ACTA SCIENTIARUM POLONORUM
Acta Sci. Pol. Hortorum Cultus, 20(5) 2021, 25–32
https://czasopisma.up.lublin.pl/index.php/asphc ISSN 1644-0692 e-ISSN 2545-1405 https://doi.org/10.24326/asphc.2021.5.3
ORIGINAL PAPER
Accepted: 8.10.2020

EFFECTS OF DOSE OF PYROPHYLLITE ON YIELD AND QUALITY OF THE CABBAGE

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ABSTRACT

In this study was researched the influence of the pyrophyllite as a nutrient, bio-stabilizer, soil conditioner, as the adsorbent in different combinations and correlated standard quantitative relations with mineral fertilizers (NPK 15 : 15 : 15), on the yield and nutritional value of Bravo cabbage (*Brassica oleraceae* var. *capitata*). Within the examined factor of fertilization treatment, the following variances were represented: a_1 – 800 kg ha^{-1} NPK 15 : 15 : 15 (control plot), a_2 – 800 kg ha^{-1} NPK 15 : 15 : 15 + 2200 kg ha^{-1} pyrophyllite, a_3 – 800 kg ha^{-1} NPK 15 : 15 : 15 + 1700 kg ha^{-1} of pyrophyllite, a_4 – 800 kg ha^{-1} NPK 15 : 15 : 15 + 1200 kg ha^{-1} of pyrophyllite, a_5 – 800 kg ha^{-1} NPK 15 : 15 : 15 + 700 kg ha^{-1} of pyrophyllite. The purpose of this research was to determine the extent to which the components of the yield and nutritional quality of cabbage depend on the different applied doses of pyrophyllite. The results indicate the fact that the treatments with the application of higher participation of pyrophyllite had a positive effect on the weight and quality of the cabbage head in relation to the control variance.

Key words: pyrophyllite, soil condicioner, fertilizer, growth, nutritional quality

INTRODUCTION

Modern agricultural production is increasingly focused on the use of natural raw materials such as fertilizers, natural bio-stabilizers, bio-stimulators and soil conditioners, particularly in terms of better use of biological potential, yield and nutritional value of products. In recent years, in the most developed countries, the amount and value of obtained materials based on natural – non-metallic minerals is three to five times higher than the value of products based on metallic products [Harby Lab 2016]. The future shall largely depend on the stable and adequate supply of non-metallic natural mineral raw materials from the perspective of importance for economy and ecology and the supply shall be basic for industrial and agricultural production. Mineral raw materials have been applied increasingly in developed agricultural countries, almost in all sectors of economy, and particularly in agriculture, chemical and food industries [Stoiljković 2002].

In the agriculture the most interesting non-metallic raw materials are primarily: pyrophyllite, quartz, quartz sand, kaolin, feldspar and ceramic and refractory clays. The mentioned mineral raw materials, their physical, chemical, mineralogical and technological characteristics, ranking and selection of the best deposits for exploitation were intensively researched. Pyrophyllite is a dioctahedral 2 : 1 clay mineral with the chemical formula $Al_2Si_4O_{10}(OH)_2$. It resembles closely with talc and the only difference between them is that talc contains Mg^{2+} instead Al^{3+} in octahedral

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positions. Resemblance to the structure with talc and some other clay minerals indicate that pyrophyllite application in soil could also be effective in increasing soil's ability to hold nutrients and thus reducing leaching [Drits et al. 2012]. Prospects for wider use of pyrophyllite in agriculture are based on the feature of its high absorption capacity, high selectivity for some heavy metals and radionuclides [Hodžić 2016]. The same author explains that the quality of pyrophyllite in terms of physical and chemical parameters significantly affects soil fertility, improves the structure and ability to retain moisture in the soil, retains, regulates and distributes nutrients and water to the plant when it is needed mostly, and in same time for its crystal structure binds metals and polycyclic hydrocarbons (PAHs), and as such has the role of a bio stabilizer.

Application of pyrophyllite under experimental conditions can reduce the use of mineral fertilizers in lettuce production with outadverse effects on its yield and quality, especially where the pyrophyllite is applied in the amount of 25% of recommended fertilizer rate [Murtić et al. 2020a]. The same author, in another study, also found a positive effect of pyrophyllite treatments to reduce heavy metals accumulation in the leaves of potato grown on the studied soil. The results of this study indicate that pyrophyllite treatment could be an effective technique for improving the environmental quality of soils and alleviating the hazards of heavy metals to plants [Murtić et al. 2020b].

One of the pyrophyllite deposits is located in BiH in city of Konjic, area Parsovići [Andrić 2010]. In the research of the resources of the mine in Parsovići. Andric found out that in addition to pyrophyllite shale, which have purple, grey and white shades and makes up 50% of the ore there is also presence of quartz, sericite, kaolinite, carbonates of Ca and Mg and hydroxides of iron.

Although pyrophyllite is ecologically and economically more profitable and more efficient than the application of industrial fertilizers, today in BiH it is only symbolically used in a wider production practice. In the context of research activities, exact and applied research was conducted on the possibilities of pyrophyllite application primarily in forestry, agriculture and pharmaceutical industry (against Escherichia coli as supplements as detoxifiers and alkalisers) [HarbyLab] 2016.

The purpose of this research was to determine whether the pyrophyllite, as a bio-stabilizer, can influence with its functional components in intensity of nutrient uptake in cabbage cultivation with the objective to reduce the use of mineral fertilizers, better nutritional value of cabbage.

The obtained results could serve as a recommendation to producers for sustainable, cheaper and better quality fertilisation of cabbage, which would give acceptable results in the quality and yield of cabbage and in the long-term preservation and improvement of soil quality.

MATERIALS AND METHODS

The field experiment was set up on the experimental land of the Agriculture Institute of the Federation of Bosnia and Herzegovina in Sarajevo during years 2018 and 2019 by using the block method with a random arrangement of plots and repeating it for four times.

More precisely, the experimental plot is located in Butmir (43°49'13.58"N, 18°19'23.59"E). Sowing of seedlings was in the first decade of January 2018. and 2019 year. Seedlings are produced in containers. Prior to sowing, the containers were filled with Klasman substrate. Before planting basic land cultivation was performed by ploughing on the depth of 25 cm and followed by pre-sowing soil preparation by tilling. The experimental plots were 7 m^2 (1.4 m wide × 5 m long). On the basic experimental plot 20 cabbage plants were planted per treatment in two-row strips at a distance of 70 cm between rows and 50 cm in a row. The distance between the plots was 10 cm.

The total experimental area was 360 m^2 with free space between the experimental plots. In the experiment, mineral fertilizer NPK formulation (15 : 15 : 15) was used in a standard amount of 800 kg ha^{-1}combined with different doses of pyrophyllite. Within the examined factor of fertilization treatment, the following variances were represented: variant 1 (without pyrophyllite), variant 2 (2.2 t pyrophyllite ha^{-1}, variant 3 (1.7 t pyrophyllite ha^{-1}), variant 4 (1.2 t pyrophyllite ha^{-1}), variant 5 (0.7 t pyrophyllite ha^{-1}). The pyrophyllite in micronized form (granulations 0–2 mm) was used and is from the deposit Parsovići, owned by the company AD Harbi Ltd. Sarajevo. A Bravo hybrid

(*Brassica oleraccea* var. *capitata*) was used for the experiment. Features of the Bravo hybrids are: the heads are round, bluish green colour of the outer leaves, the weight of the cabbage head is about 2–3 kg, the growing season is 90–95 days, the recommended time of harvest is in autumn. Hybrid Bravo is a Dutch hybrid popular mainly for the fresh consumption and is also used for fermentation. The Bravo hybrid is characterized by tightly compacted cabbage heads, good yield and uniformed morphological characteristics.

The basic features of the soil on which the experiment was set up were: pH in water 6.96, pH in KCL 5.90; content N 0.17%; content $CaCO_3$ 0.5%; content humus 2.26%; P_2O_5 7.65 mg 100 g^{-1}, K_2O 22.30 mg 100 g^{-1}. Soil analysis was performed in the Institute Agropedology of Federation of Bosnia and Herzegovina according to the standards: BAS ISO 10390:2005, pH, $CaCO_3$, content N according to BAS ISO 11261:2000, content P_2O_5 and K_2O Al – method.

During the cabbage growing, standard cabbage care measures were taken. Protection of cabbage plants was carried, preventively, on two occasions. In the first treatment Mospilan was used as the insecticidal activity. In the second treatment Pužomor was used. Cabbage was protectively treated with the insecticide Decis. All treatments were performed foliar during the evening hours. Irrigation of cabbage was done only during the production of seedlings. There was no irrigation during the experiment. The research process is performed in the "dry farming" system.

The content of total dry matter, sugar, protein, cellulose and vitamin C were analyzed in the nutritional components of the fresh cabbage. Dry matter (%) was determined by drying the plant material at a temperature of 105°C to a constant mass. Luff-Schoorl method was used to determine the total sugars (%). Kjeldahl method was used to determine the proteins (%). Method BAS ISO 5498 was used to determine the cellulose (%). HPLC method was used to determine the vitamin C (mg 100 g^{-1}).

The obtained results were processed by the method of analysis of two-factorial experiment (ANOVA) using SPSS 4,5 software. The assessment of the significance of individual examined factors and their interrelation were tested on the basis of the LSD test for significance levels of 1% and 5%.

Characteristics of the research area

Land characteristics. The land at the Butmir location, on which the experiment was set up according to the classification [Ćirić 1984], belongs to the type of brown soil on the phyllites. According to the mechanical composition, the brown soils on the filters are predominantly clay and loamy clay, which means that particles of the category below 0.01 mm dominate.

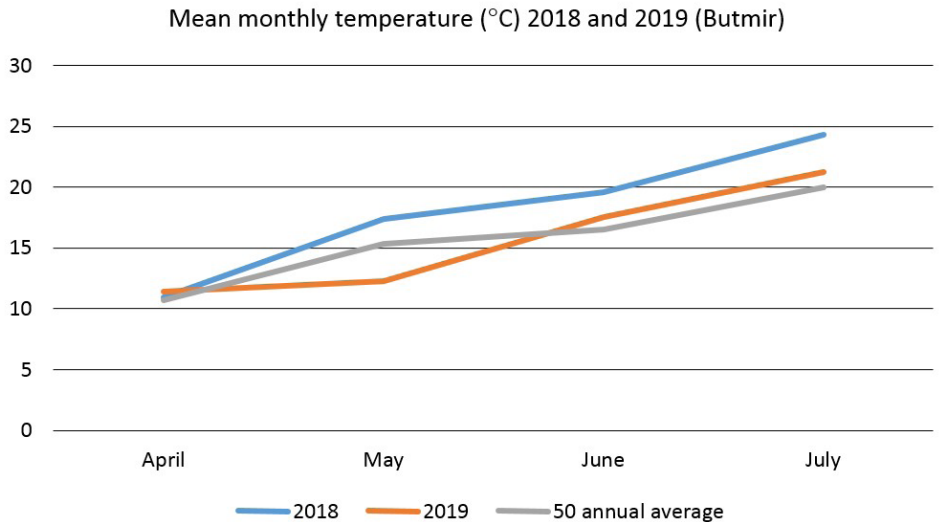

Fig. 1. Temperature conditions and precipitation in the years of the experiment

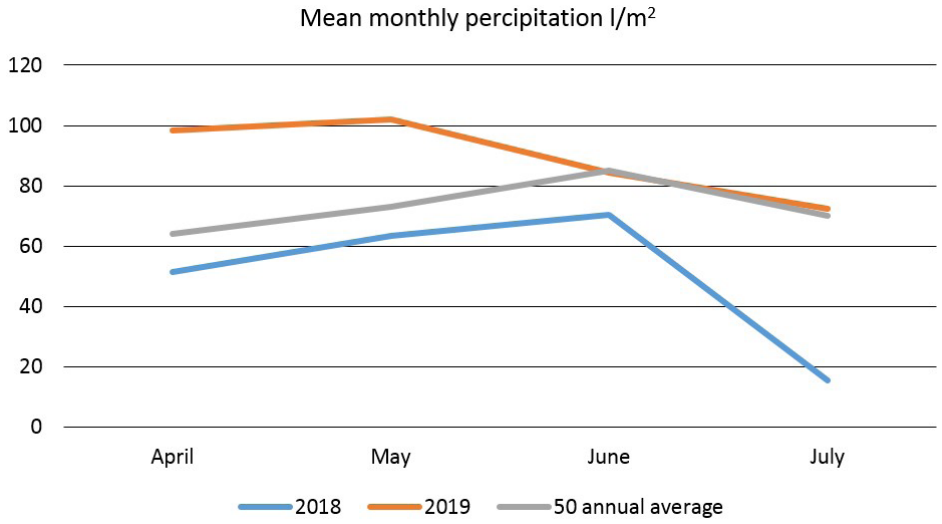

Fig. 2. Mean monthly precipitation

Their content ranges from about 55–75%. Particles of 0.05–2 mm in size are distributed at greater soil depth.

Climatic characteristics

Data from the Federal Meteorological Institute in Sarajevo were used to analyze climatic conditions during the survey. Air temperature with precipitation is the meteorological element that most participates in the formation of the climate of a certain area. Mean annual temperature in 2018 year was 11.9°C. Mean annual temperature in 2018 year was 10.16°C (Fig. 1).

The distribution of precipitation was uneven. The highest precipitation is during the spring and early summer period. However, in the summer period when they are most needed, the lack of precipitation is pronounced in both years of research (Fig. 2).

RESULTS AND DISCUSSION

During the analysis of the influence of the examined factor was recorded the significant effect of the pyrophyllite dose on the weight of the cabbage head and the total yield.

Maximum weight of cabbage heads was in the variance 2 in both years and significantly is higher compared to the control.

In accordance with the data presented in Table 1 – it can be concluded that there are statistically significant differences within particular variances. Statistical significance was shown at the variance 2 in relation to all other variances, while the variance 5 did not show statistical significance compared to the control. The variances 3 and 4 in relation to the control also showed statistical significance. Based on the average weight of cabbage plants, it can be concluded that the highest average weights of cabbage heads in both measurements had the plants in the variance number 2 with the highest applied amount of pyrophyllite.

Based on the results of the analysis of the variance, can be concluded that there were statistically significant differences in specific variance. The statistical significance was shown by the variance number 2 in relation to all other variances, while variance 5 did not show statistical significance compared to control. Variances 3 and 4 in relation to the control also showed statistical significance. Based on the average value of cabbage head yield, it can be concluded that the highest average yields of cabbage in both years of research had plants in the variance 2 with the highest amount of pyrophyllite applied.

The content of dry matter in the fresh cabbage of Bravo hybrids in year 2018 (control) was 7.56%, while in the variance 2 was 8.80%. The reduction in the amount of pyrophyllite in variances 3, 4 and 5 had the effects on reducing the value of dry matter. In the variance 5 with the smallest amount of applied pyro-

Table 1. Weight of cabbage head ($\bar{x}$ – kg/plant) depending on year and fertilization ± standard deviation

Part A

Year	Variant					Average
	1	2	3	4	5	
2018	1.02 ±0.03	1.40 ±0.02	1.21 ±0.08	1.10 ±0.06	1.02 ±0.07	1.15[a]
2019	0.98 ±0.05	1.15 ±0.03	1.10 ±0.07	1.03 ±0.03	1.04 ±0.22	1.06[b]
Average	1.00[d]	1.28[a]	1.16[b]	1.06[c]	1.03[cd]	

Part B

F exp year	24.33*
F exp variant	29.36*
F exp Y × V	6.27*
F crit	3.95 2.47 2.47
$LSD_{0.05}$	0.03
$LSD_{0.01}$	0.03

Variants: 1 – control (without pyrophyllite); 2 –2.2 t pyrophyllite ha^{-1}; 3 – 1.7 t pyrophyllite ha^{-1}; 4 – 1.2 t pyrophyllite ha^{-1}; 5 – 0.7 t pyrophyllite ha^{-1}
* Statistically significant difference; different letters indicate significant difference in mean values for the examined traits in the years and between the two years.

Part A

Year	Variant					Average
	1	2	3	4	5	
2018	29.14 ±1.02	40.26 ±2.52	34.85 ±1.09	31.72 ±0.60	28.72 ±0.40	32.936[a]
2019	27.33 ±0.34	32.85 ±0.40	31.48 ±0.22	30.44 ±0.84	27.29 ±0.38	29.876[b]
Average	28.24[d]	36.56[a]	33.17[b]	31.08[c]	28.00[e]	

Part B

F exp year	544.9*
F exp variant	597.9*
F exp Y × V	76.8*
F crit	3.95 2.47 2.47
$LSD_{0.05}$	0.18
$LSD_{0.01}$	0.24

Explanations as in Table 1.

phyllite the value of dry matter was 7.58% and had no statistical significance compared to the control.

In the year 2019, in accordance with the trends from the previous year, the highest percentage of dry matter was at the variance 2 and amounted to 10.37%. Decreasing the amount of pyrophyllite in the variances 3, 4 and 5 the value of dry matter decreased, and in the variance 5 with the lowest amount of applied pyrophyllite the amount of dry matter was 8.42% and had no statistical significance in relation on control (8.40%). The obtained values are in accordance with the statements of some authors at standard fertilization with NPK fertilizers [Lazić 1998, Kantoci 2006]. According to the obtained results, the fresh cabbage was of satisfactory quality with the amount of dry matter and indicates the degree of ripeness of cabbage.

The content of protein in both testing years showed different values in the context of different amounts of pyrophyllite applied. In the year 2018, the highest percentage of protein was at variance 2 amounted to 1.18%. Reduction of the amount of pyrophyllite in the variances 3, 4 and 5 the value of protein decreased, and in the variance 5 with the lowest amount of applied pyrophyllite the value of protein amounted to 1.13% and had no statistical significance compared to the control (1.14%).

In the year 2019, the highest value of protein was at the variance 2 amounted to 1.22%. By reducing the amount of pyrophyllite, the protein content also decreased, and in the variance 5 amounted to 1.19%, identical to the control. The cellulose content in both testing years showed different values in the context of different amounts of pyrophyllite applied. In the year 2018, the highest percentage of cellulose was at the variance 2 and amounted to 0.97%. Reduction of the amount of pyrophyllite in the variances 3, 4 and 5 the value of cellulose decreased, and in the variance 5 the amount of cellulose was 0.86% and there was no statistical significance compared to the control (0.85%).

In the year 2019, according to the trends from the previous year, the highest percentage of cellulose was at the variance 2 and amounted to 1.05%. Reduction of the amount of pyrophyllite in the variances 3, 4 and 5 the value of cellulose decreased, and in the variance 5 the cellulose content amounted to 0.80% and had no statistical significance compared to the control (0.81%) The obtained values for the stated chemical parameters are in accordance with the statements of some authors [Holzapfel et al. 2003, Martínez et al. 2010].

The content of total sugar and the content of soluble dry matter represent the basic parameter of quality and technological ripeness of vegetables or cabbage [Cvetković 2014]. The content of total sugars in both years of testing had the highest value in the variance 2. By reducing the amount of pyrophyllite, the content of total sugars also decreased, and in the variances 5 was 2.26%, identical to the control.

In the year 2019, the highest value of total sugars was at the variance 2 and was 3.19%. By reducing the amount of pyrophyllite, the content of total sugars also decreased, and in the variance 5 with the lowest applied amount of pyrophyllite amounted to 2.30%, statistically insignificant compared to the control (2.28%). The results showed that only at the variance number two the minimum characteristics of sugar content for the fermentation process of 3 to 4% is satisfied [Niketić 1988, Malinowska-Pańczyk 2012].

Vitamin C is an important factor in human nutrition. Namely, this vitamin participates in various biological processes and is the strongest antioxidant among vitamins. According to the results of the research, the content of vitamin C in the year 2018 in the control was 80 mg per 100 g of cabbage, while in the variance 2 amounted to 86 mg per 100 g of cabbage. Decreasing the amount of pyrophyllite in the variances 3, 4 and 5 the value of vitamin C decreased, and in the variance 5 the value of vitamin C amounted to 81mg per 100 g of cabbage and had no statistical significance in relation to the control.

In the year 2019, according to the trends from the previous year, the highest percentage of vitamin C was at the variance 2 and amounted to 105 mg per 100 g of cabbage. Reducing the amount of pyrophyllite in the variances 3, 4 and 5 the value of vitamin C decreased, so that in the variance 5 the value of vitamin C was 84 mg per 100 g of cabbage and is identical as in the control, what indicates the fact that the application of pyrophyllite in the amount of 0,7 t pyrophyllite ha^{-1} has no effect on the nutritional value of cabbage. According to the obtained results the fresh cabbage was of satisfactory quality with the amount of vitamin C and indicates the degree of the ripeness of the cabbage.

The results are in line with the study of organic fertilization of cabbage [Matotan 2004].

Table 3. Components of the nutrition value of the cabbage at the Bravo variety

Part A

Components of the nutrition value of cabbage	Year	Variant					Average
		1	2	3	4	5	
Dry matter (%)	2018	7.56	8.80	8.18	7.66	7.58	7.96^{b}
	2019	8.40	10.37l	9.6	8.55	8.42	9.07^{a}
	average	7.98^{c}	9.585^{a}	8.89^{b}	8.105^{c}	8^{c}	
Proteins (%)	2018	1.14	1.18	1.16	1.15	1.13	1.15^{ns}
	2019	1.19	1.22	1.20	1.19	1.19	1.20^{ns}
	average	1.17^{ns}	1.2^{ns}	1.18^{ns}	1.17^{ns}	1.16^{ns}	
Total sugars (%)	2018	2.26	3.32	2.29	2.29	2.26	2.28^{ns}
	2019	2.28	3.19	2.88	2.35	2.30	2.6^{ns}
	average	2.27^{ns}	2.76^{ns}	2.59^{ns}	2.32^{ns}	2.28^{ns}	
Cellulose (%)	2018	0.85	0.97	0.88	0.88	0.86	0.89^{ns}
	2019	0.81	1.05	1.00	0.92	0.80	0.92^{ns}
	average	0.83^{ns}	1.01^{ns}	0.94^{ns}	0.9^{ns}	0.83^{ns}	
Vitamin C (mg per 100 g)	2018	80	86	84	84	81	83^{b}
	2019	84	105	96	88	84	91.4^{a}
	average	82^{d}	95.5^{a}	90^{b}	86^{c}	82.5^{d}	

Part B

Specification	F exp Year	F exp Y × V	F exp variant
Dry matter	9.27*	3.01*	0.19^{ns}
Proteins	0.02^{ns}	0.00^{ns}	0.00^{ns}
Total sugars	0.75^{ns}	0.28^{ns}	0.23^{ns}
Cellulose	0.01^{ns}	0.04^{ns}	0.01^{ns}
Vitamin C	529.2*	190.95*	72.45*

F crit	4.35
	2.87
	2.87
$LSD_{0.05}$	0.53
$LSD_{0.01}$	0.67

Explanations as in Table 1; ns – no statistical significance.

CONCLUSION

On the basis of the two years research on the influence of the pyrophyllite as a nutrient and bio-stabiliser on the components of yield and nutritional value of cabbage head of the Bravo variety the following can be concluded.

The obtained results confirmed the efficiency of pyrophyllite as a nutrient on the yield component of cabbage head (*Brassica oleraceae* var. capitata L.) of the Bravo variety. The variance with the highest dose of pyrophyllite statistically showed the greatest significance on the yield of headed cabbage in relation to all other variances.

The variance with the lowest amount of pyrophyllite applied did not show statistical significance compared to the control.

The results of the measured components of the nutritional values of cabbage showed that in the variance 2 with the highest application of pyrophyllite in relation to the control, statistical significance was shown in both years of research. The increased nutritional values in cabbage are proportional to the amount of pyrophyllite applied.

The application of pyrophyllite in the amount of less than 0.7 t pyrophyllite ha^{-1} no effect on the nutritional value of cabbage

Based on the results obtained by this research, we conclude that for successful and sustainable production of Bravo cabbage we can reliably recommend the use of 2.2 t pyrophyllite ha^{-1} in the amount of in combination with mineral fertilizer NPK 15 : 15 : 15 in the amount of 0.8 t ha^{-1}.

It would be useful and rational to continue the research with the application of the pyrophyllite on a wider range of crops from the structure of plant production, certainly with a focus on the organic production aspects of primary plant products.

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