WFL Publisher
Science and Technology
Meri-Rastilantie 3 B, FI-00980
Helsinki, Finland
e-mail: info@world-food.net

Journal of Food, Agriculture & Environment Vol.9 (2): 289-291. 2011 *www.world-food.net*

Seasonal variations in vitamin C and mineral contents and some yield and quality parameters in komatsuna (*Brassica rapa* var. *pervidis*)

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Received 15 January 2011, accepted 9 April 2011.

Abstract
The aim of this study was to determine the changes in yield, growth and quality of komatsuna in successive growing seasons. Experiments were carried out in a PE covered cold greenhouse in late autumn-early winter and late winter-early spring growing period during 2009-2010 in Corlu, Turkey (41°11' N, 27°49' E). Results showed that vitamin C content of plants grown in late winter-early spring and late autumn-early winter growing period were 61.70 and 42.35 mg/100 g, respectively. While N (4.35%), P (0.51%), Cu (8.35 ppm), Fe (886.5 ppm) and Zn (48.15 ppm) values were higher in plants grown in late autumn-early winter in comparison with plants grown in late winter-early spring, K (4.70%), Ca (2.30%), Mg (0.42%), S (0.72%) and Mn (61.85 ppm) values of plants were higher in late winter-early spring growing period. All the quality and yield characteristics investigated in the research were also affected by season. Furthermore yield obtained in late winter-early spring growing season was about 3.79 times higher than those in late autumn-early winter growing season.

Key words: Komatsuna, sowing time, vitamin C, mineral contents, quality.

Introduction

Growth and composition of leafy vegetables varies with season or time of year [15] and some environmental and agronomic factors might significantly change the quality of the product [2]. The seasonal variation is related to changes in light and temperature that affect metabolism in leaves and roots and the rate of chemical transformations and availability of nutrients in the soil. Mineral concentrations in crucifers present large variations depending on climate conditions [18] and vitamin C likely arises from various factors including growing season [11, 23].

However, there seems to be a growing interest in Cruciferous vegetables today, owing to their wide spectrum of health-benefiting substances. It is believed that many crucifers may have been collected for medicinal purposes in northern Europe long before their domestication [12].

Crucifers are rich in dietary antioxidants, i.e. vitamin C [3].There is a considerable amount of evidence linking high fruit and vegetable intake with a reduced risk of cancer [14]. As an antioxidant source, vitamin C is involved in the protection against harmful free radicals [5].

As well as other members of Cruciferae family, komatsuna is rich in nutritional value. It contains great amount of calcium, vitamin B_6, vitamin C and vitamin E, folic acid, carotene, manganese, copper and fiber [16] and is light in calorie.Although some Brassica vegetables, such as cauliflower, kale and cabbage, have great demand for consumption and are widely grown in Turkey, komatsuna is not well known and cultivated as it is in east countries. Komatsuna, together with its dietary benefits and capacity of quick adaptation to relatively low and high temperature, has a good potential for planting throughout the year in Turkey [1].

Due to high energy cost of greenhouse growing, widely demanded vegetables in this region such as tomato, cucumber, eggplant and runner bean are cultivated when climatic conditions are favorable. Thus, in unheated greenhouses in this region, mostly rapid growing vegetables, such as lettuce, cress, rocket, spring onion, pursley and parsley, are cultivated during the cool/cold season, from late autumn to early spring. Komatsuna, on account of its relatively short cultivating period, can be an alternative crop for this period of time in an unheated greenhouse in this region.

The aim of this study was to determine the changes in yield, growth and quality of komatsuna during the cool/cold season, from late autumn to early spring.

Materials and Methods

Experimental design and location: The experiments were carried out during successive crop seasons: late autumn-early winter and late winter-early spring in an unheated, UV consisting, PE greenhouse in Corlu, Turkey (41°11'N, 27°49' E) in 2009-2010. Seeds of cv. Torasan F_1 (Chilternseeds Co.) were sown in November for late autumn-early winter growing period, and in February for late winter-early spring growing period in multicelled trays filled with peat (Klasmann-Deilmann, potground H, Germany).

In each experiment, seedlings were transplanted to greenhouse soil at the 2-3 true leaf stage with 30 cm x 30 cm distances between the rows and in the rows, respectively, and with border plant on their sides. Neither fertilization nor pesticide application of any kind was carried out during the experiment. Pests and disease incidences were not observed and weeding was carried out when needed during the growing period.

Chemical characteristics of the soil used in the experiment are given in Table 1 and climate data during the experiments are given in Table 2.

Data collection and analytical methods: In the end of each growing period the following characteristics were studied: vitamin C (mg/100 g), crude protein (%), mineral content s(%, ppm), plant height (cm), plant width (equatorial line of the plant, cm), individual plant weight (g), number of leaves, plot yield (kg $plot^{-1}$) and yield (kg ha^{-1}). Plant height, plant width, individual plant weight and number of leaves were considered to be average value obtained from all plants at the end of each experiment, plot yield was considered to be total yield gained from each plot. Total yield was measured by plot yield.

In each growing season randomly chosen plants in each plot were used. Collected plants were washed two times with tap water and three times with pure water and dried in a ventilated oven at 65°C. Vitamin C content of plants was estimated with titrimetric method. To investigate crude protein content of plants modified micro Kjeldahl method was used. Mineral contents of the plants were analyzed using methods given in Table 1.

Statistical analysis: Data obtained were subjected to the analysis of variance using SPSS statistical software (v.16.0 for Windows OS) and least significant differences between the means were calculated for 1%.

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

Parameter	Value	Unit	Method
pH	7.26	%	Saturated extract
EC	0.17	%	Saturated extract
$CaCO_3$	1.24	%	Calsimetric
Organic matter	5.62	%	Saturated extract
Total N	0.28	%	Walkley-Black
Available Ca	0.54	%	Olsen-ICP
Available P	167.46	ppm	Kjeldahl
Available K	265.47	ppm	A. Acetate-ICP
Available Mg	713.67	ppm	A. Acetate-ICP
Available Mn	6.98	ppm	A. Acetate-ICP
Available Cu	1.51	ppm	DTPA-ICP
Available Fe	6.03	ppm	DTPA-ICP
Available Zn	5.23	ppm	DTPA-ICP

Table 2. Average climate data of the experimental months*.

Month	Average temperature (°C)	Average insolation (h)	Average number of days with precipitation	Average amount of precipitation (kg m^{-2})
November	10.4	3.3	9.6	77.3
December	6.9	2.5	11.8	76.5
January	5.0	2.8	11.1	62.1
February	5.0	3.6	10.0	49.6
March	7.3	4.3	9.4	54.0
April	11.8	5.9	10.3	43.5

*Data obtained from Turkish State Meteorological Service (TSMS).

Results and Discussion

Vitamin C: Sowing time did not affect vitamin C content significantly. However, it was 61.70 mg/100 g in late winter-early spring growing period and was recorded as 42.35 mg/100 g in late autumn-early winter growing period (Table 3).

Early findings showed that limited light, clouding and low light intensity have reducing effect on vitamin C content of plant tissues[13, 20, 22]. Despite the fact that light is not essential for the ascorbic acid synthesis, the amount and intensity of light during the growing season have a definite influence on the amount of ascorbic acid formed [9]. General agreement is the lower the light intensity, the lower the content of ascorbic acid in tissues[13, 22].

Crude protein: Crude protein of plants grown in late winter-early spring (26.13%) was higher than in late autumn-early winter (30.25%) growing period (Table 3). This result can be related to the N content of plants grown in late autumn-early winter. Rosa and Heaney [17] detected that, without considering the cultivars, crude protein contents of *Brassica* crops were 94.6 g kg^{-1} DM in spring-summer period and 409.7 g kg^{-1} DM in summer-spring period.

Table 3. Vitamin C and protein contents of komatsuna sown in spring and autumn.

Sowing time	Vitamin C (mg/100 g)	Crude protein (%)
Spring	61.70	26.13
Autumn	42.35	30.25

Mineral contents: As N (4.62%), P (0.51%), Cu (8.35 ppm), Fe (886.5 ppm) and Zn (48.15 ppm) contents of plants were higher in late autumn-early winter period, K (4.70%), Ca (2.30%), Mg (0.42%), S (0.72%) and Mn (61.85 ppm) contents were higher in late winter-early spring period (Table 4).

Nutrient contents of plants may be changed by environment [7, 8, 21]. Light affects the concentration of elements in the plant by its effect on the amount of photosynthate produced, thereby altering the ratio of element to dry matter concentration. According to Jones *et al.* [10], the dilution effect due to production of carbohydrates in full light is characterized by reduced concentration for most nutrients. Authors also reported that total N in spinach leaves was reduced as light increased with no N applied. In some cabbage species total nitrogen varies from 1.36 to 4.60%, phosphorus from 0.39 to 0.81% and potassium from 2.18 to 3.77% [19]. Collard greens have more N, P, K and Mg in fall than in spring, and air temperature also affects N uptake by salad greens [8].

Rosa and Heaney [17] found that, in some *Brassica* species, with exception of Ca and Mg, contents of all minerals investigated were higher in fall sowing time than in spring sowing time and mineral contents of plants responded to environmental changes. Caruso *et al.* [4] pointed out that while Cu in plant tissues is accumulated mainly in fall growing period Ca is accumulated in spring growing period.

Yield and quality parameters: The quality and yield characteristics investigated were affected by season and, with exception of plant width, were higher in late winter-early spring than in late autumn-early winter growing period (Table 5). The most drastic difference

Table 4. Mineral contents in komatsuna sown in spring and autumn.

Sowing time	%						ppm			
	N	P	K	Ca	S	Mg	Mn	Cu	Fe	Zn
Spring	4.35	0.49	4.70	2.30	0.72	0.42	61.85	6.95	140.5	36.95
Autumn	4.62	0.51	4.33	2.23	0.58	0.39	41.50	8.35	886.5	48.15

Table 5. Yield and quality parameters of komatsuna sown in spring and autumn.

Sowing time	Plant height (cm)	Plant width (cm)	Individual plant weight (g)	Number of leaves	Plot yield (kg $plot^{-1}$)	Yield (kg ha^{-1})
Spring	37.65	8.56	143.47	11	18.27	15941
Autumn	28.87	9.41	37.86	9	4.16	4206

was in yield, it was 15,941 kg ha^{-1} in late winter-early spring growing period, being 3.79 times higher than 4206 kg ha^{-1} in late autumn-early winter growing period (Table 5).

Although plant height in late winter-early spring growing period was considerably taller than in late winter-early spring growing period, differences between two growing seasons in number of leaves and plant width were slight. In addition, plant width was smaller in plants grown in late winter-early spring growing period. It may be that striking difference in total yield may result from leaf area rather than leaf number and plant width. Furthermore it can be speculated that though plant width was larger in plants grown in late autumn-early winter growing period, loose head formation, thinner stalks and smaller leaves (data not shown) resulted in yield loss. Annual crops such as spinach, kale and mustard greens will be thinner leaved and less robust when grown in light shade rather than in full sunlight [6].

Conclusions

All yield and quality parameters investigated in this research, except plant width, were favorable in late winter-early spring growing period. K, Ca, S, Mg and Mn contents were higher in late winter-early spring, whereas N, P, Cu, Fe and Zn contents were higher in late autumn-early winter growing period. Yield was almost 4 times higher in latter growing period. In addition vitamin C and Ca contents of plants grown in late winter-early spring growing period were considerably higher. Komatsuna, on account of its relatively short cultivating period, easy growing and dietary value can be a good alternative crop for late winter-early spring growing period in an unheated greenhouse in this region.

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