Cultivation of *Brassica pekinensis* under different forms of nitrogen nutrition

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ABSTRACT: A pot trial was aimed to investigate the effect of different forms of nitrogen fertilizer on the aboveground phytomass yield, vitamin C content and uptake of some macroelements by *Brassica pekinensis*. The trial was conducted in 2000 and 2001 in pots containing 10 kg of loamy brown soil. Optimized NPK nutrition with the rate of 90.9 kg/ha N increased phytomass yields of Chinese cabbage in all treatments compared to the unfertilized control. The most marked increase (by 55.6%) of yield was obtained when N was applied in the form of $(NH_4)_2$ SO_4. The yields in the other treatments declined as follows: NH_4NO_3 > Mg $(NO_3)_2$ > KNO_3 > DAM-390. Positive effects of full NPK nutrition on vitamin C content were determined. Depending on the forms of N fertilizer, the content of vitamin C in fresh mass of cabbage decreased in the following order: DAM-390 (629.0 mg/kg of fresh mass) >$Mg(NO_3)_2$ > KNO_3 > NH_4NO_3 > $(NH_4)_2SO_4$. Optimization of NPK rates contributed to the increase in N, P, K, Ca, Mg and S uptake by the yield of final product in comparison with unfertilized control. The highest uptake of nutrients was determined in the treatment with N applied in the form of $(NH_4)_2SO_4$.

Keywords: *Brassica pekinensis*; NPK nutrition; vitamin C; macroelements

Cole vegetables with great requirements for nutrients are grown on a large scale. *Brassica pekinensis* belongs to this group of vegetables although it is not grown so frequently in Slovakia. This vegetable deserves our attention mainly for its short growing period which enables its cultivation as a subsequent crop after early species of vegetables or after other crops provided they are harvested before mid-July. Owing to the weakly developed root system and quick production of a large amount of biomass in the course of the short growing season, *Brassica pekinensis* requires nutrients in easily available form (MIAO et al. 1998). Nitrogen is a decisive nutrient for cole vegetables with regard to the quantity and quality of produced phytomass (GOODLASS et al. 1997; GUILLARD, ALLINSON 1993). The content of vitamin C is one of the most important parameters determining the nutritive value of many garden crops (LEE, KADER 2000).

The aim of this study was to investigate the effect of various forms of nitrogen nutrition on the aboveground phytomass yield, vitamin C content and uptake of some macroelements by the final product.

Table 1. Agrochemical characteristics of soil before the experiment beginning

Type of soil analysis	Available nutrient content (mg/kg)
N_{an}	19.8
$N\text{-}NH_4^+$	7.9
$N\text{-}NO_3^-$	11.9
P – by Egner	68.5
K – by Schachtschabel	86.0
Mg – by Schachtschabel	116.0
pH/KCl	5.88

MATERIAL AND METHOD

A trial (integral part of Grant Agency VEGA Project No. 1/7668/20) was established in pots with 10 kg of

Table 2. The scheme of treatments in a pot experiment

	Treatment
1	unfertilized control
2	80% N + P, K prior to seeding + 20% N in initial phase of head formation, nitrogen applied as DAM-390
3	80% N + P, K prior to seeding + 20% N in initial phase of head formation, nitrogen applied as NH_4NO_3
4	80% N + P, K prior to seeding + 20% N in initial phase of head formation, nitrogen applied as $(NH_4)_2SO_4$
5	80% N + P, K prior to seeding + 20% N in initial phase of head formation, nitrogen applied as KNO_3
6	80% N + P, K prior to seeding + 20% N in initial phase of head formation, nitrogen applied as $Mg(NO_3)_2$
	N was added to reach the level of 40 mg N/kg of soil P was added at the rate of 35 kg P/ha (calculated on the balance principle) K was added at the dose of 175 kg/ha to maintain the P:K ratio = 1:5

Table 3. The rates of applied nutrients

Experimental treatments	Fertilization prior to seeding (kg/ha)			Fertilization with N after seeding (kg/ha)
	N	P	K	
1	0	0	0	0
2	72.7	35	175	18.2
3	72.7	35	175	18.2
4	72.7	35	175	18.2
5	72.7	35	251	18.2
6	72.7	35	175	18.2

loamy brown soil in each and it lasted for two years (2000 and 2001). Table 1 shows the agrochemical characteristics of soil. Seven seeds of cultivar Parkin were sown per pot. After emergence the number of plants per pot was reduced to four. Nutrition strategy was based on the optimization of NPK rates to supply nutrients on an appropriate level in the soil profile of 0.0–0.3 m. A scheme of experimental treatments is given in Table 2 and particular nutrient rates in Table 3. During the growing season the plants were regularly irrigated. The experimental treatments were replicated 3 times and the number of plants per replication was set to three at the time of harvest. The content of vitamin C was determined by a titration method with 2.4-dichlorophenolindophenol and contents of essential macroelements by standard methods. The results were statistically processed by Statgraphics programme (LSD test).

RESULTS AND DISCUSSION

The results show (Table 4) that the yields of *Brassica pekinensis* increased from 40.7% (treatment 2) to 55.6% (treatment 4) under the influence of NPK mineral nutrition in comparison with unfertilized control. The differences were statistically significant. As far as the various forms of applied nitrogen nutrition are concerned, the most marked increase of yield was found in treatment 4 where N fertilizer was applied in the form of $(NH_4)_2SO_4$.

In this case the yield per plant was 237.8 g and was the statistically significantly highest out of all evaluated treatments. The yields of other treatments declined as follows: NH_4NO_3 (treatment 3) > Mg $(NO_3)_2$ (treatment 6) > KNO_3 (treatment 5) > DAM-390 (treatment 2).

Poudel et al. (1998) reported a strong positive correlation between the applied N fertilizer and yields of *Brassica pekinensis*. Hlušek et al. (2003) found that the weight of Chinese cabbage heads increased by 63% as a consequence of the application of N and S fertilizer (DASA fertilizer) compared to unfertilized control.

In addition, the optimization of NPK rates not only increased the yields of *Brassica pekinensis* aboveground

Table 4. Yields of Chinese cabbage heads at the end of vegetation (LSD-test)

Experimental treatments	Weight of fresh mass (grams per plant)		Average of 2000 and 2001	Relation (%)
	2000	2001		
1	162.2	143.3	152.8 Aa	100
2	221.1	208.9	215.0 Bb	140.7
3	247.2	215.6	231.4 BCb	151.4
4	228.9	246.7	237.8 Cb	155.6
5	218.3	219.4	218.9 Bb	143.3
6	206.7	237.2	222.0 BCb	145.3

Averages indicated by different letters are statistically significantly different on the significance level of $P = 0.05$ (capital letters) and $P = 0.01$ (small letters)
$D_{0.05} = 17.27$; $D_{0.01} = 23.32$

Table 5. Content of vitamin C in Chinese cabbage heads (LSD-test)

Experimental treatment	Content of vitamin C (mg/kg of fresh mass)		Average of 2000 and 2001	Relation (%)
	2000	2001		
1	374.0	364.0	369.0 Aa	100
2	628.0	630.0	629.0 Cd	170.5
3	537.0	534.0	535.5 Bb	145.1
4	537.0	526.0	531.5 Bb	144.0
5	565.0	562.0	563.5 Bbc	152.7
6	607.0	610.0	608.5 Ccd	164.9

Averages indicated by different letters are statistically significantly different on the significance level of $P = 0.05$ (capital letters) and $P = 0.01$ (small letter)
$D_{0.05} = 34.7$; $D_{0.01} = 46.9$

Table 6. The uptake of N, P, K by plant of Chinese cabbage at the end of growing season

Year	Experimental treatments	Nutrient uptake by 1 plant (mg)					
		N	(%) relation	P	(%) relation	K	(%) relation
2000	1	297.2	–	88.6	–	539.3	–
	2	329.7	–	97.1	–	621.7	–
	3	414.2	–	114.0	–	761.8	–
	4	312.5	–	110.0	–	717.0	–
	5	403.9	–	105.4	–	704.2	–
	6	429.7	–	96.3	–	638.6	–
2001	1	258.1	–	76.9	–	469.8	–
	2	306.8	–	87.8	–	585.8	–
	3	359.3	–	97.7	–	666.6	–
	4	338.1	–	116.8	–	775.7	–
	5	397.3	–	105.5	–	700.6	–
	6	469.3	–	108.4	–	751.1	–
Average of 2000 and 2001	1	277.7	100	82.8	100	504.6	100
	2	318.2	114.6	92.5	111.7	603.8	119.7
	3	386.8	139.3	105.8	127.8	714.2	141.5
	4	325.3	117.1	113.4	137.0	746.3	147.9
	5	400.6	144.3	105.5	127.4	702.4	139.2
	6	449.5	161.9	102.4	123.6	694.8	137.7

phytomass but also distinctly stimulated the production of vitamin C in the cabbage heads. This is also in accordance with the results reported by VALŠÍKOVÁ et al. (1997). The content of vitamin C was statistically significantly higher (Table 5) in all treatments with applied NPK nutrition compared to unfertilized control 1. This increase fluctuated in the range from 44% (treatment 4) to 70.5% (treatment 2). The highest content of vitamin C (629.0 mg/kg of fresh matter) was determined in treatment 2 where nitrogen was applied in the form of

Table 7. The uptake of Ca, Mg, S by plant of Chinese cabbage at the end of growing season

Year	Experimental treatments	Nutrient uptake by 1 plant (mg)					
		Ca	(%) relation	Mg	(%) relation	S	(%) relation
2000	1	262.7	–	45.1	–	79.3	–
	2	247.0	–	46.4	–	88.8	–
	3	339.6	–	51.9	–	93.2	–
	4	318.0	–	55.3	–	118.9	–
	5	295.5	–	48.0	–	98.5	–
	6	253.3	–	42.9	–	96.3	–
2001	1	227.4	–	37.8	–	69.9	–
	2	230.5	–	41.3	–	83.6	–
	3	298.4	–	43.8	–	82.2	–
	4	350.6	–	59.0	–	125.3	–
	5	301.8	–	47.9	–	98.9	–
	6	304.7	–	49.2	–	114.3	–
Average of 2000 and 2001	1	245.1	100.0	41.5	100.0	74.6	100.0
	2	238.7	97.4	43.8	105.6	86.2	115.6
	3	319.0	130.2	47.9	115.3	87.7	117.5
	4	334.3	136.4	57.1	137.7	122.1	163.7
	5	298.6	121.8	48.0	115.6	98.7	132.3
	6	279.0	113.8	46.1	111.0	105.3	141.2

DAM-390. The other experimental treatments showed a decline in this characteristic as follows:

Mg $(NO_3)_2$ (treatment 6) > KNO_3 (treatment 5) > NH_4NO_3 (treatment 3) > $(NH_4)_2SO_4$ (treatment 4). KAACK et al. (2001) reported that an increase in mineral nitrogen content in the soil caused a proportional reduction of vitamin C content in carrot roots.

An increase of nitrogen rate from 80 to 120 kg/ha reduced the content of vitamin C in cauliflower from initial 605.0–647.0 mg/kg by 7%, but in broccoli the effect was zero and the content of vitamin C fluctuated closely around the constant level of 1,163.0 mg/kg of fresh mass (LISIEWSKA, KMIECIK 1996).

Higher yields of cabbage heads under the conditions of intensive mineral fertilization caused higher uptake of essential macrobiogenic elements in comparison with unfertilized control (Tables 6 and 7). The highest nitrogen uptake was observed in treatment 6 where nitrogen was applied in the form of Mg $(NO_3)_2$ and in comparison with unfertilized control this uptake was higher by 61.9%. Positive effects of nitrogen fertilization in the form of $(NH_4)_2$ SO_4 (treatment 4) were manifested in higher uptake of P, K, Ca, Mg and S by Chinese cabbage phytomass by 37.0; 47.9; 36.4; 37.7 and 63.7%, respectively.

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Pestovanie pekinskej kapusty v rôznych podmienkach dusíkatej výživy

ABSTRAKT: Nádobový pokus zameraný na sledovanie vplyvu rôznych foriem dusíkatej výživy na tvorbu úrody nadzemnej fytomasy, vitamínu C a na odber vybraných makroelementov pri pekinskej kapuste [(*Brassica pekinensis* (Lour.) Rupr.)] sa realizoval v rokoch 2000 a 2001 na hlinitej hnedozemi v nádobách s hmotnosťou zeminy 10 kg. Pozoroval sa jednoznačne kladný vplyv optimalizovanej minerálnej NPK výživy pri dávke dusíka 90,9 kg/ha na tvorbu fytomasy pekinskej kapusty v porovnaní s nehnojeným variantom, pričom najvýraznejší nárast úrody (o 55,6 % v porovnaní s nehnojeným variantom) sme zistili na variante s dusíkom aplikovaným vo forme $(NH_4)_2SO_4$. Úroda fytomasy vo variantoch s rôznymi formami dusíkatej výživy klesala v poradí: NH_4NO_3 > $Mg(NO_3)_2$ > KNO_3 > DAM-390. Zistil sa pozitívny vplyv plnej NPK výživy na tvorbu vitamínu C, pričom jeho obsah v závislosti od rôznych foriem dusíkatej výživy klesal v poradí: DAM-390 (629,0 mg/kg vitamínu C v čerstvej hmote) > $Mg(NO_3)_2$ > KNO_3 > NH_4NO_3 > $(NH_4)_2SO_4$. Optimalizácia dávky dusíka, fosforu a draslíka prispela k nárastu odberu základných makroelementov (N, P, K, Ca, Mg a S) v porovnaní s nehnojeným variantom. Najväčšie odbery sme zistili vo variante s dusíkom aplikovaným vo forme $(NH_4)_2SO_4$.

Kľúčové slová: pekinská kapusta; NPK výživa; vitamín C; makroelementy

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