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RESPONSE OF JAPANESE BUNCHING ONION (*Allium fistulosum* L.) TO NITROGEN FERTILIZATION

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Abstract. New pseudostem cultivars of Japanese bunching onion may be a good alternative to common bulb onion grown for bunches in early spring season. There is still limited knowledge upon the requirement of this vegetable species for nitrogen fertilization. In two factorial field experiment, calcium nitrate, ammonium nitrate and Entec 26 – nitrogen mineral fertilizer containing DMPP nitrification inhibitor used as the source of N and applied at the rates of 75, 150 and 225 kg·ha^{-1} were compared. Seed propagated transplants produced in the greenhouse were planted in early April and harvested after 10 weeks of cultivation in the open field. The yield and nutritional value of edible parts expressed by the content of dry matter , vitamin C, total chlorophyll, carotenoids, volatile oils, total N, NO_3 – N, P K Ca and Mg were estimated. Results of the study proved that all tested fertilizers were equally valuable sources of nitrogen for Japanese bunching onion. The use of Entec 26 was associated with higher amounts of total chlorophyll and carotenoids in edible part of plants if compared to commonly recommended ammonium nitrate and similar to calcium nitrate. The other important advantage of this fertilizer was a substantial decline of nitrates content. The increment of preplant nitrogen rate from 75 to 150 and 225 kg·ha^{-1} did not affect the crop yield and significantly enhanced the nitrates accumulation in plants at harvest.

Key words: nitrogen form, N rate, yield, nutritional crop value

INTRODUCTION

Allium species are grown worldwide and are popular in many countries because of high level of phytochemicals that provide health benefits and have specific flavour properties [Griffith et al. 2002]. Among them, onion and leek are the most popular edible *Alliums* grown in most regions of the world [Rabinowitch and Currah 2002], while Japanese bunching onion (*Allium fistulosum* L.), predominantly in Eastern Asia countries.

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Wild relatives of Japanese bunching onion originated in the region of West China and some neighboring countries of middle Asia, where they have been cultivated for more than 2000 years [Wang et al. 2005, Liu et al. 2009]. It was probably introducted into Europe by the end of Middle Ages receiving the name of Welsh onion [Helm 1956] and mostly grown in home gardens. Although perennial, in Asia the plant is mostly grown as an annual and sometimes as a biennial for its green tops or blanched leeklike pseudostem [Rubatzky and Yamaguchi 1997, Warade and Shinde 1998]. It can be also used in the seedling stage in special Japanese dishes. In this case the plants are harvested when they are about 8–10 cm high [Jones and Mann 1963, Wang et al. 2005].

In Poland, Japanese bunching onion is still a minor crop grown predominantly as a perennial plant in home gardens for the use of green tops in early spring season [Kotlińska and Kojima 2000, Tendaj and Mysiak 2007a, 2010]. New pseudostem type cultivars available nowadays in the market producing little number of tillers [Tendaj and Mysiak 2011] can be grown for the use of whole plants harvested in early growth stages or later, usually in September, with blanched pseudostems like leek species. [Kotlińska and Kojima 2000, Kotlińska et al. 2005]. Such type of cultivars having short growing period can be considered as an alternative green bunching onion to commonly used onion for this purpose [Grevsen 1989].

The advantageous features of Japanese bunching onion are the significant length of white portion of pseudostem, fewer but longer leaves, more erect foliage habit and stronger flavour in comparison to the common onion [Abbey et al. 2002, Lazić et al. 2002, Wang et al.2005]. Martinez et al. [2005] indicate resistance of *Allium fistolosum* L. to some diseases and pests of bulb onion, and pink root rot among them.

Japanese bunching onion is generally appreciated for its high nutritional value, and unique flawour due to substantial amounts of vitamins, macro- and micronutrients, volatile oils as well as flavonoids possessing high antyoxidant properties [He et al. 1989, Horbowicz and Kotlińska 1998, 2000, Kotlińska and Kojima 2000, Lazić et al. 2002, Stainer et al. 2006, Higashio et al. 2007, Tendaj and Mysiak 2007b, Mysiak and Tendaj 2006, 2008].

Growth of bunching onion, its yield and nutritional value of the crop can be highly influenced by the nutrients supply. The recommended rates of fertilizers in cultivation for blanched pseudostems on soil with hight organic matter include 200–300 kg of nitrogen, 100–200 kg of P_2O_5, and 150–200 kg of K_2O per hectar [Warade and Shinde 1998]. The fertilizer is usually split into three or four doses [Inden and Asahira 1990]. According to Wonnenberger et al. [2004] the bunching onion harvested with green tops should have an intensive green colour of leaves and requires 180 kg $N \cdot ha^{-1}$, including about 50 kg $N \cdot ha^{-1}$ normally present in the soil in mineral forms just before planting. Much lower doses within the range of 60–80 kg $N \cdot ha^{-1}$ are recommended by Skąpski and Dąbrowska [1994]. In China 240 kg $N \cdot ha^{-1}$ is considered as the optimum level for Japanese bunching onion cultivated for early spring harvest of blanched pseustems of this crop [Jiang et al. 2007]. In the greenhouse studies nitrate appeared to be a better source of nitrogen than ammonium which caused a significant suppression of plants growth [Perner et al. 2007]. The knowledge of nitrogen requirement by Japanese bunching onion under Polish climatic conditions is still limited.

The aim of the study was to evaluate the yield and nutritional value of Japanese bunching onion in relation to nitrogen rate and source of this nutrient.

MATERIAL AND METHODS

Field experiment which the aim was to determine the response of Japanese bunching onion to nitrogen fertilization was conducted in 2010–2011 at Piastów Horticultural Experimental Station (long. 17.00 E; lat. 51.05 N) on a sandy clay soil with pH 7.1 and organic matter content 1.8%, Available forms of phosphorus and potassium expressed in 1 dm^3 of the soil were raised up to the standard level for onion equal to 80 mg P and 200 mg K by early spring fertilization with triple superphosphate and potassium chloride.

Calcium nitrate [$Ca(NO_3)_2$ – 15.5% N], ammonium nitrate [NH_4NO_3 – 34% N] and Entec 26 – a mixture of ammonium sulphate and ammonium nitrate with total amount of 26% N, 13% S and addition of DMPP nitrification inhibitor (3,4 dimethylpyrazole phosphate) were used as the sources of nitrogen for Japanese bunching onion. All tested fertilizers were applied in the amounts of 75, 150 and 225 kg $N \cdot ha^{-1}$ in the single preplant doses under harrowing, shortly before planting. The experiment was established in two factorial design in four replications, and plot area amounted 6 m^2 (1.5 × 4 m).

Seeds of Japanese bunching onion Performer cultivar (Bejo Zaden) were sown into multicell trays filled with a standard peat moss substrate on 25 of January. To each cell containing 54 cm^3 of the medium 3–4 seeds were put in, and after emergence the number of seedlings was reduced to two. Transplants produced in the greenhouse during last ten days before planting were hardened in non heated plastic tunnel. Well developed seedlings at the stage of 2–3 leaves were transplanted into field on 7 and 5 of April in the subsequent years, in spacing 30 × 15 cm, which assured the population of 44 plants per 1m^2. Crop management included hand weeding of plots and sprinkler irrigation of plants in rainfall deficiency periods. In general, weather conditions during all trial periods were favourable for the growth and development of Japanese bunching onion.

Single harvest was conducted on 14 and 15 of June. The whole plants with removed roots and yellowing leaves, and stem diameter > 10 mm were recognized as the marketable yield. Samples of 10 plants from each plot were collected for evaluation such morphological features as mean weight and total length of plant, total length of pseudostem, number of leaves and bulb diameter. In edible parts of plants there were determined the contents of dry matter (by drying at 105°C to the constant weight – PN-90/A-75101/03), total and reducing sugars (Loof-Shoorl method – PN-90A-7501/07), vitamin C (Tillmaǹs method – PN-90/A-7501/11), chlorophyll a + b (spectrophotometric method), and carotenoids (colorimetric method) according to Lichtenthaller and Welburn [1983], volatile oils (distillation method PN – 1SO 6571), total N (Kjeldahl method) according to Ostrowska et al. [1991], nitrates expressed by the amount of NO_3-N in f.w. (ion selective electrode, Orions method), P and Mg colorimetrically, Ca and K by photometric method [according to Nowosielski 1974].

The results of the field study and chemical analysis were evaluated statistically using analysis of variance for two factorial design and the least significant differences calculated by Tukey test at $\alpha = 0.05$.

RESULTS AND DISCUSSION

The relations between the tested factors, yield and nutritional value of the crop were similar in both years of the study, and for this reason all the received data are presented as the means for 2010–2011. It was confirmed a high suitability a new pseudostem type Performer cultivar for a single harvest the whole plants supplied for fresh market. Like in the study conducted by Tendaj and Mysiak [2011] it showed little tendency to tillering. The other important features of this cultivars are long pseudostem, and rapid plants growth resulted in average marketable yield of plants after 70 days from transplanting at the range of 15.0–19.5 $t \cdot ha^{-1}$.

Total yield of Japanese bunching onion was not significantly affected by the source of nitrogen used in the study. Irrespective of N dose, ammonium nitrate and Entec 26 provided similar while calcium nitrate slightly lower total yield of plants (tab. 1). In the case of marketable yield comprising plants with pseudostem diameter > 10 mm this effect was still pronounced but not confirmed statistically. The form on nitrogen fertilizer did not influence the mean weight of plant and all tested morphological features such as height of plant, number of leaves and pseudostem diameter at harvest (tab. 2–3). Also Perner et al. [2007] in pot experiment conducted in the greenhouse conditions did not observe the differences in number of leaves and shoot dry weight in treatments supplied with nitrate and ammonium nitrate forms, while the effect was pronounced in the case of ammonium application. Shoot growth and number of leaves of NH_4^+ fed plants were significantly suppressed compared to the other mentioned N sources. Similarly Hawkins and George [2001] found that NO_3^- fed wheat plants were larger than NH_4^+ fed ones.

Table 1. Total and marketable yield of Japanese bunching onion as affected by nitrogen fertilization ($t \cdot ha^{-1}$)

Kind of fertilizer	Total yield ($t \cdot ha^{-1}$)				Marketable yield ($t \cdot ha^{-1}$)			
	nitrogen rate (kg $N \cdot ha^{-1}$)							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	15.5	17.4	15.9	16.3	15.2	16.6	15.0	15.6
Ammonium nitrate	19.0	19.2	20.0	19.4	18.6	18.7	19.5	18.9
Entec 26	18.3	18.9	19.7	19.0	17.9	18.3	19.2	18.5
Mean	17.6	18.5	18.5	18.2	17.2	17.9	17.9	17.7
$LSD_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				n.s.
	B – N rate			n.s.				n.s.
	interaction A × B			n.s.				n.s.

Table 2. Mean weight of plant and pseudostem diameter of Japanese bunching onion as affected by nitrogen fertilization

Kind of fertilizer	Weight of plant (g)				Pseudostem diameter (mm)			
	nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	44.7	47.2	46.8	46.2	15.7	15.7	16.0	15.8
Ammonium nitrate	43.0	48.4	48.5	46.6	17.3	16.8	16.6	16.9
Entec 26	46.5	46.5	49.6	47.5	16.9	15.9	14.8	15.9
Mean	44.7	47.4	48.3	46.8	16.6	16.1	15.8	16.2
$LSD_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				n.s.
	B – N rate			n.s.				n.s.
	interaction A × B			n.s.				n.s.

Table 3. Height of plant and number of leaves in Japanese bunching onion influenced by nitrogen fertilization

Kind of fertilizer	Height of plant (cm)				Number of leaves			
	nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	48.2	48.7	47.5	48.1	5.1	5.0	5.0	5.0
Ammonium nitrate	50.5	52.0	50.6	51.0	5.1	5.3	5.2	5.2
Entec 26	49.9	51.5	50.4	50.6	5.1	5.2	5.1	5.1
Mean	49.5	50.7	49.5	49.9	5.1	5.2	5.1	5.1
$LSD_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				n.s.
	B – N rate			n.s.				n.s.
	interaction A × B			n.s.				n.s.

The increment of nitrogen rate from 75 to 150 and 225 kg·ha^{-1} did not affect the growth bunching onion, total, and marketable yield as well as height of plants, leaves number and pseudostem diameter. The only exception was a significant enhancement of mean plant weight in treatments fertilized with 150 and 225 kg N·ha^{-1}. In the other studies there was observed higher requirement for this nutrient and significant increment of Japanese bunching yield caused by the application of 166 kg N·ha^{-1} in comparison to the dose of 100 kg N·ha^{-1} [Leong 2001]. Similar level of nitrogen fertilization betwen 130 and 160 kg·ha^{-1} for onion is recommended by Lorenz and Maynard [1988], while 240 kg·ha^{-1} by Jiang et al. [2007] in the case of 60 t·ha^{-1} yield target. Small response to nitrogen in our study could be explained by short only 10 weeks growing period and harvest of plants arranged in early stage of maturation, when majory of them reached 10 mm of stem diameter and provided the yield below 20 t·ha^{-1}. This suggestion can be confirmed by the data of some other studies with vegetables of short growing period like Swiss chard and spinach, which requirement for N did not exceed 100 kg·ha^{-1} [Kołota and Czerniak 2010, Krężel and Kołota 2010].

Both, nitrogen form and rate of this nutrient did not influence the content of dry matter, vitamin C, total sugars and volatile oils (tab. 4–5). It is worth to notice however, that regardless of N feeding level, Japanese bunching onion like in the other trials conducted by Kotlińska and Kojima [2000], Higashio et al. [2007], Tendaj and Mysiak [2007b] appeared to be an abundant source of vitamin C, which content ranged within 28.6 and 32.9 mg·100 g^{-1} f.w.

Total chlorophyll content was significantly dependent on nitrogen form and rate (tab. 6). Plants supplied with Entec 26, especially at the doses of 150 and 225 kg·ha^{-1} contained higher amounts of this pigment then that with ammonium nitrate, and sub-

Table 4. Dry matter and vitamin C content in Japanese bunching onion influenced by nitrogen fertilization

Kind of fertilizer	Dry matter (%)				Vitamin C (mg·100 g^{-1} f.w.)			
	Nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	10.52	10.54	10.32	10.46	31.28	28.59	32.85	30.91
Ammonium nitrate	10.80	10.40	10.64	10.61	30.45	29.69	31.25	30.46
Entec 26	10.81	10.35	9.86	10.34	29.04	29.77	29.93	29.58
Mean	10.71	10.43	10.27	10.47	30.26	29.35	31.34	30.32
$LSD_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				n.s.
	B – N rate			n.s.				n.s.
	interaction A × B			n.s.				n.s.

Table 5. Total sugar and essential oils content in Japanese bunching onion influenced by nitrogen fertilization

Kind of fertilizer	Total sugar (%)				Essential oils (ml·100 g^{-1} f.w.)			
	nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	4.44	4.08	4.64	4.39	0.65	0.70	0.63	0.66
Ammonium nitrate	4.34	4.33	4.44	4.37	0.63	0.65	0.68	0.65
Entec 26	4.86	4.21	4.12	4.40	0.65	0.73	0.73	0.70
Mean	4.55	4.21	4.40	4.38	0.64	0.69	0.68	0.67
$LSD_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				n.s.
	B – N rate			n.s.				n.s.
	interaction A × B			n.s.				n.s.

stantially but not proved statistically with those fed by calcium nitrate. More intensive green color of leaves as a result of enhanced chlorophyll content in different species of vegetable crops supplied with fertilizers containing DMPP nitrification inhibitor was observed by Hähndel and Zerulla [2000], Hähndel and Strohm [2001] and Pasda et al. [2001]. Irrespective of the nitrogen form, the increment of its dose from 75 to 150 kg·ha^{-1} was a beneficial factor for the total chlorophyll amount in edible parts of Japanese bunching onion. Entec 26, beside calcium nitrate appeared to be a faraourable source of N for the content of carotenoids.

Table 6. Chlorophyl a + b and carotenoids content in Japanese bunching onion depending on nitrogen fertilization

Kind of fertilizer Rodzaj nawozu	Chlorophyll a + b (mg·100 g^{-1} f.w.)				Carotenoids (μg·100 g^{-1} f.w.)			
	nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	51.79	54.29	58.71	54.93	166.56	168.09	167.76	167.47
Ammonium nitrate	51.28	51.64	54.47	52.46	148.20	152.12	142.89	147.74
Entec 26	51.29	60.46	62.17	57.97	151.28	171.96	167.61	163.62
Mean	51.45	55.46	58.45	55.12	155.35	164.06	159.42	159.61
LSD$_{\alpha = 0.05}$ for:	A – kind of fertilizer			4.04				9.77
	B – N rate			3.99				n.s.
	interaction A × B			n.s.				n.s.

Table 7. Nitrogen and nitrates content in Japanese bunching onion depending on nitrogen fertilization

Kind of fertilizer	Total nitrogen (%)				Nitrates (mg·kg^{-1} f.w.)			
	nitrogen rate (kg N·ha^{-1})							
	75	150	225	mean	75	150	225	mean
Calcium nitrate	2.03	2.43	2.37	2.28	2329	3617	4075	3340
Ammonium nitrate	1.92	2.12	2.47	2.17	2228	2651	4092	2990
Entec 26	2.04	2.08	2.49	2.20	1932	2495	2790	2406
Mean	2.00	2.21	2.44	2.22	2163	2921	3652	2912
LSD$_{\alpha = 0.05}$ for:	A – kind of fertilizer			n.s.				325
	B – N rate			0.22				411
	interaction A × B			n.s.				n.s.

Chemical plant analysis showed that tested nitrogen forms did not cause the differences in uptake and total N content but considerably influenced nitrates accumulation in edible parts of Japanese bunching onion (tab. 7). Plants fed with Entec 26 contained lower amounts of NO_3 – N in comparison to those supplied with ammonium nitrate. The highest level of this compound comprised plants growing on plots fertilized with calcium nitrate. The decreased NO_3 – N concentration in Entec 26 and NH_4NO_3 fed plants indicate that intercellular NO^-_3 was immediately metabolized in the plants whereas in NO^-_3 only fed ones surples NO^-_3 was stored in vacuoles [Perner et al. 2007]. Beneficial effects of Entec 26 use as a source of nitrogen, expressed by the decrease of nitrates accumulation was also observed in many other vegetable species such as celeriac, red beet, lettuce, spinach, cauliflower, leek and carrot [Hähndel and Zerulla 2001, Pasda et al. 2001, Kołota et al. 2007, Kołota and Adamczewska-Sowińska 2007]. This fiding is important from the practical point of view taking into account a high tendency of Japanese bunching onion grown for top greens for nitrates accumulation, which in the trial in some treatments exceeded the level 4000 $mg \cdot kg^{-1}$ f.w.

Heavy N application at the rates of 150 and 225 $kg \cdot ha^{-1}$ caused the increment of nitrogen uptake and nitrates accumulation in edible parts, irrespective of nitrogen form. Like in the trial conducted by Smoleń et al. [2012] no relations were found between the form of nitrogen including calcium nitrate, Entec 26 and ammonium nitrate, and the content of phosphorus, potassium, calcium and magnesium (data not included in the paper). The increased N rate from 75 to 225 $kg \cdot ha^{-1}$ had only a beneficial effects on uptake and amount of magnesium in edible parts, which was enhanced from 146 to 184 mg per 1 kg f.w.

CONCLUSIONS

1. Calcium nitrate, ammonium nitrate and Entec 26 appeared to be equally valuable sources for Japanese bunching onion growth and yield.
2. Entec 26, a new concept nitrogen fertilizer containing DMPP nitrification inhibitor caused the increase of total chlorophyll and carotenoids compared to ammonium nitrate, the commonly used nitrogen source. Plants supplied with this fertilizer contained substantially lower amounts of nitrates than with ammonium nitrate and calcium nitrate.
3. The increment of nitrogen rate ower 70 $kg \cdot ha^{-1}$ was not efficient for yield of Japanese bunching onion and adversely affected the quality of the crop by significant enhancement of nitrates accumulation.

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REAKCJA CEBULI SIEDMIOLATKI (*Allium fistulosum* L.) NA NAWOŻENIE AZOTEM

Streszczenie. Wprowadzenie do uprawy nowych odmian siedmiolatki o wydłużonej łodydze rzekomej może stanowić alternatywę dla uprawianej powszechnie cebuli zwyczajnej na wczesny zbiór pęczkowy. Jak dotąd brak jest dokładnych informacji na temat potrzeb nawozowych tego warzywa w stosunku do azotu. W dwuczynnikowym doświadczeniu polowym porównywano skuteczność nawożenia saletrą wapniową, saletrą amonową i nawozem Entec 26 zawierającym DMPP jako inhibitor nitryfikacji w dawkach przedwegetacyjnych w wysokości 75, 150 i 225 $kg \cdot ha^{-1}$. Rozsadę wyprodukowaną w szklarni sadzono na miejsce stałe na początku kwietnia, zaś zbiór roślin wykonywano po 10 tygodniach uprawy. Ocenie poddano plon oraz wartość biologiczną roślin wyrażoną zawartością suchej masy, witaminy C, chlorofilu ogółem, karotenoidów, olejków lotnych, N ogólnego $N-NO_3$(V), P K Ca i Mg. Badania wykazały, że testowane nawozy miały równorzędną przydatność jako źródło azotu dla cebuli siedmiolatki. Użycie nawozu Entec 26 zapewniło większą zawartość chlorofilu i karotenoidów w roślinach w stosunku do powszechnie stosowanej w nawożeniu saletry amonowej. Innym korzystnym efektem stosowania tego nawozu był istotny spadek zawartości azotanów w częściach jadalnych. Wzrost przedwegetacyjnie stosowanej dawki azotu z 75 do 150 i 225 $kg \cdot ha^{-1}$ nie miał wpływu na wielkość plonu, przyczynił się jednak do znacznego wzrostu poziomu akumulacji azotanów w roślinach.

Słowa kluczowe: forma azotu, dawka N, plon, wartość odżywcza roślin

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