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Hay yield and quality of oat (*Avena sativa* L.) genotypes of worldwide origin

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Abstract. Oat (*Avena sativa* L.) has been traditionally a major crop for feed and forage in Turkey. The objective of this research was to study hay yield and quality of oat genotypes harvested at the late milk stage. One hundred oat varieties of worldwide origin were compared in field experiments in Samsun (northern Turkey) over two growing seasons (2007-2008 and 2008-2009). Significant differences between the tested oat varieties were observed for e plant height, hay yield, crude protein (CP), acid detergent fiber (ADF), neutral detergent fiber (NDF) and macro minerals (Ca, K, P and Mg). Plant height varied from 76.2 to 141.2 cm, hay yield varied from 6.03 to 11.83 t ha^{-1}, crude protein varied from 58.8 to 136.4 g kg^{-1} dry matter (DM), acid detergent fiber and neutral detergent fiber varied from 333.2 to 424.8 g kg^{-1} DM and from 522.5 to 652.4 g kg^{-1} DM, respectively. Genotypes such as Sisko, Akiyutaka, Longchamp, Sanova, Flämingslord, Matra and Revisor were identified as the high hay yielding genotypes although their quality s was lower than that of the other genotypes. Furthermore, while some macro minerals were insufficient, others were in excess regarding healthy feeding. Hence, some form of commercial mineral supplement would be required for oat-based ration or oat legumes mixtures should grow for feeding productive livestock.

Keywords. Oat genotypes – Hay yield – Hay quality – Mineral content.

Rendement en foin et qualité de l'avoine (*Avena sativa* L.) de génotypes d'origine mondiale

Résumé. *L'avoine (*Avena sativa* L.) a traditionnellement été une des principales cultures pour l'alimentation et le fourrage en Turquie. L'objectif de cette recherche était d'étudier le rendement en foin et la qualité des génotypes d'avoine récoltés au stade laiteux tardif. Une centaine de variétés d'avoine d'origine mondiale ont été comparées dans des expériences de terrain à Samsun (nord de la Turquie) sur deux saisons de croissance (2007-2008 et 2008-2009). Des différences significatives entre les variétés d'avoine testées ont été observées pour la hauteur des plantes, le rendement en foin, en protéines brutes (CP), en fibres au détergent acide (ADF), en fibres au détergent neutre (NDF) et macrominéraux (Ca, K, P et Mg). La hauteur de la plante varie de 76,2 à 141,2 cm, le rendement en foin varie de 6,03 à 11,83 t ha-1, la protéine brute varie de 58,8 à 136,4 g kg-1 de matière sèche (MS), les fibres au détergent acide et les fibres au détergent neutre varient de 333,2 à 424,8 g kg-1 MS et de 522,5 à 652,4 g kg-1 MS, respectivement. Les génotypes tels que Sisko, Akiyutaka, Longchamp, Sanova, Flämingslord, Matra et Revisor ont été identifiés comme génotypes à rendement en foin plus élevé bien que leur qualité était inférieure à celle des autres génotypes. En outre, alors que certains macrominéraux étaient en quantité insuffisante, d'autres étaient en excès en ce qui concerne une alimentation saine. Par conséquent, une certaine forme de supplément minéral commercial serait nécessaire pour les rations à base d'avoine ou à base de mélange avoine-légumineuses pour la croissance et l'alimentation du bétail productif.*

Mots-clés. *Génotypes d'avoine – Rendement en foin – Qualité du foin – Teneur en minéraux.*

I – Introduction

In Turkey, forage quality is needed for the livestock because the productivity of Turkey's rangeland is very low and the other forage production sources are extremely insufficient. As alternative feed source, uses of small grain cereal forages could partly solve the scarcity of forage (Çelik and Bulur, 1996). Cereals (wheat, barley, oat, rye and triticale) are important forage for livestock feeding. Traditionally, summer grazing and cereal straw feeding in winter are the major sources of ruminants in Turkey. Oats are grown for both grain and forage for livestock feeding over a long time in many parts of the world. In Turkey, oats are grown as both a sole crop and intercropped with annual forage legumes for forage. Oat forage yield and quality are determined by variable factors such as genotype, environment and management practices (Kim *et al*., 2006).

There is a need for continued effort for recent data (agronomic adaptation, hay yield and quality) as new crop genotypes become available for forage cropping systems of the region. Therefore, this research was conducted to investigate hay yield and quality among different oat genotypes.

II – Materials and methods

This study was carried out in experimental field at the Department of Field Crops at the Faculty of Agriculture of Ondokuz Mayis University (41°21´ N, 36°15´ E, and 195 m a.s.l.) during the 2007-2009 growing seasons. Long-term mean precipitation between November and June was 481.3 mm and long-term mean temperature was 11.2°C. Total precipitations in the experimental area were 437.8 and 541.2 mm for 2007-2008 and 2008-2009, respectively. Average temperature was 11.2, 11.9 and 11.2 ºC during 2007-2008, 2008-2009, respectively. The soil texture at the experimental fields was clay. The soil pH and EC were neutral and non-salty, respectively (insert soil data if possible).

One-hundred grain oat genotypes obtained from Europe, North and South America, Asia and Oceania were used in this study. The genotypes were tested in incomplete block design (10x10 alpha lattice) with three replications. Each genotype was sown in 4.8 m^2 (1.2 by 4.0 m) plots consisting of six rows with 20 cm row spacing. The sowing was at the beginning of November 2007 and 2008. Plots were fertilized with 60 kg ha^{-1} N and 60 kg ha^{-1} P at sowing. Maturity at harvest was determined using Zadoks scale. Harvest was done at late milk stage (Zadoks scale 77).

A sub-sample (800 to 1000 g) was randomly selected from each harvested plot to estimate hay yield and provide samples for forage quality analysis. The samples were weighed and dried for 72 h by forced-air drying oven at 65°C. The dried samples were reassembled and ground to pass through a 1 mm screen. Crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF) and Ca, K, Mg and P contents of samples were determined using near infrared reflectance spectroscopy (NIRS). All data for the two years were combined because of homoscedasticity and adjusted by correction factor and then analyzed with analysis of variance (ANOVA) procedures using the MSTAT-C statistical software. The mean comparison among genotypes was obtained by using the least significant difference (LSD) test.

III – Results and discussion

Analysis of variance combined over two years revealed significant differences among genotypes and years for plant height and hay yield. Plant height in the second year (115.3 cm) was higher than in the first year (95.3 cm). This difference might probably be resulted from the higher cumulative precipitation and other climatic conditions in the second year. The combined data over the two years showed that plant height for all genotypes ranged from 76.2 cm (for CROA 43) to 141.2 cm (for Akiyutaka). Cultivars like Akiyutaka, Yeşilköy 330, Cascade, Sisko, Kolpashevskii, Mantaro 15 and Faikbey were taller (141.2, 132.8, 127.7, 127.2, 124.7, 123.9 and 123.1 cm, respectively) than CROA 43, Lang, Winston, Ebe´ne and Brawn (76.2, 81.3, 82.6, 84,3 and 86.0 cm, respectively).

Data on hay yield showed that hay yield varied significantly among the genotypes. On average, the highest yielding cultivars were Sisko, Akiyutaka, Longchamp, Sanova, Flämingslord, Matra and Revisor (11.83, 11.77, 11.60, 11.53, 11.53, 11.52 and 11.50 t ha^{-1}, respectively). The lowest hay yields were observed for cultivars Lang (6.03 t ha^{-1}), Litoral (6.10 t ha^{-1}) and

IA91400-2-3 (6.37 t ha^{-1}) (Table 1). The high hay yielding genotypes were generally European genotypes. The variation in hay yield among genotypes may be attributed to their genetic characteristics and adaptation to different environmental conditions. Significant variation among oat genotypes for hay yield was reported by Chapko *et al.* (1991), Kim *et al.* (2006), Aydın *et al.* (2010).

Table 1. Means of the traits measured on hundred oat genotypes

Year/traits	PH (cm)	HY (t ha^{-1})	CP (g kg^{-1})	ADF (g kg^{-1})	NDF (g kg^{-1})	Ca (g kg^{-1})	K (g kg^{-1})	P (g kg^{-1})	Mg (g kg^{-1})
2007-2008	95.9	8.84	93.1	375.4	588.7	5.36	19.62	3.16	1.09
2008-2009	115.3	9.92	84.2	397.8	616.0	5.24	18.63	3.13	1.15
$LSD_{0.05}$	4.6	0.2	0.3	9.2	11.0	0.3	2.1	0.7	0.3
Significance	**	**	**	**	**	NS	NS	NS	NS
Overall mean	105.6	9.38	88.6	386.6	602.3	5.30	19.13	3.14	1.12
Minimum	76.2	6.03	58.8	333.2	522.5	2.67	13.32	2.33	0.56
Maximum	141.2	11.83	136.4	424.8	652.4	8.58	25.07	3.67	2.05
CV %	11.4	12.4	7.8	4.7	5.6	4.4	5.1	6.2	3.6

PH: Plant height, HY: hay yield, CP: Crude protein, NDF: Neutral detergent fiber, ADF: Acid detergent fiber, Ca: Calcium, K: Potassium, P: Phosphor, Mg: Magnesium.
* and **, significant at $P<0.05$ and $P<0.01$, respectively. NS, not significant at $P<0.05$
$LSD_{0.05}$, least significant difference at $P<0.05$. CV: coefficient of variation.

Significant differences were found among years and genotypes for crude protein, ADF and NDF. Crude protein content of forage is one of the most important criteria for hay quality evaluation (Caballero *et al.,* 1995; Assefa and Ledin, 2001). Crude protein content was higher in the first year than in the second (89.9 g kg^{-1} *vs* 87.4 g kg^{-1}) (Table 1). It ranged from 58.8 to 136.4 g kg^{-1} (Table 1). Bajka (136.4 g kg^{-1}), Aberglen (134,6 g kg^{-1}), Zvolen (132.3 g kg^{-1}), Katri (121.8 g kg^{-1}), Mantaro 15 (121.1 g kg^{-1}), Borowiak (120.7 g kg^{-1}), Pajaz (120.5 g kg^{-1}), Pal (120.1 g kg^{-1}) and Puhti (118.1 g kg^{-1}) had significantly higher crude protein content than the other genotypes. The variation in crude protein of hay between oat cultivars was also reported by other authors (Contreras-Govea and Albrecht, 2006; Kim *et al.,* 2006; Aydın *et al.,* 2010).

Other important quality for forages is the concentration of ADF and NDF (Caballero *et al.,* 1995; Assefa and Ledin, 2001). These fiber contents are strong predictors of forage quality since they represent the poorly-digested portion in the cell wall. In this study, the values for ADF and NDF in first year were lower than those in second year (Table 1). Significant variation was observed between genotypes for ADF and NDF (Table 1). They ranged from 333.2 to 424.8 for ADF and from 522.5 to 652.4 g kg^{-1} for NDF. Cavallo, Belinda, Dukat, Erasmus, Lang, CDC Packer, Boog, IA91400-2-3, Sidabres, Roope, Mara, Flämingsstern, Pharao, Edelprinz ana Yeşilköy 330 had significantly higher ADF than the other genotypes. Similarly, Lang, Flämingsstern, Mara, Boog, IA91400-2-3, Borowiak, Kolpashevskii, Belinda, Dukat, CDC Packer, Cavallo, Rodney, Flämingsplus, Triton, Skakun, Sidabres and Yeşilköy 330 had significantly higher NDF than the other genotypes. For ADF, seven genotypes with the highest hay yield (Sisko, Akiyutaka, Longchamp, Sanova, Flämingslord, Matra and Revisor) were within standard 2 of forage quality (360-400 g kg^{-1} ADF). While for NDF, only five genotypes with the highest hay yield (Longchamp, Sanova, Flämingslord and Matra) met the NDF standard 3 criteria (540-600 g kg^{-1}NDF). Also, significant differences between genotypes were observed for Ca, K, P and Mg contents. Ca contents varied from 3.12 g kg^{-1} DM for Chantilly to 8.58 g kg^{-1} DM for Pharo. According to Tajeda *et al.* (1985) and The American National Research Council (NRC, 2001), forage crops should contain at least 3.0 g kg^{-1} of Ca for ruminants and 3.1 g kg^{-1} Ca for beef cattle, respectively. Results obtained for Ca concentration in this study were more than these recommended values. In the present study, K contents of the genotypes varied from 13.32

g kg^{-1} DM (for CDC Boyer) to 25.07 g kg^{-1} DM (for Riel). The between years difference for K contents was not significant. This result is on line with those of Mut *et al.* (2006), on yield and quality of triticale, barley, rye, and barley varieties and those of Aydın *et al.* (2010), on yield and quality of oat genotypes. The values obtained by our genotypes were higher than those suggested by Tajeda *et al.* (1985) (8.0 g kg^{-1}) although, high K concentration may cause Mg deficiency. Phosphorus contents varied between 2.33 g kg^{-1} DM for Cavallo to 3.67 g kg^{-1} DM for Flämingsplus (Table 1). These values are adequate for ruminants although P concentrations of 1.6-2.6 g kg^{-1} for forage crops are recommended for ruminants (NRC, 2001). Mg concentration in all genotypes was between 0.60 and 2.05 g kg^{-1} (Table 1). The recommended Mg concentrations for forage crops are 2.0 g kg^{-1} for ruminants (Tajeda *et al.*,1985) and 1 g kg^{-1} for beef cattle and 2 g kg^{-1} for lactating cow (NRC, 2001). Magnesium deficiency may lead to a reduction in weight gain, milk production and conception rate (Stuedemann *et al.*, 1983).

IV – Conclusions

Significant differences between the tested oat genotypes were noticed for the following traits: plant height, hay yield, crude protein, acid detergent fiber (ADF), neutral detergent fiber (NDF) and some mineral contents (Ca, K, P and Mg). Generally, the highest yielding genotypes were European origin in this study. Sisko, Akiyutaka, Longchamp, Sanova, Flämingslord, Matra and Revisor were identified as the high hay yielding potential genotypes. Consequently, some forms of commercial mineral supplement would be required to oat-based forage production systems or oat should be grown in mixtures with legumes to fulfill livestock needs in effective feeding. Furthermore, to meet animal needs in oat-based forage systems, crossing high yielding genotypes with genotypes having high forage quality should be suggested for future breeding programs.

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