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Effects of phenological stages on forage yield quality traits in cocksfoot (*Dactylis glomerata*)

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Abstract

In order to determine the effect of harvest date on yield and quality traits in cocksfoot (*Dactylis glomerata*), a split plot experiment was conducted using a complete randomized block design with two replications in Research Institute of Forests and Rangelands, Karaj, Iran, during 2004-2006. Five domestic genotypes, 10505 (Gorgan), 1773 (Sari), 1053 (Karaj), 1761 (Ormia) and 412 (Ardebil), and three foreign ones, IX (Russia), 1557 (Russia) and 1715 (USA), were sown in sub plots and five phenological stages (vegetative, heading, pollination, milky and dough seed stage) were considered as main plots. The data were collected and analyzed for dry matter (DM) yield, crude protein (CP), dry matter digestibility (DMD), water-soluble carbohydrates (WSC), acid detergent fiber (ADF) and total ash. Near Infrared Spectroscopy (NIRS) was used for estimation of the quality traits. The analysis of variance showed a significant effect of phenological stages on all traits ($P \leq 0.01$). The genotypes effect was significant on all traits except DMD, CP and total ash. The genotype × phenological stage interaction was non-significant for all of traits. For DM yield, the lowest and highest values of 2567 and 3607 kg ha^{-1} were obtained at vegetative and soft dough stages, respectively. In contrast, the average values of DMD and CP concentration ranged from 64.85 to 41.77% and from 22.86 to 9.72% at vegetative and dough seed stages, respectively. In general, DM yield, plant height, WSC and ADF values dramatically increased and DMD, CP and ash values decreased due to advancing plant maturity. For DM yield, IX (Russia), 1715 (USA) and 1053 (Karaj, Iran), with average values of 3871 to 4049 kg ha^{-1}, had the highest forage production. Among them, IX (Russia), with average values of 17.2 and 55.3% for CP and DMD, respectively, had highest quality. Based on DMD and CP yield per unit of area, the heading was recognized as the best harvest date in cocksfoot under conservation management. The regression equations were developed among phenological stages and all of traits. The results showed linear models for all of quality traits and quadratic equation for DM yield and stem number.

Key words: Cocksfoot, *Dactylis glomerata*, phenological stage, yield and quality traits.

Introduction

The botanical composition of rangelands is variable in Iran. Cocksfoot (*Dactylis glomerata* L.) is one of the main perennial grasses that naturally grow in temperate pastures and rangelands in northern and western Iran. It is used for grazing and hay production. Cocksfoot grows at altitudes of 500-2900 m having more than 300 mm annual precipitation [1, 2]. The improvement of total annual yield, persistency, disease resistance and extended grazing season are important objectives in most herbage breeding programs. However, data from animal nutrition studies show the need to focus more attention on nutritive value in selection programs. Wheeler and Corbett [3] and Smith *et al.* [4] ranked forage traits in terms of their nutritional value for live weight gain and dairy production, respectively. Improved digestibility and increased water-soluble carbohydrate (WSC) content were the two most important criteria on each of the two lists [3, 4].

There is much published data which shows that digestibility is a major factor affecting intake [5] and animal performance [6]. Carlier concluded that WSC is completely digestible and has an important role in animal nutrition as primary source of the readily available energy necessary for efficient microbial fermentation in the rumen[7]. An adequate supply of soluble sugars is essential for good fermentation and protein utilization in the rumen, leading to improved feed efficiency and animal performance [8]. When considered as a separate characteristic, crude protein (CP) content was ranked as moderate or low priority in terms of quality objectives [3, 4]. However, with regard to the important interaction between WSC and CP in the efficiency of protein metabolism as discussed above, it is clear that the combined evaluation of both characteristics is desirable in relation to selection for improved nutritional value in herbage.

Chemical composition of grasses changes with advancing maturity. As grass matures the proportion of the cell wall increases and the cell content fraction decreases. Both non-structural and structural carbohydrates make up approximately 50 to 80% of dry matter of forages [9]. Maturity and herbage age generally have a greater influence on forage quality than environmental factors. As plants advance in maturity, cell wall concentration within stems and leaves increases and the proportion of cell soluble content decreases. The rate of decline in digestibility of herbage is greatest during reproductive growth [10]. Breese and Thomas showed that small differences in maturity of cocksfoot could greatly affect digestibility [11]. ADF will increase by stem elongation, and as plant matures, cellulose and other structural carbohydrates will be collected in cell wall, which process is called lignification [11]. One of the factors that affect forage production is change in the ratio of leaf to stem. With the gradual growth of plant, the ratio of leaf to stem will change (more stem and less leaf). By increasing of ADF, digestibility percent will decrease and therefore the plant quality will reduce [12].

As in the case of other quality traits, CP in herbage is strongly influenced by environment and stage of growth. CP concentration declined linearly over time in cool season grasses and this might be due to a decrease in CP concentration in both leaves and stems[10]. Today traditionally farmers know that the beginning of ear emergence is time for forage harvest. However, the reduction of quality with plant growth and the relationship with dry matter yield is greatly important in forage harvest and grazing management. This study aimed to determine the effect of harvest date on forage dry matted (DM) yield and dry matter digestibility (DMD), water-soluble carbohydrate (WSC), crude protein (CP), acid detergent fiber and total ash in cocksfoot.

Materials and Methods

Five domestic genotypes, 10505 (Gorgan), 1773 (Sari), 1053 (Karaj), 1761 (Ormia) and 412 (Ardebil), and three foreign ones, IX (Russia), 1557 (Russia) and 1715 (USA), of cocksfoot were sown as spaced plants using a split plot design with two replications under irrigated condition in Research Institute of Forests and Rangelands, Karaj, Iran, in 2004. Genotype was used as subplot and phenological stage (vegetative, stem elongation, heading, pollination, milky and dough seed stage) as main plot. For each phenological stage, 8 subplots each containing 20 spaced plants in rows 50 cm apart, with 40 cm spacing within rows were designed. Fertilizer application rates were 50 and 100 kg ha^{-1} nitrogen (N) and phosphorus (P) at sowing time, respectively. Application of nitrogen was continued at 50 kg ha^{-1} for the second and third years. No measurements were taken in the establishment year. In spring of 2005 and 2006, genotypes were harvested at five phenological stages for the quality traits.

The plants of each plot were harvested, allowed to air-dry, and dry weight (DM) was expressed in kg ha^{-1}. Thus, this represented the above-ground biological yield. Stem length (cm) from the soil surface to the tip of the tallest stem was recorded. Stem number was recorded as the stem number of 5 individual plants. A sub sample was taken, dried at 70°C for 12 h, reweighed to determine DM yield and ground with 1 mm screen mill. Quality traits (DMD, WSC, CP, ADF and total ash) were estimated in the first cuts for two subsequent years using near infrared spectroscopy (NIR). Details of the methodology and calibrations of NIR are given by Jafari [13]. Total DMD, CP and WSC yields were estimated by the product of quality traits percent by DM yield.

Phenological stage and genotype effects were determined by analysis of variance (SAS) [14]. Both phenological stage and genotype means were compared by DMRT method. Regression analysis was performed to define linear relationship between each variable and the phenological level.

Results and Discussion

Results showed significant effect of phenological stage on all of traits (Table 1, Figs 1-4). Average values of DM yield increased from 2567 to 3607 kg ha^{-1} from vegetative to soft dough stage, respectively (Table 2, Figs 1 and 2). At vegetative stage, DM yield was 40% lower than at soft dough stage. Percent of DMD and CP were highest when the plants were immature. Both traits tended to drop sharply as the plants go to dough stage (Figs 1 and 2). DMD and CP values declined from 64.85 to 41.77% and from 22.86

Table 1. Results of analysis of variances for yield and quality traits in 8 cocksfoot accessions at 5 maturity stages over two years.

S.O.V.	DM yield ton ha^{-1}	Stem No.	Plant height (cm)	DMD %	CP %	WSC %	Ash %	ADF %
Block	0.296	4113	1476.9	25.1	2.10	1.31	0.02	24.89
Stage (S)	3.27**	15786**	4218.7**	1356**	492.9**	51.72**	33.3**	564.1**
Error 1	0.165	817	113.5	22.1	4.32	1.06	0.53	18.70
Genotype (G)	0.255**	8666**	524.6**	4.7	2.40	1.31**	0.03	5.38*
G x S	0.494	1060	58.2	2.7	1.83	0.70	0.12	3.00
Error 1	0.447	1434	47.5	3.6	1.38	0.42	0.14	2.25

*, ** Means of squares are significant at 5%, 1%, respectively.

Table 2. Mean comparison for yield and quality traits in cocksfoot accessions at maturity stages over two years.

	DM yield kg ha^{-1}	Stem No.	Plant height (cm)	DMD %	CP %	WSC %	Ash %	ADF %
Phenological stage								
Vegetation	2567 b	47.0b	37.91 e	64.85 a	22.86 a	7.76 d	7.44a	39.23 e
Heading	3541 a	111.3 a	56.40 d	61.41 b	21.29 b	6.81 e	7.31a	41.01 d
Anthesis	3644 a	127.7 a	62.87 c	56.04 c	16.23 c	9.90 b	6.81b	45.32 c
Seed milky	3478 a	110.0 a	73.38 b	50.01 d	12.77 d	8.50 c	5.12c	47.51 b
Dough seed	3607 a	112.8 a	79.69 a	41.77 e	9.72 e	11.37 a	4.19d	54.30 a
Genotype								
10505	2706 b	61.6 b	48.77 e	55.20 a	16.68 ab	8.63 bcd	6.21a	46.72 a
1773	3065 b	93.1 b	59.54 cd	54.39 a	15.73 b	9.23 a	6.19a	45.87 ab
1557	2935 b	80.5 b	59.97 cbd	55.46 a	16.58 ab	9.18 ab	6.22a	44.68 b
1715	3911 a	131.6 a	65.74 abc	53.92 a	16.13 ab	9.15 abc	6.06a	45.60 ab
1053	4049 a	136.1 a	66.21 abc	53.83 a	16.48 ab	8.57 bcd	6.14a	46.02 ab
IX	3871 a	99.5 ab	66.49 ab	55.34 a	17.21 a	8.41 d	6.21a	45.25 ab
1761	3227 b	136.0 a	72.39 a	55.51 a	16.65 ab	9.24 a	6.18a	44.50 b
412	3175 b	75.8 b	57.28 d	54.87 a	17.15 a	8.52 cd	6.16a	45.16 b

Means with the same letter are not significantly different (ρ<0.01).

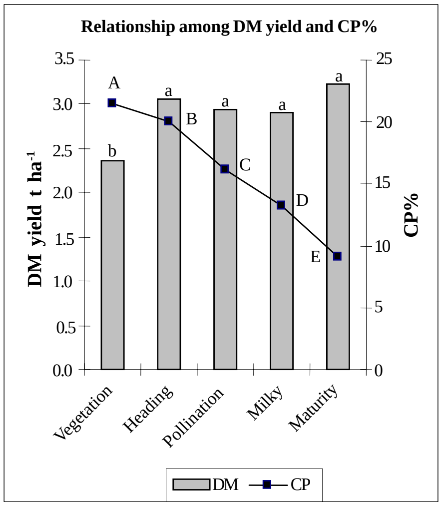

Figure 1. The effects of maturity stage on DM yield and CP% in cocksfoot.
Means with the same letter are not significantly different (ρ<0.01).

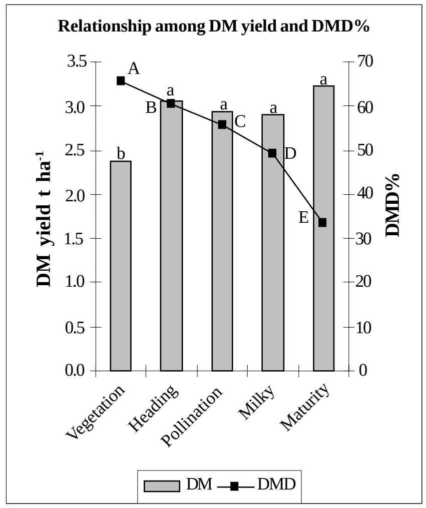

Figure 2. The effects of maturity stages on DM yield and DMD% in cocksfoot.
Means with the same letter are not significantly different (ρ<0.01).

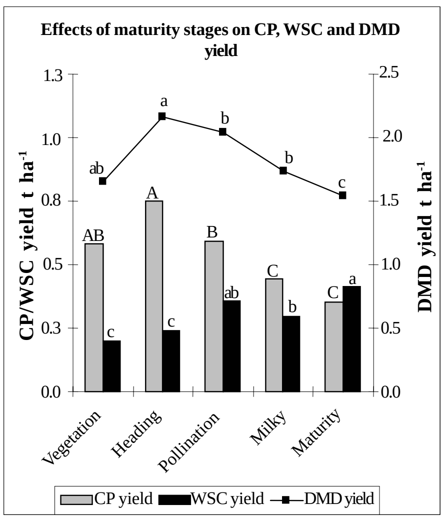

Figure 3. The effects of maturity on CP yield, WSC yield and DMD yield in cocksfoot.
Means with the same letter are not significantly different (ρ<0.01).

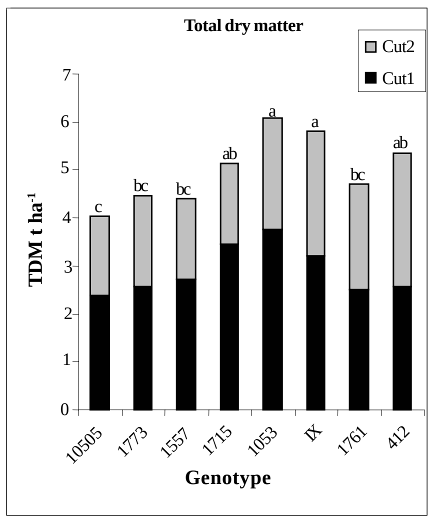

Figure 4. Mean comparison for total annual DM yield (sum of 2 cuts) in 8 cocksfoot over two years.
Means with the same letter are not significantly different (ρ<0.01).

to 9.72% from vegetative to soft dough stage, respectively (Fig. 3) Such results are in agreement with the published data for reduction of forage digestibility with plant phenological stage [12-15]. It seems that the reduction of DMD and CP% with advancing maturity is due to the reduction of leaf to stem ratio [10-16]. Some researches reported that protein content in leaves of *Agropyron intermid* are two times higher than in stems [17].

Both ADF and WSC values increased by plant growth, however, WSC increases were slower than for ADF by advancing maturity from vegetative to milky stage (Table 2, Fig. 5). Because of negative correlation among ADF and DMD this result is expected and it is in agreement with published data [12]. Contents of soluble carbohydrates, particularly fructose, are higher in stem than in leaf, so by advance of plant maturity WSC and CP contents decrease [18]. These results are expected because with plant maturity and reducing the ratio of leaf to stem, the protein density will increase in stem. In general, DM yield, plant height, WSC and ADF values dramatically increased by advancing of plant maturity, in contrast, DMD, CP and ash values decreased.

From the results of variance analysis it can be seen that the difference among genotypes was significant for all of traits except DMD, CP and total ash. For DM yield, IX (Russia), 1715 (USA) and 1053 (Karaj, Iran), with average values of 3871- 4049 kg ha^{-1}, had the highest forage production. Among them, IX (Russia), with average values of 17.2% and 55.3% for CP and DMD had highest quality, respectively. The genotype × phenological stage interaction was non-significant for all of traits indicating of minor effects of GE interactions on yield and quality of cocksfoot. Humphreys and Burner reported that interaction between tall fescue genotypes and environments for WSC concentration were minor [19, 20]. Buxton and Casler concluded that most environmental stresses have a greater effect on DM yield than on digestibility or quality-related parameters and GE interactions should be smaller for forage quality than for yield [21]. Based on DMD and CP yield per unit of area, the heading was recognized as the best harvest date in cocksfoot under conservation management.

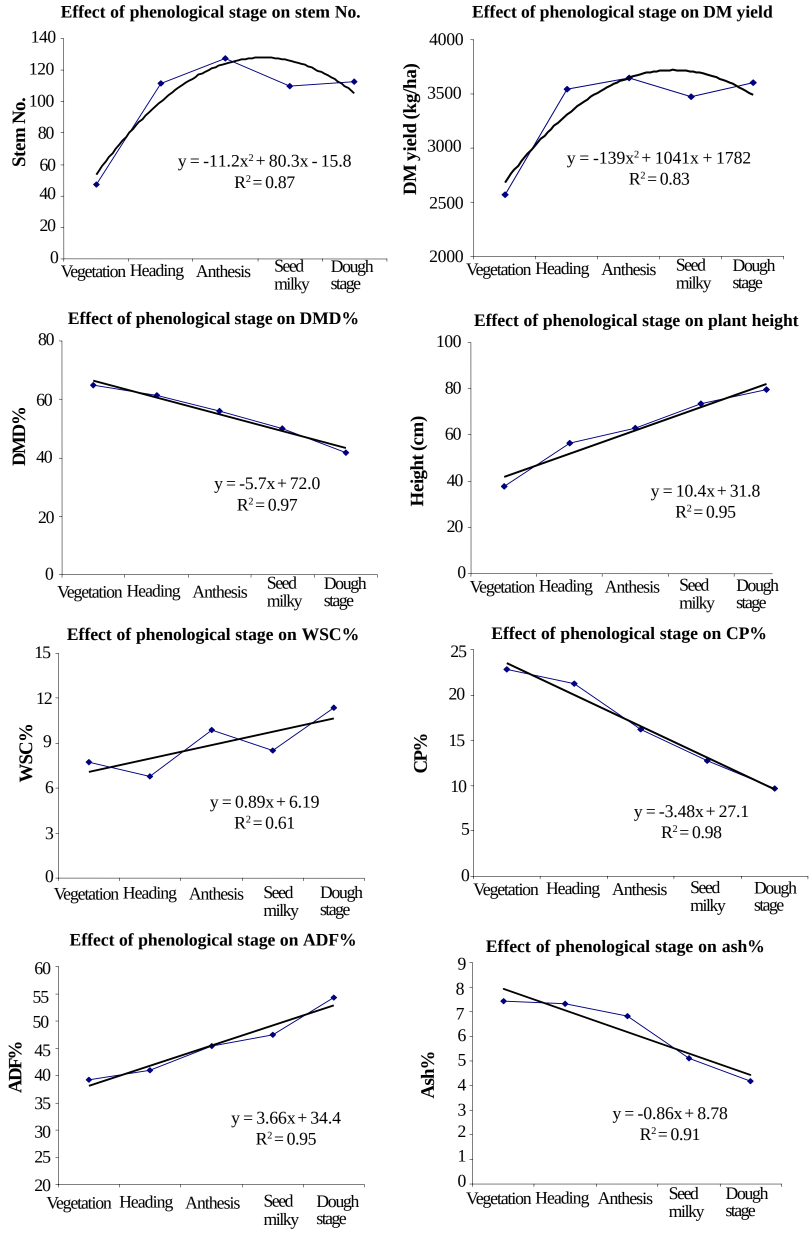

Figure 5. Maturity effects and regression equations for yield and quality traits in cocksfoot.

Regression equations were developed among phenological stages and all of traits (Fig. 5). The results showed linear models for all of quality traits and quadratic equation for DM yield and stem number.

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