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QUALITY OF CABBAGE AND KOHLRABI DEPENDING ON THE FERTILIZING REGIME AND USE OF MULCH

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OPEN ACCESS

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SUMMARY

Cabbage (Brassica oleracea var. capitata) and kohlrabi (Brassica oleracea Gongylodes group) take a very important place in vegetable farming around the world. Obtaining good-quality plants with minimal inputs is imperative in production. The experiment was set up in Sombor, on chernozem. The research analyzed the effect of 9 organic and mineral fertilizers (individually and in combinations), in the presence or absence of mulch, on the quality and the yield of cabbage (variety Adema) and kohlrabi (variety Volturno). The content of nitrates, nitrogen, phosphorus, and potassium were determined after harvesting. The highest yield was obtained by using pig manure + 500 kg NPK/ha and mulch in cabbage, and by applying the same treatment without mulch in kohlrabi. Cabbage and kohlrabi fertilized with beef manure in combination with NPK (300 and 500 kg/ha) had a lower concentration of nitrate than with other kinds of fertilizing. The combination of organic and mineral fertilizers gave the best result both in terms of quality (the content of nitrates, N, P) and yield.

Key words:
Brassica oleracea var. *capitata*, *Brassica oleracea Gongylodes group*, *nitrates, NPK, yield*

INTRODUCTION

Cabbage (*Brassica oleracea* var. *capitata*) and kohlrabi (*Brassica oleracea Gongylodes group*) are species of vegetables cultivated worldwide for vegetative mass. Monitoring the quality of vegetables and adapting production to improve the quality is imperative. The nitrate content is very important for the quality of these vegetables since it affects human health. Cabbage and kohlrabi belong to a group of vegetables prone to accumulate nitrates. Different natural resources are the most common sources of nitrate absorption (Brkić et al., 2017). Vegetables accumulate a significant portion of nitrate from nitrogen-based fertilizers (Shahid Umar & Iqbal, 2007). The content of nitrates in vegetables may range from 1 to 10000 mg kg^{-1} (Ximenes et al., 2000). About 80% of the nitrates ingested by humans come from vegetables (Brkić et al., 2017). Nitrates are normally present in human diet, but excessive levels can adversely affect health, especially in children who consume more than adults relative to their body weight. Excessive intake of nitrates has been linked to different diseases like leukemia, non-Hodgkin lymphoma, and ovarian, colon, rectal, bladder, stomach, esophageal, pancreatic, gastrointestinal, and thyroid cancer (Afzaly & Elahi, 2014; Cintya et al., 2018).

The content of N, P, and K in plants is associated with the amount of applied fertilizers. NPK fertilizers have different concentrations of the elements based on the needs of the plants. Depending on the concentration of NPK

fertilizers, the yield and growth rate of the plant can differ. Application of nitrogen from mineral fertilizers results in the highest increase in the yield of kohlrabi. However, use of organic fertilizers indicates lower concentrations of nitrates in plants compared to mineral fertilizers (Saleh et al., 2013).

Pavlou et al. (2007) concluded that accumulation of nitrates in edible parts of crops is directly related to the type of nitrogen fertilizer used, as well as the soil properties. Adequate application of fertilizers is very important for sustainability of agricultural production and also for environmental protection. The use of mulch has a positive effect on soil structure, reducing the negative effects of wind and water erosion and reducing soil warming during the summer months (Chakraborty et al., 2008). Accordingly, it is necessary to analyze the effect of mulch in combination with different types of fertilization.

This research aimed to assess the effect of different doses of organic and mineral fertilizers and mulching on the quality of cabbage and kohlrabi, the content of nitrates (NO_3) and N, P, and K in order to maximally reduce the risk of increased intake of nitrate and possible consequences during the production process. The results of the research could be widely applicable in vegetable production.

MATERIAL AND METHODS

Cabbage, variety Adema, was planted on plots sized 6 m^2, with spacing between plants 40 × 60 cm, while kohlrabi, variety Volturno, was planted on plots of the same size, with spacing between plants 30 × 25 cm. The experiment was set up in Sombor, Serbia (45°43'02.0"N, 19°10'13.7"E), on chernozem (IUSS Working Group WRB, 2015). The experiment was set up by the split-plot method. The main plot included the experiment with mulching (using the black plastic sheeting) or without mulching. Sub-plot comprised nine fertilizing treatments, with organic and mineral fertilizers (well-rotted beef and pig manure and $N_{11}P_{11}K_{21}$, in different doses and combinations), Tab. 1. All treatments were irrigated in the same way. Sampling was done at the time of harvest. The size of the sample was reduced by the random elimination method so that several thickened kohlrabi stems were completely chopped off and a sample size of about 1 kg was taken. For cabbage, a part of each head was cut, all the pieces were chopped, and a sample was 1 kg, as well. All analyzes were performed on this sample in four replications.

The assessment of the influence of mulching and different types of fertilization was made based on the content of N, P, K, and NO_3 in the plant material. The yield was also analyzed. The soil properties and chemical composition of the applied manure were analyzed earlier by Bogdanović et al. (2011), Tab. 2. The spectrophotometric method was used to determine the nitrate content (Giné et al., 1983). The analysis also determined the total yield and percentage of dry matter in cabbage and kohlrabi (by drying the samples in an oven to a constant mass at a temperature of 70 °C) under the influence of the fertilization treatments.

Table 1. Fertilization treatments

Number	Mulching	No fertilization	Beef manure 20 t/ha	Pig manure 20 t/ha	300 kg/ha NPK	500 kg/ha NPK
1		□				
2	□	□				
3			□			
4	□		□			
5				□		
6	□			□		
7			□		□	
8	□		□		□	
9				□	□	
10	□			□	□	
11			□			□
12	□		□			□
13				□		□
14	□			□		□
15					□	
16	□				□	
17						□
18	□					□

Nitrogen concentration in kohlrabi and cabbage was determined as described by Kjeldahl (1883).
The concentration of P in plant material was established by the ammonium vanadate-molybdate method (MAFF/ADAS, 1986). The concentrations of K were determined by flame photometry.

Table 2. Soil properties of the chernozem before experiment setting and chemical composition of applied manure (Bogdanović et al., 2011)

Depth (cm)	pH H_2O	pH KCl	% $CaCO_3$	% humus	% N	mg P_2O_5 $100g^{-1}$	mg K_2O $100g^{-1}$	NH_4-N kg ha^{-1}	NO_3-N kg ha^{-1}
0-30	7.6	7.0	4.59	3.12	0.16	21.9	22.1	28.0	36.1
30-60	7.8	7.0	5.42	2.96	0.15	14.3	21.0	23.4	41.6

Manure type	pH H_2O	pH KCl	%N	%P	%K
Well-rotted beef manure	6.9	6.6	1.2	1.82	0.33
Composted pig manure	7.9	7.7	1.3	3.58	1.68

Statistical analysis was performed by Excel (Microsoft Inc.) and STATISTICA 14.0.0.15 (StatSoft, University License, 2021). The data were analyzed using descriptive statistics and ANOVA, followed by the LSD *post hoc* test (α=0.05).

RESULTS AND DISCUSSION

Different doses and combinations of organic and mineral fertilizers in the presence or absence of mulch significantly affected the yield of cabbage and kohlrabi. The yield of the control plants of cabbage significantly increased in the presence of mulch (70%), while in kohlrabi fertilization with 300 kg/ha NPK combined with mulch significantly affected the yield (44%), Fig. 1. Combined pig manure and NPK with mulching had a low influence on yield, less than 10% compared to the application without mulching.

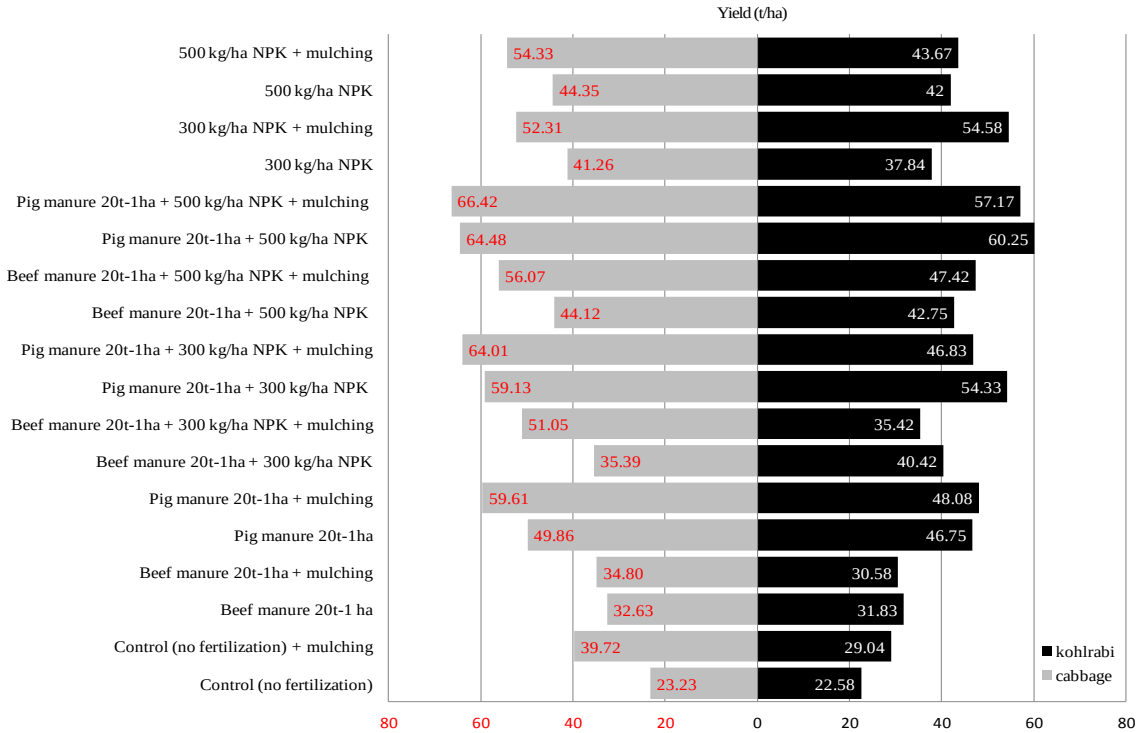

Figure 1. Cabbage and kohlrabi yield (t/ha) depending on the fertilization regime

The use of mulch was very efficient in cabbage as there was increase in yield under all treatments. The yield in the control plants (without fertilization) increased compared with some treatments when mulch was not used (20 t/ha beef manure and 20 t/ha beef manure + 300 kg/ha NPK), Fig. 1. The yield of kohlrabi was the highest when

fertilizing with pig manure 20 t/ha and with the addition of 500 kg/ha of NPK, and the yield was 2.67 times higher compared to the control. In cabbage, the above treatment also gave the highest yield, but with mulching it was 2.86 times higher compared to the control (Fig. 1). This can be explained by the composition of the applied fertilizers, as it was observed that the content of mineral elements was higher in pig manure (Tab. 2). Based on the experience and he needs of cabbage and kohlrabi as species that have short vegetation (about 70 days), the application of 20 t/ha of beef and pig manure is an appropriate amount with respect to the composition of that fertilizer and growing conditions (Tab. 3). A very high positive correlation was found between different kinds of fertilizers (Tab. 3).

Table 3. Correlations between yield (*) and concentration of nitrates in cabbage and kohlrabi as the effect of applied fertilizers

Cabbage	**NPK**	**Beef manure**	**Pig manure**
NPK		-0.4828	0.99398
Beef manure	***0.77905****		-0.5065
Pig manure	***0.97129****	***0.90279****	
Cabbage	NPK+mulch	Beef manure+mulch	Pig manure+mulch
NPK+mulch		0.47212	0.99248
Beef manure+mulch	***0.98300****		0.55552
Pig manure+mulch	***0.95632****	***0.98593****	
Kohlrabi	NPK	Beef manure	Pig manure
NPK		-0.9049	-0.8150
Beef manure	***0.98434****		0.57864
Pig manure	***0.95087****	***0.96810****	
Kohlrabi	NPK+mulch	Beef manure+mulch	Pig manure+mulch
NPK+mulch		0.26081	0.87251
Beef manure+mulch	***0.35028****		0.11686
Pig manure+mulch	***-0.336****	***0.92171****	

Large fluctuations in the content of nitrate depending on fertilizer were observed in both species (Fig. 2). Cabbage had the lowest concentration of nitrate by fertilizing with well-rotted beef manure, 20 t/ha, and the addition of 300 kg/ha of NPK (Fig. 2). The highest value of the nitrate content was when we used well-rotted beef manure, as well as pig manure. It was about three times higher than when beef manure with 300 kg of added NPK was applied. Although cabbage and kohlrabi belong to the group of vegetables with a high concentration of nitrates (1000-2500 mg/kg of fresh weight) (Santamaria, 2006), 28% of the applied fertilization treatments in cabbage and even 50% in kohlrabi caused significantly higher concentrations of nitrates with respect to the corresponding controls.

Pig manure in combination with 300 kg/ha NPK and mulching caused an increase in the nitrate content in kohlrabi (about 2 times) and cabbage (about 3 times), Fig. 2.

The harvesting season may affect the concentration of nitrates in some vegetables. For example, early cabbage in Serbia is harvested at the end of May and at the beginning of June, medium early cabbage in July, and late cabbage in October and November.

Some vegetables such as cabbage, spinach, etc. show lower accumulation of nitrate in samples collected during the summer, which directly points to the influence of climate on the nitrate content in plants (Metallana Gonzales et al., 2010). It is well known that kohlrabi is a vegetable that is exposed to a significant risk of nitrate accumulation in tissues. The changes in the nitrate content did not directly depend on the application of mulch. Fertilization had a much more significant effect on the nitrate content. It needs to be noted that the oral lethal dose of nitrate in humans is around 330 mg/kg body weight (Walker, 1990), and the obtained concentrations of nitrates are not troublesome when taking into account the number of vegetables that humans consume per day. Acceptable daily intake of nitrate in an adult human body, according to the European Food Safety Authority, is 3.7 mg/kg body weight/day (i.e. for a person with a body weight of 60 kg, it is 222.0 mg/day) (Brkić et al., 2017). Hence, if people take in the recommended amount of vegetables (up to 150 g/day), the variations in nitrates (12.59-55.28 mg/150 g portion of cabbage/day and 11.78-86.25 mg/150 g portion of kohlrabi/day) do not pose a health hazard. Serious danger may arise from a diet where people consume a large amount of low-calorie food, often cabbage or similar vegetables, and thus increase the uptake of nitrates which endanger their health.

Lošák et al. (2015) recommend the use of digestate in kohlrabi because it gives a significantly better yield as well as the qualitative characteristics of kohlrabi in relation to application of mineral fertilizers. Yields can be increased by about 18-19% with the use of mineral fertilizers and/or digestate compared to nitrogen treatment. Beef and pig manure with added 300 kg/ha $N_{11}P_{11}K_{21}$ reduced most of the content of nitrate immediately after sampling, 2-2.5 times less compared to the control (Fig. 2).

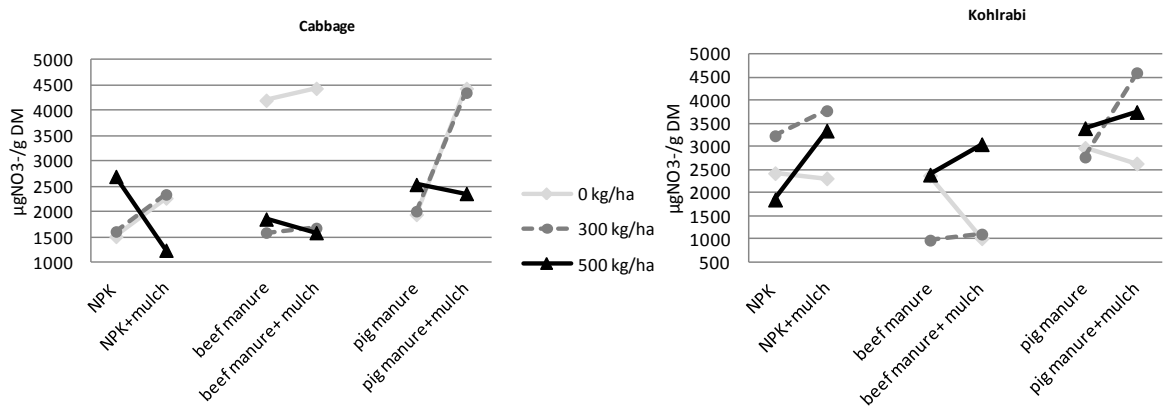

Figure 2. Nitrate concentration in cabbage and kohlrabi when applying different amounts of NPK (0, 300, and 500 kg/ha) as well as organic fertilizers (20 t/ha) with or without mulching

Studies about the correlation between soil, manure, and fertilizer chemical composition and the nutritional value of vegetables are not very frequent. Plants need potassium in high concentrations in early growth stages. High concentration of K can mitigate the effects of extreme conditions and allow the plants to reduce damage caused by osmotic stress (Kant & Kafkafi, 2002). Higher concentration of nitrogen in cabbage was determined when using pig manure + 300 kg/ha NPK rather than using a higher amount of NPK alone (500 kg/ha), Fig. 3. Guo et al. (2011) found that the fertilizer use efficiency and maintaining the quality of spring cabbage can be achieved by a combination of organic and mineral fertilizers, which is in line with our results on the medium early cabbage (Fig. 3, Fig. 4, and Fig. 5).

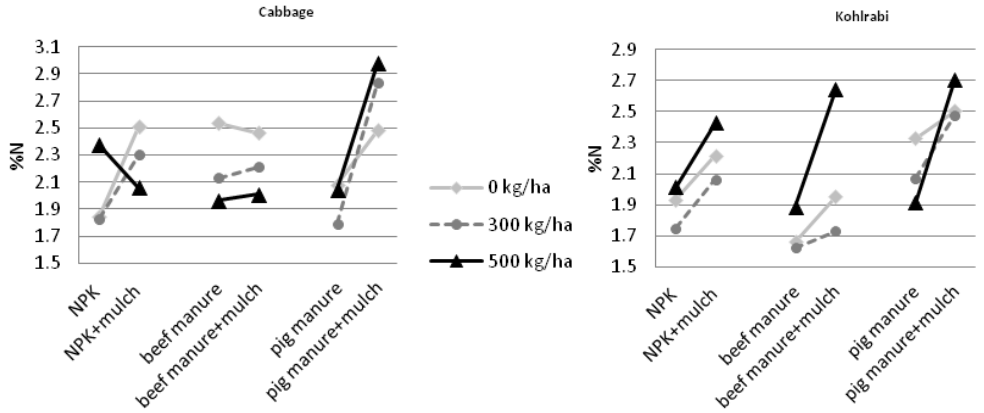

Figure 3. Concentration of N in cabbage and kohlrabi when applying different amounts of NPK (0, 300 and 500 kg/ha) as well as organic fertilizers (20 t/ha) with or without mulching

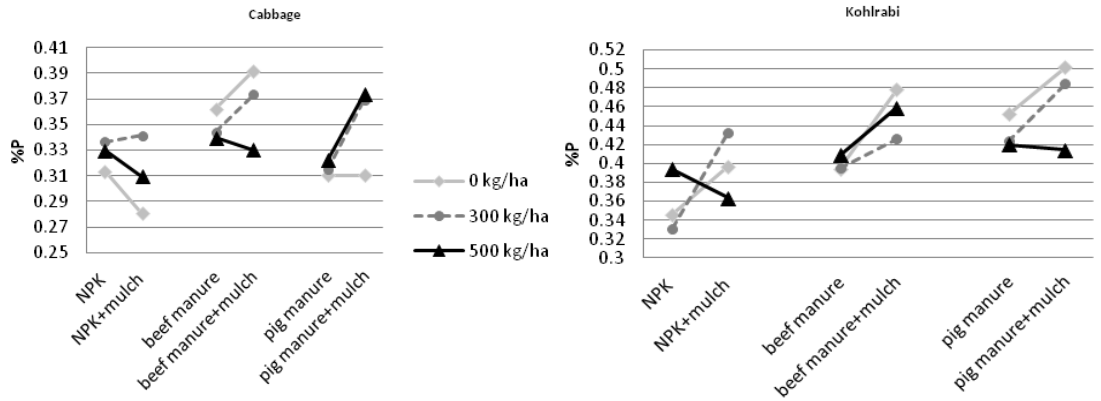

Figure 4. Concentration of P in cabbage and kohlrabi when applying different amounts of NPK (0, 300 and 500 kg/ha) as well as organic fertilizers (20 t/ha) with or without mulching

Kaur et al. (2005) also underline that by adding farmyard manure to the soil, its chemical and biological properties, in particular the content of N, P, and K, was improved. According to Chaves et al. (2004) uptake of mineral elements can be directly influenced by the chemical composition of manures, which was also confirmed in our experiment.

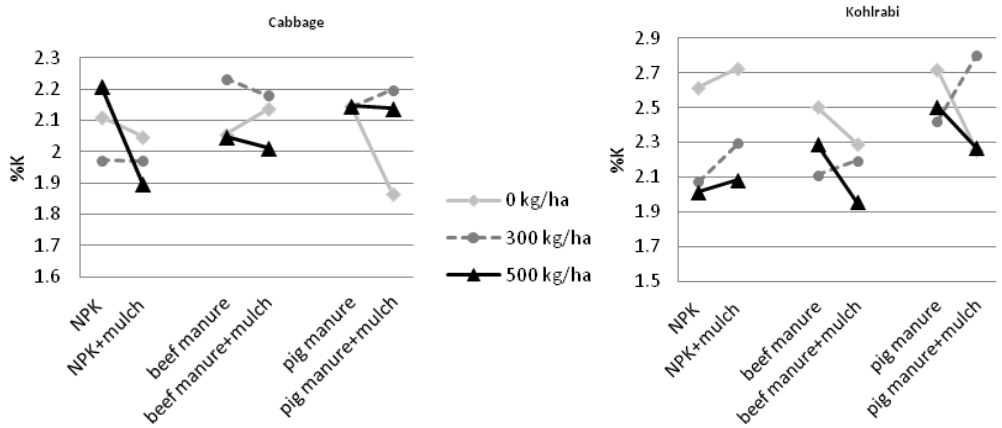

Figure 5. Concentration of K in cabbage and kohlrabi when applying different amounts of NPK (0, 300, and 500 kg/ha) as well as organic fertilizers (20 t/ha) with or without mulching

Although the quantity of fertilizers did not have a significant effect on N uptake by plants, in high N fertilization treatments, its uptake is generally higher (Laczi et al., 2017), which is in line with our results.

CONCLUSION

The combination of organic and mineral fertilizers is the most efficient, both in terms of quality and yield. The combination of fertilizers increased the yield, especially with the use of mulch. In contrast, for a lower nitrate presence, the combination of fertilizers without mulch gives better results in cabbage. A similar situation is with kohlrabi, with the exception of organic fertilizer with the addition of 300 kg/ha NPK, which was more convenient in terms of decreasing the nitrate content. The combination of organic and mineral fertilizers also enabled satisfactory adoption of NPK content for both plant species.

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Conflict of interest: The authors declare that they have no conflict of interest.

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