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Full Length Research Paper

Influence of different sowing times on mineral composition and vitamin C of some broccoli (*Brassica oleracea* var. Italica) cultivars

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Broccoli has a significant position in *Cruciferea* family through the vitamin C and mineral nutrients it contains. Vitamin C and mineral content in vegetables vary depending upon different sowing times. In this study, the change of vitamin C and minerals was examined in 3 different sowing times "July the 1st (ST_1), August the 1st (ST_2) and September the 1st (ST_3)" for 4 broccoli cultivars "CV_1 (cv Shogun F_1), CV_2 (cv Pirate F_1), CV_3 (cv Marathon F_1) and CV_4 (cv Sultan F_1)". The vitamin C content ranged in between 52.6 g 100 g $^{-1}$ and 32.4 g 100 g $^{-1}$ for broccoli cultivars grown in different sowing times. CV_3 (cv Marathon F_1) had the highest vitamin C content and the late season (ST_3) had higher vitamin C content than the early seasons (ST_1, ST_2). It was observed that different sowing times for broccoli cultivars did not affect P, Mn, Cu, and Zn contents significantly, however, the heads of the broccoli cultivars had been affected significantly for different sowing times in N, K, Ca, Mg, and Fe. In broccoli heads, N mineral content varied between 4.01 to 2.60% and attained its highest values in sowing times of ST_2 (August) and ST_3 (September). K content in broccoli heads was highest in ST_3 (September) sowing time and varied from 3.96 and 2.21%. Ca content was highest in ST_1 (July) and value varied from 1.58 to 0.80%. The highest Mg content was for ST_3 (September) sowing time and its value altered from 0.18 to 0.46%. Fe content was highest in ST_1 (July) sowing time and its content varied between 100.23 and 96.14 ppm.

Key words: Broccoli, different sowing times, mineral composition, vitamin C.

INTRODUCTION

Epidemiological evidence shows that diets rich in *Brassica* vegetables such as Broccoli (*Brassica oleracea* var. italica) are associated with a lower risk of lung and colorectal cancer. 56% of the case controlled studies demonstrate a strong relationship between increased broccoli consumption and the protection against cancer (Higdon et al., 2007; GliszczyAska-ASwigAo et al., 2006; Verhoeven et al., 1996). Several studies have recently confirmed that *Brassica* vegetables such as Broccoli may offer protection against oxidative damage and prevent chronic diseases owing to their composition (Barillari et al., 2006; Podsedek, 2007). This defensive effect has largely been attributed to phytochemicals present in broccoli that mainly contains the vitamin C (Podsedek, 2007).

As an antioxidant, vitamin C is involved in the protection against harmful free radicals (Davey et al., 2000). Four ounces of raw broccoli contains twice the vitamin C as after in an equivalent amount of reconstituted orange juice about 100 mg (ASC, 1990). Retention of vitamin C is highest in broccoli (Schnepf and Driskell, 1994).

Broccoli is a good source of the macro mineral elements; such as Na, K, Ca, Cl, P, and S and trace elements; such as Fe, Zn, Mn, and Cu that are essential for the human being (Moreno et al., 2006). Mineral concentration in broccoli presents a large variation depending on climate condition (Rosa et al., 2002) and vitamin C likely arises from various factors including seasonal selection (Koh et al., 2009; Wunderlich et al., 2008).

There is insufficient information on the effects of sowing time or date on nutritional content of broccoli. The objective of this study is therefore to determine the influence of different sowing time on the mineral

Table 1. Chemical characteristics of the soil (0 – 20 cm).

Parameter	Result of the analysis	Unit	Assessment
pH	7.350	%	Neutral
Salt	0.043	%	Sufficient
$CaCO_3$	0.290	%	Sufficient
Organic matter	1.150	%	Sufficient
Total N	0.045	%	Insufficient
Available P	11.800	ppm	Sufficient
Available K	121.000	ppm	Sufficient
Available Ca	3351.000	ppm	Sufficient
Available Mg	134.000	ppm	Sufficient
Available Mn	806.000	ppm	Sufficient
Available Cu	0.900	ppm	Sufficient
Available Fe	17.890	ppm	Sufficient
Available Zn	0.980	ppm	Sufficient

composition and vitamin C content for the examined broccoli cultivars.

MATERIALS AND METHODS

The present study was conducted in research facility of Corlu Vocational College, Namik Kemal University, Tekirdag, Turkey (41°11' N, 27°49' E). The cultivars; CV_1 (Shogun F_1); CV_2 (Pirate F_1); CV_3 (Marathon F_1); and CV_4 (Sultan F_1) and three different sowing periods or times as: July the 1st (ST_1), August the 1st (ST_2) and September the 1st (ST_3) were used in the experiment.

Broccoli seedlings were grown in PE bags filled in with peat and those of which the closed dimensions were 15 x 15 cm and a thickness of 0.15 mm; and which are black coloured in order to prevent algae. Bags were provided with drainage holes for irrigation. In the experiment, a factorial design in split plots was used with three replications where cultivars were the main plots. Seedlings were transferred to the field at the 4-5 true leaf stage with 45 x 40 cm distances between the rows and in the rows respectively and with border plant on their sides.

Cultural program followed is as below:

1st Sowing time: July 1st
1st Planting time: August 10th
2nd Sowing time: August 1st
2nd Planting time: September 5th
3rd Sowing time: September 1st
3rd Planting time: October 16th

Irrigation was supplied with a watering can in the seedling stage by furrow irrigation method during the development period. Nitrogen (N) used during growing stage increases the development of shoots by 38 to 61% (Masson et al., 1991). Therefore, 41 kg/da NH_4NO_3 was given during the growing stage (Bracy and Bergeron, 1994). All cultural treatments were neatly executed throughout the research and no herbicide were implemented since no disease or pest was traced.

Preparation of samples for analysis

Broccoli heads were dehydrated in drying oven at 65°C after being washed and cleaned with distilled water and ground dry samples were prepared to be ready for the analysis (Kacar, 1972).

Titrimetric method was used for the estimation of vitamin C; crude protein content were determined following the procedure of Association of Official Analytical Chemists (AOAC, 1990). Modified macro Kjeldahl method was used for of N value; Vanadat-Molibdat phosphoric yellow colour method and Eppendorf colorimeter for determining P value; Eppendorf flame photometer was read for total K and Ca values; and total Mg, Fe, Cu, Zn, and Mn values were determined by reading on Perkin Elmer 2380 atomic absorption spectrophotometer (Kacar, 1972).

Statistical analysis

All data were analyzed statistically with SPSS software program (v.16.0 for Windows OS) and means were after compared by LSD tests.

RESULTS AND DISCUSSION

Chemical characteristics of the experimental soil were given in Table 1 and climatic data for the months when the experiment was conducted are given in Table 2. Total available N content of the soil was low; however, available P, K, Ca, Mg, Mn, Cu, Fe, and Zn values of the soil used were sufficient.

Vitamin C and crude protein content

Vitamin C content was ranged in between 52.6 g 100 g^{-1} and 32.4 g 100 g^{-1} for broccoli cultivars grown in different sowing times. CV_3 (cv Marathon F_1) had the highest vitamin C content and the late season (ST_3) had higher vitamin C value than the early (ST_1, ST_2) seasons (Table 3).

For vitamin C, physiological functions are endorsed to its capacity to offer reducing equivalents for biochemical reactions. Moreover, 35 to 95% of the antioxidant capacity of vegetables that are by rich in vitamin C has

Table 2. Average climate data during the months of investigation*.

Months	Average temperature (°C)	Average insolation (h)	Average number of days with precipitation	Average amount of precipitation (kg m ^{2})
July	23.6	9.8	4.1	24.4
August	23.3	9.0	3.8	16.2
September	19.8	7.6	5.3	33.3
October	15.2	5.2	7.0	56.5
November	10.4	3.3	9.6	77.3
December	6.9	2.5	11.8	76.5

*Data obtained from Turkish state meteorological Service (TSMS).

Table 3. Vitamin C and crude protein content of broccoli cultivars grown in different sowing times.

Cultivars and sowing times	Vitamin C (mg 100 g $^{-1}$)	Crude protein (g 100 g $^{-1}$)
CV_1ST_1	43.1b	3.51a
CV_1ST_2	44.2b	3.43a
CV_1ST_3	47.5b	3.30a
CV_2ST_1	39.3bc	3.33a
CV_2ST_2	36.2bc	2.76b
CV_2ST_3	35.8bc	2.48b
CV_3ST_1	51.6a	3.31a
CV_3ST_2	50.5a	3.42a
CV_3ST_3	52.6a	3.61a
CV_4ST_1	37.2ab	2.82b
CV_4ST_2	35.8bc	2.73b
CV_4ST_3	32.4c	2.61b
LSD	11.08*	0.73*

CV_1: cv Shogun F_1; CV_2: cv Pirate F_1; CV_3: cv Marathon F_1; CV_4: cv Sultan F_1 and ST_1: July the 1st; ST_2: August the 1st; ST_3: September the 1st, * LSD: p<0.001.

been attributed to vitamin C content (Johnston and Hale, 2005).

Being concurrent with this research Sanwal et al. (2006) found that vitamin C amount varies in year change as broccoli grown in different years. GliszczyAska-ASwigAo et al. (2006) suggest that the content of vitamin C in edible parts of broccoli depending on variety varies from 43.2 to 146.4 g 100g $^{-1}$. In the study of Wunderlich et al.(2008) concluded that the vitamin C contents of frozen samples in both spring and fall were almost the same but those in the fall fresh samples were almost twice as high as in spring. Vallejo et al. (2003) had similar findings that vitamin C levels in broccoli were higher in the late than the early season. Among the findings of Singh et al. (2004) amount of vitamin C in broccoli, 44.21 g 100 g $^{-1}$ and it was stated that the variations in vitamin C values reported in their study and other published data might be due to genotypic differences. Similarly, Kurilich et al. (1999) suggests that the differences in vitamin C content in broccoli were associated with genetic factors and ranges from 54.0 to 119.8 g 100g $^{-1}$ and by while according to Koh et al. (2009); the vitamin C in broccoli ranges from 57.35 to 135.35 g 100 g $^{-1}$.

The earlier findings are also concurrent with the present study except for the differences in between the cultivars selected and others considered a seasonal difference for vitamin C in broccoli cultivar selections.

Crude protein value of broccoli cultivars grown in different sowing times was found by varied in between 2.48 and 3.61 g 100 g $^{-1}$. CV_3 (cv Marathon F_1) had the highest crude protein content and the late season (ST_3) had higher protein value than the early (ST_1, ST_2) seasons (Table 3).

Singh et al. (2004) determined that protein content in broccoli was 3.57 g 100 g $^{-1}$ and pointed that genotypic differences were significant on the amount of protein. Nieuwhof (1969) estimated the amount of protein in broccoli as 3.3 g 100 g $^{-1}$ that is concurrent with the findings of this study. Thus, different cultivars and seasonal change may modify the amount of protein in broccoli.

Yield

As a conclusion of the variance analysis realized, main

Table 4. Yield of broccoli cultivars grown in different sowing times (kg ha^{-1}).

Cultivars	Sowing times and Yield (kg ha^{-1})									Cultivar main effect
	ST_1			ST_2			ST_3			
	P	S	Total	P	S	Total	P	S	Total	
CV_1	10287.5	649.3	10936.8	3122.2	462.8	3585.1	1793.5	198.4	1991.9	3669.7
CV_2	8617.9	469.3	9087.3	3270.2	374.2	3644.4	1697.7	197.7	1895.5	3239.3
CV_3	11691.3	535.5	12226.8	2833.3	460.8	3294.2	1515.7	202.6	1718.4	4380.2
CV_4	10292.6	684.8	10977.5	2432.4	564.8	2997.3	1563.7	205.3	1769.1	3498.6
Sowing main effect	10222.2a	584.7a	10807.1a	2414.5b	465.6b	3380.2b	1642.6c	201.0c	1843.7c	3696.9

CV_1: cv Shogun F_1; CV_2: cv Pirate F_1; CV_3: cv Marathon F_1; CV_4: cv Sultan F_1 and ST_1: July the 1st; ST_2: August the 1st ; ST_3: September the 1st and P: primary shoot; S: secondary shoots. LSD: $p<0.001$

Table 5. Mineral composition of broccoli cultivars grown in different sowing times**.**

Cultivars and sowing times	%					ppm			
	N	P	K	Ca	Mg	Mn	Cu	Fe	Zn
CV_1ST_1	2.80bc	0.46	2.21c	1.01a	0.27ab	34.81	5.21	99.98ab	35.67
CV_1ST_2	3.90a	0.50	2.81b	0.92ab	0.19b	32.76	5.19	99.78ab	35.46
CV_1ST_3	2.87bc	0.63	3.96a	0.87b	0.27b	30.61	4.28	99.07ab	35.48
CV_2ST_1	2.60c	0.41	2.61ab	0.93ab	0.18b	31.47	4.01	100.01a	35.54
CV_2ST_2	2.78bc	0.46	2.63ab	0.87b	0.20b	30.71	3.98	99.06ab	35.50
CV_2ST_3	2.63c	0.50	2.97b	0.80b	0.23ab	30.63	3.96	99.04ab	35.41
CV_3ST_1	2.91b	0.47	2.30c	1.58a	0.19b	39.21	5.33	100.23a	35.87
CV_3ST_2	4.01a	0.51	2.71b	1.00a	0.21ab	34.91	5.10	100.18a	35.63
CV_3ST_3	3.03b	0.78	3.93a	0.80b	0.46a	30.12	5.01	99.08ab	35.41
CV_4ST_1	2.61c	0.41	2.72b	1.01a	0.19b	33.23	4.93	96.32c	35.64
CV_4ST_2	2.92b	0.53	2.61ab	0.91ab	0.21ab	30.74	4.71	96.21c	35.32
CV_4ST_3	2.87bc	0.60	3.21a	0.89b	0.29ab	30.11	4.21	96.14c	35.21
LSD	0.67*	ns	0.35*	0.04*	0.05*	ns	ns	15.21*	ns

CV_1: cv Shogun F_1; CV_2: cv Pirate F_1; CV_3: cv Marathon F_1; CV_4: cv Sultan F_1 and ST_1: July the 1st; ST_2: August the 1st; ST_3: September the 1st, Letters indicate significant differences at the $p<0.01$ between cultivars for each mineral, ns: no significant.

sowing effect was found to be significant for yield. The yield varied in between 12226.88 and 1769.1 kg ha^{-1} (Table 4). Vagen et al. (2007) suggested that broccoli yield tended to be minor in the early planting (May) than in the late planting (June / July). Grevsen and Olesen, (1999) pointed a likely reason for that was the lower temperature during the first half of the growing period; as it was in the September sowing time in this study. According to Rosa et al (2002); yield varied from 483 to 1154 kg ha^{-1} and though the differences between varieties, the greatest yield was in SS (Spring – Summer) that also covers ST_1 (July). Musnicki et al. (1999) stated that some environmental and agronomic factors might significantly change the yield. Acikgoz (2010) found that yield affected positively and varied from 3163.8 to 25470.6 kg ha^{-1} in July sowing time within 3 different sowing time practises for 4 different broccoli varieties.

Everaarts (1994) determined that higher the N ratio would increase yield however, it may result in head decay, which would decline its market quality. In this study; CV_3ST_1 in which high yield was reported, had been modest as 2.91% in significance level for N content and was considered to be a concurrent yield with market quality.

Mineral composition

N, P, K, Ca, Mg, Mn, Cu, Fe, and Zn contents in broccoli heads grown in different sowing times is given in Table 5. It was observed that different sowing times in broccoli cultivars did not affect P, Mn, Cu, and Zn content significantly. Yet; broccoli heads were affected significantly for N, K, Ca, Mg, and Fe in different sowing times.

N mineral content in broccoli heads was from 4.01 to 2.60%. Nevertheless, it was observed by its highest levels in ST_2 (August) and ST_3 (September) sowing times (Table 5). Soil N values diminished more rapidly in the late plantings than normally expected from the contemporary N uptake curves. These declines fit at the incidents of heavy rainfall and describe the negative N balances at the highest N rate in the late planting (Vagen et al., 2007). The efficiency of using N in soil depends on environmental circumstances (Gan et al., 2008). Everaarts (1994) suggested late summer or autumn sowing time to prevent excessive nitrogen amount, which may result in head decay, in broccoli growing. Temperature relatively affects the nitrate content of vegetables such as radish and lettuce (Nieuwhof, 1994). Staugaitis et al. (2008) stated that the N amount in soil was higher in summer months than in spring. This was concordant with S_2 (August) finding of the highest N content.

K content in the broccoli heads was seen at its highest in ST_3 (September) sowing time and varied from 3.96 to 2.21% (Table 5). Aires et al. (2007) stated that the K content increased significantly in relation to the N dose. Compared with the general sufficiency limits for other brassicas such as Chinese cabbage 3.3 to 4.6%. Magnusson (2002) and Nieuwhof (1969) reported that broccoli contains 3.1 to 4.2% K that is concordant with the present study. Rosa (2002) stated that the mineral levels in broccoli, excluding K, depended on the season as given by the significant interaction between season and inflorescence.

Ca content was observed at the highest in ST_1 (July) sowing time and its value varied from 1.58 to 0.80% (Table 5). Mg content was at it highest level in ST_3 (September) sowing time and varied from 0.46 to 0.18% (Table 5). Ca and Mg mineral content take place at an important level in broccoli cultures (Farnham et al., 2000; Singh et al., 2010). According to Rosa et al. (2002) broccoli grown under higher temperatures in spring or summer induced higher flow of Ca in the heads. Singh et al. (2010) determined Mg value in broccoli as 0.040 mg g $^{-1}$. Rosa et al. (2002) stated that environmental factors affect Ca and Mg concentration in broccoli. The upward Ca movement within the plant is partially due to transpiration, if high temperatures occur in spring or summer it will result in higher transpiration rates. Therefore, Ca uptake and translocation into the youngest parts of the plant will increase when compared to summer or winter conditions and that confirm with this study for the values of ST_1 (July) sowing time.

Fe content was reported at its highest in ST_1 (July) sowing time as 100.23 ppm and varied from 100.23 to 96.14 ppm (Table 5). Singh et al. (2010) determined 0.310 mg g $^{-1}$; Fe content in broccoli as; however, it was 1.2 mg g^{-1} in the finding of Splittstoesser (1990) and varied from 6.3 to 10.1 mg g^{-1} in the study of Nieuwhof (1969). The findings of the Fe content in this study are lower than the earlier reported data; but they are sufficient according to the necessary amount that should exist. Although Fe is, a micronutrient yet is necessary for plants, if in very small quantities, if not available it may adversely affect quality and reduce fruit and crop production (Rashid and Ryan, 2004). The function of Fe in plant metabolism and growth has been well studied. It plays an important role in the formation of chlorophyll and is used during photosynthesis. The stress of Fe mineral deficiency in plant alters the structure of chloroplast (He et al., 2008). Photosynthesis speed and chlorophyll formation are directly proportional to light density. ST_1 (July) sowing time is a convenient month when photosynthesis speed and chlorophyll formation are considered.

The results of this study demonstrated that the substantial seasonal variation in vitamin C content of different broccoli cultivars was affected significantly by different sowing time growing and determined in between 52.6 g 100 g $^{-1}$ and 32.4 g 100 g $^{-1}$. The highest value of vitamin C was taken from CV_3ST_3 (cv Marathon F_1-September the 1st). Different sowing times for broccoli cultivars did not affect P, Mn, Cu, and Zn contents, however, a significant effect was observed for N, K, Ca, Mg, and Fe.

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