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Araştırma Makalesi/*Research Article (Original Paper)*

Influence of Manganese and Sulphur Fertilization on the Mineral Composition of Broccoli (*Brassica oleracea L. var italica)*

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Abstract: Broccoli is a hardy vegetable that develops best during cool seasons of the year. For efficient growth, broccoli has a moderate to high fertility requirement. Sulphur deficiency is known to occur in brassica crops and Mn deficiency and toxicity has also been observed in these plants. Mn functions primarily as part of enzyme systems in plants. It activates several important metabolic reactions and plays a direct role in photosynthesis by aiding chlorophyll synthesis. However, insufficient information is available on the mineral content of this product and how fertilization might influence it. For this purpose, a greenhouse experiment was conducted in Konya to evaluate the influence of different Mn and S fertilizer doses on the productivity and element content of broccoli. The influence of Mn and S (0-0,3- 0,6- 1,2- 2,4 kg Mn /da and 0-4-8 kg S/da applications) on the mineral content of broccoli sprouts (*Brassica oleraceae var. italica* cv.) was determined in this study. In the experiment carried out under controlled conditions, plant height, leaf surface area and plant shoot fresh weight were determined in the plants. After the harvest yield, mineral concentrations (S, Mn, Fe, Zn, Cu, P, K, Ca, Mg, N) of broccoli plants were analyzed. S and Mn applications had positive effects on shoot fresh yield and especially at the dose of 8 kg S/da application significantly increased shoot fresh yield ($P<0.05$), plant Ca, Mg, K, P, S, Na, Mn, Zn, Cu, and B contents, and the amount of S and Mn uptake by shoot from the soil ($P<0.01$).

Keywords: Brassicaceae, Broccoli, Manganese, Mineral concentration, Sulphur

Mangan ve Kükürtlü Gübrelemenin Brokolinin (*Brassica Oleracea var. italica*) Mineral Element İçeriğine Etkisi

Özet: Brokoli, yılın serin dönemlerinde iyi yetişen dayanıklı bir sebzedir. Brokolinin iyi bir şekilde büyümesi için, orta ila yüksek verimliliğe ihtiyaç vardır. Kükürt eksikliğinin Brassica çeşitlerinde olduğu bilinmektedir; ayrıca mangan eksikliği ve toksisitesi de bu bitkilerde gözlemlenmiştir. Manganez öncelikle bitkilerdeki enzim sistemlerinin bir parçası olarak işlev görür. Birkaç önemli metabolik reaksiyonu aktive eder ve klorofil sentezine yardımcı olarak fotosentezde doğrudan rol oynar. Bununla birlikte, bu ürünün elverişli mineral içeriği ve verimliliğinin nasıl etkilendiği konusunda yeterli bilgi mevcut değildir. Bu amaçla brokolinin verimi ve element içeriği üzerine farklı manganez ve kükürt gübre dozlarının etkisini değerlendirmek için; Konya'da bir sera denemesi yapılmıştır. Bu çalışmada brokoli bitkisinin (*Brassica oleraceae var. italica*) mineral içeriği üzerine mangan (0- 0,3- 0,6- 1,2- 2,4 kg Mn / da) ve kükürt (0- 4- 8 kg S / da) uygulamalarının etkisi belirlenmiştir. Kontrollü koşullar altında gerçekleştirilen denemede; bitki boyu, yaprak yüzey alanı, bitki sürgün ağırlığı (g) değerleri belirlendi. Hasat sonrası verim, brokoli bitkisinin mineral konsantrasyonları (S, Mn, Fe, Zn, Cu, P, K, Ca, Mg, N) belirlenmiştir. Çalışma sonunda mangan ve kükürt uygulamaları ile taze gövde verimine pozitif etki ettiği ve özellikle de 8 kg S/da kükürt uygulamasının taze gövde verimini önemli oranda artırdığı ($P<0.05$) belirlendi. Bitkide Ca, Mg, K, P, S, Na, Mn, Zn, Cu ve B içerikleri ve bitki gövde kısmı ile topraktan S ve Mn alımının önemli oranda arttığı tespit edilmiştir ($P<0.01$).

Anahtar kelimeler: Brassicaceae, Brokoli, Mangan, Mineral konsantrasyonu, Kükürt

Introduction

Vegetables play a very important role in human nutrition, being the basis of a food chain with an indisputable health importance. Nevertheless, the annual consumption of vegetables is still insufficient (Šlosár a Čekey 2008). Broccoli (*Brassica oleracea* L. *var. italica*) is a member of the Brassicaceae family, native to the Mediterranean region (Decoteau 2000). It is an important vegetable crop with high nutritional and good commercial value (Yoldas et al. 2008). Broccoli is a winter vegetable crop, which is more nutritious than other coles, such as cabbage, cauliflower and kohlrabi (Thomson and Kelly 1985).

Broccoli contains large amounts of phytochemicals with demonstrated anticarcinogenic activities. It is a rich source of vitamins A, C and E, folic acid, selenium, carotenoids, flavonoids, glucosinolates, phenols ascorbic acid, calcium, niacin and riboflavin. Fresh broccoli heads contain high levels of glucosinolates and flavonoids (Winkler et al. 2007), which are phytochemicals with anticarcinogenic properties. In addition, consumption of broccoli is linked to reduced risks of prostate cancer (Joseph et al. 2004), cardiovascular diseases (Jones et al. 2006) and lung cancer (Spitz et al. 2000). In addition, Glucosinolates and products of their breakdown are known for antifungal, bactericidal, nematicidal, and allelopathic properties (Fahey et al. 2002).

Compared to other grown crops, vegetables have relatively high nutrient requirements. For this reason, nutrition and fertilization are very important processes in growing vegetables (Hlušek et al. 2002). The role of sulfur in plant nutrition has attracted more attention in recent years. Today, S has become one of the limiting elements of plant nutrition in agricultural production (Eriksen et al. 2004). Most crop species have higher yield and better quality products when there is plenty amount of S available in the soil (Biswas and Tewatia 1991). Plants assimilate inorganic sulfate into methionine, the precursor for glucosinolate production (Nicoforova et al. 2003). Schonhof et al. (2007) demonstrated that sufficient S supply increased broccoli head weight and the content of glucosinolate under optimal nitrogen fertilization. Elwan and Abd El-Hamed (2011) conducted a study to determine the effects of N sources and S, and found that additions of ammonium sulfate and sulfur application in the field of broccoli were essential to produce higher yield with good quality curds. In the study where the available S content in the soil was between 13-19 ppm, the amount of S calculated for maximum yield was 55 kg/ha (McKeown and Bakker 2003).

Mn is important for the synthesis of the organic substance in plants and for the metabolism of a number of nutrient elements in a plant organism. For most cultivated plants, the critical concentration of Mn in leaves is 25 mg kg^{-1} dry matter (Epstein 1961; Mutaftchiev 2001; Mutaftchiev 2003).

The present study investigated the effect of S and Mn fertilizer applications on the yield of broccoli and nutrient element uptake by the broccoli plant in the cultivation of this highly nutritious and important plant in the soils of Konya with high lime content and low available Mn concentration. In this way, it was endeavored to determine the appropriate dose of Mn and S for broccoli.

Material and Methods

The broccoli seed used in the greenhouse experiment was a commercial product sold for use by farmers. When the seeds develop into seedlings and are ready to be planted to the field or a closed greenhouse, they have a middle-sized dark green structure with a hard texture. Before the pot experiment, the seeds were planted in a turf environment and kept in vials until they turned into seedlings. The soil used in the pot experiment was taken from the lands of Selcuk University Agricultural Faculty Saricalar Research and Application Farm. A sufficient amount of soil was taken from a depth of 0-20 cm and put into cloth bags to be brought to the greenhouse. At the greenhouse, the soil was spread on plastic sheets and cleaned from plant residues. The soil was allowed to air dry and sieved through a 4 mm mesh. The sieved soil was weighed (3,5 kg) and filled into pots. The experiment was carried out in a randomized plot design with 4 replications. The soil used in the experiments was analyzed physically and chemically (sand, silt, clay and textural class), Bouyoucos (1951); pH (H_2O,1:2,5) and EC (H_2O;1:2,5) Jackson (1969); organic matter (Walkley 1947); calcium carbonate by Scheibler method as described by Jackson (1958); available P, Olsen (1954); available Fe, Cu, Zn, Mn, Lindsay and Norvell (1978). The results of the soil analyses are presented in Table 1.

Table 1. Physical and chemical characteristics of the soil in the experiment area

	Texture	EC (ds/m)	pH	$CaCO_3$ (%)	Organic Matter (%)	P (mg kg^{-1})	K (mg kg^{-1})
Experiment Soil	Clay loam	0.93	7.90	12.94	1.98	5.15	831.88
		without salt	mild alkaline	high	Low	middle	very high
	Fe	**Cu**	**Mn**	**Zn**	**Field capacity (%)**	**Wilting point (%)**	**Available water (%)**
	(mg kg^{-1})						
	2.46	0.96	1.30	0.58	36.83	15.84	20.99
	low	middle	middle	low			

The experiment was set up as 1 (broccoli) x 3 (S doses) x 5 (Mn doses) x 4 replications = 60 pots. In the experiment, S was applied in liquid form (80%) at doses of 0 - 4 - 8 kg S/da(S1-S2-S3), and Mn was applied using Mn-EDTA (containing 8% Mn) at doses of 0 – 0,3 – 0,6 – 1,2 – 2,4 kg Mn/da (Mn1-Mn2-Mn3-Mn4-Mn5). Broccoli seeds were planted in vials containing turf in the greenhouse in December 2015. In February 2016, the broccoli seedlings at the 2-3 leaf stage were transplanted to the pots for the experiment. The water needs of the plants during the experiment were met considering the soil moisture and the required water demand of the plant. The plants were harvested by cutting above the soil on June 13, 2016.

Measurements and analyses performed on the plants: plant height (cm) and leaf surface area (cm^2) were determined before the harvest; plant shoot fresh weight (g) was measured after the harvest.

Elemental analyses of the plants: Plant samples were analyzed by the wet method and 0.2 g of plant sample was dissolved in HNO_3 on a hot plate. The filtrate in each case was analyzed for K, P, S, Ca, Mg, Fe, Zn, Mn, Cu, Na contents by AAS. In this study, all the results were expressed on a dry weight basis.

The results obtained from the greenhouse experiment were compared through two way Anova variance analysis (manganese doses, sulfur doses and MnxS interaction) and Tukey's tests by using the MINITAB software.

Results and Discussion

The results obtained from this study are presented in Tables 2, 3, and 4.

Plant height (cm) and leaf surface area (cm^2): The results of the statistical analyses showed that S, Mn and S x Mn interaction did not have a statistically significant effect on average plant height and leaf surface area. The highest plant height was observed with the S1Mn5 dose (32.00 cm), and the largest leaf surface area was observed with the S3Mn2 dose (0.53 cm^2)(Table 2).

Shoot fresh weight (g pot^{-1}): It was observed that the shoot fresh weight of the plants showed a statistically significant ($P<0.05$) increase with increasing S applications. Significant differences were observed with S x Mn interaction ($P<0.05$), and the highest average shoot fresh weight was obtained with the S3Mn3 dose (46.51 g) (Table 2).

Shoot fresh yield (kg da^{-1}): Similar to shoot fresh weight, it was found that S application had a significant effect on shoot fresh yield (P<0,05), whereas the S x Mn interaction was not found to be statistically significant. The highest average shoot fresh yield was achieved as 3222 kg da^{-1} with the S3Mn3 dose (Table 2).

Table 2. The effect of different doses of S and Mn applications on certain growth and yield characteristics of the broccoli plant

S doses (kg S da^{-1})	Mn doses (kg Mn da^{-1})	Plant height(cm)	Leaf surface area (cm^2)	Shoot fresh weight (g pot^{-1})	Shoot fresh yield (kg da^{-1})
0	**0**	26.75	0.33	23.77	1698
	0.3	26.75	0.43	31.18	2227
	0.6	27.25	0.50	27.25	1946
	1.2	26.00	0.48	30.00	2143
	2.4	32.00	0.46	33.49	2392
4	**0**	27.00	0.37	25.63	1830
	0.3	30.25	0.45	33.12	2365
	0.6	29.25	0.37	27.19	1949
	1.2	27.25	0.46	33.71	2409
	2.4	29.25	0.40	33.39	2385
8	**0**	28.00	0.39	32.18	2299
	0.3	27.50	0.53	33.11	2365
	0.6	30.75	0.45	46.51	3322
	1.2	28.50	0.46	32.12	2294
	2.4	28.00	0.45	32.87	2348

S uptake by shoot from the soil (mg kg^{-1} dry matter): The results of the statistical analyses showed that the amount of S uptake by shoot from the soil significantly increased with increasing doses of S ($P<0.01$). While Mn application did not have a significant effect on S uptake, S x Mn interaction was found to have a significant effect on the amount of S uptake by shoot from the soil(P<0.05). The highest S uptake was obtained with the S3Mn3 dose (493.5 mg kg^{-1} dry matter) (Table 3). In general, the amount of S taken from the soil at the S3 dose was higher compared to the amount of S taken from the soil at the S1 and S2 doses.

Table 3. The effect of different doses of S and Mn applications on the S and Mn uptake by shoot from the soil and nutrient element content of the broccoli plant

S doses (kg S da^{-1})	Mn doses (kg Mn da^{-1})	S uptake by shoot from the soil (mg kg-1 dry matter)	Mn uptake by shoot from the soil (mg kg^{-1} dry matter)	Ca (%)	Mg (%)	K (%)	P (mg kg^{-1})
	0	149.23^{c*}	0.554^{ns}	1.57^{ns}	0.25^{ns}	2.45^{ns}	1291^{ns}
	0.3	191.68^{bc*}	0.798^{ns}	1.54^{ns}	0.24^{ns}	2.46^{ns}	1372^{ns}
0	**0.6**	170.59^{c*}	0.704^{ns}	1.74^{ns}	0.20^{ns}	2.62^{ns}	1291^{ns}
	1.2	221.73^{bc*}	0.754^{ns}	1.76^{ns}	0.27^{ns}	2.74^{ns}	1495^{ns}
	2.4	217.71^{bc*}	0.727^{ns}	1.79^{ns}	0.22^{ns}	2.58^{ns}	1385^{ns}
	0	144.10^{c*}	0.729^{ns}	1.66^{ns}	0.19^{ns}	2.49^{ns}	1211^{ns}
	0.3	211.96^{bc*}	0.823^{ns}	1.56^{ns}	0.21^{ns}	2.33^{ns}	1237^{ns}
4	**0.6**	169.09^{c*}	0.778^{ns}	1.71^{ns}	0.19^{ns}	2.46^{ns}	1455^{ns}
	1.2	198.78^{bc*}	0.667^{ns}	1.31^{ns}	0.19^{ns}	2.19^{ns}	1255^{ns}
	2.4	245.10^{bc*}	0.711^{ns}	1.50^{ns}	0.22^{ns}	2.55^{ns}	1504^{ns}
	0	296.11^{bc*}	0.850^{ns}	1.84^{ns}	0.21^{ns}	2.80^{ns}	1620^{ns}
	0.3	329.83^{abc*}	0.961^{ns}	1.74^{ns}	0.21^{ns}	3.14^{ns}	1686^{ns}
8	**0.6**	493.45^{a*}	1.435^{ns}	2.25^{ns}	0.25^{ns}	3.40^{ns}	1697^{ns}
	1.2	377.41^{ab*}	1.017^{ns}	2.13^{ns}	0.26^{ns}	3.47^{ns}	1779^{ns}
	2.4	294.47^{bc*}	0.980^{ns}	2.21^{ns}	0.25^{ns}	2.85^{ns}	1644^{ns}

$^{a-c}$ Values marked with different letters are statistically different from each other.
^{ns}No significant difference.
*P < 0.05.

Mn uptake by shoot from the soil (mg kg^{-1} dry matter): It was observed that S application increased the Mn uptake by shoot from the soil (P<0.01), and the highest Mn uptake occurred with the S3 dose of sulfur (1.05 mg kg^{-1} dry matter) (Table 3). Mn applications and S x Mn interaction did not have a statistically significant effect on Mn uptake by shoot from soil.

Ca content (mg kg^{-1}): Application of S in increasing doses had a significant and positive effect on Ca content(P<0.01). While the average Ca content was 2.03% with the S3 dose, it was 1.68% in the control application. Mn applications and S x Mn interaction did not have a statistically significant effect on Ca content.

Mg content (mg kg^{-1}): S application had a significant effect on the Mg content of the plant (P<0.01). Mn applications and S x Mn interaction did not have a statistically significant effect on Mg content.

K content (mg kg^{-1}): It was found that S application significantly increased the K content of the plant(P<0.01). While the average K content was 3.13% with the S3 dose of sulfur, it was 2.57% in the control application. Mn applications and S x Mn interaction did not have a statistically significant effect on K content. However, plant K content with the S3 dose was found to be higher than that with the other S doses in general.

P content (mg kg^{-1}): S application had a statistically significant effect on the P content of broccoli (P<0.01). The average P content was 1685 mg kg^{-1} with the S3 dose of sulfur, whereas it was 1367 mg kg^{-1} in the control application. Mn applications and S x Mn interaction did not have a statistically significant effect on P content. Plant P content with the S3 dose was again higher compared to the P content observed with the other S doses. While the P content of the plant was 1779 mg kg^{-1} with the S3Mn4 dose, it was 1291 mg kg^{-1} in the control application (Table 3).

Table 4. The effect of different doses of S and Mn applications on the S, Na, and microelement contents of the broccoli plant

S doses (kg S da^{-1})	Mn doses (kg Mn da^{-1})	S	Na	Fe	Mn	Zn	Cu	B	Mo
		(mg kg^{-1})							
0	0	6333^{ns}	184.52^{bc**}	35.78^{ns}	23.25^{ns}	11.49^{ns}	1.56^{abcd*}	29.08^{ns}	1.40^{ns}
	0.3	6204^{ns}	187.53^{bc**}	43.08^{ns}	25.94^{ns}	10.96^{ns}	1.45^{abcd*}	30.65^{ns}	1.49^{ns}
	0.6	6303^{ns}	145.99^{c**}	49.28^{ns}	25.80^{ns}	12.47^{ns}	1.49^{abcd*}	33.63^{ns}	1.61^{ns}
	1.2	7400^{ns}	246.99^{abc**}	43.31^{ns}	25.11^{ns}	13.75^{ns}	1.73^{abcd*}	32.93^{ns}	1.26^{ns}
	2.4	6474^{ns}	172.22^{bc**}	43.02^{ns}	21.70^{ns}	12.68^{ns}	1.43^{abcd*}	32.61^{ns}	1.35^{ns}
4	0	5604^{ns}	103.85^{c**}	36.29^{ns}	28.82^{ns}	10.33^{ns}	1.35^{bcd*}	32.25^{ns}	0.82^{ns}
	0.3	6373^{ns}	142.66^{c**}	43.13^{ns}	25.03^{ns}	11.20^{ns}	1.24^{cd*}	32.66^{ns}	0.89^{ns}
	0.6	6331^{ns}	127.07^{c**}	53.00^{ns}	29.46^{ns}	11.55^{ns}	1.46^{abcd*}	31.35^{ns}	1.08^{ns}
	1.2	5967^{ns}	154.63^{bc**}	43.95^{ns}	19.35^{ns}	11.62^{ns}	1.17^{d*}	25.74^{ns}	1.09^{ns}
	2.4	7337^{ns}	206.25^{bc**}	41.88^{ns}	21.38^{ns}	13.95^{ns}	1.76^{abcd*}	26.22^{ns}	1.20^{ns}
8	0	9105^{ns}	209.15^{abc**}	40.31^{ns}	26.30^{ns}	16.12^{ns}	2.02^{a*}	36.41^{ns}	0.87^{ns}
	0.3	9800^{ns}	196.46^{bc**}	45.79^{ns}	29.25^{ns}	15.12^{ns}	2.04^{a*}	39.40^{ns}	0.83^{ns}
	0.6	10834^{ns}	344.75^{a**}	57.54^{ns}	31.40^{ns}	16.86^{ns}	1.98^{ab*}	40.11^{ns}	0.77^{ns}
	1.2	12212^{ns}	286.76^{ab**}	48.08^{ns}	33.72^{ns}	16.32^{ns}	1.81^{abc*}	40.60^{ns}	1.00^{ns}
	2.4	8650^{ns}	123.66^{c**}	54.36^{ns}	29.76^{ns}	13.42^{ns}	1.88^{ab*}	35.52^{ns}	0.90^{ns}

$^{a-d}$ Values marked with different letters are statistically different from each other.
^{ns} No significant difference.
*P < 0.05; **P < 0.01.

S content (mg kg^{-1}): Increasing doses of S had a positive effect on S content at a significance level of P<0.01. Mn applications and S x Mn interaction did not have a statistically significant effect on S content. Aires et al. (2007) was found that N and S fertilization significantly (P < 0.001) influenced the uptake of all elements except phosphorus (P), and in this study sulfur concentrations in broccoli sprouts varied between 11.4 and 15.2 mg· g^{-1} (dw), while the Ca, Mg, P, K, and Na concentrations were below 10 mg· g^{-1} (dw).

Na content (mg kg^{-1}): Plant Na content showed a significant increase with increasing doses of S(P<0.01). Mn doses did not have a significant effect on plant Na content. However, S x Mn interaction had a statistically significant effect on plant Na content (P<0.01). Average Na content reached the highest value of 344.75 mg kg^{-1} with the S3Mn3 dose (Table 4).

Fe content mg kg^{-1}): It was observed that increasing doses of S did not have an effect on plant Fe content. However, increasing doses of Mn caused a statistically significant increase in plant Fe content (P<0.05), and the highest Fe content of approximately 53.27 mg /kg was obtained with the Mn3 dose. While S x Mn interaction did not yield a statistically significant difference in Fe content, the highest Fe content was observed with the S3Mn3 dose (57.54 mg kg^{-1}) (Table 4).

Mn content (mg kg^{-1}): According to the results of the statistical analyses, S application was found to have a significant effect on plant Mn content (P<0.01). Plant Mn content, which was 24.36 mg kg^{-1} in the control application, was found to be 30.09 mg/kg on average with the S3 dose of sulfur. While Mn application and S x Mn interaction did not have any statistically significant effects on Mn content, the highest values were obtained with the S3Mn4 dose and the S3Mn3 dose as 33.72 and 31.40 mg kg^{-1}, respectively (Table 4).

Zn content (mg kg^{-1}): S application was found to have a positive and significant effect on plant Zn content (P<0.01). However, Mn application or S x Mn interaction did not have any statistically significant effects on Zn content. It was observed that plant Zn content showed an increase with the 8 kg S/da application of S, and the highest Zn content was achieved with the S3Mn3 dose (16.86 mg kg^{-1}) (Table 4).

Cu content (mg kg^{-1}): Plant Cu content showed a significant increase with increasing doses of S(P<0.01). The effect of Mn application on plant Cu content wasn't found to be statistically insignificant. However, S x Mn interaction was observed to have a significant effect on Cu content, and the highest Cu content was observed with the S3Mn2 dose (2.04 mg kg^{-1}) (Table 4).

B content (mg kg^{-1}): B content of the plants showed a significant increase with increasing doses of S application (P<0.05). The average B content with the S3 dose was found as 38.41 mg kg^{-1}. In general, an increase was observed in B content with the 8 kg S/da application of S compared to other S doses. Plant B content varied between 25.74-40.60 mg kg^{-1} (Table 4).

Mo content (mg kg^{-1}): Plant Mo content significantly decreased with increasing doses of S application(P<0.01). While plant Mo content was 1.42 mg kg^{-1} with the application of the S1 dose, it decreased to 0.87 mg kg^{-1} with the application of the S3 dose.

Conclusion

In this experiment conducted under greenhouse conditions, head formation did not occur in all broccoli plants due to the high greenhouse indoor temperature. Although the pots were exposed to outdoor conditions in the spring period, head formation was still very low. The findings obtained in the study were the results of the analyses conducted on fresh plant shoot. S and Mn applications had positive effects on shoot fresh yield. Especially at the dose of 8 kg S da^{-1}, S application significantly increased shoot fresh yield (P<0.05), plant Ca, Mg, K, P, S, Na, Mn, Zn, Cu, and B contents, and the amount of S and Mn uptake by shoot from the soil (P<0.01). Regarding S x Mn interaction, the highest values in the aforementioned characteristics were obtained with the S3Mn3 dose and the S3Mn4 dose. The use of S and Mn at doses of 8 kg S and 0.6 kg Mn can be suggested for yield and plant nutrient uptake in the cultivation studies that will be carried out in our region. However, it is considered that it would be useful to determine the head formation and yield in broccoli through new studies that includes sowing dates with respect to climatic requirements.

References

Aires A, Rosa E, Carvalho R, Haneklaus S, Schnug E (2007). Influence of nitrogen and sulfur fertilization on the mineral composition of broccoli sprouts. Journal of Plant Nutrition.30:1035-1046.

Biswas BC, Tewatia RK (1991). Role of sülfür in balanced plant nutrition Indian experience. In: Proc. International Symposium on the role of Sulfur, Magnesium and Micronutrients in Balanced Plant Nutrition, China, pp:98-106.

Bouyoucos GJ (1951). A recalibration of the hydrometer method for making mechanical analysis of soils. Agronomy Journal 43:434-438

Decoteau DR (2000). Vegetable Crops. Upper Rever Company. New Jersey, USA.

Elwan MW and Abd El-Hamed KE (2011). Influence of nitrogen form, growing season and sulfur fertilization on yield and the content of nitrate and vitamin C of broccoli. Scientia Horticulturae 127(3) :181-187.

Epstein E (1961). The essential role of calcium in selective cation transport by plant cells.Plant Phy. 36(4) : 437.

Eriksen JK, Kristensen T, Askegard M (2004). Plant availability of catch crop sulfur following spring incorporation. J. Plant Nutr. Soil Sci. 167:609–615.

Lindsay WL, Norvell WA (1978). Development of a DTPA soil test for zinc, iron, manganese, and copper. Soil Science Society of America Journal. 42:421-428.

Fahey JW, Harıstoy X, Dolan PM, Kensler TW, Scholtus I, Stephenson KK, Talalay P, Loznıewskı A (2002).Sulforaphane inhibits extracellular, intracellular, and antibiotic-resistant strains of Helicobacter pylori and prevents benzo[a]pyrene-induced stomach tumors. Proc Natl Acad Sci. USA. 99: 7610-7615.

Hlusek J, Rıchter R, Ryant P, Kolar L (2002). Vyziva a hnojeni zahradnich plodin. Praha Zemedelec, 94s. ISBN 80-902413-5-2.

Jackson ML (1958). Soil Chemical Analysis. Prentice-Hall, Inc.; Englewood Cliffs.

Jackson ML (1969). Soil Chemical Analysis-Advanced Course: A Manual of Mehods Useful for Instruction and Research in Soil Chemistry, Physical Chemistry of Soils. Soil Fertility and Soil Genesis. ML Jackson.

Jones RB, Faragher JD, Winkler S (2006). A review of the influence of post harvest treatments on quality and glucosinalate content in broccoli (Brassica oleracea L. var. italica) heads. Post harvest Biology and Technology. 41:1–8.

Joseph MA, Moysich KB, Freudenheim JL, Shields PG, Bowman ED, Zhang Y, Marshall JR, Ambrosone CB (2004). Cruciferous vegetables, genetic polymorphisms in glutathione S-transferases M1 and T1, and prostate cancer risk. In: Nutrition and cancer, 50(2): 206–213.

McKeown AW, Bakker CJ (2003). The response of late storage cabbage and broccoli to applications of sulphur and calcium. Canadian journal of plant science 83(4) : 947-950.

Mutaftchiev LK (2001). Determination of free state manganese (II) in decoctions of some medicinal plants by a kinetic spectrophotometric method. Analytical letters 34(8) : 1401-1411.

Mutaftchiev LK (2003). Catalytic spectrophotometric determination of manganese in some medicinal plants and their infusions. Turkish Journal of Chemistry 27(5): 619-626.

Nicoforova V, Freitag J, Kempa S, Adamik M, Hesse H, Hoefgen R (2003). Transcriptome analysis of sulfur depletion in Arabidopsis thaliana: interacting of biosynthetic pathways provides response specificity. Plant J. 33: 633– 650.

Olsen SR (1954). Estimation of Available Phosphorus in Soils by Extraction with Sodium Bicarbonate. United States Department Of Agriculture; Washington.

Schonhof I, Blankenburg D, Mueller S, Krumbein A (2007). Sulfur and nitrogen supply influence growth, product appearance, andglucosinolate concentration of broccoli. J. Plant Nutr. Soil Sci. 170: 1–8.

Slosar M, Cekey N (2008). Hlubova zelenina – vyznamna sucastvyzivy cloveka. In: Zahradnictvi, 12(8):16–17.

Spitz MR, Duphorne CM, Detry MA, Pillow PC, Amos CL, De Andrade LLM, Xiangjun G, Hong WK, Xifeng W (2000). Dietary intake of isothiocyanates: evidence of a joint effect with glutathione S-transferase polymorphisms in lung cancer risk. In: Cancer Epidemi. Biomarkers and Prevention, 9, (10):1017–1020.

Thomson HC, Kelly WC (1985). Vegetable Crops. 5th ed. Mcgrow-Hill Book Co. p. 15.

Walkley A (1947). A critical examination of a rapid method for determination of organic carbon in soils - effect of variations in digestion conditions and of inorganic soil constituents. Soil Sci. 63: 251-257.

Winkler S, Faragher J, Franz P, Imsic M, Jones R (2007). Glucoraphanin and flavonoid levels remain stable during simulated transport and marketing of broccoli (Bassica oleracea L. var. italica) heads. Post harvest Biology and Technology, 43(1): 89-94.

Yoldas F, Ceylan S, Yagmur B, Mordogan N (2008). Effect of nitrogen fertilizer on yield quality and nutrient content in broccoli. J. Plant Nutr. 31: 13-43.