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Effect of Vermicompost Application on Mineral Nutrient Composition of Grains of Buckwheat (*Fagopyrum esculentum* M.)

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Abstract: Poor soil organic content is a major cause of declining crop productivity in developing countries. Less precipitation and high temperatures oxidize organic matter in the soils of semi-arid regions. Such a deficiency in the organic matter of the soils decreases the bioavailability of many nutrients. Organic amendments like vermicompost (VM) have the potential to overcome this problem, while decreasing the dependency on inorganic fertilizers. Thus, the aim of our study was to explore the best application rate of VM for the improvement of nutrient contents in buckwheat. We used two buckwheat cultivars i.e., Aktaş and Güneş were sown under variable rates of soil-applied VM (0, 0.75, 1.50, 2.25 and 3.00 t ha^{-1}) in semi-arid highland conditions. The results demonstrated that the nutritional quality parameters were improved when VM was applied at the rate of 2.25 t ha^{-1}. In addition, VM at 2.25 t ha^{-1} resulted in an improvement of the N and P contents of the grains. The P contents in the grains of the Güneş variety was higher (0.26%) than the Aktaş variety (0.24%). A significant improvement in Fe (%), Cu (%), Zn (%) and Mn contents (%) in the grains of buckwheat validated the efficacious functioning of 2.25 t ha^{-1} of VM. The Zn content of the grains was higher in the Güneş variety (34.06%) than the Aktaş variety (31.96%). However, no significant change in K, Ca and Mg was noted at any level of VM in both Aktaş and Güneş. It is concluded that a 2.25 t ha^{-1} VM application in the buckwheat crop under zero conventional fertilizer was the best level to boost the nutritional quality of the grains.

Keywords: buckwheat; vermicompost; zero fertilizer; semi-arid; grain nutrition

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1. Introduction

Buckwheat (BW; *Fagopyrum esculentum* Moench) is a grain crop that has recently attained much attention for human consumption, especially in gluten-sensitive and hypertensive people [1]. Fagopyrum is a genus containing 15 species, most of which are indigenous to temperate Eastern Asia and common BW is the most important species in this genus [2]. BW is an alternative crop belonging to the eudicot family *Polygonaceae* [3]. The major producers of buckwheat are China, the Russian Federation, Ukraine, and Kazakhstan [4]. It is an annual crop of secondary importance in many countries.

BW is a short-season grain crop containing "rutin" and many phenolic compounds [5]. According to pharmacological studies, *F. esculentum* has antioxidant, anti-inflammatory, antigenotoxic, antidiabetic, renoprotective, antimicrobial, anticancer, wound healing and photoprotective effects [6]. A higher antioxidant capacity in its achenes is related to higher phenol and flavonoid contents, whereas the maximum phenol content in its seeds is at the seed coat layers [7]. Grains of BW have a good balanced nutrition, but the digestibility of grains is relatively low [8]. Moreover, lodging can also affect the yield and reduce the quality of the BW [9]. BW is a heterostylous self-incompatible species with two types of floral architecture named thrum (short style) and pin (long style). The flowers can effect foregut fermentation in ruminant animals as result of their phenolics [10]. The dehulling of its grains produces a high amount of a by-product named hulls [11].

BW is valuable for crop rotation and agro-ecology due to its intensive flowering properties and strong rooting system [12]. This dicotyledonous crop grows quickly at high altitudes. However, it also has a high tolerance to acidity and the ability to grow in poor soils [13]. BW has a good suppression capacity on redroot pigweed (*Amaranthus retroflexus*) partly due to its allelopathic root exudates [14]. Moreover, the genus of Fagopyrum is one of the aluminium-tolerant taxonomic units of plants [15]. Buckwheat is highly tolerant to aluminium [16] and it accumulates high levels of it [17]. *F. esculentum* is determined as a bioindicator of environmental conditions in nanoparticle-polluted environments [18]. The crop is also a hyperaccumulator of Ni [19].

BW is a robust plant with a high resistance to discrete environmental conditions. The role of its high level of calcium oxalate (CaOx) druse crystals remains obscure. Strong relationships were observed between its calcium and sulphur contents, size and the density of CaOx druse crystals and its water-related parameters [20]. Nitrogen fertilizers seriously affect the yield of buckwheat [21]. The crop can use P from a tied inorganic pool unavailable to other crops [22]. When buckwheat was grown in low P and a P-fertilized field, soil P availability was not affected by buckwheat [23]. Nitrogen, phosphorus, and potassium fertilizers in buckwheat can be reduced by applying 10 t ha^{-1} of composted manure [24].

The loss of mineral fertilizers, especially nitrogenous fertilizers, from agricultural fields has been considered a major contributor to global greenhouse gas emissions [25,26]. Organic amendments applied solely or in conjunction with reduced doses of mineral fertilizers can further cut the gaseous emissions [27–30]. Vermicomposting (VM) means converting organic materials into humus-like substances (vermicompost) by earthworms [31]. In a non-thermophilic and bio-oxidative process of associated VM, microbes also help to decompose biological organic wastes [32]. VM is a low-cost and environmentally friendly process [33]. The resultant VM is a finely divided, peat-like material with high porosity and good aeration, drainage, water holding capacity, and buffering capacity, which enhances the soil and is beneficial to microbial biodiversity [32]. VM contains a luxury concentration of N, P, K, Ca, Mg, S, Fe, Mn, Zn, Cu, B and humic acids [34]. It also improves the physical, chemical, and biological attributes of the soil with its better nutrient profile more than traditional compost [29]. This positively affects the plant nutrition, photosynthesis, and the nutrient content of the roots, shoots and fruits. Furthermore, it also promotes the synthesis of anthocyanins and flavonoids to improve the quality and pest and disease tolerance of the plants [34]. VM enhances plant growth through the production of plant growth-regulating hormones and enzymes [32]. Therefore, this agricultural and horticultural organic fertilizer is increasingly seen as a good alternative to inorganic fertilizers [33].

However, the application of VM at a higher concentration may reduce the growth due to higher concentrations of soluble salts. The application of moderate quantities of VM is a better approach to escape this possibility [31]. Previous research has shown that the radicle growth of legumes was found to be sensitive and was negatively affected by higher doses of VM [35]. We hypothesized that buckwheat cultivars might respond differently to the soil application of vermicompost due to differences in their genetic make-up and the potential and bioavailability of nutrients. Considering the potential of VM, a field trial was undertaken to examine the impact of varying levels of VM on different cultivars of buckwheat in terms of the nutritional quality of the grain under semi-arid conditions.

2. Materials and Methods

2.1. Study Location

The research was conducted at the Research and Application field, Department of Field Crops, Siirt University, Siirt province, Turkey, in July–October 2017, as per the presented geographic data in Figure 1.

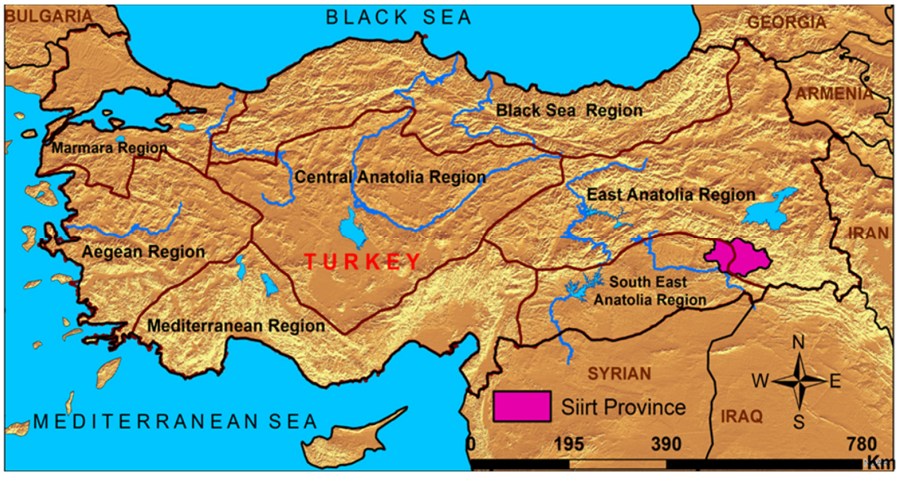


Figure 1. Location of the study area in Turkey.

2.2. Soil

The soil samples were collected from the depth of 0–20 cm at the research area before experimentation and analysis in the laboratory following the standard protocols. The soil was high in clay, slightly alkaline, non-saline, medium-level calcareous, and deficient in available phosphorus (P) and organic matter, and sufficient in potassium (K) contents. Some physical and chemical properties of the soil are given in Table 1.

Table 1. Physical and chemical properties of the research area soil.

Soil Properties	Values
Sand (%)	7.90
Clay (%)	55.84
Silt (%)	36.26
pH	7.98
Electrical conductivity (EC) (mS cm^{-1})	0.363
$CaCO_3$ (%)	13.0
Organic matter (%)	1.31
Available P (kg P_2O_5 ha^{-1})	74.7
Available K (kg P_2O_5 ha^{-1})	3800

2.3. Meteorological Information

Data on weather parameters such as temperature, precipitation and relative humidity were recorded during the experimental period. When climate data was analyzed, the average temperature in the July–October period of the research year was found to be similar to long term values, but the relative humidity values were found to be lower than the long-term averages. While the total amount of precipitation between July–October 2017 was 5.6 mm, for many years this value was 58.0 mm for the same months (Table 2). Selected climatic data for July–October 2017 and long term (1950–2017) are given in Table 2.

Table 2. Long term and research year climatic data of the Siirt province.

Meteorological Elements	Years	July	August	September	October	Average/ Total
Relative humidity (%)	2017	19.0	19.0	19.1	34.6	22.9
	1950–2017	26.8	26.1	31.0	47.2	32.8
Average temperature (°C)	2017	32.3	32.0	28.4	18.4	27.8
	1950–2017	30.6	30.1	25.2	18.1	26.0
Total precipitation (mm)	2017	0.0	0.4	0.0	5.2	5.6
	1950–2017	3.1	2.3	4.7	47.9	58.0

2.4. Planting Material

Aktaş and Güneş buckwheat varieties were used in the study. The chemical properties of the vermicompost used in the study are given in Table 3.

Table 3. Chemical properties of the vermicompost used in the study.

	EC (dS m^{-1})	pH	Organic Matter Content (%)	Total Humic and Fulvic Acid (%)	Total Nitrogen (N) Content (%)	Organic Nitrogen (N) Content (%)	C/N Ratio	Total P (P_2O_5) Content (%)	Water Soluble K_2O Content (%)
Value	**3.2**	**6.8**	**57.0**	**40.0**	**3.1**	**2.0**	**9.2**	**1.2**	**0.89**

2.5. Experimental Treatments and Design

The experiment consisted of two factors: varieties (Aktaş and Güneş) and vermicompost doses (0, 0.75, 1.50, 2.25 and 3.00 t ha^{-1}). The field trial was carried out in the factorial arrangement of a randomized complete block design with three replications. Varieties and vermicompost doses were assigned to the main plots and subplots, respectively.

2.6. Experimentation

A solid form of vermicompost was used in the study. VM treatments were incubated 20 days prior to seed sowings. VM was applied to the experimental parcels by hand and then mixed with a harrow. Buckwheat was planted in the last week of July at the seed rate of 50 kg per hectare. Each parcel was formed of six rows with a 25 cm inter row distance. After planting, a drip irrigation system was set up for the "emergence irrigation" and post-emergence irrigations occurred twice a week. Weed control was carried out regularly by hand pulling. No pesticide application was required. Harvesting was carried out by hand when 75% of the grains were browned (Figure 2). Harvested plants were dried in the open air for a week and the above-ground parts of the plant were separated. The grains were cleaned and prepared for laboratory analysis.



Figure 2. Buckwheat during the seed maturation period.

2.7. Data Collection

The N content of the grain was determined by the Kjeldahl method and the P, K, Ca, Mg, Fe, Zn, Cu and Mn contents were determined with the filtered ICP-OES (Perkin Elmer 2100V) device with the wet combustion method [36].

2.8. Statistical Analysis

The data were subjected to the variance of analysis technique according to the divided plots in the randomized complete block design. The differences between statistically significant applications were subjected to the Tukey test at 5% level of probability [37].

3. Results and Discussion

3.1. Macronutrient (N, P and K) Contents

The varying levels of soil applied VM had a significant effect on the nutritional quality parameters of buckwheat cultivars under semi-arid conditions. The macroelement (N, P and K) contents in the grains of the two varieties were evaluated, and the VC significantly influenced the P contents, but the effect was non-significant for N and K. However, the concentrations of N, P and K in the grains of buckwheat varieties varied within the range of 1.65–1.92, 0.23–0.27 and 0.75–0.84%, respectively. The P contents in the grains of the Güneş variety was higher (0.26%) than the Aktaş variety (0.24%) (Table 4). Unal et al. [38] reported that buckwheat grains contained 14% protein indicating 2.2% of N (6.25 conversion ratio will transform average 14% protein ratio approximately to 14/6.25 = 2.2% N content), which was much higher than our results. A varietal source of N-containing fertilizer might be the major reason for the difference of the N content. According to [39], the P content of buckwheat grains was 330 mg 100 g^{-1} (equal to 0.33%) and the K content of buckwheat grains was 450 mg 100 g^{-1} (equal to 0.45%). Values in our study for P and K were lower compared to [40]. The probable source of this variance was the zero conventional fertilizer application and/or the addition of vermicompost to the soil in our study and/or a different genotype selection.

Table 4. The effect of vermicompost doses on the nutrient contents of seeds of buckwheat varieties.

Varieties	Vermicompost Doses (t ha^{-1})	Macroelements (%)				
		N	P	K	Ca	Mg
Aktaş	0	1.651 ± 0.110	0.230 ± 0.010	0.750 ± 0.017	0.033 ± 0.006	0.160 ± 0.017
	0.75	1.749 ± 0.089	0.243 ± 0.012	0.763 ± 0.015	0.040 ± 0.000	0.160 ± 0.017
	1.5	1.831 ± 0.167	0.250 ± 0.010	0.770 ± 0.053	0.053 ± 0.015	0.167 ± 0.025
	2.25	1.901 ± 0.071	0.260 ± 0.010	0.767 ± 0.035	0.063 ± 0.023	0.203 ± 0.015
	3	1.850 ± 0.074	0.256 ± 0.006	0.793 ± 0.023	0.057 ± 0.015	0.173 ± 0.006
Average		1.796 ± 0.073	0.248 ± 0.002 B	0.769 ± 0.008	0.049 ± 0.004	0.173 ± 0.009
Güneş	0	1.658 ± 0.110	0.240 ± 0.012	0.787 ± 0.006	0.043 ± 0.006	0.163 ± 0.015
	0.75	1.774 ± 0.109	0.260 ± 0.006	0.753 ± 0.025	0.037 ± 0.006	0.190 ± 0.020
	1.5	1.812 ± 0.063	0.260 ± 0.006	0.790 ± 0.026	0.043 ± 0.015	0.177 ± 0.012
	2.25	1.915 ± 0.117	0.270 ± 0.012	0.766 ± 0.058	0.053 ± 0.012	0.193 ± 0.032
	3	1.925 ± 0.115	0.265 ± 0.010	0.840 ± 0.026	0.050 ± 0.000	0.197 ± 0.006
Average		1.817 ± 0.091	0.262 ± 0.006 A	0.79 ± 0.015	0.045 ± 0.003	0.184 ± 0.009
Vermicompost Doses (t ha^{-1})						
0		1.655 ± 0.106 c	0.242 ± 0.008 b	0.768 ± 0.008	0.038 ± 0.003	0.162 ± 0.010
0.75		1.762 ± 0.089 bc	0.253 ± 0.008 ab	0.758 ± 0.010	0.038 ± 0.003	0.175 ± 0.018
1.5		1.822 ± 0.109 ab	0.253 ± 0.008 ab	0.780 ± 0.040	0.048 ± 0.015	0.172 ± 0.018
2.25		1.908 ± 0.091 a	0.263 ± 0.003 a	0.767 ± 0.033	0.058 ± 0.006	0.198 ± 0.013
3		1.888 ± 0.051 ab	0.263 ± 0.003 a	0.817 ± 0.014	0.053 ± 0.008	0.185 ± 0.005
p value	Variety (V)	0.4664	0.0008	0.1497	0.4087	0.0987
	Dose (D)	0.0001	0.0055	0.0634	0.0568	0.0251
	V × D	0.8530	0.4408	0.5727	0.6547	0.3439

The difference between the means indicated by the same letter in the same column and group is not significant.

According to [38], P contents of buckwheat grains were 3445–3640 mg kg^{-1} (equal to average 0.35%) and K contents of buckwheat grains were 3900–5460 mg kg^{-1} (equal

to average 0.46%). *p* values in our investigation were lower, but K values were higher than the results of [38]. These findings agree with those of [25], who inferred that organic manures of animal origin were more effective in boosting the nutritional quality of crops than organic manures belonging to plant origin. It was also assumed that due to the superior quality and the mineral-enriched organic wastes, the plant growth and quality were improved. Evaluations based on vermicompost doses revealed that the N content in the grains gradually increased with increasing VC levels, and the highest N content (1.91%) was recorded with the application of VC at 3 t ha^{-1} which is statistically similar to 2.25 t ha^{-1} VC. The lowest level (1.65%) was recorded in the control treatment which was also similar to 0.75 t ha^{-1} VC. For the P content values, all vermicompost applications similarly increased the *p* values of grains compared to the control. No significant change was noted for the K values due to the treatment of VC.

When secondary macroelement (Ca and Mg) contents in the grains of two varieties were estimated, the range of Ca and Mg contents were between 0.03 and 0.06%, and 0.16 and 0.20, respectively. The vermicompost application was not significantly effective on Ca and Mg contents (Table 4). According to [40], buckwheat grains contain 110 mg/100 g (equal to 0.11%) of Ca and 390 mg 100 g^{-1} (equal to 0.39%) of Mg. Values of both Ca and Mg were lower in our study compared to [40]. The possible source of this variance was the zero conventional fertilizer application and/or the addition of the vermicompost to the soil in our study and/or a different genotype selection. On the other hand, [40] reported that buckwheat grains contain 130–910 mg kg^{-1} (equal to average 0.01–0.09%) Ca, and 1890–2080 mg kg^{-1} (equal to average 0.19–0.21%) Mg. Both Ca and Mg values in our study were similar to [38]. This may be showing us that Ca and Mg contents of the buckwheat grains are very stable. The values were similar to another study based on very different agronomic conditions with the same variety (Güneş variety). The assessments based on the vermicompost doses demonstrated that Ca and Mg contents of grains were not significantly affected by any tested vermicompost application doses.

3.2. Microelement (Fe, Cu, Zn and Mn) Content

Microelement (Fe, Cu, Zn and Mn) content in the grains of both varieties were evaluated, and the range of Fe, Cu, Zn and Mn contents were between 56.68–97.71 ppm, 7.08–9.03 ppm, 27.70–36.39 and 11.33–17.99 ppm, respectively. The examined vermicompost applications were not significantly efficient on Fe, Cu and Mn content, but was successful on the Zn content of the grains which was higher for the Güneş variety (34.06%) than the Aktaş variety (31.96%) (Table 5).

In previous investigations, buckwheat grains were higher in Zn, Cu and Mn than cereals [39]. According to [40], buckwheat grains contained 40 mg kg^{-1} (40 ppm) Fe, 33.7 mg kg^{-1} (equal to 33.7 ppm) Mn, 9.5 mg kg^{-1} (equal to 9.5 ppm) Cu, and 8.7 mg kg^{-1} (equal to 8.7 ppm) Zn. Values in our investigation were high for Fe and Cu; very high for Zn and low for Mn compared to [40]. According to [38], it was concluded that buckwheat grain contains 44–170 mg kg^{-1} (equal to 44–170 ppm) of Fe, 7.9–8.3 mg kg^{-1} (equal to 7.9–8.3 ppm) of Cu, 24–30 mg kg^{-1} (equal to 24–30 ppm) of Zn and 13.9–14.9 mg kg^{-1} (equal to 13.9–14.9 ppm) of Mn. The values in our study were similar for Fe, Cu and Mn but were higher for Zn values compared to [39]. Assessments based on vermicompost doses showed that the highest Fe content in the buckwheat grain was recorded using 3 t ha^{-1} vermicompost followed by 2.25 and 1.5 t ha^{-1}. The lowest was in the control condition followed by 0.75 t ha^{-1} vermicompost. Cu, Zn and Mn contents in grains were highest at 0.75, 1.5, 2.25 and 3 t ha^{-1} vermicompost application doses and lowest at a zero dose of vermicompost.

Table 5. The effect of vermicompost doses on the microelement (ppm) contents of seeds of buckwheat varieties.

Varieties	Vermicompost Doses (t ha^{-1})	Microelements (ppm)			
		Fe	Cu	Zn	Mn
Aktaş	0	56.68 ± 4.45	7.08 ± 0.09	27.70 ± 0.96 b	11.33 ± 0.77
	0.75	69.23 ± 3.88	7.59 ± 0.91	29.43 ± 1.05 ab	12.20 ± 0.95
	1.5	75.81 ± 5.07	7.92 ± 0.30	34.91 ± 1.67 ab	13.79 ± 1.03
	2.25	93.35 ± 2.56	8.66 ± 0.48	34.55 ± 0.74 ab	16.43 ± 1.11
	3	97.71 ± 4.29	8.39 ± 0.26	33.19 ± 0.55 ab	13.62 ± 1.06
Average		78.56 ± 0.92	7.92 ± 0.24	31.96 ± 0.32 B	13.47 ± 0.23
Güneş	0	69.56 ± 3.69	7.40 ± 0.52	30.56 ± 0.50 ab	12.42 ± 1.34
	0.75	72.88 ± 4.32	8.35 ± 1.00	34.81 ± 1.22 ab	13.83 ± 0.79
	1.5	77.88 ± 3.06	8.18 ± 0.58	32.46 ± 1.00 ab	14.68 ± 1.01
	2.25	82.12 ± 4.52	8.49 ± 0.54	36.09 ± 0.60 a	17.99 ± 1.68
	3	85.00 ± 5.05	9.30 ± 1.19	36.39 ± 0.88 a	13.94 ± 0.76
Average		77.49 ± 2.12	8.34 ± 0.58	34.06 ± 0.81 A	14.57 ± 0.09
Vermicompost Doses (t ha^{-1})					
0		63.12 ± 4.02 c	7.24 ± 0.29 b	29.13 ± 0.69 b	11.87 ± 0.99 b
0.75		71.06 ± 3.94 bc	7.97 ± 0.77 ab	32.12 ± 1.01 ab	13.01 ± 1.14 ab
1.5		76.84 ± 2.44 abc	8.05 ± 0.37 ab	33.69 ± 1.30 a	14.23 ± 0.92 ab
2.25		87.74 ± 2.56 ab	8.58 ± 0.44 a	35.32 ± 0.08 a	17.21 ± 1.23 a
3		91.35 ± 3.59 a	8.84 ± 0.72 a	34.79 ± 0.19 a	13.78 ± 0.91 ab
p value	Variety (V)	0.7710	0.0613	0.0328	0.2740
	Dose (D)	0.0008	0.0016	0.0035	0.0344
	V × D	0.1801	0.5053	0.1330	0.9925

The difference between the means indicated by the same letter in the same column and group is not significant.

4. Conclusions

The study findings were partially in line with the postulated hypothesis as buckwheat cultivars remained at par in nutritional quality while varying doses of vermicompost boosted the nutritional value of the grains. Vermicompost significantly increased the N and P content in the grains of buckwheat. No significant differences was observed for the K, Ca and Mg content of the grains from any tested vermicompost application doses but remarkable increases in the Fe, Cu, Zn and Mn contents were observed. In general, the VC at 2.25 t ha^{-1} showed the best results but exceeding 2.25 t ha^{-1} the vermicompost dose numerically reduced the N, Ca, Mg, Zn and Mn contents in the grains. The findings from our study suggest that applying 2.25 t ha^{-1} of vermicompost to buckwheat crops under zero conventional fertilizer applied conditions can obtain a better nutritive value of the grain.

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