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YIELD AND NUTRITIONAL VALUE OF JAPANESE BUNCHING ONION (*ALLIUM FISTULOSUM* L.) DEPENDING ON THE GROWING SEASON AND PLANT MATURATION STAGE*

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Abstract

Japanese bunching onion remains a less common crop in Poland, where it is mostly grown in home gardens as a perennial plant species and used as cut foliage in early spring. Recently, some pseudostem type cultivars producing few tillers have been developed, which can be grown for the use of whole plants in early growth stages or for blanched pseudostems like leek species. This study, comprising two field trials, has been undertaken to evaluate the yield, its quality and nutritional value of cv. Performer Japanese bunching onion as affected by the growing season and age of plants. Seed propagated transplants were grown for a similar period of time from 5 Apr to 8 Jun, 6 May-8 Jul, 7 Jun-10 Aug, 8 Jul-10 Sep, 5 Aug-11 Oct or harvested 60, 75, 90, 105, 120, 135 and 150 days after planting. Plants grown for 135 and 150 days were blanched by mounding soil around the lower leaf bases.

The results of the study indicated that plants of the same age harvested in monthly intervals since early June to September produced similar yields, while those in October gave lower yields, with a gradual decrease of dry matter, carotenoids, sugars, volatile oils and nitrates (V). The delay of harvest date from 60 to 120 days after planting resulted in a substantial yield increment with a simultaneous depletion of vitamin C, carotenoids, chlorophyll a+b, sugars, volatile oils, nitrates, total N, K and Ca content. Blanched plants were characterized by a considerably longer white portion of the pseudostem, lower content of chlorophyll a+b, and carotenoids, and higher amounts of vitamin C.

Key words: growing period, harvest date, yield, plant composition.

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PLON I WARTOŚĆ ODŻYWCZA CEBULI SIEDMIOLATKI W ZALEŻNOŚCI OD TERMINU UPRAWY I STOPNIA DOJRZAŁOŚCI ROŚLIN

Abstrakt

Cebula siedmiolatka jest w Polsce warzywem o małym znaczeniu gospodarczym, uprawianym jedynie amatorsko jako roślina wieloletnia, której częścią użytkową jest szczypior zbierany na wiosnę. Uzyskane w ostatnich latach odmiany tej rośliny tworzące małą liczbę odrostów mogą być uprawiane na zbiór pęczkowy całych roślin lub bardziej zaawansowane we wzroście, po wybieleniu łodygi rzekomej, podobnie jak por. Celem badań obejmujących dwa doświadczenia polowe była ocena plonowania oraz wartości biologicznej cebuli siedmiolatki odmiany Performer w zależności od okresu uprawy i terminu zbioru. Rośliny uprawiano przez taki sam okres w następujących terminach: 5 IV - 8 VI, 6 V - 8 VII, 7 VI - 10 VIII, 8 VII - 10 IX i 5 VIII - 11 X, lub zbierano odpowiednio po 60, 75, 90, 105, 120, 135 i 150 dniach po posadzeniu rozsady. Rośliny uprawiane przez okres 135 i 150 dni były bielone przez podsypanie ziemią dolnej części łodygi rzekomej.

Wyniki badań dowiodły, że rośliny w takiej samej fazie wzrostu zbierane w miesięcznych odstępach od początku czerwca do września plonowały na zbliżonym poziomie, w październiku zaś na niższym. W tym okresie następował systematyczny spadek zawartości suchej masy, karotenoidów, cukrów, olejków lotnych i azotanów. Opóźnienie terminu zbioru z 60 do 120 dni od posadzenia roślin przyczyniło się do znacznego wzrostu plonu a jednocześnie spadku zawartości witaminy C, karotenoidów, chlorofilu a+b, cukrów, olejków lotnych, azotanów (V), N ogólnego, K i Ca. Rośliny charakteryzujące się większym udziałem części wybielonej zawierały mniej chlorofilu a+b oraz karetonoidów, więcej zaś witaminy C.

Słowa kluczowe: termin uprawy, data zbioru, plon, skład chemiczny.

INTRODUCTION

Genus *Allium* includes about 780 plant species, of which onion, Japanese bunching onion, leek and garlic are the most important edible onion plants. Onion, the principal *Allium* representative, ranks second after tomato in the scale of production among cultivated vegetable crops worldwide and is grown in most regions of the world (Rabinowitch, Currah 2002). Regional preferences shape the popularity of other *Allium* crops, e.g. leek is popular in Western Europe and Japanese bunching onion (syn. Welsh onion) is common in China, Japan, Korea and Taiwan (Wang et al. 2005). The latter is still a less popular crop in Poland, mostly grown as a perennial plant in home gardens to use as cut foliage in early spring (Kotlińska, Kojima 2000, Tendaj, Mysiak 2007a).

The advantages of Japanese bunching onion are its high resistance to low temperatures, little soil requirements (Kotlińska, Kojima 2000, Yamasaki et al. 2003, Su et al. 2007), high nutritive value and unique flavour (He et al. 1989, Lazić et al. 2002, Štainer et al. 2006, Tendaj, Mysiak 2007b). According to Kotlińska and Kojima (2000) and Higashio et al. (2007), Japanese bunching onion is particularly abundant in vitamin C, but also contains other valuable compounds such as carotenoids, macro- and micronutrients, especially Ca and K, as well as flavonoids, which are potent antioxidants (AOYAMA, YAMAMOTO 2007, MYSIAK, TENDAJ 2006, 2008). Normally, leaf blades contain more vitamin C, carotenoids, vitamins B_1, B_2, niacin and minerals than the pseudostem (WARADE, SHINDE 1998). The specific odour of the crop is attributed to volatile allyl sulphides.

In Eastern Asia, where bunching onion receives considerable attention, many cultivars are available for different latitudes and climatic conditions (RUBATZKY, YAMAGUCHI 1997). In Poland, a local population called Siedmiolatka is widely grown in home gardens (TENDAJ, MYSIAK 2011). Lately however, two new cultivars called Kroll and Wita have been developed. They are both resistant to bolting, produce numerous tillers and abundant foliage, thus they are suitable for harvest of green tops (Polish National List of Vegetable Plant Varieties 2010). Bejo Zaden, a Dutch seed company, has recently developed some pseudostem type cultivars producing few tillers, which can be grown for the use of whole plants in early stages of the growth or – like leek species – for blanched pseudostems, usually harvested in September (KOTLIŃSKA, KOJIMA 2000, KOTLIŃSKA et al. 2005). The cultivars Parade and Performer belong to this type of cultivars and, having a short growing period, they may be considered as an alternative green bunching onion to bulb onion normally used for this purpose (GREVSEN 1989). The advantage of *Allium fistulosum* L. is its resistance to many diseases and pests of bulb onion, including pink root (MARTINEZ 2005).

The common practice is to use seed propagated transplants in order to shorten a long growth period and to enhance the blanched part of the pseudostem. Plants with green leaves can be harvested 2-3 month after transplanting, but it may take 6 to 9 months before plants are ready to harvest for blanched pseudostems (RUBATZKY, YAMAGUCHI 1997). Under favourable weather conditions, Japanese bunching onion may be grown all year round for green tops (INDEN, ASAHIRA 1990).

The aim of this study has been to evaluate the volume and biological value of the yield of Japanese bunching onion cultivated and harvested on different dates during a growing season.

MATERIAL AND METHODS

The study comprising two field experiments was conducted in 2009-2010 on sandy clay soil with pH 7.1 and organic matter content 1.8%. In experiment I, the effects of different dates of growing the plants on field on yield, its market quality and nutritional value of the crop were evaluated (5 Apr to 08 Jun, 6 May-8 Jul, 7 Jun-10 Aug, 8 Jul-10 Sep, 5 Aug-11 Okt). In experiment II, seedlings in all treatments were planted on 3-4 of April, while harvest for bunches started 60 days after transplanting and continued in

15-day intervals until 150 days after planting. Both trials were established in a single factor design, with four replications and the plot area of 6 m^2 (1.5 x 4.0 m).

Seeds of the cultivar Performer Japanese bunching onion were sown in multicell trays filled with standard peat moss substrate. 3-4 seeds were put into each cell containing 54 cm^3 of the medium. After emergence, the number of seedlings was reduced to two. Seedlings for experiment II and for the first two plantings in experiment I were produced in a greenhouse and hardened in a non-heated foil tunnel for the last ten days, while seedlings for the later plantings were raised in a high plastic tunnel. Well-developed seedlings with 2-3 true leaves were transplanted into a field at 30x15 cm spacing, which provided the population of 44 plants per 1 m^2.

Available forms of phosphorus and potassium were elevated to 80 mg P and 200 mg K per 1 dm^3 of soil by early spring fertilization with triple superphosphate and potassium chloride. Nitrogen in the form of ammonium nitrate had been supplied in a preplant dose of 150 kg ha^{-1} shortly before seedlings were transplanted, and mixed with the soil by harrowing. Crop management included hand weeding of plots and irrigation of plants in a rainfall deficiency period. In treatments harvested after 135 and 150 days from the planting date, pseudostems of plants were blanched by mounding soil around the lower leaf bases to a height of about 20 cm. The treatment was conducted twice: six and three weeks before the harvest date.

Single harvest on an appropriate date for each treatment was conducted manually. Whole plants with removed roots and yellowing leaves and pseudostems of the diameter >10 mm were considered marketable yield of Japanese bunching onion. The leaves of blanched plants were trimmed to 2/3 of total length. A sample of 10 plants from each plot was collected for evaluation of such morphological traits as the mean weight and total length of plant, total length of the pseudostem and its blanched portion, number of leaves and bulb diameter.

The following were determined in samples of whole plants taken separately from 3 replications: the content of dry matter (by drying at 105°C to the constant weight), vitamin C (Tillman's method), total and reducing sugars (Loof-Shoorl method), chlorophyll a+b (spectrophotometric method), carotenoids (colorimetric method), sum of volatile oils (Farmakopea Polska VI 2002), total N (Kjeldahl´s method), nitrates (V) expressed by the amount of NO_3 – N in f.w. (ion selective electrode, Orions method), P and Mg (colorimetrically), Ca and K (photometric method).

The results of the field experiment and chemical analysis were evaluated statistically using analysis of variance for a single-factor design and the least significant differences were calculated by Tukey's test at α=0.05.

RESULTS AND DISCUSSION

The relationships between the examined factors, yield and nutritive value of the crop were similar in both years, hence the data are shown as means for 2010-2011. The results suggest high suitability of the tested cultivar Performer for production of whole plants for bunches owing to its rapid growth, long pseudostem and low tendency to tillering. Similar, favourable features of this cultivar were also noted in a study conducted by TENDAJ and MYSIAK (2011).

In experiment I, where the plants were harvested in approximately one-month intervals since 8 June to 10 September, usually 63-64 days after transplanting, they produced the marketable yield in the range of 13.20-16.14 t ha^{-1} with an average weight of a plant equal 48.08-50.89 g (Table 1). Such yield is generally considered satisfactory when plants are harvested within 2.5 and 3 months after planting (GRUBBEN 1994). A significant decrease in the crop yield to 8.72 t ha^{-1} and in the mean plant weight to 33.32 g occurred only in the treatment where seedlings were planted on 5 August and harvested on 11 October. This was due to the unfavourable weather conditions, and especially a high drop in the daily air temperature.

Table 1

The effects of growing term on yield and morphological characteristics of plants at harvest time (mean for 2010-2011)

Growing term	Marketable yield (t ha^{-1})	Mean weight of plant (g)	Height of plant (cm)	Number of leaves per plant	Legth of pseudostem (cm)	Legth of blanched pseudostem (cm)	Bulb diameter (mm)
5 Apr-8 Jun	16.14	48.08	50.2	5.4	13.3	4.5	17.3
6 May-8 Jul	13.96	50.89	48.4	5.4	12.3	3.5	17.2
7 Jun-10 Aug	14.18	48.56	53.7	5.7	12.9	3.3	14.5
9 Jul-10 Sep	13.20	49.40	53.4	4.9	14.1	3.8	13.9
5 Aug-11 Oct	8.72	33.32	46.1	4.1	12.2	4.0	13.9
Mean	13.24	46.05	50.4	5.1	13.0	3.8	15.4
LSD α = 0.05	3.14	5.86	2.1	0.3	0.6	0.4	1.2

Generally, plants harvested from early June until September were not differentiated in the total height, number of leaves or length of the pseudostem, while the plants collected in October demonstrated significant growth reduction expressed in all the above measures. The bulb diameter of plants from the first two growing terms was significantly higher than from the later terms.

By postponing the growing period from 5 Apr-8 Jun to 5 Aug-11 Oct, a decrease of dry matter, carotenoids, total and reducing sugars, volatile oils and nitrates content was induced (Tables 2, 3). Plants harvested in early June contained 3929 mg NO_3-N kg^{-1} f.w. A substantial decrement in the nitrate content, down to 3378 mg kg^{-1} f.w., was found in Japanese bunching onion harvested in July. Further delay of the plant cultivation period was ineffective in accumulating NO_3-N, which varied from 3001 to 3120 mg kg^{-1} f.w. Cultivation of plants in the summer months, from 7 June to 10 August, appeared to be beneficial for the content of chlorophyll, total nitrogen, potassium and calcium.

The content of vitamin C was rather stable and not influenced by the cultivation term. The only exception was a high increment of this compound in plants harvested in October. Similar, positive effects of the autumn growing season on vitamin C was observed in Swiss chard (KOŁOTA et al. 2010).

Table 2

Content of dry matter and selected organic compounds in Japanese bunching onion in relation to the growing term (mean for 2010-2011)

Growing term	Dry matter (%)	Vitamin C (mg %)	Carotenoids (mg 100 g^{-1} f.w.)	Chlorophyl a+b (mg 100 g^{-1} f.w.)	Total sugars (%)	Reducing sugars (%)	Volatile oils (mg 100 g^{-1} f.w.)
5 Apr-8 Jun	10.87	27.80	192.28	85.98	5.45	5.13	0.76
6 May-8 Jul	10.90	28.42	185.37	90.08	4.88	4.39	0.68
7 Jun-10 Aug	9.85	28.69	184.52	94.00	4.52	3.91	0.58
9 Jul-10 Sep	9.79	26.33	177.47	84.15	4.24	3.84	0.55
5 Aug-11 Oct	9.75	36.27	122.57	75.05	3.52	3.04	0.58
Mean	10.23	29.50	172.44	85.35	4.52	4.06	0.63
LSD $\alpha = 0.05$	0.57	3.48	14.37	10.43	0.66	0.64	-

Table 3

Content of macronutrients in Japanese bunching onion in relation to the growing term (mean for 2010-2011)

Growing term	NO_3–N (mg kg^{-1} f.w.)	Total N (%)	P (%)	K (%)	Mg (%)	Ca (%)
5 Apr-8 Jun	3929	1.87	0.24	2.63	0.15	0.97
6 May-8 Jul	3378	2.32	0.22	2.51	0.13	0.85
7 Jun-10 Aug	3120	2.68	0.23	2.92	0.16	1.16
9 Jul-10 Sep	3001	1.75	0.25	2.47	0.17	1.01
5 Aug-11 Oct	3053	1.92	0.22	2.12	0.15	0.77
Mean	3296	2.31	0.23	2.53	0.15	0.95
LSD $\alpha = 0.05$	3381	0.35	n.s.	0.25	0.08	0.12

This phenomenon can be probably explained by an earlier stage of plant maturation during harvest conducted in October. This explanation is somewhat supported by our previous studies on leek, kohlrabi and zucchini (BIESIADA et al. 2007), where plants harvested earlier or smaller fruits were a richer source of vitamin C than plants or fruits more advanced in maturation.

The data from experiment II indicate a high and significant increment of crop yield associated with a later harvest date, postponed from 60 to 120 days after transplanting (Table 4). Within this period of time, the marketable yield of Japanese bunching onion increased more than 4.5-fold and the mean weight of plant rose from 42.75 g to 196.25 g, with significant enhancement of the plant height, number of leaves, length of the pseudostem and bulb diameter. The size of plants obtained in the study satisfies the requirements described by WONNEBERGER et al. (2004), such as 40-50 g for

Table 4

Yield and morphological traits of Japanese bunching onion at harvest time in relation to the stage of maturity (mean for 2010-2011)

Term of harvest (days after planting)	Marketable yield (t ha^{-1})	Mean weight of plant (g)	Height of plant (cm)	Number of leaves per plant	Legth of pseudostem (cm)	Legth of blanched pseudostem (cm)	Bulb diameter (mm)
60	14.25	42.75	48.5	5.2	12.9	4.2	16.4
75	19.70	67.93	52.8	5.5	15.5	4.5	19.4
90	33.47	116.82	55.1	6.1	17.3	4.7	21.5
105	45.83	174.15	64.6	7.1	20.9	5.1	25.4
120	64.38	196.25	67.7	8.5	22.2	5.2	26.4
135	65.71	211.35	72.1	8.6	22.2	10.0	25.1
150	69.62	195.07	69.1	7.7	24.4	11.0	24.9
LSD α= 0.05	6.63	18.53	3.6	0.7	2.7	0.9	1.2

early harvested bunching onions and at least 150 g or for those obtained from prolonged cultivation. Plants harvested after 130 and 150 days after transplanting were blanched for 6 weeks by mounding soil around plants and tops of leaves were cut off at harvest. As a result, the length of the pseudostem's white portion increased from the maximum of 5.2 cm in plants harvested after 120 days of growing up to 10.0 cm and 11.0 cm, respectively. The yield and mean weight of plant Japanese bunching onion did not change significantly in comparison to the plants harvested 120 days after transplanting. The length of the blanched portion of the pseudostem is an important market quality parameter and according to RUBATZKY and YAMAGUCHI (1997) should reach from a quarter to a third of the total length. This requirement was fulfilled by plants whose leaved had been trimmed by 1/3.

The chemical analysis of edible parts showed that the content of most of the investigated compounds, e.g. vitamin C, carotenoids, total and reducing sugars, volatile oils, total nitrogen, potassium and calcium, in early harvested plants was higher then in those obtained during harvest delayed up to 120 days after transplanting (Tables 5, 6). Japanese bunching onion grown for 60 days contained the highest amount of chlorophyll a+b. High accumulation of nitrates, exceeding 4000 mg, found in plants harvested 60 and 75 days after transplanting was substantially reduced in plants harvested later. In treatments harvested after 105 and 120 days as well as in plants with blanched pseudostems, the accumulation of nitrates oscillated within 2527-2771 mg kg^{-1} f.w., and the differences were not significant. A similar relationship between the age of harvested plants and NO_3–N content was found in kohlrabi and leek (BIESIADA et al. 2007). Considering the data obtained from both field trials, we could not confirm the claim expressed by ZHU et

Table 5

Content of dry matter and selected organic compounds in Japanese bunching onion in relation to the stage of maturity (mean for 2010-2011)

Term of harvest (days after planting)	Dry matter (%)	Vitamin C (mg%)	Carotenoids (mg 100 g^{-1} f.w.)	Chlorophyll a+b (mg 100 g^{-1} f.w.)	Total sugars (%)	Reducing sugars (%)	Volatile oils (mg 100 g^{-1} f.w.)
60	10.88	20.95	177.99	98.43	5.31	4.97	0.79
75	11.65	22.93	137.63	80.01	5.31	4.64	0.67
90	10.45	15.15	116.56	79.11	5.09	4.64	0.55
105	10.25	17.15	115.91	83.88	4.96	4.24	0.49
120	10.60	16.58	117.85	85.89	5.20	4.69	0.50
135	11.58	24.96	109.57	45.69	5.38	5.05	0.62
150	10.62	31.95	111.94	48.02	5.45	4.95	0.68
LSD α= 0.05	n.s	3.66	19.04	10.11	0.25	0.23	-

Table 6

Content of macronutrients in Japanese bunching onion in relation to the stage of maturity (mean for 2010-2011)

Term of harvest (in days after planting)	NO_3–N (mg kg^{-1} f.w.)	Total N (%)	P (%)	K (%)	Mg (%)	Ca (%)
60	4173	2.42	0.21	2.71	0.12	0.96
75	4101	1.74	0.20	2.12	0.12	0.87
90	3290	1.79	0.21	2.04	0.12	0.70
105	2771	1.67	0.21	1.99	0.13	0.73
120	2527	1.62	0.24	1.85	0.14	0.59
135	2605	1.79	0.24	1.80	0.12	0.58
150	2560	1.74	0.26	2.55	0.15	0.80
LSD α = 0.05	3.94	0.19	0.03	0.23	n.s.	0.11

al. (1998) regarding a weak tendency of this vegetable crop to accumulate nitrates, irrespective of the stage of plant maturation.

Japanese bunching onion with a blanched pseudostem contained more vitamin C, sugars and volatile oils in comparison to plants harvested 120 days after transplanting. Adverse effects of this treatment were observed in the case of chlorophyll a+b and carotenoids.

CONCLUSIONS

1. The results of this study indicate that Japanese bunching onion can be produced for fresh market supply from June until October by selecting differet dates for planting seed propagated transplants or by harvesting plants at different stages of growth within 60 and 150 days of cultivation on a field.

2. Plants of the some age harvested in on-month intervals from June to September produced similar yields and themean weight of plant, unlike plants harvested in October, when these parameters were significantly lower.

3. The delay of a growing season from April – June to August – October resulted in a decreased content of dry matter, carotenoids, total and reducing sugars, volatile oils and nitrates in Japanese bunching onion plants.

4. The yield of plants was highly dependent on their age at harvest time and increased from 14.25 t ha^{-1} after 60 days to 64.38 t ha^{-1} after 120 days from transplanting. The mean weight of plant improved during that time from 42.75 g to 196.25 g.

5. A more advanced stage of plant development at harvest time was associated with a decrease of vitamin C, carotenoids, chlorophyll a+b, sugars, volatile oils, nitrates, total nitrogen, potassium and calcium content.

6. Japanese bunching onion grown for 135 or 150 days whose pseudostems were blanched produced similar marketable yields as those harvested after 120 days without blanching. Blanched plants had a substantially longer white portion of the pseudostem, a lower content of chlorophyll a+b and carotenoids but more vitamin C.

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