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VARIATIONS IN NUTRIENT CONCENTRATIONS OF TRITICALE AND BARLEY AT DIFFERENT GROWTH STAGES

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Abstract

The objective of this research was to examine the concentrations of crude protein, P, K, Mg, Fe, Mn and Zn of 5 triticale genotypes and 2 barley cultivars (two-row) at different growth stages. The experiments were carried out at Süleyman Demirel University farm in Isparta during the growing season of 2012-2013. Three hexaploid triticale lines (SDÜ-21, SDÜ-27, SDÜ-43) and 2 cultivars (Karma-2000 and Tatlıcak-97), and two-row barley cultivars (Hamidiye and Cumhuriyet) were used in the experiment. The experimental design was a randomized split block design with three replication. The genotypes were used as main plots and growth stage were used as sub-plots. The basic pre-sowing fertilization rates for all plots were 30 kg N·ha^{-1} and 50 kg P·ha^{-1}, the rest of 30 kg N·ha^{-1} was applied at the early spring (stem-elongation stage). Plants were harvested at four stages, stem elongation, milk development, dough development and mature stage. Samples taken from each plot were dried to constant weight at 65°C in oven. After cooling, the samples were milled for crude protein and mineral element analyses.

According to the results of variance analysis, the nutrient concentrations of triticale and barley genotypes showed variations depending on the genotypes and different growth stages. The crude protein content of barley cultivars were higher than triticale genotypes. The concentration of K, Fe, Mn and Zn in whole plants decreased from stem elongation to maturity, while Mg and P contents increased. Crude protein rate (18.59%) at dough development stage was higher than other growth stages. The nitrogen use efficiency of SDÜ-27 line, which can be used for cultivar registration, was higher than control cultivar (Karma – 2000; Tatlıcak-1997).

Keywords: triticale, barley, growth stages, protein, macro and micro elements

INTRODUCTION

Triticale (×*Triticosecale*) is a new cereal, cross of wheat (*Triticum)* and rye *(Secale),* first grown during the late 19th century. But its development didn't really begin until the 1930's. Global production of triticale increased nearly 60% from 2000 to 2013. The primary producers of triticale are Poland, Germany, Belarus, France and Russia. In 2014, according to the Food and Agriculture Organization (FAO), 17.1 million tons were harvested in 37 countries across the world (Anonymous, 2016a). The CIMMYT triticale improvement program wanted to improve food production and nutrition in developing countries. In spite of potential in the production of bread and other food products, triticale is sparingly used for human. A majority of production used for feed. Triticale also is suitable for the production of bio-ethanol fuel and research is currently being conducted on the use of the crop's biomass in bioethanol production (McGoverin *et al*., 2011).

Despite these positive features of triticale, use of commercial crop of triticale has not been widespread due to different reasons in Turkey. In Turkey, statistical data has been available since 2004. On the other hand improved triticale varieties in recent years are high yielding, and grain is plumper and has a heavier test weight than the older varieties. According to the year 2016 data in Turkey, triticale and barley had been planted in 37634.8 ha and 2740052.1 ha, and production were 125000 tones and 6 million tones, respectively (Anonymous, 2016b).

Triticale is used for different purposes in particular for feeding as grain, hay, silage or grazing. At early stages of plant development Triticale grains have as high a feeding quality as barley, wheat or corn the crude protein content of triticale grain varies between 90 and 200 $g \cdot kg^{-1}$ of dry matter (Tuah *et al*., 1986; Heger and Eggum, 1991; Erekul and Kohn, 2006; McGoverin *et al*., 2011). The biological value of triticale protein has been shown to be greater than wheat protein and is positively correlated with lysine (Pena and Bates, 1982). In addition triticale straw can be used in animal feeding systems since it has as high a feeding quality as barley or oat straw (Tuah *et al*., 1986). The cereal straws feeding in winter are important for ruminants in Turkey. Forage productions are intertwined with climate, genotype, and management practices, including the type, number, and period of the cuttings (Akgun and Altindal, 2015).

The present study was carried out to determine the composition of mineral elements and crude protein rate at different growth stages in the selected triticale genotypes and barley cultivars. The other aim of this research was to determine the most suitable cutting time for mineral elements and crude protein rate when it is planned to use as forage crop and optimum fertilization program for healthy plant growth is programmed.

MATERIALS AND METHODS

The experiment was conducted in the semi-arid climatic conditions in Isparta, Turkey during the growing season of 2012-2013. There was no irrigation at any growing stage. Hexaploid triticale lines (SDÜ-21, SDÜ-27, SDÜ-43) and 2 cultivars (Karma-2000 and Tatlıcak-97), and two-row barley cultivars (Hamidiye and Cumhuriyet) were used in the experiment. The triticale lines (obtained from CIMMYT) were selected, based on results of a previous study, in which they were the most promising lines for growing conditions in Isparta. The experimental design was a randomized split block design with three replications. The genotypes were used as main plots and growth stage was used as sub-plots. Each plot area was 4.8 m^2 and consisted of 6 rows. Seedling rates were 450 $seeds \cdot m^{-2}$. Plants from 6 rows in the center of each plot were harvested manually. The basic pre-sowing fertilization rates for all plots were 30 kg $N \cdot ha^{-1}$ and 40 kg $P \cdot ha^{-1}$, the rest of 30 kg $N \cdot ha^{-1}$ was applied at the early spring (stem-elongation stage). Plants were harvested at four stages, stem elongation (3 to 4; 34-36), milk development, (7 to 8), dough development (8 to 9) and mature stage (scale 99) according to Zadoks scale. Samples (whole plants) taken from each plot were dried to constant weight at 65° C in an oven. After cooling the samples were milled for crude protein and mineral element analyses. Phosphorus concentrations of samples were determined with molibdo-vanado phosphoric acid method using spectrophotometer; potassium concentration was determined using flame photometer and micro nutrient (Mg, Fe, Mn, Zn) concentrations were determined by using atomic absorption spectrophotometer (Kacar and Inal, 2008). The crude protein content of the samples was calculated by multiplying the Kjeldahl N by 6.25. In the analysis of variance, the software package program MSTAT-C was used. Means of treatments were evaluated and ranged according to Duncan test. The soil of the experiment was sandy-loam in texture with 55, 23, 22 percent sand, silt and clay respectively. The soil had 29.5% $CaCO_3$, 1.1% organic matter content, 72 $mg \cdot kg^{-1}$ phosphorus, 2.00 ppm Mg, 0.31 ppm Fe, 4.62 ppm Mn and 0.52 ppm Zn. The pH was 8.1. The available K was 0.78 $me \cdot 100\ g^{-1}$. Long-term mean precipitation and average temperature between October and July (growing seasons) was 477.7 mm and 10.2°C respectively. In the experimental year (2012-2013 growing seasons) total precipitation was 569.6 mm, average temperature was 11.7°C. Meteorological data of the experimental year were higher compared to long-term meteorological data.

RESULTS AND DISCUSSION

Crude Protein Content: The average rate of crude protein are provided in Table 1. The crude protein content for all genotypes varied from 12.95 to 16.35% and these differences were significant among genotypes (Table 1; P<0.01). As general average, the highest crude protein content was determined at two-row Hamidiye cultivar, whereas the lowest in SDU-43 line. Compared to triticale genotypes, two-row barley cultivars had higher crude protein rate (except for SDU-27). On the other hand, among the triticale genotypes SDU-27 had the highest crude protein content (15.21%) and other triticale cultivars had similar crude protein content.

It was shown that there was significant difference in the protein content according to the growth period of the plant (Table 1; P<0.01). The interaction between different growth stages and genotypes was also significant. The highest crude protein content in all genotypes (except for Hamidiye) was determined during dough development stage. But, the protein content decreased during the mature stage and the protein content of Hamidiye and Cumhuriyet cultivars were 15.58% and 11.54% respectively. In the triticale genotypes, the protein content varied from 10.21 to 13.85%. The highest protein rate (19.1%) was obtained during dough development stage in SDÜ-27 and the differences between the other growth stages were significant.

Table 1. The crude protein content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	Crude Protein Content (%)				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	14.35c[1]	18.06a	17.42a	15.58b	16.35
Cumhuriyet	11.40c	16.33b	18.35a	11.54c	14.41
Tatlıcak-97	11.73b	16.58a	17.00 a	11.52b	13.71
Karma-2000	10.27d	14.85b	17.90a	12.83c	13.96
SDÜ-21	12.73b	13.08b	15.54a	12.85b	13.55
SDÜ-27	12.15d	15.73b	19.10a	13.85c	15.21
SDÜ-43	11.33c	13.83b	16.42a	10.21c	12.95
Average	11.99	15.49	17.39	12.63	

F cultivar (c) = 87.34** F stage (s) = 587.25** F cxs= 46.79**

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

Nitrogen is the key element in achieving high protein content in cereals and N uptake is important because it is positively correlated to kernel protein content. Nitrogen is involved in all of the plant's metabolic functions, its rate of uptake and partition was determined by supply and demand during the various stages of plant growth. Many studies have been conducted in different species to explain the factors controlling N uptake and its efficient use—extent of root–soil association, amount of N supply, uptake effciency of the root system, soil-moisture supply, and the intra-and intergenotype differences (Delogua *et al*., 1998). Different authors reported that the nitrogen use efficiency in cereals vary depending on genotype (Tilman *et al*., 1991; Isfan *et al*., 1991) and seasonal trends, etc. (Blankenau *et al*., 2002). Similarly, the mineral and protein contents in grain could change according to year and location (Feil and Fossati, 1995). In our research there was a significant interaction between genotype and the different growth stages. This situation has been thought to result from leave density, remobilization of N, the differences of tillering and the root system besides different taking abilities of the plant nutrition element.

In this research, the lowest crude protein content was determined at stem elongation stage (11.99%) and crude protein content increased during following stages. This can be explained by the fact that winter cereals can't usually benefit enough from the nitrogen given to the soil by planting on account of the very short time between planting date and the plant entrance into the winter dormancy. According to the Alley *et al.,* (1986), it was stated that taking the nitrogen of wheat plant is hardly little from November to the end of February and constantly increases as from April. Our results support this idea. These results showed that triticale and barley need more nitrogen from stem elongation to soft dough growth period.

Phosphorus (P): Phosphorus content varied between 0.270-0.403% in the research and this difference among genotypes was significant (Table 2; $P<0.01$). As average, the highest P concentration was determined in SDÜ-27 triticale line and the lowest was in Karma and SDÜ-43 line. Compared to Tatlıcak and SDÜ-27 line triticale genotypes, two-row barley cultivars had lower P content.

The phosphorus uptake increased as growth period progressed and the highest P content 0.409% was determined during mature stage. This difference among growth stages was significant. The lowest P content (0.253%) was determined during stem elongation in which the first cutting was done (Table 2).

In this research there was significant interactions between genotype and the different growth stages (Table 2; $P<0.01$) in terms of P uptake. The phosphorus uptake efficiency of genotypes was not similar and its rate of uptake and partition varied during the different stages of plant growth in barley and triticale genotypes. The two-row barley cultivars had higher value in mature stage and there was significant difference. The phosphorus content between dough and mature stages were not significant in Karma and Tatlıcak cultivars. A similar result to this study on triticale was obtained in wheat by Erdal and Kocakaya (2003). The researchers found the highest P amount in grain of wheat and the lowest value was also determined in the samples of stem elongation stage. Differences among plant species and even among genotypes of the same species in phosphorus efficiency and use can be seen in studies carried out (Feil and Fossati, 1995; Fageria and Baligar 1999; Dechassa *et al*., 2003). The differences in taking useful phosphorus in soil are partially explained by the differences in root morphology (Föhse *et al*., 1991; He *et al*., 2003; Shane *et al*., 2003). Therefore, at reproductive stage, root activity and nutrient uptake generally decrease. The high metabolic activity minerals such as phosphorus or nitrogen move easily from older tissue to storage organs. Being a lot of the plant parts including in the remobilization and also having a lot of phosphorus in their vegetative tissue will increase the phosphorus amount in grain. Triticale genotypes can be said to use useful phosphorus in soil better depending on the increase of the soil temperature during the following development periods and widening of the root surface according to the early development stage.

Table 2. The phosphorus content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	**Phosphorus (%)**				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	0.220c[1]	0.377b	0.353b	0.507a	0.364
Cumhuriyet	0.233b	0.263b	0.240b	0.460a	0.299
Tatlıcak-97	0.330b	0.370b	0.430a	0.383ab	0.378
Karma-200	0.230b	0.253b	0.280ab	0.317a	0.270
SDÜ – 21	0.240b	0.248b	0.277b	0.347a	0.278
SDÜ-27	0.297c	0.373bc	0.400b	0.543a	0.403
SDÜ-43	0.223b	0.263ab	0.290a	0.303a	0.270
Average	0.253	0.307	0.324	0.409	

F cultivar(c) = 58.69** F stage (s) = 81.69** F cxs= 18.49**

[1]Means with different superscript in the same row differ (P<0,01); **: significant at 1% levels of probability

Potassium (K): Genotyp, development stage, and their interaction significantly affected the K contents of barley and triticale genotypes (P<0.01; Table 3). As overall average, potassium content of Cumhuriyet barley cultivar was higher than those of other genotypes. The lowest K concentration among triticale genotypes was obtained from Tatlıcak (1.48%) and SDÜ-21 line (1.44%) and the highest potassium content was in SDÜ-27 line (1.69%).

Table 3. Potassium (K) content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	Potassium (%)				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	2.20a[1]	1.55c	1.96b	0.32d	1.51
Cumhuriyet	2.23b	2.93a	1.57c	0.37d	1.78
Tatlıcak	2.13a	1.53b	1.96a	0.30c	1.48
Karma	2.87a	1.40c	1.93b	0.33d	1.63
SDÜ – 21	2.57a	1.30c	1.60b	0.32d	1.44
SDÜ-27	1.99b	2.93a	1.50c	0.33d	1.69
SDÜ-43	2.27a	1.80b	1.73b	0.32c	1.53
Average	2.32	1.92	1.75	0.33	

F cultivar(c) = 41.50**; F stage (s)= 3748.31** F cxs= 134.92**

[1]Means with different superscript in the same row differ (P<0.1); **: significant at 1% levels of probability

In the study, it was observed that the potassium content decreased depending on the progress in the developmental stages of triticale genotypes. The highest K content was obtained during stem elongation (2,32%), the lowest was 0,33% during mature stages (Table 3). Since potassium content in genotypes were different during the development period, interaction of genotype x development stages was found significant. Nutrient use efficiency among the genotypes might be affected from the genetic structure and ecological factors, management practices. Potassium-efficient genotypes have the potential to enhance the productivity and sustainability of cereal cropping systems (Damon and Rengel, 2007). George *et al* (2002) reported that K utilization efficiency was correlated with total plant biomass and root yield. Similar genotypic variation in mineral nutrient content was also reported by a different researcher. In another study, the plants of triticale and other cereal genotypes were harvested at two stages and at the heading stage, K contents of the genotypes varied between 1.41 to 2.39%, while K contents of the genotypes varied from 0.998 to 1.784% at the milk–dough stage (Mut *et al*., 2006). Delay of the cutting time, in that study on perennial rye, made the potassium content decrease at a significant level and the highest potassium content was in stem elongation (3.84%), the lowest was obtained during flowering stage (1.47%) (Akgün *et al*., 2001). It is reported that plants get a great quantity of K need during the vegetative growth stage and especially K uptake between tillering and head formation in cereals increases (Kacar and Katkat, 1988). Our results showed that K content in plants decreased with advanced in growth stage.

Magnesium (Mg): Mg content varied between 0.250-0.313% in examined genotypes. As overall average, Mg content of Tatlıcak cultivar was higher than those in other genotypes. According to the growth stages it was also between, 0.251-0.334%. During the stem elongation and mature stages, Mg content was higher than other stages ($P<0.01$; Table 4). The amounts of magnesium in mature stages of the plants increased significantly. In this research there was a significant the interaction between genotype and the different growth stages. Mg content in barley and triticale plants was highest during mature stages, and lowest in milk and dough development stages (Table 4). On the other hand, Mg content in SDÜ-27 was not significantly different among developmental stages. In this research it is shown that magnesium content is influenced by different factors such as cutting time, uptake to the root cells of species.

There has been little work on magnesium content in whole plants. Feil and Fossati (1995) reported that Mg contents of the genotypes varied from 1.20 to 1.46 $g \cdot kg^{-1}$ in triticale grains. The high Mg content could be due to the antagonistic relationship between Mg and K (Loreda *et al*., 1986). While Tatlıcak cultivar had lower potassium concentration, its Mg content was the highest. In this research, results showed that Mg concentration in plant increased with advance in growth stage.

Microelement Contents (Fe, Mn, Zn): The analyses of variance showed that the concentrations of Fe, Mn, and Zn were significantly affected by genotypes and growth stages (Table 5, 6 and 7). As overall average, the Fe, Mn, Cu and Zn contents for all genotypes varied from 154.70 to 242.59 ppm, from 43.62 to 73.92 ppm and from 24.08 to 73.92 ppm respectively. The highest Fe, Mn and Zn content were determined in Karma, Hamidiye and Tatlıcak while the lowest content were obtained in Tatlıcak and SDÜ-43 triticale lines, respectively. Barley cultivars had higher Mn content than triticale genotypes. Similar genotypic variation in mineral nutrient content was reported by different research groups (Feil and Fossati, 1995; Mut *et al*., 2006). This variation in microelement contents of the triticale genotypes might be related to the differences in root morphological properties.

At the different growth stages, there are significant variations among microelement contents of the triticale genotypes. According to the growth stages (stem elongation, milk development, dough development and mature stages), the average Fe, Mn and Zn contents varied from 89.04 to 328.84 ppm, from 50.02 to 64.22 ppm, 17.47 to 66.73 ppm, respectively (Table 5, 6 and 7). These results showed that the microelements such as Fe, Mn, and Zn are taken in the early stage of the plant growth. The results for Zn contents in this study were similar to previous study results on triticale. Zn contents of all genotypes were higher at the heading stage than at the milk-dough stage (Mut *et al*., 2006).

Since microelement content in genotypes were different during the development periods, interaction of genotype x development stages was significant (Table 4, 5 and 6). While uptake of microelement in all genotypes accumulated in the early stage, its transport and accumulation during growing period was different.

CONCLUSIONS

As a result, although there was a difference among genotypes, generally the highest crude protein content was found at dough development stage, the highest phosphorus and Mg contents were at mature stage, the highest potassium content was at stem elongation or milk development stages and Fe, Mn and Zn were highest at stem elongation stage. Present results showed that triticale and barley genotypes can also be used as a forage source in animal feeding. Therefore, it can be concluded that if triticale and barley genotypes are to be used as forage crop in animal feeding, their microelement content should be sufficient since Fe and Mn contents in forage crops are recommended at least around 50 ppm for ruminants (Periguad, 1970; Mut *et al.*,2006). The nitrogen use efficiency of SDÜ-27 line which can be used for cultivar registration were higher than control cultivar (Karma – 2000; Tatlıcak-1997). In addition, this research was able to determine optimum fertilization program for healthy plant growth.

Table 4. Magnesium content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	**Magnesium (Mg) %**				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	0.317a[1]	0.246b	0.247b	0.303a	0.278
Cumhuriyet	0.276ab	0.247b	0.250b	0.323a	0.274
Tatlıcak	0.326b	0.263c	0.250c	0.413a	0.313
Karma	0.267b	0.250b	0.250b	0.343a	0.278
SDÜ – 21	0.290ab	0.250bc	0.243c	0.303a	0.272
SDÜ-27	0.246a	0.250a	0.250a	0.252a	0.250
SDÜ-43	0.226b	0.250b	0.263b	0.403a	0.286
Average	0.278	0.251	0.251	0.334	
F cultivar(c) = 10.62** F stage (s) = 77.36** F cxs= 8.52**					

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

Table 5. Fe content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	Fe (ppm)				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	337.50a[1]	72.17d	141.43c	235.20b	196.58
Cumhuriyet	397.90a	132.50c	151.17c	252.20b	233.44
Tatlıcak	264.70a	57.67d	98.13c	198.30b	154.70
Karma	445.10a	41.57d	122.90c	360.80b	242.59
SDÜ – 21	294.30a	95.60d	198.20b	124.63c	178.18
SDÜ-27	296.90a	146.90c	142.90c	175.40b	190.53
SDÜ-43	265.47a	76.90d	119.83c	187.77b	162.36
Average	328.84	89.04	139.22	219.19	
F cultivar (c) = 122.53** F stage (s) = 1722.77** F cxs= 138.47**					

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

Table 6. Mn content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	Mn (ppm)				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	55.63c[1]	111.30a	41.63d	87.13b	73.92
Cumhuriyet	57.40c	80.10A	41.13d	68.70b	61.83
Tatlıcak	71.63a	43.47c	62.20b	48.10c	56.35
Karma	75.33a	34.27d	68.77b	39.67c	59.51
SDÜ – 21	64.47a	48.03b	46.83b	35.50c	48.71
SDÜ-27	67.77a	36.63c	63.20b	33.80c	50.35
SDÜ-43	57.30a	42.33c	47.60b	37.23d	43.62
Average	64.22	56.59	53.05	50.02	
F cultivar(c)= 248.15** F stage(s)= 137.85** F cxs= 218.96**					

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

Table 7. Zn content of two-row barley and triticale genotypes at different growth stages.

Cultivars/lines	Zn (ppm)				
	Stem elongation	Milk development	Dough development	Mature stage	Average
Hamidiye	49.80a	23.90b	18.80c	18.30c	27.70
Cumhuriyet	70.67a	23.51b	19.50c	17.76c	32.86
Tatlıcak	124.97a	69.03b	19.50c	16.73c	57.60
Karma	77.00a	29.26b	19.30c	18.30c	35.97
SDÜ – 21	40.17a	32.87b	23.10c	17.53d	28.42
SDÜ-27	71.57a	30.46b	25.60c	18.27d	36.48
SDÜ-43	32.90a	28.76b	19.26c	15.40d	24.08
Average	66.73	38.82	20.72	17.47	

F cultivar (c) = 870.99** F stage (s)= 4178.41** F cxs= 783.64**

[1]Means with different superscript in the same row differ (P<0.01); **: significant at 1% levels of probability

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