Effects of Phenological Stages on Yield and Quality Traits in 22 Populations of Tall Wheatgrass *Agropyron elongatum* Grown in Lorestan, Iran

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Abstract. The objective of this research was to study the effects of phenological stages on yield and quality traits in 22 populations of tall wheatgrass *Agropyron elongatum*. A split plot design was conducted using a complete randomized block with two replications in Lorestan (Borujerd), Iran during 2007-2008. The genotypes were cut in five maturity stages as vegetation, stem elongation, heading date, anthesis, milky development and dough seed stage as main plots. Data were collected and analyzed for DM yield, stem number, plant height and three quality traits as; dry matter digestibility (DMD), water soluble carbohydrate (WSC) and crude protein (CP). The results showed the significant effects of phonological stages, genotypes and genotypes×phonology interaction effects for all of traits except stem number. The stem elongation and dough seed stages with average values of 2.58 and 5.08 Kg/ha had the lowest and highest yield production, respectively. In contrast, the average values of DMD and CP were high in both vegetation and stem elongation stages and they dramatically decreased in mature hay by 13% and 35% lower than those of vegetation hay, respectively. For WSC, the highest values (14.3 and 14.4%) were obtained in heading and pollination stages. Based on both yield and quality traits, it concluded that heading and pollination stages were the best stage for harvesting maximum DM yield couple with three quality traits DMD, WSC and CP yields in tall wheatgrass under conservation management. In comparison among genotypes, 301P10 (Alborz), 301M2 (Alborz) and 1599P10 (Gorgan), 1599P4 (Gorgan) 774M (Takestan) and 1755P9 (Ormia) with the range of 4.03 and 4.98 ton/ha had the higher forage production. Among them, 1599P10 (Gorgan), 774M (Takestan) and 1755P9 (Ormia) were recognized as the best genotypes for both yield and quality trait.

Keywords: Tall wheatgrass, *Agropyron elongatum*, Yield, Digestibility, Carbohydrates, phenological stages.

Introduction

Iran comprises of 165 million hectares of which about 90 mils, ha (54.5%) is rangelands (Anonymous 1999). according to vegetation cover, about 14 mils ha occur in the cooler high altitude regions of the country. They are grazed during spring and summer and their vegetation cover is in general a combination of soft herbs and grass species. These rangelands are in fairly good condition. In herbs dominant areas, over a long period of time, shifting cultivation within the rangelands had to increased soil erosion by decreasing the perennial component of the vegetation. This has been occurred without obtaining viable crop yields and forcing the farmers to abandon such less vegetation and eroded area. Therefore sowing the seeds of adaptable range species (grass and legumes) will be an integral part of country ranges rehabilitation.

Tall wheatgrass (*Agropyron elongatum* Host.) is an important cool-season grass that used for ranges improvement in Iran. It is good adapted to steppe or semi-steppe region of Iran. It is used for pasture, hay, and erosion control. It is native to the Eastern Mediterranean Region (Darbyshire 1997).

Because of its late maturing characteristic, tall wheatgrass provides a long grazing period (USDA 2005). Tall wheatgrass is most palatable during the early spring months. As the grass matures its nutrient value is rapidly declines (Cohen *et al.* 1991). In a study to determine influence of clipping frequency on yield, Undersander and Naylor (1987) found the highest yields of tall wheatgrass when it clipped at 4 week intervals (USDA 2005).

The improvement of forage quality has a great effect on dairy production. Crude protein (CP) is one of the main factors of forage quality. Absorbable protein in rumen can be increased by decreasing the process of protein resolution in rumen. For livestock to absorb more protein, it is needed to increase soluble carbohydrates in order to provide the necessary energy for protein microbes (Hoffman *et al.* 2003). Animal performance depends on the intake of digestible nutrients. Walters (1984) reported that even a small change in digestibility could lead to a relatively large change in voluntary intake. Chemical composition of grasses changes with advancing maturity. 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 (Buxton *et al.* 1996). Breese and Thomas (1967) showed that small differences in maturity of cocksfoot could greatly affect digestibility.

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 was due to a decrease in CP concentration in both leaves and stems (Buxton *et al.* 1996). Today traditionally, farmers know that the beginning of ear emergence time for forage harvest. However, the reduction of quality with plant growth and their relationships with dry matter yield is greatly important in forage harvest and grazing management. Being aware of forage quality, and its changes in different phenological stages is one of the fundamental items for estimating of accurate amount of daily feed requirement for livestock and estimating grazing capacity in pastures to determine suitable time that livestock enter into pasture.

The objective of this work was to study the variation of dry matter yield (DM), Dry matter digestibility (DMD%), Water soluble carbohydrates (WSC%) and Crude protein (CP%) using 22 locally collected population of tall wheatgrass.

Material and Methods

A split plot design was conducted using a complete randomized block with two replications in Lorestan (Borujerd), Iran during 2007-2008. Twenty two local populations of tall wheatgrass (*Agropyron elongatum)*, were provide from Iranian natural resources gene bank. They were sown as drilled sward using a split plot design with two replications in Agricultural research station, Borujerd, Iran during 2007-2008. The genotypes were used as subplot and they were cut in five maturity stages as: vegetation, stem elongation, heading date, anthesis, milky development and seed ripening stage as main plots. The station is located in a flat area southern of Borujerd (25 Km). The altitude of station is 1632 m. The rainiest month is March with 104 mm rainfall. The mean annual rainfall is 475 mm and means annual temperature is 14.9 C°. The average maximum temperature is 27.8 C° in August and medium temperature is 1.1C° in January (Fig. 1). The climate of this region with using Emberger method is moderate sub steppic (IRIMO 2006). The Embrothemic diagram shows that drought period of station is for five months of year and wet season starts in November and it continued until May (Fig. 5).

Each plot containing four 2 m length drilled rows with 25 cm spacing within rows. Fertilizer application rates were 50 and 100 kgha-1 nitrogen (N) and phosphorus (P) at sowing time, respectively. Application of nitrogen was continued at 50 kgh-1 for the second year. To provide similar growth the field were irrigated for two times in establishment year. No further irrigation was made in the second year and No measurements were taken in the establishment year. In spring 2007, genotypes were harvested at six phenological stages for the following traits: Stem length (cm): from the soil surface to the tip of tallest stem was recorded

Stem number: was recorded as the stem number per m square.

DM yield: the plants of each plot were harvested, allowed to air dry, and dry weight was expressed in Kgh-1. Thus, this represented the aboveground biological yield.

Quality traits: A sub sample was taken, at first air dried and late on dried at 70°C for 12h, and reweighed to determine DM yield, then ground with 1 mm screen mill. Five quality traits (DMD, WSC and CP) were estimated in using near infrared spectroscopy (NIR). Details of the methodology and calibrations of NIR are given by Jafari *et al.* (2003b).

Phenological stages and genotype effects was determined by analysis of variance (SAS Inst. 2004). Both phenological stages and genotypes effects mean were compared by DMRT method.

Results and Discussions

The results of analysis of variance showed significant effect of phenological stages for all of traits except stem density (Table 1). For DM yield, the lower and higher values of 2.85 and 5.08 Kgh-1 were obtained, in vegetation and seed maturity stage, respectively (Table 2 and Fig. 1). In vegetative stage, DM yield values were 44% lower than seed ripening. Therefore, as a general rule one can estimate about half the yield at vegetative than what would be expected at seed ripening in tall wheatgrass. Similar trend was observed for plant height. The average values of plant height were 40.9 and 71.2 cm in vegetation and seed maturity stage, respectively (Table 2 and Fig. 1). The positive relationship between DM yield and plant height indicated that this traits are yield components and it is included in aerial biomass. Similar to this result Jafari *et al.* (2007) in tall fescue found that plant height were highly correlated with dry matter yield. For stem density, there were no differences among phonological stages. This result is expected, since the plant density is not too changes over a growing season period.

Percent of both DMD and CP were highest when the plants were immature (Table 2 and Fig. 2 and 3). CP tends to drop sharply as the plants go to heading stage and then its value was consistent from heading to seed ripening stage (Fig. 3). DMD values were declined from 40.7% to 35.9% for vegetative and seed ripening stage, respectively. For CP, the higher and lower values of 20.5 and 13.0% were obtained, in vegetation and seed maturity stage, respectively (Table 2 and Fig. 3). The average values of DMD and CP concentration were trend to be high from vegetation to heading stages and they dramatically decreased in mature hay by 13% and 35% lower than those of vegetation hay, respectively. DMD% declines were slower than did for CP by advancing maturity from vegetative to milky stages. But, CP values were dropped off sharply from vegetative to heading stage (Fig. 2 and 3). Such results are in agreement with the published data for reduction of forage digestibility with plant phenological growth (Hoffman *et al.* 2003; Marten 1989; Rezaifard *et al.* 2010). It seems the reduction of DMD and CP with advancing maturity is due to the reduction of leaf to stem ratio (Buxton *et al.* 1996; Wilkins and Lovatt 1989). Berdahl *et al.* (1994) reported that protein content in leaves of *Agropyrone inttermidim* is two times larger than its stems. The negative relationship among DM yield with both DMD and CP has also been reported by Jafari and Naseri, (2007) and Jafari *et al.* (2003a). This negative relationship indicates that combined selection for both yield and quality traits is necessary in order to prevent loss in DM yield that might occur if selection for quality traits alone was employed.

For WSC, The average values were increased from vegetation to heading stages and they decreased from anthesis to seed milky stage. The increasing of WSC in by four early stages is expected because with plant maturity and reducing the ratio of leaf to stem, the WSC density will increase in stem. McGrath (1988) reported that the percent of WSC in stems is 50% more than leaves. The reduction of WSC% from anthesis to seed milky stage is due to converting of non-structural carbohydrates to structural carbohydrates. Since, DM yield had almost the same values for Heading, Anthesis and Seed milky stages, It was concluded that heading and pollination stages were the best stage for harvesting maximum DM yield couple with three quality traits DMD, WSC and CP yields in tall wheatgrass under conservation management.

The results showed significant differences among genotypes for all of traits (Table 1). The genotypes, 1599p10 (Gorgan), 1599p4 (Gorgan), 774 (Takestan), 301m2 (Alborz), 301p10 (Alborz) and 1755p9 (Ourmia) with average values of 4.03 to 4.99 ton h-1 had higher DM production (Table 2).

For stem number, the genotypes 1599p10, 1599p4 and 240m had the highest vales over growing stages and for plant height. The genotypes, 301m2, 1599p4, 240m and 774 with average values of 56 cm over 6 growing stages had higher stem length (Table 2). For both DMD and CP, the range of variation among genotypes was small. The genotypes of 1599 groups with average values of 37% had the higher DMD%. For CP, the genotypes 240p11, 843p4, 843p10, 1755p12 and 1599p10 with average values of 14.7 had the higher CP%. For WSC, 240p11, 3424 and 1599p14 with 13.3 to 13.5 had higher values. In comparison among genotypes it was concluded that genotypes 1599p10 (Gorgan), 774m (Takestan) and 1755p9 (Ourmia) were recognized as the best genotypes for both yield and quality trait and it was suggested for improved new synthetic forage grass varieties.

The genotype × phenological stage interaction was significant for all of traits (Table 1). Similarly, Rezaifard *et al.* (2010) and Jafari and Naseri (2007) in cocksfoot reported significant genotypes by environments interactions for the same traits. Buxton and Casler (1993), in a review, concluded that most environment stresses have a greater effect on DM yield than on quality traits and G ×E interactions should be smaller for forage quality than for yield. When G x E interactions is significant then evaluation prior to selection is more difficult. Ideally, more than one environment (e.g. years, harvesting frequency, locations etc.) should be used to assess the breeding material. In contrast to present results, Jafari *et al.* (2003a) in Ireland did not find genotype × management interaction for DMD and CP under two cutting management. It seems in grasses, quality traits are more stable than DM yield under various cutting management in rainy European country, but for steppe or semi-steppe region as Iran, due to low and irregular precipitation and other environmental stress, the genotype × environment interactions are present for quality traits. Part of the aim of current study, was to describe differences among genotypes. Some genotypes had less reduction with maturity than others genotypes.

Table 1. Analysis of Variances for Yield and Quality Traits Tall Wheatgrass Populations in 6 Maturity Stages.

S.O.V	DF	DM Yield Tonh^{-1}	Stem No.	Plant height (cm)	DMD%	CP%	WSC%
Block	1	1.38	65	40	3.65	0.71	3.40
Stage (S)	5	34.78*	4699	5035**	174.2**	556.2**	72.0**
Error1	5	13.23	2378	110	1.19	1.64	1.34
Genotype (G)	21	3.31**	2445**	186**	4.24*	2.66**	1.43**
G x S	105	3.04**	1907**	133**	5.12**	2.55**	1.11**
Error1	126	1.07	499	35	2/50	0.90	0.42
CV%		27.8	12.1	11.5	4.29	6.68	5.1

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

Table 2. Mean Comparison for Yield and Quality Traits for 6 Phenological Stages (Averaged over 22 Tall wheatgrass Populations).

Phenological Stages	DM Yield Kgh-1	Stem No.	Plant Height (cm)	DMD%	CP%	WSC%
Vegetation	2.85 d	179 bc	40.9 c	40.7 a	20.5 a	11.2 e
Stem elongation	2.76 d	169 c	43.2 c	37.1 b	16.0 b	12.0 d
Heading	3.45 c	192 ab	51.5 b	36.2 c	10.8 e	14.3 a
Anthesis	3.88 cb	195 a	49.7 b	35.3 c	11.6 d	14.4 a
Seed milky	4.28 b	177 c	51.7 b	35.9 c	13.4 c	12.4 c
Seed ripening	5.08 a	192 ab	71.2 a	35.9 c	13.0 c	13.2 b

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

Table 2. Mean Comparison for Yield and Quality Traits for 22 Populations of Tall Wheatgrass (Data Averaged over 6 Phenological Stages).

Name	Origin	DM Yield Kgh^{-1}		Stem No.		Plant Height(cm)		DMD%		CP%		WSC%	
240p_{11}	Tabriz	3.23	cd	158	d	42.4	g	37.7	ab	14.7	ab	13.3	abc
240m	Tabriz	3.82	a-d	202	ab	56.1	ab	37.3	abc	14.2	ab	13.0	a-d
685	Tabriz	3.85	a-d	186	a-d	52.1	a-f	36.9	abc	13.8	ab	12.7	bcd
301p_{10}	Alborz	4.99	a	185	a-d	50.1	a-f	36.7	abc	14.3	ab	13.0	a-d
301m_1	Alborz	3.74	a-d	167	cd	48.4	c-g	36.9	abc	14.2	ab	13.1	a-d
301m_2	Alborz	4.05	a-d	191	abc	55.6	abc	36.1	bc	13.6	b	12.9	a-d
774	Takestan	4.04	a-d	188	abc	56.6	a	36.7	abc	14.5	ab	12.7	bcd
843p_4	Yazd	3.45	bcd	178	bcd	52.8	a-f	36.4	abc	14.7	ab	13.1	a-d
843p_{10}	Yazd	3.43	bcd	177	bcd	49.4	b-g	36.9	abc	14.7	ab	12.3	d
843m	Yazd	2.95	d	178	bcd	47.3	d-g	36.5	abc	15.0	a	13.0	a-d
1360	Ourmia	3.27	cd	166	cd	45.9	efg	37.1	abc	14.3	ab	12.9	a-d
1755p_{12}	Ourmia	3.46	bcd	199	ab	45.4	fg	36.8	abc	14.7	ab	12.8	bcd
1755p_9	Ourmia	4.62	ab	199	ab	53.2	a-e	36.5	abc	14.6	ab	12.9	a-d
1755m	Ourmia	3.34	bcd	175	bcd	48.8	b-g	35.6	c	14.1	ab	13.1	a-d
1599p_1	Gorgan	3.47	bcd	191	abc	55.3	abc	37.3	abc	13.6	b	12.5	cd
1599p_3	Gorgan	3.26	cd	177	bcd	51.5	a-f	37.2	abc	13.7	b	12.5	d
1599p_2	Gorgan	3.82	abcd	175	bcd	52.8	a-f	37.5	abc	13.8	ab	12.8	a-d
1599p_4	Gorgan	4.34	abc	199	ab	55.9	abc	37.2	abc	13.5	b	12.3	d
1599p_{10}	Gorgan	4.03	abcd	209	a	54.6	a-d	38.3	a	14.7	ab	13.6	a
1599p_{14}	Gorgan	3.38	bcd	208	a	52.4	a-f	36.2	bc	13.8	b	13.5	ab
1599m	Gorgan	3.22	cd	165	cd	48.5	c-g	37.0	abc	13.7	b	12.7	bcd
3424	Sharkord	3.20	cd	179	bcd	54.7	a-d	36.3	bc	13.7	b	13.4	ab
Mean		3.68		184		51.4		36.9		14.2		12.9	

Means with the same letter are not significantly different ($\rho<0.01$).

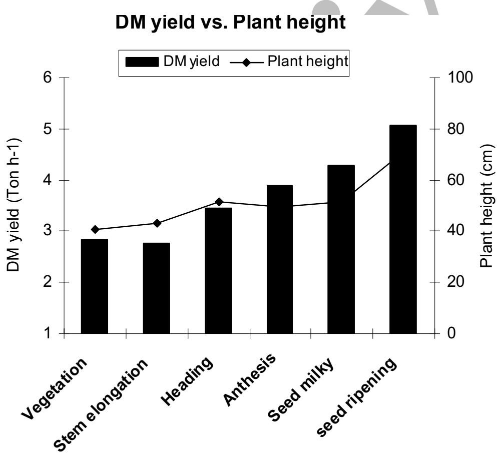

Fig. 1. The Effects of Maturity Stages on Both DM Yield and Plant Height in Tall Wheatgrass

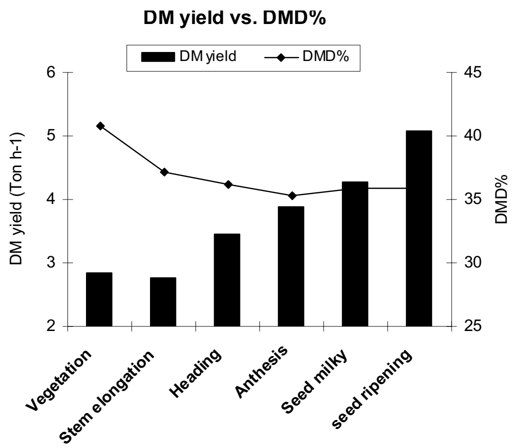

Fig. 2. The Effects of Maturity Stages on Both DM Yield and DMD% in Tall Wheatgrass

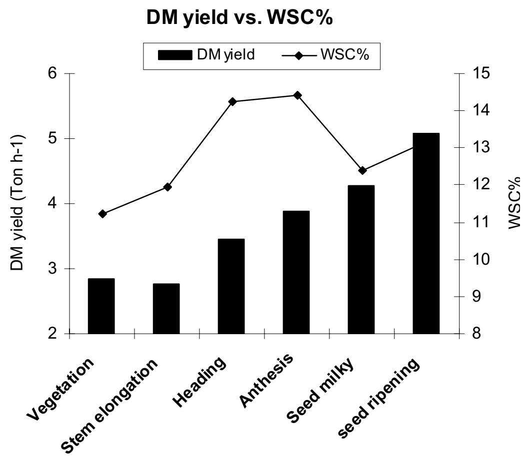

Fig. 3. The Effects of Maturity Stages on Both DM Yield and WSC% in Tall Wheatgrass

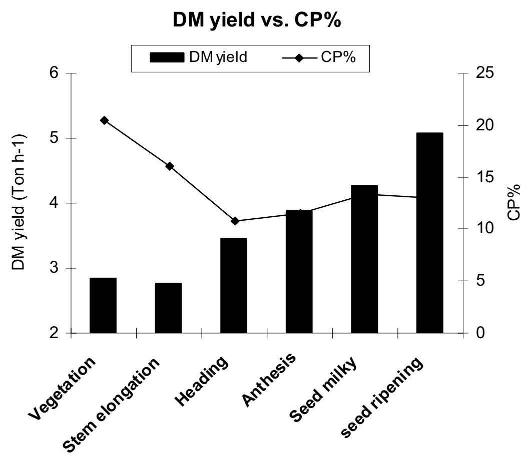

Fig. 4. The Effects of Maturity Stages on Both DM Yield and CP% in Tall Wheatgrass

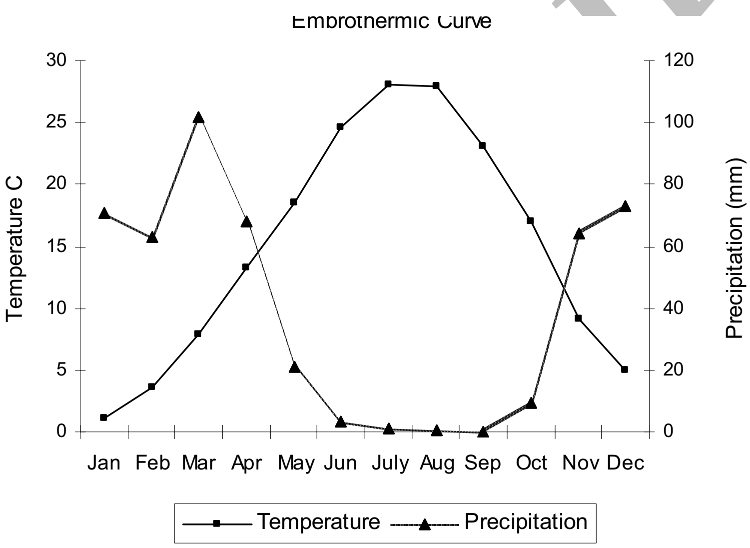

Fig. 5. The Lines of Two Axes Chart of Embrothermic Curve for Borujerd Agricultural Station. (Extracted from Iran Meteorological Organization)

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