Scientific Papers. Series D. Animal Science. Vol. LVII, 2014
ISSN 2285-5750; ISSN CD-ROM 2285-5769; ISSN-L 2285-5750

DRY MATTER PRODUCTION AND NUTRITIVE VALUE OF CEREAL SPECIES HARVESTED AT BOOT OR DOUGH STAGE OF MATURITY

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Abstract

*The comparative advantages of winter cereals have not been thoroughly evaluated for their forage production potentials in the semi-arid conditions of the Central Anatolian Region of Turkey. The effect of maturity on dry matter (DM) production (t/ha) and nutritive value of the whole-crop cereal forage of barley (*Hordeum vulgare L.*), wheat (Triticum aestivum* L.*), rye (*Secale cereale L.*), triticale (X* Triticosecale *wittmack) and oat (*Avena sativa L.*) were investigated at booting and dough stages of the forage cereals. Barley had higher (P<0.001) DM production at booting stage, whereas DM production of triticale, rye and oat was the highest (P<0.001) at the dough stage. Overall, the increase in DM production and digestible DM production with advancing maturity was 34, 42, 60, 49, 51 % and 23, 29, 51, 43, 38 % for barley, wheat, triticale, oat and rye, respectively at dough stage. The metabolizable energy values (ME MJ/kg DM) of cereal forages were higher (P<0.05) at booting stage. Neutral detergent fibre did not differ (P>0.05) with maturity or forage species, while non-fiber carbohydrates increased (P<0.001) with advancing maturity.*
In conclusion, all cereal crops should be harvested for forage production at their boot stage of maturity to obtain higher nutritive value forage. Barley provided more promising cereal forage at booting stage with its higher DM and digestible DM production. Triticale, rye and oat produced more DM at dough stage with triticale having higher digestible nutrients indicating its superior value compared to other cereal forages at this stage. However, the choice of cereal for forage production should include consideration of class and breed of livestock to be fed, agronomic characteristics and soil type requirements under the semi-arid conditions of Central Anatolia.

Keywords: *Cereal forage, digestibility, dry matter production, nutritive value.*

INTRODUCTION

The cereal crops are mainly grown for grain production in the Central Anatolia region where crop–livestock farming is a common practice. Despite the fact that high quality forage is in shortage in the region, using cereal crops for forage production is not a widespread practice. However, in a double cropping system, small grain forage cereals are sown as winter crops in rotation with maize planted in summer. In this system, the cost of the maize silage is often lower because early seeding allows maize to benefit from the late spring rains more efficiently and provides increased dry matter (DM) production. However, the low dry matter content of cereal crops in early stage of maturity requires longer wilting time which may pose a challenge for hay or silage productions, particularly in rainy weather conditions. On the other hand, as maturity advanced from boot to dough stage, dry matter content of cereal crop increases proportionally an average of 0.42 (Khorasani et al., 1997). At this DM level (over 350 g/kg), cereal crops do not require pre-wilting before ensiling to get sufficient silage fermentation (McDonald et al., 1991) and the time necessary to get well dried hay production is shorter. Moreover, when cereal crops reach the dough stage of maturity it is easier to produce well fermented silages or well dried hay with less soil contaminations due to more favourable and drier weather conditions in late spring. Furthermore, because high drying rate in late spring compared to early spring, less mechanization is needed to produce silage or hay production from cereal crop harvested at dough stage.

It is well documented that the DM production of cereal crops is low but the nutritive value of cereal crop is high when they are harvested at early stage of maturity (Helsel and Thomas, 1987; Crovetto et al., 1998; Beck et al., 2009). Because DM production are related to increased DM concentration and biomass accumulation with maturity, delaying the harvest time from boot to dough stages increases DM production. However, this may also reduce the nutritive value of the forages (Khorasani et al., 1997; Nadeau, 2007). There were also differences between cereal crops for their feeding value (Helsel and Thomas, 1987; Khorasani et al., 1993; Emile et al., 2007).

The studies investigating the effect of maturity on the DM production and nutritive value of different cereal species (barley, wheat, triticale, rye and oat) are not consistent and present significant variations. Moreover, few studies have assessed the responses to maturity of a wide range of cereal species which could be grown for forage production. The main aim of this study was to assess the DM production potential and nutritive value of barley, wheat, rye, triticale and oat to get the information necessary on which cereal species should be most advantageous when they are harvested at booting or dough stage of maturity.

MATERIALS AND METHODS

Establishment and experimental design

This study was carried out at Bahri Dagdas International Agricultural Research Institute (37° 51' N, 32° 33' E, 1008 m a.s.l.), Konya, Turkey from October 2010 to July 2011. The site was on a clay–loam soil with slightly alkaline characteristics. The cereal grains of barley (cv. "beysehir"), wheat (cv. "goksu"), rye (*cv* "aslim"), triticale ("tatlicak") and oat ("faikbey") were sown in 16 m x 78 m plots using a commercial grain drill with 0.2 m row spacing on 9 November. Treatments were arranged with three replicates. Based on soil test results, a total of 100 kg ha^{-1} fertilizer (18% N and 46% P_2O_5) was applied at sowing. Cereal grains were seeded at rates typical for the region, which were 210 kg/ha for wheat, 200 kg/ha for triticale, 172 kg/ha for rye 166 kg/ha for barley and 146 kg/ha for oat. 2.4–D was applied by small sprayers for weed control in each plot on 12 April. The dry matter production (kg/ha) of cereal crop was measured by three quadrat cutting selected to be representative of each plot in cereal crop's boot and dough stage of maturity. All herbage from the quadrat cuts was weighed and DM content was determined.

Meteorological data

Average mean temperature and monthly rainfall at the trial site during the growing season are presented in Table 1. Total rainfall was 396 mm between October 2010 and July 2011 which was 102 mm higher than the long–term average. Of note was that the higher than usual rainfall in the spring and in the early summer was evenly distributed. The mean temperature was higher during November through February, while it was lower for the rest of the growing season.

Table 1. Monthly rainfall and mean daily air temperatures at Bahri Dagdas International Agricultural Research Institute, Konya, Turkey during the 2010–2011 growing season

	Oct	Nov	Dec	Jan	Feb	Mar	Apr	May	June
Temperature (^oC)	12.0	8.8	4.6	1.1	1.7	4.6	8.7	13.2	18.4
LTM	12.6	5.9	1.3	-0.3	1.2	5.8	11.0	15.8	20.3
Rainfall (mm)	71.8	2.4	71.2	37.8	40.4	23.0	44.6	62.6	42.6
LTM	33.3	35.3	41.8	32.9	24.5	25.6	37.4	40.5	22.9

Analytical procedures

The forage samples were assayed for DM by oven drying at 60 ^oC for 48 h. Crude protein (CP) was determined by Kjeldahl method (AOAC, 2003). The ash and the crude fat (CF) was also determined by AOAC (2003). Neutral detergent fiber (NDF), acid detergent fiber (ADF) and acid detergent lignin (ADL) was assayed according to Van Soest et al., 1991. The NDF was expressed with the inclusion of a heat stable amylase and sodium sulfite, but both NDF and ADF expressed inclusive of residual ash. Neutral (NDICP) and acid (ADICP) detergent insoluble CP necessary for calculating metabolizable energy (ME; NRC, 2001) was determined on the samples obtained from NDF and ADF residues and discussed in previous paper (Coskun et al., 2013) together with protein quality. Non-fiber carbohydrates were: 100-(NDF+ash+CP+CF). *In vitro* true DM digestibility (DMD) was determined with the DAISY[11] incubator. Ruminal fluid used for

DMD was collected from a non-pregnant, dry cow fed an alfalfa pellet and concentrate (60:40).

Statistical analysis

The experimental data were analysed via analysis of variance for a split-split plot design. Cereal crop was treated as main plot and stage of maturity was sub-plot in SPSS 10. Where ANOVA was significant, comparisons between treatments were made using the least significant difference procedure.

RESULT AND DISCUSSIONS

The mean DM content and DM production of cereal crops are summarized in Table 2. Among the cereal crops, rye had the lowest (P<0.001) DM content at booting stage which is in line with the work reported by Helsel and Thomas (1987). This could be a challenge when ensiling rye as it would require more drying time at booting stage especially in time when drying conditions are not favourable in early spring. The higher (P<0.001) DM content at dough stage of wheat silage was also reported by the (Beck et al., 2009). Cereal species used in this experiment may be partly due to the fact that these crops were originally developed for grain production. However, higher DM of cereal crops also poses a challenge when making high DM baled silage where there is no precision chopping (Keles and Demirci, 2011).

Table 2. Agronomic data of the cereal forages

Stage of maturity	Cereal crop	Dry matter, g/kg DM	DM production, t/ha	Digestible DM production, t/ha
Boot	barley	211	9.9	7.2
Boot	wheat	220	8.9	6.7
Boot	rye	140	7.2	5.3
Boot	triticale	184	9.1	6.6
Boot	oat	183	8.6	6.1
Dough	barley	370	14.9	9.3
Dough	wheat	509	15.5	9.5
Dough	rye	438	18.0	10.9
Dough	triticale	439	17.7	11.5
Dough	oat	438	17.6	9.9
	s.e.m[1]	4.6	0.20	0.15
P				
Stage of maturity		***	***	***
Cereal crop		***	***	***
Maturity x crop		***	***	***

[1]: for the two-way interactions. *= P < 0.05; **= P < 0.01; ***= P < 0.001.

The DM production ranged between 7.2 (rye) and 9.9 t/ha (barley) at boot and varied from 14.9 (barley) to 18.0 t/ha (rye) at dough stage. The rye had lower (P<0.001) DM content than other cereal forages which also resulted in rye having the lowest (P<0.001) DM production. The DM production of rye, triticale and oat were higher (P<0.001) than DMP of wheat and barley at the dough stage. Digestible DM production increased (P<0.001) with maturity with the value being the highest (P<0.001) in triticale at dough stage. The highest digestible DM production of barley at boot stage was contrasted with the lowest DM production (P<0.001) at dough stage compared to other cereal crop. Overall DM productions of barley, wheat, oat and rye at boot and dough stage of maturity were higher than the values reported by Helsel and Thomas (1987), who also reported that DM production could vary among different barley cultivars. But, DM production of wheat at dough stage was similar to the value reported by Filya (2003) who measured 15.2 t/ha DM production for "Gonen" wheat.

The rainfall in Konya during spring 2011 was higher than the long term means and evenly distributed through the spring period providing favourable growing conditions for plant growth. Due to unusually wet spring, it is hard to identify which cereal crop was superior to another for their dry matter production potentials. In dryer conditions, the advantage of cereal species may change. Barley having had more (P<0.001) DM production as well as more digestible DM production was evaluated the most promising cereal forage at boot stage, while triticale was superior over the other species at dough stage. However, the same samples were also used for protein quality (Coskun et al., 2013) and, in terms of digestible CP production, oat was evaluated the more promising species at dough stage. The DM production of cereal crops increased (P<0.001) with advancing maturity but at different rates (P<0.001). The increase in DM production with advancing maturity were higher than the mean values reported by Helsel and Thomas (1987), but lower than the value reported by Filya (2003) with two wheat cultivar harvested at flowering and dough stage or wheat reported by Crovetto et al. (1998). Different rate in DM production with maturity among cereal crops could a key factor when choosing which crop could be harvested different stage of maturity for DM production together with the nutrient composition.

Table 3. Chemical composition of cereal crop

Factors		Chemical composition[1]								
Maturity	Crop	CP	Ash	CF	NDF	ADF	ADL	NFC	DMD	ME[2]
Boot	barley	169	97	26	521	297	45	187	729	8.5
Boot	wheat	142	87	21	503	292	51	247	755	8.5
Boot	rye	162	80	31	541	308	44	186	735	9.0
Boot	triticale	161	94	30	516	308	50	199	726	8.7
Boot	oat	123	82	32	524	317	51	240	706	8.7
Dough	barley	100	63	20	509	288	67	309	622	8.2
Dough	wheat	91	59	23	497	314	67	330	612	8.4
Dough	rye	74	49	28	516	316	64	334	605	8.4
Dough	triticale	85	54	25	504	278	64	332	650	8.4
Dough	oat	93	67	42	511	316	68	287	562	8.4
s.e.m[3]		2.7	2.2	1.9	15.9	6.4	2.4	16.7	10.2	0.11
p										
Stage of maturity		***	***	NS	NS	NS	***	***	***	*
Cereal crop		***	***	***	NS	**	NS	NS	**	*
Maturity x crop		***	**	**	NS	NS	NS	NS	*	***

[1]: CP: crude protein, g kg^{-1} DM, CF: crude fat, g kg^{-1} DM; NDF: Neutral detergent fibre, g kg^{-1} DM; ADF: Acid detergent fibre, g kg^{-1} DM; ADL: Acid detergent lignin, g kg^{-1} DM; NFC: non fibre carbohydrates, g kg^{-1} DM; DMD: *in vitro* dry matter digestibility, g kg^{-1} DM.

[2]: ME: Metabolizable energy (MJ/kg DM). Calculated according to tabular value of NRC (2001)

[3]: for the two-way interactions. *= P < 0.05; **= P < 0.01; ***= P < 0.001.

The chemical composition of cereal crops are presented in Table 3.The main effect of the stage of maturity was significant for CP, ash, ADL, NFC, DMD and ME of cereal crops with the values being higher (P<0.05) with maturity for ADL and NFC. Nutritive values of cereal crops were higher (P<0.05) when they were harvested at their booting stages as evidenced by higher CP, ash, ME and DMD values. The highest (P<0.001) decrease in nutritive value occurred in CP content for all cereal crops and this was the sharpest (P<0.001) in rye with an overall 54 % decrease. This is in line with the results, reported by Helsel and Thomas (1987) for the barley, wheat, rye and oat silages and by Beck et al. (2009) for the wheat silage. The reduction in DMD was not as sharp as CP as similarly reported by Crovetto et al (2009) and

NDF content of forages were similar at both maturity. This was due to accumulation of NFC with maturity (Nadeau, 2007).

CONCLUSIONS

The main aim of the study was to assess the DM potential and nutritive value of cereal species to get the information necessary which cereal species should be most adventanegeous when they harvested their suggested stage of maturity. Barley at boot stage and triticale at dough stage are more promising cereal species for forage production in terms higher digestible values under the semi-arid conditions of Central Anatolia rather than their nutritive value or DM production. However, because requirement of climate and soil factors are different, the choice of cereal species for forage production should include consideration of animal type to be fed, requirement for protein quality and agronomic characteristics under the semi-arid conditions of Central Anatolia.

ACKNOWLEDGEMENTS

The financial support of the University of Selcuk project BAP 11401094 is acknowledged.

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