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THE INFLUENCE OF NITROGEN AND SUPLHUR FERTILIZATION ON THE YIELD FORMATION AND QUALITY OF BROCCOLI

MIROSLAV ŠLOSÁR, ANTON UHER, JÁN KÓŇA, TOMÁŠ PECHOČIAK[1]

SUMMARY: In the field experiment with broccoli, we investigated an effect of four different variants of nitrogen and sulphur fertilization on the yield formation and broccoli quality in the term of acid ascorbic content and nitrate accumulation in broccoli florets. The influence of fertilization on the selected parameters of broccoli yield was similar in different years. The broccoli yield was statistically significantly increased at all fertilization variants compared to the control variant. The highest yield of broccoli was reached at the variant 4 when it was fertilized on the level of nutrients N:S = 200:60 kg.ha^{-1}. The increase of yield compared with the control variant was 26.8 %. The applied fertilization positively affected the accumulation of acid ascorbic in the broccoli florets. The highest content of ascorbic acid was determined at the variant 2 (N = 200 kg.ha^{-1}). In comparison with control variant, the ascorbic acid content was increased about 12.9 %. On the other hand, the applied nutrition resulted in increased accumulation of nitrates in the broccoli. The greatest increase of nitrates content, in comparison with the control variant, was ascertained at the variant 4 (about 31.0 %).

Key words: *broccoli, fertilization, yield, acid ascorbic, nitrates.*

INTRODUCTION

Vegetables have a very important role in human nutrition and their health benefit is undoubted. Nevertheless, we can observe a deficient level of annual vegetable consumption today. According to human nutrition specialists, the recommended consumption of vegetables is on the level of 128 kilograms. But in Slovakia, we are deeply below this value - 85 kilograms (Valšíková and Uher, 2009). This fact was also confirmed in previous research by Dudrikova, et al. (2009) and Kubicová and Fatrcová-Šramková (2010), who point to very low consumption of vegetables, especially by young people.

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[1]Miroslav Šlosár, Anton Uher, PhD., Ján Kóňa, PhD., Department of vegetable production, Horticulture and Landscape Engineering Faculty, Slovak University of Agriculture, Tr. A. Hlinku 2, 949 76 Nitra. Tomáš Pechočiak, PhD., Department of Mathematics, Faculty of Economics and Management, Slovak University of Agriculture, Tr. A. Hlinku 2, 949 76 Nitra
Corresponding author: Miroslav Šlosár, Department of vegetable production, Horticulture and Landscape Engineering Faculty, Slovak University of Agriculture, Tr. A. Hlinku 2, 949 76 Nitra, e-mail: miroslav.slosar@uniag.sk

In comparison with other agricultural crops, vegetables require relatively high rates of nutrients for cultivation. It is well known that nitrogen nutrition markedly affects the quantity and quality of grown crops. But it is also very important not to forget to apply other macroelements (Fecenko and Ložek, 2000). Nitrogen and sulphur, as well as phosphorus and potassium, are determining nutrients for growing of broccoli and other cruciferous vegetables in relation to quality, but also quantity of harvested phytomass (Goodlass et al., 1997).

The vitamin C (ascorbic acid) is one of most important nutritional compounds in broccoli. It must be ingested in food form because human body is not able to form ascorbic acid (Lee and Kader, 2000). Byers and Perry (1992) indicate that acid ascorbic prevents cancer by inhibiting creation of nitroso-compounds in stomach and stimulation of immune system. The content of acid ascorbic in broccoli can be influenced by various factors such as genotypic differences (Singh et al., 2007), climatic conditions (Vallejo, F. et al., 2003), farming technology – for example fertilization (Kováčik and Takáč, 2009), maturity and harvesting methods (Lee and Kader, 2000), and postharvest handling procedures (Serrano et al., 2006).

Nitrates are present naturally in soils, water, plants – particularly in vegetables as a consequence of nitrogen fixation (Mor et al., 2010). The natural levels of nitrate in vegetables generally are high in comparison with other food groups. It is estimated that 75-80% of the total daily intake comes from vegetables (Dennis and Wilson, 2003). Nitrate content varies considerably according to species (Mor et al., 2010). Nitrate contamination in vegetables occurs when crops absorb more than they require for their sustainable growth. Spinach, lettuce, broccoli, radish, etc., have the tendency to accumulate nitrates (Greenwood and Hunt, 2006).

Nitrate is largely unreactive but can be reduced to nitrite. Nitrite ion can react with secondary or tertiary amines to form nitrosocompounds – some of them being implicated in the etiology of cancers (Sebecic and Dragojevic, 1999). Another important concern is that vegetables are an important part of most babies' diets (Huarte-Mendicoa et al., 1997). Young babies with low stomach acidity may suffer from infantile methemoglobinemia due to excessive nitrates in their diet where nitrite is substituted for oxygen in hemoglobin and death may occur (Ezeagu, 1996).

MATERIAL AND METHODS

The small-plot field trial with broccoli was established in the area of the Botanical Garden of Slovak Agricultural University in Nitra in 2008 and 2009. In this trial, we used a middle-late broccoli cultivar CORONADO F1 which forms compact and finely-granular florets of dark green colour.

In the field trial, we monitored the effect of four different fertilization variants on the quantity and quality of broccoli yield:

1) variant – control (without application of fertilizers),
2) variant – application of nitrogen at the level N = 200 $kg.ha^{-1}$,
3) variant – application of nitrogen and sulphur at the level N:S = 200:50 $kg.ha^{-1}$,
4) variant – application of nitrogen and sulphur at the level N:S = 200:60 $kg.ha^{-1}$.

Table 1. Agrochemical soil characteristics before the establishment of the trial

Year	Content of nutrients in mg.kg^{-1} of soil							Humus (%)
	pH/KCl	N_{an}	P	K	S	Ca	Mg	
2008	7.13	16.8	130	570	67.5	6300	695	3.42
2009	7.24	10.5	200	580	34.0	6700	660	4.38

Broccoli seedlings were planted out at the experimental area on 24th June 2008 and 22nd June 2009. Each variant had four repeats. In every repeat, we planted nine seedlings into the plating space 0.5 x 0.5 m.

At the fertilization variants 2, 3 and 4, we used the following fertilizers: LAD 27 (27% of N) and DASA 26/13 (26% of N and 13% of S). The fertilizer DASA 26/13 was applied three weeks before outplanting. The calculated dose of LAD 27 was applied in two terms - three (50%) and six weeks (50%) after planting.

The harvest of broccoli was realized in four terms from 15th August to 9th September 2008 and from 20th August to 3rd September 2009. We harvested broccoli florets included the edible part of stump which was 10 centimetres long. The content of the monitored qualitative compounds was determined in average sample which was prepared from broccoli florets harvested on 3rd September 2008 and 31st August 2009. The content of acid ascorbic was analyzed by titration method. The nitrates content was determined by nitrate electrode screening method. The obtained results were evaluated by analysis of variance (ANOVA). The tests were performed on confidence level 95%.

RESULTS AND DISCUSSION

The influence of fertilization on the selected quantitative and qualitative yield parameters of broccoli yield was similar in different years. In addition, there were no significant differences in the experimental years. Therefore, the results are presented as the means of two years of the experiment (Table 2).

Table 2. Quantitative and qualitative parameters of broccoli yield

Variant	Yield			AW[1]	Acid ascorbic			Nitrates		
	t.ha^{-1}	Rel. %[2]		(g)	mg.kg^{-1}	Rel. %		mg.kg^{-1}	Rel. %	
1	15.32	100	-	382.9	405.70	100	-	703.9	100	-
2	19.91	129.9	100	497.7	467.50	115.2	100	833.7	118.4	100
3	20.40	133.2	102.5	509.8	440.45	108.6	94.2	897.1	127.5	107.6
4	20.70	135.1	104.0	517.6	448.35	110.5	95.9	922.1	131.0	110.6

[1]Average weight of broccoli florets, [2]Relatively in %

On the basis of the obtained results, it can be concluded that a statistically significant increase of broccoli yield was observed at all variants with applied fertilization in comparison with unfertilized control variant in both years of the experiment (Table 3). The highest yield of broccoli was attained at the variant 4 – 20.70 t.ha^{-1}. This value, in comparison with the control variant, introduced an increase of broccoli yield about 35.1% (Table 2). If we compare nitrogen and combined nitrogen-sulphur variants with each other, it can be seen that the significant yield of broccoli florets was showed only in 2009 (Table 3).

The average weight of broccoli florets ranged from 382.9 to 517.6 g and it increased in the following variants order: 1 (control) < 2 < 3 < 4 (Table 2). At the variant 4, we achieved the increase of average florets weight about 134.7 g compared to the control variant.

Thus, the obtained results of our research confirmed the fact that applied nitrogen nutrition has fundamental affect on the yield of grown vegetable as it was demonstrated in the previous research by Babik and Elkner (2002) and Varga, et al. (2004).

The applied nitrogen fertilization also affected the quality of the grown broccoli or content of monitored qualitative parameters of broccoli florets. We observed statistically significant increase of ascorbic acid content at all fertilization variants compared to the control variant in both experimental years, besides variant 3 in 2009. Differences between variant 2 (N) and variants 3 and 4 (N+S) were not statistically significant.

The average content of ascorbic acid in broccoli ranged from 405.70 to 467.50 $mg.kg^{-1}$ of fresh matter (Table 2). The highest vitamin C content was determined at the variant 2 where nitrogen only was applied. At this variant, we achieved the increase of ascorbic acid content about 15.2% in comparison with the control variant. At variants with nitrogen-sulphur fertilization, we observed decrease of vitamin C content compared to the variant where only nitrogen was applied.

Table 3. P-value for dependence of several fertilization variants

Compared variants	Yield		Acid ascorbic		Nitrates	
	2008	2009	2008	2009	2008	2009
1-2	0.000*	0.000*	0.002*	0.004*	0.000*	0.000*
1-3	0.000*	0.000*	0.011*	0.053	0.000*	0.000*
1-4	0.000*	0.000*	0.005*	0.006*	0.000*	0.000*
2-3	0.440	0.049*	0.059	0.154	0.006*	0.009*
2-4	0.081	0.026*	0.072	0.373	0.004*	0.002*
3-4	0.036*	0.460	0.709	0.400	0.458	0.043*

*P-value is statistically significant ($P<0.05$)

Opinions regarding the influence of nitrogen fertilization on the acid ascorbic content are very different. Xu, et al. (2010) found that applied nitrogen fertilization tended to decrease the acid ascorbic content in broccoli florets. On the other hand, our results confirmed the fact that we can reach the higher content of acid ascorbic in grown vegetable by optimization of nutrient doses. This fact was presented by Ducsay and Varga (2001) in the trial with Chinese cabbage. Vallejo, et al. (2003) observed the positive effect of sulphur fertilization on the accumulation of vitamin C content in selected broccoli cultivars. On the basis of the gained results, we can also state increased accumulation of ascorbic acid at the variants where sulphur was applied.

Table 4. Correlation coefficient (*R*) between yield and qualitative parameters of broccoli

Variant	Correlation coefficient					
	A x B		A x C		B x C	
	2008	2009	2008	2009	2008	2009
1	0.997***	0.144*	0.784***	0.777***	0.732***	0.293*
2	0.374**	0.257*	0.438**	0.315*	0.573**	0.622**
3	0.456**	0.257*	0.686***	0.362**	0.143*	0.339**
4	0.892***	0.054*	0.788***	0.705***	0.942***	0.125*
Total	0.747***	0.670***	0.894***	0.934***	0.520**	0.601**

A–yield; B–acid ascorbic; C-nitrates
*weak dependence–R (0;0.33); **middle dependence–R (0.33;0.66).
***strong dependence–R (0.66;1.0)

Broccoli belongs to vegetables species which tend to accumulate nitrates in its edible parts. We observed statistically significant differences between unfertilized control and variants with nitrogen fertilization in both experimental years. There were also statistically significant differences detected between nitrogen and nitrogen-sulphur variants (Table 3).

The average nitrate content ranged from 703.90 to 922.1 mg.kg^{-1} of fresh matter (Table 2). The highest nitrate content was determined at the variant 4 where only nitrogen was applied. At this variant, the increase of nitrate content about 31.0% was detected in comparison with the control variant. We also observed the cumulative effect of nitrates in broccoli florets at variants 2 and 3 where the nitrates content was increased compared to the control variant about 18.4 and 27.5%. Thus, the obtained experimental results confirm the fact that nitrate fertilization has statistically significant cumulative effect on nitrate contents in edible part of the vegetable (Table 3). This fact was showed in previous research by Babik and Elkner (2002), Rop (2000), Wang and Li (2004) and Ahmadil, et al. (2010), who studied the effect of nitrogen fertilization on the nitrates content in broccoli or other vegetable species (spinach, cabbage, Peking cabbage et al.).

CONCLUSION

In our research, we studied the effect of four different variants of nitrogen fertilization on the quantity and quality of broccoli yield. On the basis of the obtained results, we can conclude that the statistically significant increase of broccoli yield was reached at all variants with applied fertilization compared to the control variant. The highest broccoli yield was reached at the combined nitrogen-sulphur variant (N:S=200:60 kg.ha^{-1}). In the term of broccoli quality, we observed the positive effect of applied fertilization on the amount of ascorbic acid in broccoli florets. Its highest content was determined at the variant where nitrogen only was applied (fertilized at the level N=200 kg.ha^{-1}). The applied nitrogen fertilization tended towards increased accumulation of nitrates in broccoli. The greatest increase of nitrates content was determined at the combined nitrogen-sulphur variant (N:S=200:60 kg.ha^{-1}).

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UTICAJ ĐUBRENJA AZOTOM I SUMPOROM NA FORMIRANJE PRINOSA I KVALITET BROKOLE

MIROSLAV ŠLOSÁR, ANTON UHER, JÁN KÓŇA, TOMÁŠ PECHOČIAK

Izvod

U ogledu sa brokolom ispitivan je uticaj četiri različite varijante đubrenja azotom i sumporom na formiranje prinosa i kvalitet brokole (sadržaj vitamina C i nakupljanje nitrata u cvasti brokole). Uticaj đubrenja na odabrane komponente prinosa brokole, je bio sličan u obe godine ispitivanja. Kod svih ispitivanih varijanti đubrenja uočeno je statistički značajno povećanje prinosa u odnosu na kontrolu. Najveći prinos brokole je postignut na varijanti 4 (đubrenje u dozi N : S = 200 : 60), gde je u poređenju sa kontrolom uočeno povećanje prinosa od 26,8%. Primenjena đubriva su imala uticaj na akumulaciju vitamina C u cvasti brokole. Najveći sadržaj vitamina C je ostvaren na varijanti 2 (200 kg N/ha). Na ovoj varijanti uočeno je povećanje sadržaja vitamina C u odnosu na kontrolu za 12,9 %. Nasuprot tome, primenjena đubriva su dovela do povećanja sadržaja nitrata u konzumnim cvastima brokole. Najveći porast sadržaja nitrata u poređenju sa kontrolnom varijantom je ostvaren na varijanti 4 (za 31%).

Ključne reči: brokola, đubrenje, prinos, vitamin C, nitrati.

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