4.21
Oat	4.41	4.38	3.98	4.26	4.87	4.16	3.83	4.29	4.64	4.27	3.91	4.27
Mean	4.68	4.47	4.23	4.46	4.64	4.26	4.05	4.32	4.66	4.37	4.14	4.39
LSD (.05)	Y:0.080 C:0.126 HS:0.096 YxC:0.176 YxHS:ns CxHS:0.215 YxCxHS:0.308 CV(%): 4.32											

(I: early heading stage, II: milky stage, III: mid-dough stage)

Plant height

The plant height was affected by YxC interactions. The highest plant height (167.3 cm) was obtained from oat in the first year, whereas the lowest was 95.1 cm for wheat in the first year. Year effect was also significant and average cereal height of first year (116.7 cm) was higher than the second year (101.4 cm) due to the average temperature and total precipitation of the first year which was clearly higher than second year (Table 2). The plant height was also affected by CxHS interaction that means the maximum plant height was recorded at mid-dough harvest stage in the first year (123.6 cm) and oat crop had the highest. The plant height of cereals increased with progressing harvesting stage in both years. There is diversity of information's about plant height of cereals that maturation is an important factor to increase plant height (McCartney and Vaage, 1994; De Ruiter et al., 2002).

Dry Matter Yield

The highest dry matter yield (13707 kg ha^{-1}) was obtained from triticale at mid-dough harvest stage in the second year, whereas the lowest yield (3241 kg ha^{-1}) was in rye at early heading harvest stage in the second year. Year effect was also significant and average dry dry matter yield of first year (8535 kg ha^{-1}) was higher than the second year (8167 kg ha^{-1}) because of favourable climatic parameters of the first year (Table 2). Two year average monitored that average dry matter yields across cultivars were 6179, 7947 and 10926 kg ha^{-1}, respectively (Table 3). Dry matter production increased with delaying harvesting stage and, triticale and oat were the most productive (~10 t ha^{-1}) cereals tested in the study. In the study, the dry matter yields of triticale and oat for three harvest stages were high; with an average 170% and 180% increase from early heading to milk dough, as expected and according to the data reported by Brink and Martin (1986) and Cherney and Martin (1982), respectively. This finding can be attributed to the completion of growing cycle by the crop and to the storage of newly formed photosynthetic activity in the grain. The accumulated dry matter by early heading is the determinant factor for the yield capacity of the subsequent growth stage (mid dough) and it is also largely dependent on the climatic conditions of the experimental environments (De Ruiter and Hanson, 2004; De Ruiter et al., 2002). Barley also showed the acceptable dry matter yield performance at both milky and mid dough harvests. In effect, the crop combines a high earliness with good cold tolerance (Pugnaire and Chapin, 1992).

Silage pH

Y x C x HS interaction was significant on silage pH. The favourable silage pH value (3.83) was obtained from oat harvested at mid-dough stage in the second year, whereas the highest pH (5.53) was in wheat harvested at early heading stage in the first year. Year effect was also significant on pH values and average pH of first year (4.46) was higher than the second year (4.32). Two year average showed that average pH values among harvest stages were 4.66, 4.37 and 4.14, respectively (Table 3). The most important physicochemical parameter for the evaluation of silage quality is a pH below 5, which was observed for all the silages tested. All indicators were characteristic of good silage conservation whatever the treatments were. The silage quality was especially confirmed by the proportion of fermentation products at the end of the storage period (Kristensen et al., 2010). Wheat silage at early heading stage had undergone secondary fermentations, which were characterized by the presence of some amounts of butyric acid and ammonia N (Siefers and Bolsen, 1997). All milky stage and mid-dough stage silages were satisfactorily preserved, as evidence by a pH range of 4.14 to 4.37. pH values of cereal silages decreased with delaying harvesting stage as expected because of the crops contained high level moisture and low level of carbohydrates in the first cut. Mid-dough triticale and oat silages performed slightly better than the other cereal silages and harvest stages in terms of pH values in the study.

Crude protein (CP) content

There were significant Y x C and Y x HS interactions for CP content of silages. The highest CP content recorded in oat in both years (11.9-11.8%) whereas the lowest CP was 9.4% for rye in 2010 (Table 4). CP content was also affected by YxHS interactions that mean the highest CP level was determined at early heading stage (12.3%) in 2011 whereas the lowest CP was at mid-dough stage (9.0%) in 2010. Between-year differences in CP invariably had greater influence than the cultivar and maturation effects. For example, mean CP content was significantly higher in 2011 (10.8%) than in 2010 (10.5%). The two year average has shown that average CP contents declined by increasing crop maturity. CP levels showed considerable variation in the silages of cereals. Generally, CP was lower for rye but was somewhat higher for oat and triticale. The largest variation in CP content occurred with the triticale (12.4 vs. 9.5%) depending on maturity. As with grass or legume silage production, cereal forage production is a compromise between forage quality and nutrient yield. As the crop developing from the boot to soft dough stage, CP content decreases and fiber concentration increases (Brand et al., 2003). On the other hand, both dry matter and CP yield increase with advancing maturity (Pereira-Crespo et al., 2010) and appear to be maximized at the soft dough stage. The difference in stage of maturity among the forages in the present experiment may have influenced both composition and yield. However, the effect was likely minimal since changes in nutrient density between the milk and soft dough stages appear to be relatively small (McCartney and Vaage, 1994).

Table 4: Effect of different harvest stages on the content of CP, NDF and ADF of some winter cereals silage.

	---------- 2010 ----------				---------- 2011 ----------				--------- 2 yrs average ---------			
Cereals	I	II	III	Mean	I	II	III	Mean	I	II	III	Mean
						Crude protein (%)						
Barley	11.7	10.1	8.6	10.2	11.7	10.0	9.0	10.2	11.7	10.1	8.8	10.2
Wheat	11.7	10.0	8.6	10.1	12.6	10.9	10.0	11.1	12.1	10.5	9.3	10.6
Rye	11.0	9.3	7.9	9.4	11.6	9.5	8.7	9.9	11.3	9.4	8.3	9.7
Triticale	12.6	11.0	9.4	11.0	12.3	10.8	9.5	10.8	12.4	10.9	9.5	10.9
Oat	13.6	11.7	10.1	11.8	13.5	11.7	10.7	11.9	13.5	11.7	10.4	11.9
Mean	12.1	10.4	9.0	10.5	12.3	10.6	9.5	10.8	12.2	10.5	9.2	10.7
LSD (.05)	Y:0.099 C:0.156 HS:0.121 YxC:0.220 YxHS:0.171 CxHS:ns YxCxHS:ns CV(%):2.21											
						NDF (%)						
Barley	55.3	57.4	60.0	57.6	52.1	55.2	58.5	55.3	53.7	56.3	59.3	56.4
Wheat	57.2	59.8	62.0	59.7	54.0	57.5	60.4	57.3	55.6	58.7	61.2	58.5
Rye	59.2	61.8	63.2	61.4	56.4	59.3	61.6	59.1	57.8	60.6	62.4	60.3
Triticale	58.0	60.5	61.5	60.0	54.8	58.1	60.3	57.7	56.4	59.3	60.9	58.9
Oat	53.1	54.6	56.2	54.6	49.4	51.5	53.7	51.5	51.3	53.1	54.9	53.1
Mean	56.6	58.8	60.6	58.7	53.4	56.3	58.9	56.2	55.0	57.6	59.7	57.4
LSD (.05)	Y:0.268 C:0.424 HS:0.329 YxC:ns YxHS:0.465 CxHS:0.735 YxCxHS:ns CV(%):1.11											
						ADF (%)						
Barley	35.4	37.4	38.9	37.2	32.3	35.3	38.0	35.2	33.9	36.3	38.5	36.2
Wheat	39.4	41.2	42.8	41.1	35.2	38.8	42.3	38.7	37.3	40.0	42.6	39.9
Rye	40.0	42.4	45.1	42.5	37.2	41.3	44.7	41.1	38.6	41.9	44.9	41.8
Triticale	34.0	35.9	38.5	36.2	31.2	33.2	37.1	33.8	32.6	34.6	37.8	35.0
Oat	29.9	32.1	35.4	32.5	27.2	30.5	34.6	30.8	28.6	31.3	35.0	31.6
Mean	35.7	37.8	40.2	37.9	32.6	35.8	39.3	35.9	34.2	36.8	39.7	36.9
LSD (.05)	Y:0.180 C:0.284 HS:0.220 YxC:0.402 YxHS:0.311 CxHS:0.492 YxCxHS:ns CV(%):1.16											

Neutral Detergent Fibre (NDF) content

There were significant Y x HS and C x HS interactions on NDF content of cereal silages. The favourable average NDF content (53.4%) was recorded at early heading stage in the second year, whereas the highest content (60.6%) was in the first year at mid-dough stage. On the other hand, the lowest average NDF content (51.3%) was determined in oat harvested at early heading stage, while the maximum NDF (62.4%) was in rye cut at mid-dough stage. Year effect was also significant (Table 4) and average NDF content of first year (58.7%) was higher than the second year (56.2%). The two year average demonstrated that average NDF content among harvest stages were 55.0%, 57.6% and 59.7%, respectively (Table 4). NDF contents of cereal silages increased with delaying harvesting stage as expected because of the progressing maturation of cereals. At large, mid-dough oat silage performed better than the other cereal silages with regard to NDF content in the study. The rye silage, however, had greater NDF concentrations than the other silages. It also had a greater ADF concentration than the other silages. Many research workers emphasized that rye silage is not a good option to feed livestock due to the lower quality and biomass yield (Neal et al., 2010,).

Acid Detergent Fibre (ADF) content

Excepting Y x C x HS interaction, all factors and their interactions were significant on ADF content of silages. Average ADF content of cereal silage in 2010 (37.9%) was higher than in 2011 (35.9%). Two year average shown that average ADF content among harvest stages (early heading, milky stage and mid-dough) were 34.2%, 36.8 and 39.7%, respectively (Table 4), while average ADF contents among cereal silages were 36.2%, 39.9%, 41.8%, 35.0% and 31.6% in barley, wheat, rye, triticale and oat, respectively. Generally, oat silage had performance better than the other cereal silages with regard to ADF content in the study. ADF contents of cereal silages increased from early heading stage to mid-dough stage that means maturation of cereals. Both the oat and triticale had lower ADF concentrations than the rye and wheat, despite their harvests at earlier stages of growth. These results were comparable to values reported by Pereira-Crespo et al. (2010) and Brand et al. (2003) for barley and oat harvested as forage at the milk to soft dough stage. Brand et al. (2003) also reported higher ADF levels for triticale compared with barley and oat. ADF levels in the barley silages, although higher than the wheat or rye silage, were very similar to values reported by many researchers (McCartney and Vaage, 1994; De Ruiter and Hanson, 2004).

CONCLUSION

Winter cereals can provide feed earlier than annual grasses like *Lolium italicum*, etc because they are generally more adaptable to early sowing due to higher tolerance of dry conditions. Cereals are also better suited to single-cut silage-making, whereas annual grasses require multiple cuts or grazings to be fully utilised. The results of our two-year study testing a total of five winter cereals (*Hordeum vulgare Triticum aestivum*, *Secale cereale*, *Triticale*, *Avena sativa*) showed that it was possible to produce an average of 10.9 t ha^{-1} dry matter yield with an average of 9.2% crude protein content at mid-dough stage in regions with Mediterranean-type climates. It was also concluded that *Avena sativa* should be preferred for high biomass yield and should be cut at the beginning of mid-dough maturity stages for higher quality silage.

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