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ARTICLE

Influence of Organic and Conventional Growing Conditions on the Nutrient Contents of White Head Cabbage (*Brassica oleracea* var. *capitata*) during Two Successive Seasons

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Organically and conventionally grown white head cabbage (*Brassica oleracea* var. *capitata*) plants were cultivated during two successive seasons (spring and autumn) to evaluate the effects of the applications on the nutrient content of the edible part of cabbage plants. Seventeen different organic applications containing farmyard manure (FM), chicken manure (CM), and blood meal (BM) and 1 chemical fertilizer and 1 control, collectively 19 treatments, were examined under the open-field conditions. Recommendations of the best results obtained should be divided into groups in the following order regarding the mineral contents and also the seasons: 0.6 BM + 7.5 FM in the spring season, and 3.5 CM in the autumn season for N, P, and K content of cabbage. For Ca and Mg, the group division should be 1.7 CM + 0.6 BM in the spring season and 10.0 FM + 1.2 CM in the autumn season. The optimum recommendations for the micronutrients could be 5.0 FM + 1.0 BM in the spring season and 0.9 BM + 0.85 CM in the autumn season for Fe and Cu and 15.0 FM in the spring season, and 10.0 FM + 0.4 BM in the autumn season for Mn and Zn. FM and CM could be used in high rates in producing organic cabbage and could be substituted for chemical fertilizer especially in the spring season.

KEYWORDS: Organic; conventional; cabbage; mineral content

INTRODUCTION

Care about the growing conditions of foods has often been taken into consideration by customers nowadays. This is probably because of some health problem arising from the consumption of the unhealthy foods grown under intensive farming conditions such as excessive pesticides or chemical fertilizers; therefore, growing foods organically has gained popularity around the world. Additionally, Ekelund (*1*) reported that more than half of the persons polled claimed to be willing to pay more for organically grown products. Moreover, environmental concerns have made a gradual steady increase because of the chemicals polluting the limited sources of the world such as water and soil.

One of the most important roles of agricultural production is to provide almost all essential minerals and organic nutrients to humans (*2*). Organically grown crops are believed to be healthier and to contain more minerals and vitamins than that of the conventional counterparts (*3*, *4*). Leafy vegetables are an important source of vitamins and nutrients in the human diet (*5*). Of leafy vegetables, cabbages belong to the Cruciferae family and are related to turnips, cauliflowers, and brussels sprouts (*6*). Cabbage has been used as food for more than 3000 years and the ancient Greeks held cabbage in high esteem (*7*).

El-Shinawy et al. (*8*) stated that there is a correlation between the amount of nitrogen applied and the quality of cabbage. Cabbage head could not form if there is a nitrogen shortage; phosphorus and potassium are also important for head formation and quality of cabbage. The economic importance of cabbages results from their nutritious value, high yields from a unit area, and the possibilities of differentiated utilization throughout the year (*9*). Cabbage is rich in nutrient and contains a range of essential vitamins and minerals as well as small amount protein and good caloric value (*10*); it also contains potassium, soluble and insoluble fiber, is low in sodium, and is free of fat and cholesterol. A 100 g serving of fresh green cabbage contains over three-fourths of the recommended daily allowance (RDA) for vitamin C, and also a 100 g serving of undrained sauerkraut contains 19 calories, has no fat, provides fiber, and has 25% of the RDA for vitamin C (*11*). Moreover, cabbage ranks higher than tomato but lower than spinach in mineral content (*7*). In addition, organically grown cabbage contains 43% vitamin C, 41% iron, 40% magnesium, and 22% phosphorus in higher amounts than that of the conventionally counterparts (*12*). Cabbages could be easily grown under a wide variety of conditions and are adaptable to many areas (*6*). On the basis of the Food and Agriculture Organization (FAO) data, the production area of cabbage and other brassicas occupied 3 082 058 ha (ha) and the world production was 68 918 014 tons in 2007 (*13*).

In organic farming, it is important for there to be a sufficient plant nutrient in soil, and organic manure application is sure to supply the plant nutrient to some extent depending on the material. Therefore, as stated by Abou El-Magd et al. (*14*) organic manure plays a direct role in plant growth as a source of all necessary macro- and micronutrients in available forms during mineralization, improving the physical and physiological properties of soils.

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Table 1. Some Chemical Properties of the Soil, Initial and After the Excluded Season[a]

	treatments ton ha^{-1}	pH	EC	SOM[b]	N	P	K	Ca	Mg	Fe	Mn	Cu	Zn
initial soil[c]		8.16	0.090	1.49	0.11	3.80	0.60	31.4	1.28	1.30	5.1	0.40	0.26
1-	3.5 CM	8.16	0.081	2.62	0.08	6.87	0.67	33.2	1.52	1.50	5.0	0.53	0.46
2-	2.5 CM + 4.0 FM	8.09	0.107	2.36	0.10	7.33	0.69	32.2	1.30	1.70	8.8	0.60	0.51
3-	2.5 CM + 0.3 BM	8.10	0.108	2.07	0.10	5.97	0.62	30.7	1.22	1.64	5.0	0.45	0.36
4-	1.7 CM + 7.5 FM	8.13	0.110	2.31	0.04	7.03	0.70	31.6	1.38	1.40	5.5	0.47	0.35
5-	1.7 CM + 0.6 BM	8.07	0.120	2.84	0.04	5.50	0.68	33.0	1.28	1.54	6.3	0.47	0.42
6-	1.7 CM + 4.0 FM + 0.3 BM	8.07	0.167	1.87	0.10	6.04	0.73	32.8	1.29	1.54	6.0	0.49	0.45
7-	15.0 FM	8.21	0.102	2.28	0.12	7.16	0.86	34.4	1.43	1.57	6.1	0.48	0.34
8-	10.0 FM + 1.2 CM	8.13	0.120	2.38	0.12	7.89	0.73	31.6	1.31	1.36	7.2	0.45	0.36
9-	10.0 FM + 0.4 BM	8.07	0.169	2.34	0.12	5.81	0.73	31.6	1.47	1.66	7.6	0.55	0.31
10-	5.0 FM + 2.5 CM	8.25	0.115	2.52	0.13	5.73	0.71	33.3	1.37	1.68	8.6	0.61	0.44
11-	5.0 FM + 1.0 BM	8.05	0.158	2.33	0.13	4.42	0.74	32.0	1.34	1.26	5.0	0.41	0.26
12-	5.0 FM + 1.2 CM + 0.4 BM	8.20	0.117	2.55	0.11	5.11	0.64	31.8	1.34	1.30	5.0	0.41	0.30
13-	1.2 BM	8.16	0.151	2.30	0.13	4.80	0.64	30.2	1.37	1.51	6.5	0.47	0.26
14-	0.9 BM + 0.85 CM	8.22	0.148	1.84	0.06	4.64	0.67	30.5	1.31	1.27	5.1	0.38	0.27
15-	0.9 BM + 4.0 FM	8.18	0.155	2.15	0.09	5.03	0.67	31.9	1.25	1.35	6.5	0.45	0.30
16-	0.6 BM + 7.5 FM	8.19	0.157	2.09	0.08	4.57	0.64	31.7	1.23	1.66	6.7	0.54	0.31
17-	0.6 BM + 0.85 CM+4.0 FM	8.15	0.162	1.72	0.13	5.84	0.70	31.0	1.22	1.42	4.8	0.42	0.37
18-	chemical fertilizer	8.05	0.183	1.76	0.14	9.99	0.88	39.4	1.50	1.27	4.5	0.43	0.28
19-	control	8.15	0.104	1.55	0.11	3.86	0.68	31.1	1.24	1.36	5.1	0.46	0.29

[a]Abbreviations: FM (farmyard manure), CM (chicken manure), BM (blood meal). [b]Soil organic matter, % (SOM). [c]Initial soil before establishing the experiment in 2006.

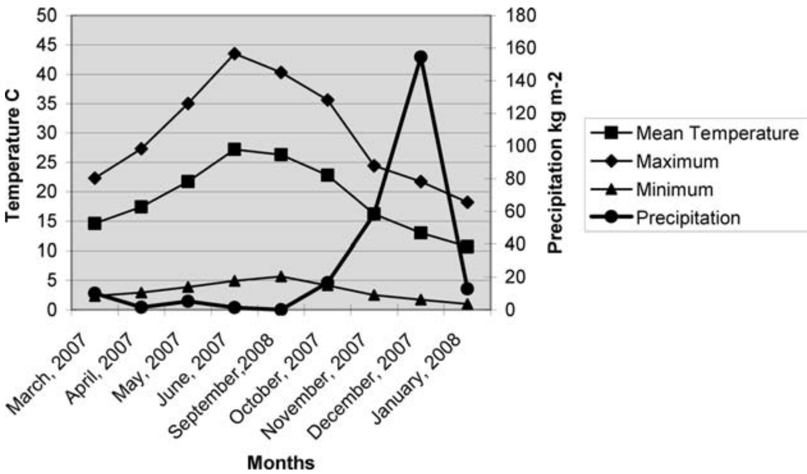

Figure 1. Climatic conditions during the cabbage growing seasons.

This study aims to elaborate the individual or mixture characteristics of different organic manures in organically grown cabbages and also to compare them with conventionally grown cabbage. This work also recommends a suitable application regarding the mineral content of cabbage plants.

MATERIAL AND METHODS

Location and Experimental Design. The experiment was laid out in Akdeniz University, Faculty of Agriculture, and Research Station in Antalya, Turkey during 2006 and 2008. The area was never used before establishing the experiment. Initially, the experiment was supposed to be carried out in the late autumn in 2006 and spring season in 2007, but due to the unsuitable conditions occurring in the late autumn season, plant samples could not be taken. Having not taken the plant samples, the experiment had to be canceled then. Therefore, the late autumn season was excluded and the new experiment was planned to be carried out in spring and in autumn seasons in 2007 to 2008 on the same experimental area and also the same plot; thus, the experiment consisted of three seasons soil applications but two seasons plant growth cycles in the end. Having canceled the experiment, all treatments were resampled and analyzed before starting the new experiment. **Table 1** gives the initial and resampled soil properties of the experimental area.

In the spring season, called the first growing season, application of the treatments were applied to the same plots on March 10, 2007 and seedlings were transferred to the experimental area after the incubation on March 27, 2007; the harvest date was on June 17, 2007. In the autumn season, called the second growing season, application of the treatments was scattered on September 25, 2007 and the establishment of the seedlings was on October 10, 2007; the harvest was done on January 1, 2008. The climatic conditions including mean, minimum, and maximum temperature (°C), and also precipitation (kg m^{-2}) occurred during the experiment is given in **Figure 1**.

Three different organic manures, farmyard manure (FM), chicken manure (CM), and blood meal (BM) were used as organic manures. CM was supplied from Akdeniz University, Animal Production Department, from an organic production, FM was supplied from dairy cattle, and BM was supplied from a commercial slaughterhouse. **Table 2** gives some chemical properties of the manures.

A series of 19 different applications including 17 organic manures, 1 mineral fertilizer, and 1 control were examined. All treatments were adjusted to 150 kg nitrogen (N) ha^{-1} regarding the doses taken up by plants (*15*). The experiment was established as a randomized block design with four replicates and was carried out under open-field conditions. All organic manures were applied at one time by broadcasting and incorporated into the soil. Regarding mineral application, the total amount of phosphorus (P_2O_5, P as triple super phosphate 42−44% P_2O_5) and potassium (K_2O, K as potassium sulfate 50% K_2O), and one-third of the nitrogen fertilizer (as ammonium sulfate, 21% NH_4−N) was applied at the beginning of the growing season at the same time with organic manure

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

application. The other two-thirds of the nitrogen fertilizer was applied (as ammonium nitrate, 33% NO_3−N) during the growing season and the other one-third N was side-dressed 30 days after transplanting and the remaining one-third of the N was applied 60 days after transplanting as ammonium nitrate.

Cultivation. White head cabbage (*Brassica oleracea* var. *capitata*), Brunswick, was used as test plant and 15 plants per plot were established with 60 × 60 cm apart in 5.4 m^2. Regarding the experimental area, 1 m between the plots and blocks were left in order to manage the cultivation practices properly. Seeds were germinated on the seedling tray containing 3:1 peatmoss−perlite mixture in greenhouse. Irrigation was applied by furrow irrigation method in each plot separately, 15 times in the spring season and 12 times in the autumn season. Weed control was practiced by hand and all plant protection methods were performed by obeying the organic farming rules (*16*).

Analytical Methods. For mineral analysis, three heads per plot selected representatively were separated from the root and stem and taken to the laboratory. After that, wrapper leaves were removed and the edible part of the cabbage was washed three times with distilled water. The head was cut vertically into two pieces and the other half part of cabbage was cut again vertically into two pieces; one of these pieces was selected randomly and used for analysis. Thus, the whole edible part of the head was aimed to be analyzed representatively. Having cut three heads, the three randomly selected subsamples per plot were dried at 65 °C until the samples reach a stable weight; afterward, all samples to be analyzed were ground and an analytical regime was performed as stated by Kacar and Inal (*17*). 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 (*17*).

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

RESULTS AND DISCUSSION

Macronutrient Content of Cabbage. Table 3 gives the results of the application on the total N, P, and K content of cabbages, and a statistical significance was found in both seasons ($P < 0.001$). In general, the decrease in the P and K contents of cabbage was recorded from the spring season to the autumn season except for N with a slight increment in the autumn season. The total N contents of cabbage ranged from 1.82 to 4.42% in the spring season and were taken from 2.5 CM + 4.0 FM and 1.2 BM application, respectively. In the autumn season, 1.2 BM application gave the highest level of total N, 4.12%, as did in the spring season, but the lowest level of total N, 2.45%, was taken from the 5.0 FM + 1.0 BM application (**Table 3**).

The noticeable fluctuation was recognized among the applications in both seasons regarding the total N content of cabbage. The more mineralization occurs the more plant available nutrients release. BM is characterized to be rapidly mineralized organic manure (*18−20*), and rapid mineralization represents that more than 70% of the organic N is expected to mineralize in a growing season (*20*); therefore, the applications containing BM that often gave the higher plant N content may be attributed to the quick mineralization characteristics of the material. However, the result of current experiment was found to be higher compared to Warman and Harvard (*3*), stating that the N content of cabbage in organic production is between 1.78 and 2.03%. This was probably related to the different variety and also the initial soil conditions affecting the plant growth to a large extent.

The P content of cabbage varied among the applications and the lowest and the highest level of the P was found to be between 0.21 and 0.38% and was attained from 0.9 BM + 4.0 FM and 1.2 BM application in the spring season, respectively. In the autumn season, highest and lowest P level were found with 1.7 CM + 7.5 FM (0.34%) and control (0.13%), respectively. Though the highest level of P was determined in 1.2 BM application (0.38%) in the spring season, CM was determined to have increased the P content of cabbages compared to the other applications, FM and BM. As seen in **Table 2**, CM contains larger amounts of P than the other treatments; therefore, the tangible effect of CM on the P content of cabbages must have been related to the P content of the material. Moreover, as reported by Materechera and Morutse (*21*), CM presents viable options for supplying P. Regarding the former studies, the P content of organically grown cabbage was reported to be between 0.20 and 0.23% (*3*) and further was cited that the P content to be on average 0.22% (*22*).

The K content of cabbages ranged from 2.90 to 3.65% in the spring season and was taken from 0.9 BM + 4.0 FM and from mineral fertilizer application, respectively. In the autumn season, a decrease in the K content was realized and was fixed in the range of 1.80 and 2.71%, obtaining from control and 15.0 FM application, respectively (**Table 3**). Generally, FM gave the better results in terms of the K content of cabbages in both seasons. This result could be attributed to the K content of FM (**Table 2**) and also to the mineralization rate driven by the factors including soil and the climatic conditions, assuming to be 90−100% in the autumn season (*23*); that is, obtaining a higher level of K in the spring season may be explained by the enhanced mineralization rate of the manures. Regarding the former studies, Warman and Harvard (*3*) found the K content of organic cabbage in the range of 2.00−2.44% in the spring season and further values were reported by Masamba and Nguyen (*24*) of 2.53−2.87%.

The influence of the applications on the Ca and Mg is given in **Table 4**. The Ca contents of cabbages were found to be statistically significant in both seasons ($P < 0.001$). The highest levels were taken from 1.7 CM + 0.6 BM and 1.7 CM + 4.0 FM + 0.3 BM applications with 0.92%, and the lowest level of Ca was recorded as 0.48% and was attained from the 10.0 FM + 1.2 CM application. According to Warman and Harvard (*3*), the Ca content of organically grown cabbage ranged from 0.31 to 0.61% in spring season, and further was recorded by Fjelkner-Modig et al. (*22*), reporting 0.44% Ca in organic cabbage. The cabbage plant requires a high level of Ca (*25*), and Ca is required during the whole growing stage (*26*). The treatments had a statistically significant effect on the Mg content ($P < 0.01$) in the spring season, but insignificant effect was observed in the autumn season for Mg. Though it was found to be insignificant, the Mg content of cabbages ranged from 0.12 to 0.16% in the autumn season (**Table 4**). The Mg content of the cabbage head was reported on average to be 0.11 (*22*) and further was reported to be in the range of 0.12−0.15% (*3*), proving the consistency with the current study.

Comparing the seasonal mean, the average P, K, and Mg contents tended to descend in the autumn season while the total N and Ca were observed to have ascended in the spring season

Table 3. Effects of the Different Applications and the Seasons on the Total N, P, and K Content of Cabbage[a,b]

		N (%)		P (%)		K (%)	
		seasons[c]					
treatments (ton ha^{-1})		spring	autumn	spring	autumn	spring	autumn
1-	3.5 CM	2.56 fg	3.35 c	0.37 ab	0.33 a	3.26 bcde	2.55 abcd
2-	2.5 CM + 4.0 FM	1.82 j	2.74 f	0.32 bcd	0.26 def	2.98 fg	2.30 gh
3-	2.5 CM + 0.3 BM	2.39 ghi	2.66 g	0.32 bcd	0.31 abc	3.16 cdef	2.31 efgh
4-	1.7 CM + 7.5 FM	2.35 ghi	2.53 hi	0.34 abcd	0.34 a	3.36 bc	2.51 bcdef
5-	1.7 CM + 0.6 BM	3.14 cde	2.96 e	0.35 abcd	0.24 efg	3.26 bcde	2.43 cdefgh
6-	1.7 CM + 4.0 FM + 0.3 BM	2.20 hi	2.53 hi	0.31 bcde	0.27 de	3.08 efg	2.64 ab
7-	15.0 FM	3.00 de	2.56 h	0.35 abcd	0.28 bcd	3.43 b	2.71 a
8-	10.0 FM + 1.2 CM	2.06 ij	2.46 l	0.34 abcd	0.29 bcd	3.08 efg	2.70 a
9-	10.0 FM + 0.4 BM	2.41 fgh	2.63 g	0.27 ef	0.28 cd	3.02 fg	2.61 abc
10-	5.0 FM + 2.5 CM	2.48 fg	2.78 f	0.33 bcd	0.32 ab	3.33 bcd	2.26 h
11-	5.0 FM + 1.0 BM	3.03 de	2.45 l	0.26 ef	0.17 h	3.18 cdef	2.36 defgh
12-	5.0 FM + 1.2 CM + 0.4 BM	2.37 gh	2.52 hi	0.33 abcd	0.26 def	3.34 bcd	2.24 h
13-	1.2 BM	4.42 a	4.12 a	0.38 a	0.23 fg	3.31 bcd	2.60 abc
14-	0.9 BM + 0.85 CM	3.02 de	3.32 c	0.24 fg	0.28 cd	3.13 def	2.31 fgh
15-	0.9 BM + 4.0 FM	3.02 de	2.95 e	0.21 g	0.16 hi	2.90 g	2.23 h
16-	0.6 BM + 7.5 FM	3.45 c	2.47 f	0.30 de	0.22 g	3.16 cdef	2.49 bcdefg
17-	0.6 BM + 0.85 CM + 4.0 FM	2.79 ef	3.60 b	0.31 cde	0.28 bcd	3.20 cdef	2.51 abcde
18-	mineral fertilizer	3.16 cd	3.24 d	0.33 abcd	0.31 abc	3.65 a	2.42 cdefg
19-	control	3.79 b	3.40 c	0.36 abc	0.13 i	3.08 efg	1.80 i

[a]Abbreviations: FM (farmyard manure), CM (chicken manure), BM (blood meal). [b]Average of 12 samples. [c]Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 4. Effects of the Different Applications and the Seasons on the Ca and Mg Content of Cabbage[a,b]

		Ca (%)		Mg (%)	
		seasons[c]			
treatments (ton ha^{-1})		spring	autumn	spring	autumn
1-	3.5 CM	0.87 ab	0.52 fgh	0.16 cde	0.16
2-	2.5 CM + 4.0 FM	0.53 def	0.78 bcd	0.13 g	0.12
3-	2.5 CM + 0.3 BM	0.52 ef	0.51 fgh	0.14 f	0.14
4-	1.7 CM + 7.5 FM	0.61 cdef	0.81 bc	0.15 ef	0.14
5-	1.7 CM + 0.6 BM	0.92 a	0.56 efgh	0.17 c	0.13
6-	1.7 CM + 4.0 FM + 0.3 BM	0.92 a	0.61 cdefg	0.15 ef	0.13
7-	15.0 FM	0.63 bcdef	0.77 bcd	0.17 c	0.15
8-	10.0 FM + 1.2 CM	0.48 f	0.93 b	0.13 g	0.13
9-	10.0 FM + 0.4 BM	0.54 def	0.48 fgh	0.15 ef	0.14
10-	5.0 FM + 2.5 CM	0.61 cdef	0.76 bcde	0.15 def	0.14
11-	5.0 FM + 1.0 BM	0.75 abcde	0.62 cdefg	0.18 b	0.13
12-	5.0 FM + 1.2 CM + 0.4 BM	0.51 ef	0.56 efgh	0.15 def	0.12
13-	1.2 BM	0.84 abc	0.55 fgh	0.20 a	0.15
14-	0.9 BM + 0.85 CM	0.73 abcdef	0.38 h	0.16 cd	0.14
15-	0.9 BM + 4.0 FM	0.85 abc	0.41 gh	0.17 c	0.12
16-	0.6 BM + 7.5 FM	0.65 bcdef	0.48 fgh	0.17 c	0.13
17-	0.6 BM + 0.85 CM + 4.0 FM	0.51 ef	0.58 defgh	0.16 cde	0.12
18-	mineral fertilizer	0.79 abcd	0.64 cdef	0.18 b	0.13
19-	control	0.60 cdef	1.24 a	0.16 cde	0.15

[a]Abbreviations: FM (farmyard manure), CM (chicken manure), BM (blood meal). [b]Average of 12 samples. [c]Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

(**Figure 2**). Warman and Havard (*3*) compared organically and conventionally grown cabbage during three years sequences in every spring seasons and found that the N, P, and K content of cabbage as follows: for N content, 1.78, 1.90, and 2.03%; for P content, 0.23, 0.22, and 0.20%; for K content, 2.42, 2.00, and 2.44% in the first, second, and the third years of the experiment, respectively. The same was reported for Ca and Mg content of cabbage as follows: for Ca content, 0.36, 0.31, and 0.61%; for Mg content, 0.15, 0.12, and 0.13% in the first, second, and the third years of the experiment, respectively. These results revealed that the successively grown organic cabbage showed a fluctuation in nutrient contents, some of which increased or decreased. We have also noticed nearly the same results compared to Warman and

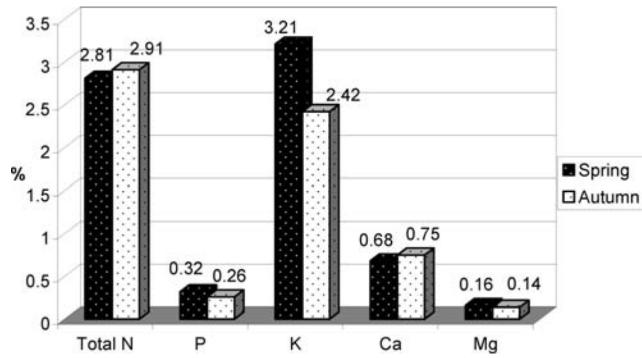

Figure 2. Seasonal changes of the macronutrient contents of cabbage.

Havard (*3*). As we compared the seasonal differences in successive application, N and Ca tended to increase and P, K, and Mg tended to decrease at the end of the two successive seasons.

Micronutrient Content of Cabbage. The Fe and Cu content of cabbage influenced by the applications are given in **Table 5**. In the spring season, the applications had a statistically significant effect on the Fe content ($P < 0.001$), the Fe content varied among 88.2 and 39.3 mg kg^{-1} within the applications and the highest values were obtained from 5.0 FM + 1.0 BM and 0.6 BM + 7.5 FM, and the lowest was from 2.5 CM + 4.0 FM application. In the autumn season, the effects of the applications on the Fe content of cabbage were found statistically significant ($P < 0.05$) and were recorded 123.0 mg kg^{-1} in 0.9 BM + 4.0 FM and 70.0 mg kg^{-1} in 5.0 FM + 1.2 CM + 0.4 BM application as the highest and the lowest levels, respectively (**Table 5**). It was noticed that the mixture of BM and FM gave the better results for the Fe content. This may be probably related to the Fe content of the materials applied to it. The Fe content of organic cabbage was fixed in the range of 22.4 and 54.2 mg kg^{-1} (*3*).

The influence of the applications on the Cu content was found to be statistically significant in the spring season ($P < 0.001$) whereas there was no significant effect observed in the autumn season. The Cu content of cabbage varied among 5.60 and 1.20 mg kg^{-1} and obtained from 0.9 BM + 0.85 CM and 2.5 CM + 0.3 BM application, respectively (**Table 5**). In the autumn season, the

Table 5. Effects of the Different Applications and the Seasons on the Fe and Cu Content of Cabbage[a,b]

	Fe (mg kg^{-1})		Cu (mg kg^{-1})	
	seasons[c]			
treatments (ton ha)$^{-1}$	spring	autumn	spring	autumn
1- 3.5 CM	55.0 cdef	117.1 abc	1.70 ef	3.00
2- 2.5 CM + 4.0 FM	39.3 f	92.3 abcde	2.00 def	2.30
3- 2.5 CM + 0.3 BM	40.6 f	71.7 e	1.20 f	2.10
4- 1.7 CM + 7.5 FM	59.8 bcdef	115.2 abcd	1.90 def	2.90
5- 1.7 CM + 0.6 BM	72.2 abcd	89.2 abcde	2.70 bcd	2.80
6- 1.7 CM + 4.0 FM + 0.3 BM	43.6 ef	81.4 bcde	2.50 cde	2.95
7- 15.0 FM	69.0 abcde	86.2 abcde	1.90 def	2.60
8- 10.0 FM + 1.2 CM	52.8 cdef	102.8 abcde	1.80 def	1.50
9- 10.0 FM + 0.4 BM	48.7 def	84.1 abcde	1.50 f	2.70
10- 5.0 FM + 2.5 CM	56.7 cdef	77.3 cde	2.50 cde	2.30
11- 5.0 FM + 1.0 BM	88.2 a	97.2 abcde	3.50 b	5.45
12- 5.0 FM + 1.2 CM + 0.4 BM	78.3 abc	70.0 e	3.20 bc	2.10
13- 1.2 BM	85.4 ab	106.1 abcde	5.10 a	2.90
14- 0.9 BM + 0.85 CM	54.6 cdef	120.3 ab	5.60 a	4.50
15- 0.9 BM + 4.0 FM	74.4 abcd	123.0 a	4.90 a	1.90
16- 0.6 BM + 7.5 FM	88.2 a	95.4 abcde	3.40 bc	2.60
17- 0.6 BM + 0.85 CM + 4.0 FM	59.1 cdef	74.9 de	3.10 bc	2.50
18- mineral fertilizer	76.7 abc	74.3 de	2.70 bcd	2.50
19- control	69.8 abcd	98.7 abcde	3.60 b	3.00

[a]Abbreviations: FM (farmyard manure), CM (chicken manure), BM (blood meal). [b]Average of 12 samples. [c]Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

Table 6. Effects of the Different Applications and the Seasons on the Mn and Zn Content of Cabbage[a,b]

	Fe (mg kg^{-1})		Fe (mg kg^{-1})	
	seasons[c]			
treatments (ton ha^{-1})	spring	autumn	spring	autumn
1- 3.5 CM	24.0 cd	23.2 ab	48.0 abc	45.0 b
2- 2.5 CM + 4.0 FM	23.0 cd	21.3 ab	23.0 e	46.0 b
3- 2.5 CM + 0.3 BM	24.0 cd	23.2 ab	33.8 cde	47.1 b
4- 1.7 CM + 7.5 FM	24.8 cd	22.0 ab	40.6 bcd	65.0 ab
5- 1.7 CM + 0.6 BM	41.5 a	21.6 ab	41.5 bcd	48.0 b
6- 1.7 CM + 4.0 FM + 0.3 BM	23.8 cd	21.6 ab	37.3 cd	40.2 b
7- 15.0 FM	37.7 ab	23.4 ab	58.3 a	97.0 a
8- 10.0 FM + 1.2 CM	22.4 cd	20.2 abc	34.2 cde	35.2 b
9- 10.0 FM + 0.4 BM	21.5 d	20.3 abc	32.5 de	90.5 a
10- 5.0 FM + 2.5 CM	26.1 cd	24.1 a	46.9 abcd	56.2 ab
11- 5.0 FM + 1.0 BM	25.8 cd	19.3 bcd	57.9 a	34.1 b
12- 5.0 FM + 1.2 CM + 0.4 BM	22.8 cd	21.0 ab	43.8 abcd	31.3 b
13- 1.2 BM	28.9 bcd	15.6 d	58.2 a	32.1 b
14- 0.9 BM + 0.85 CM	27.8 cd	23.2 ab	47.6 abc	35.3 b
15- 0.9 BM + 4.0 FM	28.6 bcd	16.1 cd	44.6 abcd	56.5 ab
16- 0.6 BM + 7.5 FM	29.8 bcd	20.0 abc	54.7 ab	31.1 b
17- 0.6 BM + 0.85 CM + 4.0 FM	28.9 bcd	20.4 abc	47.8 abc	30.7 b
18- mineral fertilizer	32.1 bc	15.3 d	40.6 bcd	46.5 b
19- control	21.9 d	24.1 a	46.1 abcd	31.3 b

[a]Abbreviations: FM (farmyard manure), CM (chicken manure), BM (blood meal). [b]Average of 12 samples. [c]Values within the same column followed by the same letter are not significantly different ($P \leq 0.05$).

Cu content values were fixed between 5.45 and 1.50 mg kg^{-1} though no statistical significance were observed. The average Cu content of cabbage head was recorded between 1.8 and 4.2 mg kg^{-1}(*3*).

The applications affected the Mn content of cabbages to a different extent and the differences between the applications were found to be statistically significant in both seasons ($P < 0.001$) and the results are given in **Table 6**. In the spring season, the highest and the lowest values were found to be between 41.5 and 21.5 mg kg^{-1} and attained from 1.7 CM + 0.6 BM and from 10.0 FM + 0.4 BM application, respectively. Regarding the autumn season, these values were fixed as follows; 24.1 mg kg^{-1} from 5.0 FM + 2.5 CM and control applications gave the highest value and 15.3 mg kg^{-1} from mineral fertilizer application gave the lowest value (**Table 6**). Warman and Harvard (*3*) reported the Mn content of cabbage to be between 8.2 and 23.0 mg kg^{-1} and further was reported to be 11.0 mg kg^{-1} (*22*) The effects of the applications on the Zn content of cabbage was found to be statistically significant in the spring ($P < 0.001$) and in the autumn season ($P < 0.05$). The Zn content of cabbage ranged from 58.3 to 23.0 mg kg^{-1} in the spring season and the higher value of the Zn was achieved from 15.0 FM and the lowest was from 2.5 CM + 4.0 FM, respectively (**Table 6**). In the autumn season, the same as in the spring season, the higher value of the Zn was taken from 15.0 FM application with 97.0 mg kg^{-1} although the lowest level of the Zn was observed from 0.6 BM + 0.85 CM + 4.0 FM application with 30.0 mg kg^{-1}. FM was observed to have a positive effect on the Zn content of cabbages to some extent.

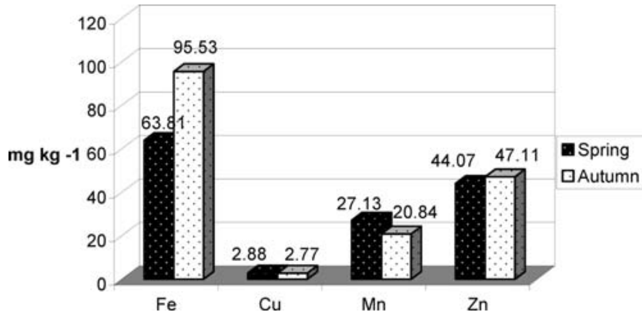

Figure 3. Seasonal changes of the micronutrient contents of cabbage.

Upon regard to the seasonal mean of the micronutrients, the fluctuation was realized not only between the seasons but also between the micronutrients as well. **Figure 3** shows the relationships between the seasons and the changes in micronutrient content of cabbage. The Fe and Zn content of cabbage was determined to have increased from the spring season to the autumn season, whereas the decrease was detected in the Cu and Mn content of cabbage from the spring season to the autumn season (**Figure 3**).

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 (*27*). Moreover, Citak and Sonmez (*28*) reported that the comparison of organically and conventionally produce between different seasons is not easy due to the different response of the material depending on the soil and also the seasonal conditions.

The macronutrient content of cabbage samples differed between the applications and also the seasons. The mineral composition of cabbage was found to be related to the mineral content of the manures. Generally, CM containing applications caused a high level of cabbage P, and FM caused a high level of cabbage K and also N. These results inferred from the **Table 3** may have been linked to the mineral composition of the material (**Table 2**). Regarding the N content of cabbage, BM appeared not to be a suitable material even though the highest level of plant N was determined in BM. As a consequence, CM and FM were found to be quite effective sources for organic applications especially in the autumn season.

Giving a recommendation is not easy due to the great variations in mineral contents of cabbage within the applications and also the seasons. Thus, the optimum doses to be recommended should be divided into groups within the seasons for macronutrients as follows: 0.6 BM + 7.5 FM in the spring season and 3.5 CM in the autumn season for N, P, and K content of cabbage. For Ca and Mg, the group division should be 1.7 CM + 0.6 BM in the spring season and 10.0 FM + 1.2 CM in the autumn season.

Micronutrient contents of cabbage also showed variations as the same as the macronutrients. Recommended doses could be the 5.0 FM + 1.0 BM in the spring season and 0.9 BM + 0.85 CM in the autumn season for Fe and Cu. Evaluating the Mn and Zn content of cabbage, the doses should be 15.0 FM in the spring season, and 10.0 FM + 0.4 BM in the autumn season.

Scrutinizing the reasonable application appeared not to be easy due to the great variations; however, that the mineral contents of cabbage receiving organic applications tended to be higher than that of chemical fertilizer application was clear. On the whole, cabbage responded the best to FM and CM containing applications both as a single and a mixture. Though BM often gave the highest cabbage N and also the micronutrient values, we do not recommend that BM be used in single applications because of having some undesired features such as bad smell and difficult application.

Moreover, if BM is to be applied it should be used in small quantities within the mixtures and also be applied as a top dressing instead of the basal dressing. Therefore, these materials could be easily transferred as a valuable tool for producing white head cabbage in organic farming system.

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