

Seasonal Variations on Quality Parameters of Pak Choi (*Brassica rapa* L. subsp. *chinensis* L.)

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Abstract

The aim of this study is to determine the changes in quality of pak choi 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 in Turkey (41°11' N, 27°49' E). Results showed that morphological features, the leaf area (73.82 mm²), leaf length (31.21 mm), average leaf width (2.70 mm), maximum leaf width (3.92 mm), mass (95.27 g) and moisture content values of leaves (0.90% w.b.) were higher in late autumn-early winter period but leaf thickness (0.33 mm) contents were higher in late winter-early spring period. Yield characteristics investigated were affected by season and were found relatively higher in late autumn-early winter than late winter-early spring growing period. And it was 5713 kg ha⁻¹ in late autumn-early winter growing period and 5034 kg ha⁻¹ in late winter-early spring growing period. In point of the dry matter content investigated were affected by season, and were higher in late autumn-early winter than late winter-early spring growing period. It was 12.4% in late autumn-early winter growing period and 10.25% in late winter-early spring growing period. Account of total protein of plants grown in late autumn-early winter (25.16%) was higher than in late winter-early spring (22.45%) growing period. Sowing time did affect ascorbic acid content significantly. It was 44.21 mg.100⁻¹ g in late autumn-early winter growing period and was recorded as 38.02 mg.100⁻¹ g in late winter-early spring growing period. Color parameters L, a, b values were measured as 27.92; -6.98 and 8.53 in late autumn-early winter and as 21.64; -5.48; 7.49 late winter-early spring. Sowing time did affect color parameters content significantly. Late autumn-early winter growing time result was higher than in late winter-early spring growing time. With regard to mineral content N (4.67%), P (0.65%), Cu (9.32 ppm), Fe (879.6 ppm) and Zn (49.13 ppm) values were higher in plants grown in late autumn-early winter in comparison with plants grown in late winter-early spring as K (4.45%), Ca (2.36%), Mg (0.41%) and Mn (62.25 ppm) values of plants were higher in late winter-early spring growing period. Results of the study indicated that different weather conditions influenced the pak choi yield and the chemical composition of the leaf as well. Pak choi with its relatively short cultivating period, easy growing, and dietary value can be a good alternative crop for late autumn-early winter growing period in cold greenhouses.

Keywords: Pak Choi (*Brassica rapa* L. subsp. *chinensis* L.); Morphological features; Ascorbic acid; Total protein; Color parameters; Yield; Mineral contents

Introduction

As a highly rated leafy variety of vegetables and a marvelous food alternative, brassicas is grown for its enlarged, edible, terminal buds; and is preferably eaten almost everywhere in the world as well [1]. This green vegetable was made known around the world by the efforts of the travelers and immigrants [2-4]. Pak Choi: syn. *Brassica Chinensis* L. (1759), *Brassica Campestris* L. subsp. *Chinensis* (L.) Makino [5], *Brassica rapa* L. subsp. *Chinensis* (L.) Hanelt [6] evolved in China, and its cultivation was recorded since the 5th century AD. It is widely grown in southern and central China, and also Taiwan. This group is a relatively new comer vegetable in Japan where it is still referred to as 'Chinese vegetable' [7]. As a leafy vegetable, Chinese cabbage presents short storing life and therefore it should be produced near the markets. This species can be possibly cultivated in climatic zone of Central Europe from spring to winter because of not having high thermal needs and possessing a rather short vegetation period. Leaves of the crop can be consumed from a stage of transplant, but it is recommended to harvest rosettes after 50 to 60 days from sowing or 30 to 40 days from transplanting [8]. The crisp leaves and thick petioles of bitter taste are excellent for cooking as a boiled vegetable [9]. Food nutrition is becoming one of the most important features in the choice of products in modern conditions. *Brassica* vegetables are characterized by high water content, low caloric value, containing high quality of protein, carbohydrates, fibre, vitamins, minerals, and also secondary plant metabolites. In humans, the last given issues have anti-carcinogenic,

antioxidant, antibacterial and antiviral effects, and they encourage the immune system and reduce inflammation. Nevertheless, *Brassicac*s prevent the development of cardiovascular diseases and illnesses associated with ageing as well [10,11]. The objectives of this study have focused on the evaluation of nutritive aspects by determining the changes in quality of *Brassica rapa* L. subsp. *Chinensis* L. in successive growing seasons.

Materials and Methods

Using high tunnel cold greenhouse covered by polyetilen (PE) with UV additive which belongs to Namik Kemal University, Vocational College of Technical Sciences, Plant and Animal Production Department, the experiments were carried out during successive crop seasons: late autumn-early winter and late winter-early spring in Tekirdag city (40°98' N, 27°48' E) Turkey. Research was designed as 3 replications according to randomized block experimental design.

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The 1340C variety of Pak Choi (Chilternseeds Firm) was used for the research (Figure 1). Seeds were sown in multi-celled trays filled with peat (Klasmann-Deilmann, Potground H, Germany) in October. Some specifications of the used peat are: 160-260 mg/L N, 180-280 mg/L P₂O₅, 200-150 mg/L K₂O, 80-150 mg/L Mg, pH: 6, 0.8% N, 70% organic matter, and 35% C. When the seedlings became 2 to 3 true leaves (21 days for pak choi after seed sowing) they were planted to pre-prepared places in high tunnel cold greenhouse with 10 × 10 cm intervals and 10 plants in each parcel. Some chemical contents of the soil used in the experimental field can be seen in Table 1. The climate data measured inside the tunnel during the growing of the plants can be seen in Table 2. Plants were harvested 40 days after seed sowing. Since there were no diseases and pests, no pesticides was used during the growing period.

Morphological features

The LI-COR brand LI-3000C model's portable area measurement device was used to measure of the leaf length, width and surface area of Pak Choi plants. A mechanical type micrometer, which has measurement range between 0-25 mm, was used in order to determine leaf thickness, and the digital sliding caliper, which has 0.01 accuracy, was used in order to define stalk thickness. The AND GF-610 brand precision balance with 0.001 accuracy was used for measuring the mass of plants. The measurements were performed using 10 plants with 3 replications by randomly choosing the leaves of the experiment from these plants.

Dry matter

The dry matter content in leaves was determined by drying the sample at 68°C up until constant weight is obtained [12].

Yield

The marketable yield was determined. Harvest was performed only once in particular growing periods, specifying the mass of leaves. The leaves which were fully developed and without damages were treated as they are marketable [13].

Determination of color parameters

Color measurements were performed using Hunter Lab D25LT Color Measurement device, which has big measurement range, and especially which is suitable for color measurements of non-homogeneous materials. The color parameters that are brightness (L) and color coordinates of 'a' and 'b'. L value changes between 0 and 100.0 shows black color and 100 shows white color. Color coordinates of 'a' and 'b' don't have any specific measurement interval and they

Soil Properties	Results
pH	8.01
Salinity (%)	0.07
CaCO ₃ (%)	2.74
Organic matter (%)	1.35
Ca (%)	0.54
P (ppm)	36.40
K (ppm)	253.80
Mg (ppm)	473.10
Mn (ppm)	5.68
Cu (ppm)	0.81
Fe (ppm)	7.43
Zn (ppm)	0.97

Table 1: Some Chemical Properties of Soil of Growing Soil.

Month	Average temperature (°C)	Maximum temperature (°C)	Minimum temperature (°C)	Average humidity (%)
October	16.01	19.02	13.05	89
November	12.4	14.8	10.0	87
December	9.4	12.5	6.4	88
January	7.1	10.1	4.1	89
February	7.6	10.9	4.3	87
March	9.5	13.0	6.1	90
April	14	17.8	10.2	84

Table 2: Average climate data in unheated greenhouse during the months of the experiment.

can have positive and negative values. The 'a' value represents red-green axis, where positive values are for red color, negative values are for green color, and 0 is neutral. If color coordinate of 'b' is positive it shows yellow color and the negative values show the blue color [14]. The measurements were made using 10 plants and 3 replications were performed on the every plant by randomly choosing the leaves. The 3 replication measurements on the randomly chosen leaves from the same plant were made by 3 replications.

Ascorbic acid

Ascorbic acid was determined in direct plant extracts with 2, 6-dichloroindophenol by visual titration.

Total protein

The content of total proteins was estimated in dry material by the Kjeldahl method [15].

Mineral contents

Leaf samples were analyzed by ICP optical emission spectrometry (ICP-OES) total nitrogen, phosphorus, potassium, calcium, magnesium and some trace elements Fe, Cu, Zn, and Mn in each plant leaf sample [15].

Statistical analysis

All data were analyzed statistically with SPSS software program (v.16.0 for Windows OS) and the differences between practices were compared by using least significant difference (LSD) test at (p<0.05) probability [16].

Results and Discussion

Morphological features

The leaf area (73.82 mm²), leaf length (31.21 mm), average leaf width (2.70 mm), maximum leaf width (3.92 mm), mass (95.27 g)

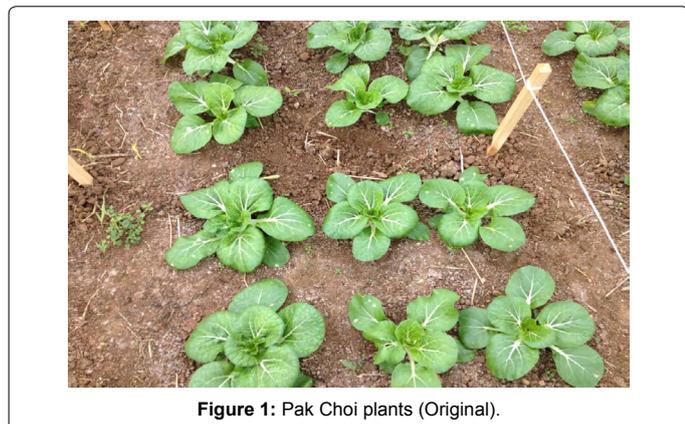


Figure 1: Pak Choi plants (Original).

and moisture content values of leaves (0.90% w.b.) were higher in late autumn-early winter period but leaf thickness (0.33 mm) contents were higher in late winter-early spring period (Table 3). According to (Maynard et al. and Barillari et al.) and Cengel et al. [17-19] growth and composition of leafy vegetables varies with season or time of year and some environmental and agronomic factors might significantly change the quality of the product. According to (Siomos and Kalisz et al.) and (Kalisz and Kalisz et al.) [20-23] effect of different sowing dates on transplant characteristics were found both for non-heading Chinese cabbage and for heading group of Chinese cabbage.

Yield

Yield characteristics investigated were affected by season and were found relatively higher in late autumn-early winter than late winter-early spring growing period. It was 5713 kg ha⁻¹ in late autumn-early winter growing period and 5034 kg ha⁻¹ in late winter-early spring growing period (Table 4).

In this experiment, pak choi responded positively to plantings in late autumn-early winter. Plants were grown in lower temperatures and less intensive sunlight therefore they resulted in higher yields. A significant effect of growing period on the yield and quality were stated for many *Brassicaceae* species: leafy cultivars of *Brassica rapa* [24]; broccoli [25]; Acikgoz, [26]; red cabbage [27]; cauliflower [28]; Brussels sprouts [29] and *Brassica rapa* var. *narinosa* [30].

Dry matter

The dry matter content investigated were affected by season, and were higher in late autumn-early winter than late winter-early spring growing period. It was 12.4% in late autumn-early winter growing period and 10.25% in late winter-early spring growing period. The dry matter content changed significantly amongst *Brassica rapa* cultivars [31]. Hara and Sonoda, [32] found that grown cabbage had lower dry matter content at higher temperatures.

Physical properties	Growing Date			LSD _{0.05}
	Late autumn-early winter	Late winter-early spring	Mean	
Leaf area (mm ²)	73.82a	71.62b	72.72	2.15
Leaf length (mm)	31.21a	29.11b	30.16	2.98
Average leaf width (mm)	2.70a	1.90b	2.33	0.37
Maximum leaf width (mm)	3.92a	2.91b	3.41	0.51
Leaf thickness (mm)	0.33b	0.34a	0.33	0.02
Mass (g)	95.27a	90.36b	92.81	10.1
Moisture content values leaf (% w.b.)	0.90a	0.90a	0.90	0.06

Table 3: Some Morphological Properties of Plants.

	Growing Date			LSD _{0.05}
	Late autumn-early winter	Late winter-early spring	Mean	
Yield (kg ha ⁻¹)	5713a	5034b	5373.5	54.09
Dry matter %	12.4a	10.25b	11.32	6.02
Protein %	25.16a	22.45b	23.80	1.98
Ascorbic acid mg.100 ⁻¹ g	44.21a	38.02b	41.11	2.71
a	-6.98b	-5.48a	-6.23	4.21
b	8.53a	7.49b	8.01	5.71
L	27.92a	21.64b	24.78	2.07
YI	42.54a	39.95b	41.24	2.76

Table 4: Influence of sowing time on the yielding, content of nutritive and color parameters of plants.

Total protein

Total protein of plants grown in late autumn-early winter (25.16%) was higher than in late winter-early spring (22.45%) growing period (Table 4). This result can be related to the N content of plants grown in late autumn-early winter. Rosa and Heaney, [33] detected that, without considering the cultivars, total 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.

Ascorbic acid

Sowing time did affect ascorbic acid content significantly. It was 44.21 mg.100⁻¹ g in late autumn-early winter growing period and was recorded as 38.02 mg.100⁻¹ g in late winter-early spring growing period (Table 4). Early findings showed that limited light, clouding and low light intensity have reducing effects on ascorbic acid content of the plant tissues (Lee and Kader and Shinihara and Suzuki) (Weston, Barth and Tamura) [34-37]. Despite this 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 [38].

Color parameters

The measured whiteness or brightness/darkness value (L), the value for greenness (-a), the value for yellowness (b) and the yellowness index (YI) values for leaves of Pak Choi plant were given in Table 4. When the results of 3 replications measurement were analyzed, it was determined that the differences between L, a, b and yellowness index were significant (p<0.05). L, a, b values were measured as 27.92; -6.98 and 8.53 in late autumn-early winter and as 21.64; -5.48; 7.49 late winter-early spring. Sowing time did affect color parameters content significantly. Late autumn-early winter growing time result was higher than in late winter-early spring growing time. According to Fallovo et al. [39], a value (greenness) of leafy lettuce increased owing to lower N levels in the leaves, and it is consistent with this study. Similarly according to Ali et al. the 'b' value resulted in a higher level in non-shaded conditions, and showed deeper color with lower lightness.

Mineral contents

The N (4.67%), P (0.65%), Cu (9.32 ppm), Fe (879.6 ppm) and Zn (49.13 ppm) contents of plants were higher in late autumn-early winter period, and the K (4.45%), Ca (2.36%), Mg (0.41%) and Mn (62.25 ppm) contents were higher in late winter-early spring period (Table 5). Nutrient contents of plants may be changed by environment [40-42]. Light affects the concentration of the elements in the plant by its effect on the amount of photosynthate produced, and alters the ratio of element to dry matter concentration. According to Jones et al. [43] the dilution effect due to production of carbohydrates in full light is rather characterized by reduced concentration for most nutrients, they 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% [44]. Kale have more N, P, K and Mg in fall than in spring, and air temperature also affects N uptaken by salad greens [41]. Rosa and Heaney [45] found that, in some *Brassica* species, with exception of Ca and Mg, the 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. [46] states that while Cu accumulated in plant tissues mainly in fall on the other hand Ca accumulated in spring growing period.

	Growing Date			LSD _{0.05}
	Late autumn-early winter	Late winter-early spring	Mean	
N (%)	4.67a	4.59b	4.63	1.34
P (%)	0.65a	0.57b	0.61	0.41
K (%)	4.39b	4.45a	4.42	1.23
Ca (%)	2.27b	2.36a	2.31	0.45
Mg (%)	0.38b	0.41a	0.39	0.25
Mn (ppm)	42.13b	62.25a	31.19	2.01
Cu (ppm)	9.32a	7.01b	8.16	0.85
Fe (ppm)	879.6a	139.2b	509.4	12.21
Zn (ppm)	49.13a	37.98b	43.55	2.23

Table 5: Influence of sowing time Mineral contents of plants.

Conclusions

In this study, some morphological properties of plants except leaf thickness were found to be favorable in late autumn-early winter growing period. And content of nutritive elements and color parameters of plants except a (greenness) were rather favorable in late autumn-early winter growing period. In terms of the mineral contents as K, Ca, Mg, and Mn higher results held in late winter-early spring, whereas N, P, Cu, Fe and Zn contents were higher in late autumn-early winter growing period. Pak choi with its relatively short cultivating period, easy growing, and dietary value can be a good alternative crop for late autumn-early winter growing period in cold greenhouses.

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