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Yield and Mineral Nutrition Content of Buckwheat (*Fagopyrum esculentum* Moench): The Effect of Harvest Times

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Abstract: Buckwheat (*Fagopyrum esculentum* Moench) is cultivated primarily to obtain grains for human consumption, especially gluten sensitive patients and hypertensive people. The present study was conducted to investigate the yield and mineral nutrient contents in plant organs, the harvest times and grain of buckwheat in 2012 and 2013. The Güneş species were used as the buckwheat cultivar.
The results revealed that the yield and mineral nutrient content of buckwheat varied according to both plant organs and harvest times. The herbage-hay yields and mineral nutrient contents in plant organs and harvest times of buckwheat were statistically ($p<0.01$) significant in both years. A mean grain yield of 1460.8 kg ha^{-1} was obtained in 2012 and 1592.6 kg ha^{-1} in 2013. The mean seed mineral nutrient contents of both years were found to be very close to each other. At harvest times, the highest herbage (27393.3 and 27603.1 kg ha^{-1}, respectively) and hay yield (7661.3 and 8536.7 kg ha^{-1}, respectively) were determined at the 5th harvest time (the latest harvest time), the lowest herbage and hay yield was obtained from the first harvest time in both 2012 and 2013. The herbage and hay yields increased by delaying harvest times. The highest mineral nutrition contents, except for Zn, were determined in the second harvest time. The lowest mineral nutrition contents varied according to the harvest times in both years.
In comparison with different plant parts, the highest herbage (4638.4 and 4975.7 kg ha^{-1}, respectively) and hay yield (1616.2 and 1684.3 kg ha^{-1}, respectively) were determined in the stem, while the lowest herbage and hay yields were obtained from flower organs in both 2012 and 2013. The highest mineral nutrition contents were obtained from the leaf and flower organs whereas the lowest mineral nutrition contents, except for K, were determined in the stem in both years.

Key words: Buckwheat, mineral nutrient, grain yield, herbage and hay yield

Karabuğday (*Fagopyrum esculentum* Moench)'ın Verim ve Mineral Besin İçeriği: Hasat Zamanının Etkisi

Özet: Karabuğday (*Fagopyrum esculentum* Moench)'ın temel yetiştirme amacı, insan beslenmesinde özellikle glütene hassas ve hipertansiyon hastalığı olan insanların beslenmesi için tane elde etmektir. Bu çalışma karabuğdayın verim, farklı hasat zamanlarında bitkide, bitki organlarında ve tanesinde mineral besin içeriğini araştırmak amacıyla 2012 ve 2013 yıllarında yürütülmüştür. Araştırmada Güneş karabuğday çeşidi kullanılmıştır.
Karabuğdayın verim ve mineral besin içeriği bitki organlarına ve hasat zamanlarına göre değişmiştir. Karabuğdayın taze ve kuru ot verimi, farklı bitki organlarında ve hasat zamanlarında mineral besin içeriği istatistiksel olarak ($p<0.01$) önemli olmuştur. Tane verimi 2012'de 146.08 kg/da ve 2013'de 159.26 kg/da olarak elde edilmiştir. Tanenin mineral besin içeriği her iki yılda da birbirine yakın çıkmıştır.
Hasat zamanları karşılaştırıldığında, her iki yılda da en yüksek yeşil ot (sırasıyla, 2739.33 ve 2760.31 kg/da) ve kuru ot (766.13 ve 853.67 kg/da, sırasıyla) verimi 5. hasat zamanından (en son hasat zamanı), en düşük yeşil ve kuru ot verimi ilk hasat zamanından elde edilmiştir. Taze ve kuru ot verimi hasat zamanının gecikmesiyle artmıştır. Her iki yılda da çinko dışında, en yüksek mineral besin içeriği 2. hasat zamanında belirlenmiş, en düşük besin içeriği ise hasat zamanlarına göre değişmişti.
Bitki organları karşılaştırıldığında, her iki yılda da en yüksek taze ot (sırasıyla 463.84 ve 497.57 kg/da) ve kuru ot (sırasıyla, 161.62 ve 168.3 kg/da) verimi sapta belirlenirken, en düşük taze ve kuru

ot verimi çiçekten elde edilmiştir. Her iki yılda da en yüksek mineral besin içeriği yaprak ve çiçekten, en düşük mineral besin içeriği ise (K hariç) saptan elde edilmiştir.

Anahtar kelimeler: Karabuğday, mineral besin, tane verimi, taze ve kuru ot verimi

Introduction

Buckwheat (*Fagopyrum esculentum* Moench), a plant belonging to the family *Polygonaceae*, is most commonly cultivated and produced in China, Russia, Ukraine and Kazakhstan, but in recent years, it has been cultivated all over the world and in particular in Asia, Europe and America (Christensen et al., 2010). Although about 15 species of buckwheat have been reported (Ye and Guo, 1992), common buckwheat *(Fagopyrum esculentum* Moench) and tartary buckwheat *(Fagopyrum tataricum* (L) Gaertn.) are grown. Common buckwheat accounts for up to 90% of buckwheat production, tartary buckwheat is less common and is often defined as bitter buckwheat (Campbell, 1997). The main user purpose of buckwheat is in the treatment of celiac disease due to the fact that it is gluten-free (in the form of flour-bread, rice, soup, cakes, pasta, crackers, cookies, pancakes and tortillas). It is also grown for forage plants (livestock and poultry feed), green manure, weed control, erosion prevention, as a source of honey and in the paint industry (Wijngaard and Arendt, 2006).

As an annual crop buckwheat is a pseudo-cereal since it does not a grass like wheat, but its grains are used like cereals because of their similar use and chemical composition (Christa and Soral-Smietana, 2008). Buckwheat can be planted as a warm-season forage crop with cowpeas, grain sorghum or soybeans and also as a stand-alone crop. It is easy to grow in areas with little or no seedbed preparation. Another important characteristic of the crop is its fast growth and it can mature within a 7 to 10-week period (Tahir and Farooq, 1988; Tsuneo, 2004).

Buckwheat is a valuable source of minerals for the people who consume it. Buckwheat contains a relatively high level of some minerals (Ikeda and Yamashita, 1994; Ikeda et al., 1995). Buckwheat grains are an important source of microelements such as Fe, Zn, Cu, Mn, and Se (Wei et al., 1995; Stibilj et al., 2004) and the macro elements such as K, Na, Ca and Mg (Wei et al., 2003). The hull, straw and leaves of buckwheat are the major by-products of buckwheat flour production despite of being not usually utilized for human consumption. However, these by-products contain minerals and are usually utilized as animal feed. In addition, these by-products are used as a traditional food preparing with the dried buckwheat straw and leaves in some countries. In traditional Chinese medicine, seeds, stems and leaves of buckwheat have been used for the treatment of gastrointestinal problems, zoster, inflammation and hypertension (Zhou, 2003).

In Turkey, there are 300,000 cases of celiac disease, and a significant problem for these people is the supply of reliable food (Dizlek et al., 2009). Various foods serve as dietary sources; especially cereals such as buckwheat may be an important source of minerals in terms of daily consumption. Buckwheat is rich in term of gluten-free products especially with proteins, micro-and macro elements and vitamins (Kozak et al., 2011).

Buckwheat can be a significant forage crop for livestock and poultry feeds (Tahir and Farooq, 1988). Turkey’s roughage production constitutes approximately half of the total roughage requirement. The reason for this is the low ratio of forage crop cultivation (7.4%) in total arable land in Turkey (TÜİK, 2012). In the next few years in Turkey, the target should be to meet the need for high-quality roughage with a fast production program. To eliminate the need for roughage deficits in animal feed, alternative roughage sources such as cereals, straw, horticultural and industrial residues and buckwheat can be used.

In Turkey, buckwheat has begun to be intentionally cultivated in recent years and it can be cultivated twice a year from April to August due to favorable climatic conditions. It is grown in spring in the west, south and central Anatolia regions of Turkey. Buckwheat is an important source of food for gluten-sensitive patients and it may be an alternative forage crop due to its short-lived, fast-growing characteristics and the high herbage yield. However, there is not sufficient research regarding the yield, seed and roughage mineral nutritional content of buckwheat in Turkey. Therefore, the objectives of the research were: to determine the grain, herbage and hay yield period of buckwheat in the ecological conditions of Isparta, and to analyze the distribution of mineral nutrients in the seeds and plant organs of buckwheat at different growing stages.

Materials and Methods

The experiment was conducted during the growing seasons of 2012 and 2013 in the Experimental Area of the Suleyman Demirel University, Isparta. Meteorological data for the growing seasons were shown in Table 1.

Some physical and chemical characteristics of the experimental area are shown in Table 2.

Table 1. Meteorological data of the experimental field

Climatic factors	Years	Months				Total or Average
		May	June	July	August	
Precipitation (mm)	2012	107.4	18.1	0.8	34.6	160.9
	2013	66.5	34.4	88.2	15.4	204.5
	Long Years	50.8	28.4	18.4	0.8	98.4
Average Temperature (^{0}C)	2012	14.5	22.5	25.4	22.8	21.3
	2013	17.1	20.5	23.0	23.7	21.1
	Long Years	15.6	20.1	22.3	23.9	20.4
Relative humidity (%)	2012	66.0	46.0	42.0	43.0	49.2
	2013	52.0	50.0	44.0	41.0	46.8
	Long Years	50.3	53.0	45.8	44.5	48.4

Regional Meteorology Station, Isparta

Table 2. Some physical and chemical characteristics of the experimental area

Depth (cm)	pH	ECx10^6	$CaCO_3$ g.kg^{-1}	Org.M. g.kg^{-1}	Texture Class
0-30	7.8	378	292	16.9	CL
30-60	7.8	381	221	12.8	CL
60-90	7.9	404	309	14.3	SiCL

The cultivar Güneş was sown on the 2nd and 5th of May in 2012 and 2013, respectively. The distances between rows and within the rows were 15 and 5 cm, respectively. Each plot area was 7.2 m^2 and consisted of 8 rows. Seeds were sown at 3-4 cm depths using a dibbler. The experiment was arranged according to a randomized complete block design with three replications.

Nitrogen (60 kg ha^{-1}), phosphorus (50 kg ha^{-1}) and potassium (40 kg ha^{-1}) fertilizers were applied to the plots in the form of ammonium sulfate, P_2O_4 and K_2O, respectively. The all of P_2O_4 and K_2O fertilizers were applied at the time of sowing. Ammonium sulfate was applied in times of sowing and the seedlings reached a height of 10 cm.

Irrigation

The experimental areas were irrigated at three times, which were at the beginning of flowering, after 20 days from the beginning of flowering (around the full blooming period) and the beginning of the grain filling periods. In both years, the irrigations were applied using a sprinkler irrigation system.

Yield and Analysis of Mineral Nutrient Contents

Flowering in buckwheat begins in 4th or 5th weeks from after sowing and continues for at least a month due to the indeterminate nature of the inflorescences. Flowers, green grains and mature grains are present on the plants at the same time (Campbell, 1983). Therefore, in order to determine the highest herbage, hay yield stage and mineral nutrient contents, the buckwheat plants were harvested at five different growing stages. The harvest times were planned at five different stages as follows; 1st harvest stage: the beginning of flowering (01.06.2012 and 03.06.2013), 2th harvest stage: 20 days (21.06.2012 and 23.06.2013) from the beginning of flowering (around the full blooming period), 3rd harvest stage: 32 days (03.07.2012 and 05.07.2013) from the beginning of flowering (about the end of flowering), 4th harvest stage: 45 days (15.07.2012 and 17.07.2013) from the beginning of flowering (about 25% of grains had turned brown) and, and 5th harvest stage: 55 days (25.07.2012 and 27.07.2013) from the beginning of flowering (about 50% of grains had turned brown).

The samples were brought to the laboratory. The fresh herbage yield was calculated by converting from parcel herb yield to hectare herb yield. The samples were dried on a wire rack in the shade for a two-week period, and then recorded the change from parcel dry hay yield to hectare.

In this research, only the herbage and hay yields of plant organs at the second harvest time were given because of the higher mineral nutrient contents than at the other harvest times, except for Zn. Fresh herbage harvested at the second harvest time was left to the leaves, flowers and stems. Later, these samples were dried on a wire rack in the shade for a two-week period, and then calculated in terms of the change from parcel dry hay yield to hectare.

When about 75% of grains had turned brown and dried (Campbell, 1983), plants in the center (6 rows) of each plot were harvested manually (August 15th and 18th in 2012 and 2013, respectively) and then they were threshed with a threshing machine. Data from plots obtained were converted from parcel grain yield to hectare basis.

The samples taken from the grain, harvest times and plant organs (leaves, flower and steem) were dried in an air-forced oven at 55 ^{0}C until the weight became stable. Then dried samples were ground to pass through a 1-mm screen. Mineral nutrient contents including nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), iron (Fe), zinc (Zn), manganese (Mn), zinc (Zn) and boron (B) were determined. The N content was determined using the Kjeldahl method. The phosphorus content was determined according to the Molibdovanado-phosphoric acid method. K content was measured by flame emission Spectrophotometry. Ca, Mg, Fe, Zn, Mn, Zn and B contents were analyzed with an atomic absorption spectrophotometer.

Statistical Analysis

All the data were analyzed using the JUMP 5.0.1 statistical package program; significant differences between the means were separated using the LSD test.

Results

Significant differences were found between the two subsequent years in terms of herbage and hay yield, except for the hay yield of plant organs (Table 3). The herbage and hay yields of the second year were higher than that of the first year. A mean grain yield of 1460.8 kg ha^{-1} was obtained in 2012 and 1592.6 kg ha^{-1} in 2013 (Table 3). Concerning the harvest times, while the highest herbage (27379.3 and 27603.1 kg ha^{-1}, respectively) and hay yield (7661.3 and 8536.7 kg ha^{-1}, respectively) were determined in the 5th harvest time, the lowest herbage (3839.6 and 4066.1 kg ha^{-1}, respectively) and hay yields (1200.3 and 1356.1 kg ha^{-1}, respectively) were determined at the first harvest time in 2012 and 2013. With regards to the plant organs, the highest herbage and hay yields were obtained from the stem and the lowest from the flowers in both years (Table 3).

Table 3. Grain yield, herbage and hay yield in harvest times and aboveground plant organs of buckwheat

Plant organs		Herbage yield (kg ha^{-1})		Hay yield (kg ha^{-1})	
		2012	2013	2012	2013
The second harvest time	Flower	1522.6 c	1660.6 c	578.6 b	635.7 b
	Leaf	1868.3 b	1960.3 b	779.7 b	846.1 b
	Stem	4638.4 a	4975.7 a	1616.2 a	1684.3 a
Years		2676.4B	2865.5A	991.4 ^{ns}	1055.3
Lsd		179.68	29.746	261.55	423.97
CV (%)		9.78	6.76	7.01	10.68
F value		3830.2	161.08	187.56	72.59
P value		0.001	0.001	0.001	0.001
Harvest times					
1st stage		3839.6 e	4066.1 e	1200.3 d	1356.1 e
2th "		14522.1 d	15025.7 d	4651.3 c	4909.1 d
3rd "		23707.3 c	24371.6 c	7116.4 b	7567.2 c
4th "		25904.6 b	26104.7 b	7434.1 a	7991.7 b
5th "		27379.3 a	27603.1 a	7661.3 a	8536.7 a
Years		19070.1 B	19433.6 A	5612.7 B	6072.2A
Lsd		88.144	831.63	270.72	221.99
CV (%)		10.16	8.56	12.50	6.99
F value		282.50	3184.20	223.13	4235.13
P value		0.001	0.001	0.001	0.001
		Grain yield (kg ha^{-1})			
		2012	2013		
		1460.8 b	1592.6 a		
		Lsd: 50.124**			

Means in the same columns followed by the same letters are not significantly different at the 0.001 level as statistically, **: significant at P<0.001 probability levels, ns: non significant

No significant differences were found between the two subsequent years in any of the mineral nutrient contents of grain (Table 4). The mean mineral nutrient contents of years in grain were found to be very close to each other.

Mineral nutrient contents at harvest times and the plant organs of buckwheat were statistically (p<0.001) significant in both years. No significant differences between the two subsequent years in any of the mineral nutrient contents were found (Table 4). Mean mineral nutrient contents of years in both harvest times and plant organs were found to be very close to each other.

In terms of the harvest times, the highest N (3.26 and 3.29%, respectively), P (0.294 and 0.288%, respectively), K (5.76 and 4.86%, respectively), Ca (3.431 and 3.35%, respectively), Mg (0.643 and 0.642%, respectively), Fe (436.1 and 414.5 ppm, respectively), Cu (8.90 and 8.65 ppm, respectively), Mn (61.18 and 57.45 ppm, respectively) and B (26.50 and 25.76 ppm, respectively) were obtained from the second harvest time, and the highest Zn (125.7 and 113.9 ppm) from the 5th harvest time in 2012 and 2013 (Table 4). The lowest mineral nutrient contents varied according to harvest times in both 2012 and 2013.

When the plant parts are compared, the highest N (3.6 and 3.70%, respectively), Ca (4.02 and 4.01%, respectively), Mg (0.810 and 0.807%, respectively), Fe (652.9 and 677.4 ppm, respectively), Mn (98.84 and 99.95 ppm, respectively) and Zn (85.40 and 88.25 ppm, respectively) were obtained from the leaf, whereas the highest P (0.434 and 0.439%, respectively), Cu (10.86 and 10.74 ppm, respectively) and B (32.84 and 32.92 ppm, respectively) from the flowers and the highest K (5.38 and 5.67%, respectively) from the stem in 2012 and 2013 were found (Table 5). In general, the lowest mineral nutrient contents were determined in the stem organs, except for K and Ca; the lowest K and Ca were determined in the flower organs in both 2012 and 2013.

Table 4. Mineral nutrient contents in harvest times and grain of buckwheat

	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Grain (seed)	1.92^{ns}	1.89	0.312^{ns}	0.314	0.58^{ns}	0.60	0.10^{ns}	0.11	0.179^{ns}	0.184
Harvest times										
1st stage	3.06a	3.08a	0.283a	0.289a	5.48a	4.25a	3.28a	2.22a	0.627a	0.622a
2th "	3.26a	3.29a	0.294a	0.288a	5.76a	4.86a	3.43a	3.35a	0.643a	0.642a
3rd "	2.02b	2.05b	0.209b	0.208c	3.26b	3.22b	2.42b	2.39b	0.437b	0.439b
4th "	1.42c	1.46d	0.204b	0.204c	2.19b	2.23c	2.14c	2.20bc	0.349c	0.338c
5th "	1.54c	1.56c	0.212b	0.234b	1.90b	1.83d	2.14c	1.99bc	0.330c	0.314c
Years	2.26^{ns}	2.29	0.240^{ns}	0.244	3.71^{ns}	2.27	2.68^{ns}	2.43	0.477^{ns}	0.471
Lsd	0.201	0.097	0.010	0.022	1.737	0.264	0.263	0.525	0.033	0.040
CV (%)	4.15	3.98	1.75	3.67	14.85	4.08	5.07	10.27	3.36	4.16
F value	290.8	1264.8	495.4	98.49	20.19	590.8	341.4	81.1	434.3	296.9
P value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
	Fe (ppm)		Cu (ppm)		Mn (ppm)		Zn (ppm)		B (ppm)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Grain (seed)	45.5^{ns}	44.7	7.20^{ns}	7.15	15.54^{ns}	15.13	55.84^{ns}	55.22	9.85^{ns}	9.68
Harvest times										
1st stage	416.0a	406.2a	8.64a	8.20a	58.83ab	56.36a	44.66e	44.13e	25.35a	24.95a
2th "	436.1a	414.5a	8.90a	8.65a	61.18a	57.45a	65.77d	63.13d	26.50a	25.76a
3rd "	352.3ab	370.6ab	7.45b	7.79b	49.03b	50.87b	86.65c	90.64c	22.73b	23.54b
4th "	332.4bc	325.6b	5.59d	5.52c	38.66c	38.51c	95.69b	95.33b	22.81b	22.05c
5th "	244.0c	235.3c	6.31cd	6.46c	53.43b	50.08b	125.7a	113.9a	19.57c	19.62d
Years	356.1.7^{ns}	350.4	7.37^{ns}	7.32	52.23^{ns}	50.65	83.69^{ns}	81.43	23.39^{ns}	23.18
Lsd	94.02	46.83	0.958	0.509	7.468	3.305	6.290	3.086	1.798	0.929
CV (%)	13.21	6.93	5.27	2.82	6.74	3.08	3.07	4.54	3.50	5.83
F value	40.99	174.6	28.18	100.6	91.17	421.6	448.2	1533.2	208.1	768.1
P value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Means in the same columns followed by the letters are not significantly different at the 0.001 level as statistically, ns: non significant

Table 5. Mineral nutrient contents in different organs of buckwheat in the second harvest time

Plant organs	N (%)		P (%)		K (%)		Ca (%)		Mg (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Flower	3.14 b	3.24b	0.434a	0.439a	1.94c	1.98c	1.597c	1.608c	0.443b	0.449b
Leaf	3.60 a	3.70a	0.304b	0.298b	3.53b	3.44b	4.022a	4.018a	0.810a	0.807a
Stem	0.62 c	0.66c	0.227c	0.238c	5.38a	5.67a	3.033b	3.164b	0.384c	0.416b
Years	2.45^{ns}	2.53	0.322^{ns}	0.328	3.61^{ns}	3.70	2.87^{ns}	2.93	0.546^{ns}	0.557
LSD	0.386	0.411	0.018	0.029	0.207	0.286	0.275	0.570	0.025	0.035
CV (%)	4.18	4.31	3.50	2.47	4.52	3.06	2.54	5.17	3.23	3.68
F value	728.0	673.6	1386.8	523.3	2934.3	1782.7	827.8	194.5	3520.4	1592.1
P value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001
Plant organs	Fe (ppm)		Cu (ppm)		Mn (ppm)		Zn (ppm)		B (ppm)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Flower	518.5b	528.2b	10.86a	10.74a	61.56b	62.78b	63.49b	63.52a	32.84a	32.92a
Leaf	652.9a	677.4a	9.66a	9.61b	98.84a	99.95a	85.40a	88.25a	30.95a	31.95a
Stem	154.4c	156.7c	5.42b	5.49c	20.03c	21.44c	28.79c	30.07c	17.34c	16.87c
Years	441.9^{ns}	454.1	8.65^{ns}	8.60	60.14^{ns}	61.39	59.23^{ns}	60.61	27.04^{ns}	27.29
LSD	50.543	44.193	1.517	0.538	4.750	3.461	4.892	2.523	2.481	2.405
CV (%)	3.04	2.58	4.66	3.60	2.10	2.49	2.19	2.10	4.40	2.34
F value	1104.3	1560.6	150.5	1112.7	2919.7	5456.0	1443.0	5677.4	492.1	591.0
P value	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001

Means in the same columns followed by the same letters are not significantly different at the 0.001 level as statistically, ns: non significant

Discussion

In the study there were significant variations in the herbage and hay yields of buckwheat in terms of both plant parts and harvest times. Among the harvest times, herbage and hay yield increased by delaying the harvest time to maturity and ripening due to the higher dry matter accumulation and the longer season growing period than in a short season. Additionally, plant parts such as the leaf, stem and seeds also continue to grow and development with a delayed harvest time and therefore, herbage and hay yields increase. Kara et al. (2012) stated that dry matter in plants depends on the growth period between sowing and harvesting. Girma et al. (2011) reported that the herbage and hay yields increase with crop maturity, but there is generally a decrease in nutritive value. Yields of most species generally increase with time up to anthesis, after which yields decline due to increased losses from shading and respiration (Dear et al., 2005).

The mean grain yield, herbage and hay yields of the second year were higher than the first year. These differences between the years might be due to the higher rainfall during the growing period in the second year. The yield was directly related to the mean air temperature and rainfall. Russelle et al. (2004) stated that the grain yield of plants varies according to different climatic conditions, especially temperature and rainfall.

There were significant variations in the mineral elements' contents of the buckwheat grain. In the grain of buckwheat, while N, P, Mg, Cu and Zn levels were found to be high, lower levels were found of K, Ca, Fe, Mn and B. Ikeda and Yamashita (1994) determined that there were variations in the mineral element contents of buckwheat flour. Ikeda et al. (1999) stated that buckwheat flour contained high levels of magnesium, phosphorus and potassium. Dias et al. (2009) stated that high photosynthetic activity at final grain filling increased the Fe content of the grain.

There were significant variations in mineral composition among the harvest times of buckwheat. The highest N, P, K, Ca, Mg, Fe, Cu, Mn and B contents were determined at the second harvest time, and these mineral elements were significantly decreased in the later harvest times (3rd, 4th and 5th harvest times) in both 2011 and 2012. However, the highest Zn content was determined at the latest harvest time. The most influential factor on nutritive value in plants is growing periods. Nutrient accumulation occurs mainly before anthesis, and its ratio in subsequent growing periods decreases because the plant continues to grow (Girma et al., 2011). Kilcher and Troelsen (1973) reported that N content was significantly decreased from vegetative period (30-35%) towards to maturity (8-10%). The macro nutrient elements of forage crops varied depending on harvesting stage, and generally the macro nutrient elements decreased with a delayed harvesting stage (Martin et al., 1989). Smith (1976) found that the K rate of oats decreased from 5.2% to 1.4, the Ca rate decreased from 4.2% to 0.30% and the P rate decreased from 0.52% to 0.26% with delayed harvest time. Similarly, Korkmaz et al. (1993) reported that the Mg rate decreased with delayed harvest time. Girma et al. (2011) determined that N accumulation was relatively rapid at the early season satge; it decreased in the later season and continued at a decreased rate until maturity.

In the parts of plants, mineral nutrient contents, including N, P, K, Ca, Mg, Fe, Cu, Mn, Zn and B significantly varied according to plant organs. The leaves of buckwheat contained higher levels of N, Ca, Mg, Fe, Mn and Zn but there were lower levels of P, Cu, B and K. The flowers contained higher levels of P, Cu and B, and K was higher in the stem. Generally, the results of the present study showed that the accumulation of the examined mineral concentration was higher in the leaves and blossoms of the buckwheat plant. However, the leaves and flowers of buckwheat contained relatively high or low levels of some minerals. Similar results were reported by Nashriyah et al. (2010). Ikeda et al. (1999) found higher levels of potassium, calcium and manganese characterized at the leaves and hull when compared to buckwheat seed. Vojtiskova et al. (2012) reported that the N content in leaves and blossoms of the buckwheat plant was higher than in its seed, and a lowest amount of N was found in the hull.

In general, the recommended that harvest time of forage crops for herbage yield is at the flowering and the soft dough stage (Açıkgöz, 2001). In this study, the recommended harvest time for quality forage is the second harvest time due to the high mineral nutrient content. In the later stages, the yield is much higher, but of lower nutrient content than at the second harvest time.

The yield and total nutrient content could be influenced by many factors, e.g. the variety of the plant, fertilization, different climatic conditions, harvest time, processing of the seed, laboratory conditions, etc. (Barta et al., 2004).

Conclusions

The results indicated that herbage, hay yield and mineral composition of buckwheat significantly varied according to the plant organs and harvest times. Mean grain yields of 1460.8 kg ha^{-1} and 1592.6 kg ha^{-1} were obtained. The herbage and hay yields of buckwheat were increased with delayed harvest time, and the highest herbage and hay yield was obtained from the latest harvest time (5^{th} harvest stage). In plant organs, the highest herbage and hay yields were obtained from stem.

High levels of N, P, Mg, Cu and Zn and lower levels of K, Ca, Fe, Mn and B were found in the grain of buckwheat.

The mineral nutrient composition of the second harvest time was higher than that of other harvest times, but the highest Zn content was determined at the latest harvest time.

The buckwheat leaves contained higher levels of N, Ca, Mg, Fe, Mn and Zn but lower levels of P, Cu, B and K. The flowers contained higher levels of P, Cu and B, and K was higher in the stem.

Based on the results of the research: 1- Having obtained high grain, herbage and hay yields, it is possible to say that buckwheat can be successfully produced in Isparta's, Turkey, ecological conditions, 2- the latest harvest time (5^{th} stage) is very important for maximum herbage and hay yield, but if the economic yield and quality (the highest nutrient content) are desired, the second harvest time can be suggested.

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