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ARTICLE

Mineral Contents of Organically and Conventionally Grown Spinach (*Spinacea oleracea* L.) during Two Successive Seasons

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Spinach (*Spinacea oleracea* L.) plants were grown organically and conventionally during two successive seasons (late autumn and early winter) in order to examine the nutrient content of the plants. In a series of 17 organic applications including chicken manure (CM), farmyard manure (FM), blood meal (BM), and one mineral fertilizer treatment and one control, collectively 19 treatments, were used at each season. The optimum doses to be recommended should be divided into groups depending on the mineral nutrients and also the seasons as follows: 1.7 CM+7.5 FM in the late autumn season and 2.5 CM + 4.0 FM in the early winter season for N, P, K content; 5.0 FM + 1.2 CM + 0.4 BM in the late autumn; and 2.5 CM + 4.0 FM in the early winter season for Ca and Mg. Regarding the micro nutrients, the group divisions should be as follows: 10.0 FM + 0.4 BM in the late autumn season and 5.0 FM + 2.5 CM in the early winter season for Fe and Cu, and 3.5 CM in the late autumn season and 10.0 FM + 1.2 CM in the early winter season for Mn and Zn content. High rates of farmyard manure (FM) and chicken manure (CM) can be successfully used in organic production, and high rates of these manures may substitute for mineral fertilizer, especially in the late autumn season.

KEYWORDS: Organic; conventional; mineral content; spinach

INTRODUCTION

Spinach (*Spinacia oleracea* L.) is an annual, cool season plant, and it is popular as a green leafy vegetable fresh, canned or frozen (*1*). Leafy vegetables are the main part of the human diet (*2*). According to Kansal et al. (*3*), spinach (*Spinacea oleracea* L.) is the most important leafy vegetable and is also an important source of minerals.

Spinach is a mineral-rich vegetable and also is a good source of vitamin B complex, ascorbic acid, vitamin A, and carotin. An earlier study on the edible portion (87%) of spinach records (%) the following: moisture, 92.1; protein, 2.0; fat, 0.7; fiber, 0.6; mineral matter, 1.7; carbohydrate, 2.9; and oxalic acid, 658 (mg per 100 g). Mineral composition includes (mg per 100 g) the following: calcium, 73; magnesium, 84; potassium, 206; iron, 10.9; phosphorus, 21; sodium, 58.5; copper, 0.01; sulfur, 30; nickel, 0.42; manganese, 9.61; molybdenum, 0.08; zinc, 13.53; and strontium, 0.077 (*4*). Spinach is arguably the first or the second most nutritious vegetable. It is very versatile since it is commonly used as a salad, a cooked vegetable, or as a component of many other cooked meat and vegetable dishes (*5*). On the basis of FAO statistics (*6*), spinach production area occupied a 893.494 ha area and produced 14.044.816 tons around the world in 2007.

Spinach prefers a cool climate, the minimum temperature for seed germination is 2 °C, and the optimum range is 7 to 24 °C (*7*). Fertilization is the basic factor affecting the size and quality of the yield (*8*). The application of fertilizer not only affects the yield but also the nutritional quality of the produce. The nutritional quality induced by different fertilizers relates to the mineral constituents of the fertilizer; of these, nitrogen (N) plays a dominant role. A combination of organic and inorganic fertilizers has been found to affect quality to a maximum extent (*3*).

Many consumers perceive that organically grown foods are of better quality, are healthier, and more nutritious than conventional counterparts (*9*). The 1240 studies compared by Worthington (*10*) showed that organically grown fruits or vegetables contain more mineral and vitamins than conventionally grown ones and cited that organically grown spinach contains 17% more Fe and 14% more P but contains 13% less Mg. Furthermore, Wszelaki et al. (*11*) examined the mineral content of organically grown potatoes and found more K, Mg, P, S, and Cu in tubers. It is also reported that organically grown vegetables contains more P and K than conventional ones (*12*).

This study focused on the comparison of a mineral fertilizer and different organic manures used in organic agriculture and the effects of mineral contents of spinach during two successive seasons. At the end of the experiment, we aimed to determine the individual and mixture characteristics of the manures and the usage possibilities of the manures instead of the mineral fertilizers.

MATERIALS AND METHODS

Location and Experimental Design. The experiment was carried out during two successive seasons including late autumn (from October 10 to November 15, 2007, taking 36 days) and early winter (from December 12, 2007 to February 10, 2008, taking 52 days) at Akdeniz University, Faculty

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Table 1. Some Physical and Chemical Parameters of Experimental Area

measured parameters	0−20 cm	20−40 cm
N (%)	0.10	0.09
P (mg kg^{-1})	14.0	8.0
K (me 100 g^{-1})	0.70	0.55
Ca (me 100 g^{-1})	24.9	18.2
Mg (me 100 g^{-1})	2.55	1.25
Fe (mg kg^{-1})	4.52	3.50
Cu (mg kg^{-1})	0.60	0.43
Mn (mg kg^{-1})	6.75	5.54
Zn (mg kg^{-1})	1.13	0.90
pH (1:2.5 distilled water)	8.12	8.15
EC_{25} (1:2.5 distilled water)	0.08	0.06
$CaCO_3$ (%)	32	28
organic matter (%)	1.74	1.55
texture	clayey loam (CL)	

of Agriculture, Research Station, Antalya, Turkey. The experimental area was not used for any agricultural activity before setting up an experiment. Some physical and chemical properties of experimental area are given in **Table 1**.

In this experiment, three different organic manures, farmyard manure (FM), chicken manure (CM), and blood meal (BM) were used as organic manures. Chicken manure was supplied from Akdeniz University, Animal Production Department, from an organic production, farmyard manure from dairy cattle, and blood meal from a commercial slaughterhouse. All manures were selected by obeying the organic farming regulation rules issued by the Ministry of Agriculture in Turkey (*13*). Some chemical properties of the manures are given in **Table 2**.

Treatments consisting of 19 different applications including 17 organic manures, 1 mineral fertilizer, and 1 control were examined. All treatments were adjusted to 150 kg N ha^{-1} regarding the doses taken up by plants (*14*). The experiment was established as a randomized block design with four replicates and was carried out under open-field conditions. Treatments and doses of each application are given in **Table 3**. All organic manures were applied at one time by broadcasting and incorporated into the soil. As for mineral application, the total amount of phosphorus (P_2O_5) and potassium (K_2O), and one-third of the nitrogen fertilizer (as ammonium sulfate) were applied at the beginning of the growing season at the same time with organic manure application. The other two-thirds of the nitrogen fertilizer was applied during the growing season as ammonium nitrate.

Cultivation. Organically certified spinach seeds, matador, were supplied from Ataturk Horticultural Research Institute, Yalova, Turkey. Each plot consisted of 50 plants, 25 × 10 cm apart in 1.25 m^2. Having applied all treatments (**Table 3**), each plot was kept for 15 days in incubation, then the spinach seeds were sowed. In the second crop season, the incubation time was 20 days because of excessive precipitation; thus, the conditions were not conducive to sowing. The sowing was done by hand, and having sowed, all parcels were watered immediately by a sprinkler system.

In order to carry out cultivation practices such as splitting fertilizer and manures, and uprooting weeds and proper growing, 50 cm between plots, 70 cm between blocks, and a 1 m buffer zone around the experimental area were left. All cultivation practices were done according to the organic farming regulation (*13*). As irrigation, a sprinkler system was used at different frequencies depending on the climatic conditions. In late autumn season, 9× irrigation was applied, but in the spring season, 3× irrigation was sufficient because of the precipitation and cold weather conditions. Harvest time was determined by when the control parcel's plants reached 3−4 leaves per plant (*15*) and was done by hand. Climatic conditions during growing periods are given in **Table 4**.

Analytical Methods. For mineral analysis, 12 samples per each plot to be analyzed were separated from the root, and the edible part of spinach was dried at 65 °C until the samples reached a stable weight. Before drying, all samples to be analyzed were washed with distilled water three times and then were ground (200 mesh); after that, an analytical regime was performed as stated by Kacar and Inal (*16*). Total N content of the vegetable samples were analyzed according to a modified Kjeldahl method; P, K, Ca, Mg, Fe, Mn, Zn and Cu in the same solution were determined at the wet-digested samples via ICP (*16*).

Table 2. Some Physical and Chemical Properties of the Manures Used This Experiment

measured parameters	farmyard manure (FM)	chicken manure (CM)	blood meal (BM)
N (%)	0.99	4.28	12.93
P (%)	0.47	3.40	0.10
K (%)	2.65	2.60	0.28
Ca (%)	4.25	2.55	0.17
Mg (%)	0.53	0.05	0.03
Fe (mg kg^{-1})	2760	238	3880
Cu (mg kg^{-1})	13.8	36	7.4
Mn (mg kg^{-1})	15.4	25	28.2
Zn (mg kg^{-1})	38	8	29
pH (1:5 distilled water)	7.05	7.80	6.50
EC (1:5 distilled water) (dS/m)	0.5	3.7	6
organic matter (%)	55	26.6	41

Table 3. Treatments and Doses of Different Applications

(1) 3.5 ton ha^{-1} chicken manure (CM)
(2) 2.5 ton ha^{-1} chicken manure (CM) + 4.0 ton ha^{-1} farmyard manure (FM)
(3) 2.5 ton ha^{-1} chicken manure (CM) + 0.3 ton ha^{-1} blood meal (BM)
(4) 1.7 ton ha^{-1} chicken manure (CM) + 7.5 ton ha^{-1} farmyard manure (FM)
(5) 1.7 ton ha^{-1} chicken manure (CM) + 0.6 ton ha^{-1} blood meal (BM)
(6) 1.7 ton ha^{-1} chicken manure (CM) + 4.0 ton ha^{-1} farmyard manure (FM) + 0.3 ton ha^{-1} blood meal (CM)
(7) 15.0 ton ha^{-1} farmyard manure (FM)
(8) 10.0 ton ha^{-1} farmyard manure (FM) + 1.2 ton ha^{-1} chicken manure (CM)
(9) 10.0 ton ha^{-1} farmyard manure (FM) + 0.4 ton ha^{-1} blood meal (BM)
(10) 5.0 ton ha^{-1} farmyard manure (FM) + 2.5 ton ha^{-1} chicken manure (CM)
(11) 5.0 ton ha^{-1} farmyard manure (FM) + 1.0 ton ha^{-1} blood meal (BM)
(12) 5.0 ton ha^{-1} farmyard manure (FM) + 1.2 ton ha^{-1} chicken manure (CM) + 0.4 ton ha^{-1} blood meal (BM)
(13) 1.2 ton ha^{-1} blood meal (BM)
(14) 0.9 ton ha^{-1} blood meal (BM) + 0.85 ton ha^{-1} chicken manure (CM)
(15) 0.9 ton ha^{-1} blood meal (BM) + 4.0 ton ha^{-1} farmyard manure (FM)
(16) 0.6 ton ha^{-1} blood meal (BM) + 7.5 ton ha^{-1} farmyard manure (FM)
(17) 0.6 ton ha^{-1} blood meal (BM) + 0.85 ton ha^{-1} chicken manure (CM) + 4.0 ton ha^{-1} farmyard manure (FM)
(18) mineral fertilizer (150 kg ha^{-1} N; 40 kg ha^{-1} P_2O_5; 130 kg ha^{-1} K_2O)
(19) control (without any treatments)

Table 4. Climatic Conditions during Two Successive Seasons

parameters	first crop season (late autumn)		second crop season (early winter)		
	October	November	December	January	February
mean temperature (°C)	22.8	16.2	13.0	10.7	11.3
minimum (°C)	14.9	9.0	6.2	3.5	0.6
maximum(°C)	35.6	24.4	21.7	18.2	23.2
precipitation (kg m^{-2})	16.6	58.2	154.5	12.8	8.0

Statistical Methods. Analysis of variance was performed to evaluate differences in measured parameters. Thereafter, parameters were compared by Duncan's multiple range test ($p \le 0.05$).

RESULTS AND DICCUSSION

Macro Nutrient Content of Spinach Plants. The effects of applications on the total N, P, and K content of spinach plants were found to be statistically significant both in the late autumn season and in the early winter season ($p < 0.001$). The results of applications on these parameters are given in **Table 5**. The total N content of spinach plants varied among applications and also the seasons. It is obvious that the adverse climatic conditions occurring in the early winter season resulted in a decrease in total N content of spinach plants. According to Peavy (*1*), this tendency was probably related to the slow mineralization rate of the organic manures applied.

Table 5. Effects of Different Treatments and Seasons on the Macro Nutrient (Total N, P, and K) Content of Spinach[a]

	seasons					
	N (%)		P (%)		K (%)	
treatments (ton ha^{-1})	late autumn[b]	early winter[b]	late autumn[b]	early winter[b]	late autumn[b]	early winter[b]
(1) 3.5 CM	3.30 h	1.94 h	0.48 bc	0.63 e	8.52 abc	3.57 g
(2) 2.5 CM + 4.0 FM	3.98 c	2.51 bc	0.45 cde	0.80 a	7.94 abc	4.30 bc
(3) 2.5 CM + 0.3 BM	3.73 def	2.38 de	0.44 cde	0.58 f	8.53 abc	4.20 cd
(4) 1.7 CM + 7.5 FM	3.79 d	2.46 cd	0.60 a	0.65 d	9.02 ab	4.43 b
(5) 1.7 CM + 0.6 BM	4.04 c	2.15 f	0.37 defg	0.49 i	7.11 de	3.54 g
(6) 1.7 CM + 4.0 FM + 0.3 BM	4.29 b	2.31 e	0.37 defg	0.53 h	7.50 cde	4.02 ef
(7) 15.0 FM	3.75 de	2.55 b	0.53 cb	0.73 c	9.32 a	4.44 b
(8) 10.0 FM + 1.2 CM	3.48 g	2.04 g	0.58 a	0.77 b	9.67 a	4.26 cd
(9) 10.0 FM + 0.4 BM	4.02 c	1.68 i	0.42 cdef	0.59 f	9.59 a	4.28 cd
(10) 5.0 FM + 2.5 CM	3.70 ef	2.00 gh	0.45 cde	0.77 b	6.34 e	3.89 f
(11) 5.0 FM + 1.0 BM	3.76 de	2.20 f	0.38 defg	0.39 k	7.92 bcd	3.66 g
(12) 5.0 FM + 1.2 CM + 0.4 BM	4.35 b	2.16 f	0.43 cdef	0.57 f	9.28 a	4.12 de
(13) 1.2 BM	4.37 c	2.42 d	0.30 h	0.21 n	9.21 ab	3.87 f
(14) 0.9 BM + 0.85 CM	4.01 c	2.16 f	0.36 fgh	0.35 l	8.61 abc	3.37 h
(15) 0.9 BM + 4.0 FM	3.76 de	2.14 f	0.45 cd	0.34 l	9.46 a	3.92 f
(16) 0.6 BM + 7.5 FM	4.00 c	2.39 de	0.45 cd	0.55 g	9.30 a	4.46 b
(17) 0.6 BM + 0.85 CM + 4.0 FM	3.66 f	2.02 gh	0.46 bc	0.44 j	9.19 ab	3.57 g
(18) mineral fertilizer	4.94 a	2.15 f	0.45 cd	0.47 i	9.03 ab	3.13 i
(19) control	3.74 de	2.76 a	0.32 gh	0.30 m	9.80 a	4.77 a
seasonal mean	3.93	2.23	0.44	0.53	8.78	3.99

[a] Average of 12 samples. [b] Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

The most important problem in organic agriculture is to ensure the imbalance between the mineralization rate of manure and the crop demand (*17*). However, the mineralization rate of manure, depending on the conditions and manure type, in the winter season is assumed to be 0−20% (*18*). Therefore, the lowest level of the total N achieved in the early winter season was probably because of the inhibited mineralization rate of the manures. In the late autumn season, the total N content of the spinach plants was found to be between 3.30 and 4.94%, and the highest and the lowest level was obtained from the mineral fertilizer and 3.5 CM application, respectively (**Table 5**). In single application, blood meal was better than the other treatments including farmyard manure (FM) and chicken manure (CM). As the mixture applications, 1.7 CM + 4.0 FM + 0.3 BM gave better results compared to those of the others. In the early winter season, in contrast to late autumn season, the highest level was attained from control application with 2.76%. Within organic applications, the 2.5 CM + 4.0 FM application gave the highest level, the 2.51%, and 10.0 FM + 0.4 BM applications gave the lowest level, 1.68%. In general, total N content of the spinach plants tended to be lower in early winter season (**Table 5**).

Peavy (*1*) reported that spinach plants grown by using feedlot manure and mineral fertilizer during three crop seasons contained total N as follows: on average, 5.12% in the first crop season (April, 17 to May, 21), 5.11% in the second crop (overwintered) season (September, 25 to May, 3), and 3.65% in the third crop season (April, 21 to June, 8). Furthermore, Peyvast et al. (*19*) pointed out that organic spinach contains on average 2.77−4.22%. Another study carried out by Kutuk et al. (*20*) showed that the total N content of spinach grown by using different levels of farmyard manure was found to be between 3.23 and 3.72% in the autumn season.

The P content of spinach plants was found to be between 0.60 and 0.30% within the applications and the highest and lowest level was found at 1.7 CM + 7.5 FM and 1.2 BM applications, respectively (**Table 5**). In a single application, FM gave the better results with 0.53% P than the others, and 10.0 FM + 1.2 CM gave the better result with 0.58% P within the mixture applications. These results are in agreement with the finding of Peavy (*1*); the P content of spinach was 0.38% in the spring season, 0.45% in the fall season, and 0.30% in the spring season. Zengin et al. (*21*) and Peyvast et al. (*19*) found the P content of spinach grown by using organic manure in the range of 0.71−0.77% and 0.27−0.40%, respectively.

The K content of spinach plants varied between 6.34 and 9.80% K and was observed from 5.0 FM + 2.5 CM and control applications in the late autumn season, respectively. In the early winter season, this range was found to be between 3.13 and 4.77% K and was attained from the mineral fertilizer and the control application, respectively (**Table 5**). According to Peavy (*1*), the K content of spinach was 9.3% in the spring season, 7.3% in the fall season, and 8.6% in the spring season. Kutuk et al. (*20*) studied the effects of different doses of farmyard manure on spinach growth and found the K content of spinach varied between 6.75 and 8.98% in the autumn season. Bhattacharjee et al. (*4*) and Peyvast et al. (*19*) determined the average K content of spinach in the range of 1.91−7.48% K and 5.7−6.4% K, respectively. These results showed an agreement of the relevant studies.

The effects of the applications on the Ca and Mg content of spinach were found to be statistically significant in both seasons ($p < 0.001$). The results are given in **Table 6**. The Ca contents of spinach plants ranged from 1.13 to 2.02% Ca and was attained from 1.7 CM + 4.0 FM + 0.3 BM and mineral fertilizer applications in the late autumn season (**Table 6**). As organic manures, the 0.9 BM + 4.0 FM application gave the highest level (1.96%) within the organic manures. In the early winter season, the range was between 1.51 and 0.91% Ca and was obtained from the control and 3.5 CM applications. The average Ca content of spinach was found by Peavy (*1*) on average to be 0.8% in the spring season, 1.2% in the fall season, and 1.1% in the spring season. Bhattacharjee et al. (*4*) and Peyvast et al. (*19*) reported that spinach contains on average 0.67−2.12% Ca and 1.2−1.7% Ca, respectively.

The Mg content of spinach was found to be between 0.52 and 0.88% Mg within the applications in the late autumn season and was obtained from 5.0 FM + 2.5 CM and 5.0 FM + 1.2 CM + 0.4 BM respectively (**Table 6**). In the early winter season, Mg content ranged from 0.38 to 0.59% Mg and was found in 3.5 CM and the control applications, respectively. Peavy (*1*) determined the Mg

Table 6. Effects of Different Treatments and Seasons on the Macro Nutrient (Ca and Mg) Content of Spinach[a]

	seasons			
	Ca (%)		Mg (%)	
treatments (ton ha^{-1})	late autumn[b]	early winter[b]	late autumn[b]	early winter[b]
(1) 3.5 CM	1.83 abc	0.91 h	0.68 bcd	0.38 j
(2) 2.5 CM + 4.0 FM	1.63 cd	1.25 cd	0.74 abc	0.44 ef
(3) 2.5 CM + 0.3 BM	1.77 bcd	1.41 ab	0.73 abc	0.46 e
(4) 1.7 CM + 7.5 FM	1.60 cde	1.04 g	0.72 abc	0.50 c
(5) 1.7 CM + 0.6 BM	1.38 ef	1.25 cd	0.65 cd	0.44 ef
(6) 1.7 CM + 4.0 FM + 0.3 BM	1.13 g	1.07 fg	0.71 abc	0.41 hi
(7) 15.0 FM	1.54 de	1.16 def	0.67 bcd	0.46 e
(8) 10.0 FM + 1.2 CM	1.65 cd	1.32 bc	0.58 cd	0.42 ghi
(9) 10.0 FM + 0.4 BM	1.72 bcd	1.17 def	0.65 cd	0.41 hi
(10) 5.0 FM + 2.5 CM	1.22 fg	1.12 efg	0.52 d	0.42 ghi
(11) 5.0 FM + 1.0 BM	1.66 cd	1.16 def	0.61 cd	0.46 e
(12) 5.0 FM + 1.2 CM + 0.4 BM	1.86 abc	1.07 fg	0.88 a	0.46 e
(13) 1.2 BM	1.72 bcd	1.34 bc	0.86 ab	0.48 d
(14) 0.9 BM + 0.85 CM	1.64 cd	1.19 de	0.73 abc	0.52 b
(15) 0.9 BM + 4.0 FM	1.96 ab	1.31 bc	0.74 abc	0.43 fg
(16) 0.6 BM + 7.5 FM	1.55 de	1.11 efg	0.72 abc	0.42 gh
(17) 0.6 BM + 0.85 CM + 4.0 FM	1.74 bcd	1.45 ab	0.70 abcd	0.40 i
(18) mineral fertilizer	2.02 a	1.50 a	0.75 abc	0.45 ef
(19) control	1.84 abc	1.51 a	0.85 ab	0.59 a
seasonal mean	1.66	1.23	0.71	0.45

[a] Average of 12 samples. [b] Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

content of spinach on average to be 0.37% in the spring season, 0.53% in the fall season, and 0.52% in the spring season. According to Bhattacharjee et al. (*4*) the Mg is generally appreciable in all green vegetables because of its association with chlorophyll, but the abundance of Na, K, and Ca shows the mineral-rich nature of spinach.

Seasonal mean of the macro nutrient content of spinach is shown in **Figure 1**. On comparing seasonal changes, there appeared to be an augmentation in the late autumn seasons, especially for total N and K. Only P content of spinach was found to be nearly similar in each season. The Ca and Mg contents were observed to have decreased in the early winter season, the same as the other macro nutrients except for P.

The mineral content of spinach in the spring and in autumn seasons found by Jaworska and Kmiecik (*22*) is as follows: for the spring season, 5.84% K, 0.32% P, 3.16% Ca, and 0.63% Mg, and for the autumn season, 7.50% K, 0.67% P, 1.23% Ca, and 0.88% Mg. From the values determined, we can clearly observe that the spring season values were higher than the autumn season values except for Ca. Spinach grows well at 15−20 °C (*7*); therefore, the climatic conditions affected the growth and also the root activity (*1*). Therefore, the lowest levels were obtained in the early winter season.

Micro Nutrient Content of Spinach Plants. The effects of applications on the Fe and Cu contents of spinach plants were found to be statistically significant both in the late autumn season and in the early winter season ($p < 0.001$). The results of the experiment are given in **Table 7**. In the late autumn season, the Fe content of spinach was found to be between 188 and 634 mg kg^{-1} and was obtained from 1.7 CM + 0.6 BM and the mineral fertilizer applications, respectively. As organic manure, 1.2 BM gave the highest level of 465 mg kg^{-1} Fe content of spinach. In the early winter season, the Fe content of plants ranged from 500 to 1255 mg kg^{-1} and was observed from the mineral fertilizer and 5.0 FM + 2.5 CM applications, respectively (**Table 6**). In general, the Fe content of the samples was higher in the early winter season than that of the late autumn season. It is stated that spinach contains 520−710 mg kg^{-1} of Fe (*19*). The average Fe content of spinach was recorded by Peavy (*1*) to be on average 112 mg kg^{-1} in the spring season, 304 mg kg^{-1} in the fall season, and 306 mg kg^{-1} in the spring season. Another study carried out by Jaworska and Kmiecik (*22*) showed that the Fe content of spinach was 400 mg kg^{-1} in the spring season and 500 mg kg^{-1} in the autumn season.

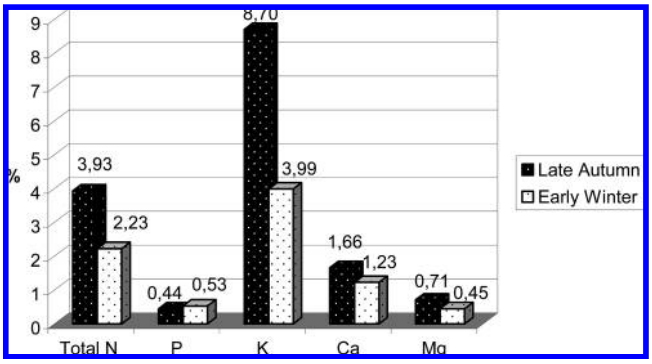

Figure 1. Seasonal changes of the macro nutrient content of spinach.

The Cu content of spinach ranged from 4.30 to 7.50 mg kg^{-1} and was obtained from 5.0 FM + 2.5 CM and the control applications, respectively (**Table 6**). In organic applications, 0.9 BM + 4.0 FM gave the highest Cu level (7.30 mg kg^{-1}) of spinach. In the early winter season, 4.50 and 7.70 mg kg^{-1} Cu contents were observed from 0.9 BM + 4.0 FM and 3.5 CM application, respectively (**Table 7**). The effects of the applications on the Mn and Zn content of spinach plants were found to be statistically significant in both seasons ($p < 0.001$). The results are given in **Table 8**. The Mn content was found to be between 40.0 and 74.0 mg kg^{-1} within the applications and was obtained from 1.7 CM + 4.0 FM + 0.3 BM and 5.0 FM + 1.0 BM applications in the late autumn season. In the early winter season, the Mn content ranged from 38.6 to 56.4 mg kg^{-1};. 38.6 mg kg^{-1} of Mn was observed from 0.6 BM + 0.85 CM + 4.0 FM applications and 56.4 mg kg^{-1} of Mn from 10.0 FM + 1.2 CM and 5.0 FM + 1.2 CM + 0.4 BM (**Table 6**). Peavy (*1*) stated that the Mn content of spinach plants ranged from 27.0 to 69.0 mg kg^{-1} depending on the seasons.

Table 7. Effects of Different Treatments and Seasons on the Micro Nutrient (Fe and Cu) Content of Spinach[a]

	seasons			
	Fe (mg kg^{-1})		Cu (mg kg^{-1})	
treatments (ton ha^{-1})	late autumn[b]	early winter[b]	late autumn[b]	early winter[b]
(1) 3.5 CM	374 bcd	516 h	7.20 abc	7.70 a
(2) 2.5 CM + 4.0 FM	311 bcde	916 bc	6.00 cdefg	6.90 abcd
(3) 2.5 CM + 0.3 BM	377 bcd	724 efg	6.10 bcdef	5.40 efg
(4) 1.7 CM + 7.5 FM	342 de	663 g	6.70 abcde	5.40 efg
(5) 1.7 CM + 0.6 BM	188 e	903 bcd	4.95 fg	5.40 efg
(6) 1.7 CM + 4.0 FM + 0.3 BM	248 bcde	917 bc	4.90 gh	5.70 ef
(7) 15.0 FM	313 bcd	938 b	6.50 abcde	7.40 ab
(8) 10.0 FM + 1.2 CM	377 bcd	766 cdefg	6.10 bcdef	6.40 bcde
(9) 10.0 FM + 0.4 BM	436 bc	759 defg	7.30 ab	6.00 de
(10) 5.0 FM + 2.5 CM	236 de	1255 a	4.30 h	7.20 abc
(11) 5.0 FM + 1.0 BM	322 bcde	764 cdefg	5.80 efg	5.70 ef
(12) 5.0 FM + 1.2 CM + 0.4 BM	286 cde	861 bcdef	7.10 abcd	6.10 de
(13) 1.2 BM	465 b	972 b	6.80 abcde	6.40 bcde
(14) 0.9 BM + 0.85 CM	452 b	714 fg	6.10 bcdef	5.70 ef
(15) 0.9 BM + 4.0 FM	373 bcd	877 bcde	7.30 ab	4.50 g
(16) 0.6 BM + 7.5 FM	371 bcd	713 fg	6.30 bcde	5.60 ef
(17) 0.6 BM + 0.85 CM + 4.0 FM	326 bcd	499 h	6.50 abcde	4.60 fg
(18) mineral fertilizer	634 a	500 h	5.95 def	6.20 cde
(19) control	437 bc	696 g	7.50 a	5.85 de
seasonal mean	361.47	787.00	6.28	6.01

[a] Average of 12 samples. [b] Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 8. Effects of Different Treatments and Seasons on the Micro Nutrient (Mn and Zn) Content of Spinach[a]

	seasons			
	Mn (mg kg^{-1})		Zn (mg kg^{-1})	
treatments (ton ha^{-1})	late autumn[b]	early winter[b]	late autumn[b]	early winter[b]
(1) 3.5 CM	73.7 ab	42.5 e	121.3 ab	87.9 bc
(2) 2.5 CM + 4.0 FM	55.0 cdefg	46.9 cd	80.1 efgh	92.9 bc
(3) 2.5 CM + 0.3 BM	68.2 abc	42.7 e	84.0 fgh	95.7 bc
(4) 1.7 CM + 7.5 FM	53.1 cdef	41.5 ef	68.0 hi	75.4 bcd
(5) 1.7 CM + 0.6 BM	43.3 fg	50.3 b	54.1 defg	67.8 cde
(6) 1.7 CM + 4.0 FM + 0.3 BM	40.0 g	53.8 a	85.0 efgh	76.1 bcd
(7) 15.0 FM	55.0 cdefg	50.4 b	79.7 def	84.8 bc
(8) 10.0 FM + 1.2 CM	62.0 abcde	56.4 a	90.0 def	99.2 b
(9) 10.0 FM + 0.4 BM	58.0 abcdef	49.4 bc	133.0 a	87.0 bc
(10) 5.0 FM + 2.5 CM	48.3 efg	49.4 bc	61.0 hi	92.8 bcd
(11) 5.0 FM + 1.0 BM	74.0 a	42.0 e	111.0 abcd	74.5 bcd
(12) 5.0 FM + 1.2 CM + 0.4 BM	51.0 defg	56.4 a	69.0 fgh	72.4 bcd
(13) 1.2 BM	57.0 bcdef	49.5 bc	98.0 bcde	141.2 a
(14) 0.9 BM + 0.85 CM	64.0 abcde	49.0 bc	69.0 fgh	69.6 cde
(15) 0.9 BM + 4.0 FM	73.0 ab	45.8 d	82.0 fg	56.1 de
(16) 0.6 BM + 7.5 FM	59.0 abcdef	41.5 ef	93.0 cdef	84.6 bc
(17) 0.6 BM + 0.85 CM + 4.0 FM	57.5 abcdef	38.6 f	76.4 efgh	95.3 bc
(18) mineral fertilizer	52.0 cdef	42.5 e	40.2 i	44.4 e
(19) control	68.0 abcd	48.9 bc	118.1 abc	93.5 bc
seasonal mean	58.53	47.24	84.89	83.75

[a] Average of 12 samples. [b] Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

The highest and the lowest levels of Zn content of spinach samples were found to be 133.0 mg kg^{-1} of Zn at 10.0 FM + 0.4 BM and 40.2 mg kg^{-1} Zn at the mineral fertilizer applications in the late autumn season (**Table 6**). The effects of applications on the Zn content of spinach in the early winter season ranged from 44.4 to 141.2 mg kg^{-1} within the applications and was attained from the mineral fertilizer and 1.2 BM application, respectively. According to Peavy (*1*), the Zn content of spinach plants varies from 68.0 to 28.0 mg kg^{-1} between the seasons.

Seasonal mean of the micro nutrient content of spinach plants is shown in **Figure 2**. In contrast to the macro nutrients, the micro nutrient content of plants decreased in the late autumn season. As seen, the Fe content of spinach significantly differed between the two seasons, and an approximately 3-fold decrease was observed from the late autumn to the early winter season. The Cu content of spinach tended to decrease slightly in the late autumn season. The Zn and Mn contents also decreased in the late autumn season.

Peavy (*1*) recorded the Fe, Zn, and Mn contents of spinach as follows (mg kg^{-1}); for the spring season, 111.7, 28.1, and 27.2, and for the fall season, 304.5, 68.53, and 57.3, respectively. Jaworska and Kmiecik (*22*) cited the Fe content of spinach as 400 mg kg^{-1} for the spring season and 500 mg kg^{-1} for the autumn season. Consequently, these values are similar to the values of this experiment.

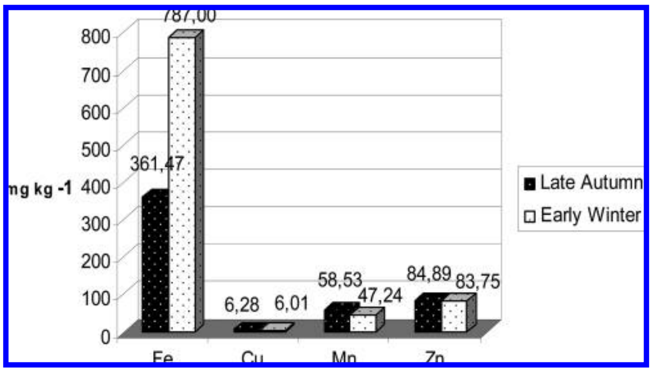

Figure 2. Seasonal changes of the micro nutrient content of spinach.

The comparison between inorganic and organic fertilizer N sources is not easy to perform since there is usually a dramatic difference in N availability from these two sources (*23*). The main factor determining the availability of organic sources is the mineralization potential of the manure used. Kaplan et al. (*24*) pointed out that the combinations of different organic fertilizers were important for sufficient and balanced plant nutrition in organic farming and that seasonal conditions might have considerable effects on the effectiveness of the fertilizers. According to Sonmez et al. (*25*), it is necessary to have more information about the effectiveness of organic fertilizers in the different periods.

The macro nutrient content of spinach samples differed between applications. The mineral composition of spinach was related to the mineral content of the manures. Chicken manure caused a high level of spinach phosphorus (P), and farmyard manure (FM) caused a high level of spinach potassium (K). As a consequence, chicken manure (CM) and farmyard manure (FM) were found to be quite effective sources for organic applications especially in the late autumn season.

At the end of the study, we do not find it easy to recommend a dose to be applied because of the great variations between not only the applications but also the seasons. We decided to evaluate them as an individual group in each season as follows: N, P, K, Ca, and Mg for macro elements, and Fe, Cu, Mn, and Zn for micro elements. The optimum doses to be recommended for N, P, and K content of spinach should be 1.7 CM + 7.5 FM in the late autumn season and 2.5 CM + 4.0 FM in the early winter season (**Table 5**). For Ca and Mg, it should be 5.0 FM + 1.2 CM + 0.4 BM in the late autumn and 2.5 CM + 4.0 FM in the early winter season (**Table 6**).

The micro nutrient content of spinach was found to be higher in organic applications than that of the mineral application. All manures used in this experiment contain micro nutrients to some extent (**Table 2**). When mineralization occurs, these nutrients are released and serve as a micro nutrient source to the plants. This may be the reason for containing more micro nutrients in organic applications than that of the mineral application. Within organic manures, blood meal (BM) often gave the better results. According to Termine et al. (*26*), mineral fertilizers and blood meal give rise to similar effects. Abraham-Gutierrez (*27*) recommended that blood meal not be used as a single application.

For the micro elements, 10.0 FM + 0.4 BM for the Fe, Cu content of spinach in the late autumn season and 5.0 FM + 2.5 CM in the early winter season (**Table 7**), and for the Mn, Zn, 3.5 CM in the late autumn season and 10.0 FM + 1.2 CM in the early winter season would be recommended (**Table 8**).

In conclusion, spinach plant growth was effected positively by the application of farmyard manure (FM) and chicken manure. The blood meal (BM) showed some disadvantages regarding the application and also had a bad smell. Blood meal should be used as a top dressing application instead of as a basal dressing application. High rates of farmyard manure (FM) and chicken manure may be substituted for mineral fertilizer especially in the late autumn season, and we found that they can be successfully used in producing spinach plants. Therefore, these materials regarded as invaluable material can be transferred into an asset.

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