ELVYRA JARIENĖ [1]
HONORATA DANILČENKO [1]
NIJOLE VAITKEVIČIENĖ [1]
AGNIESZKA KITA [2]
[1] Aleksandras Stulginskis University, Agronomy Faculty, Institute of Agriculture and Food Sciences, LT-53361 Kaunas district, Lithuania
[2] Wroclaw University of Environmental and Life Sciences, Faculty of Food Science, Poland

Effects of biodynamic preparations on the growth and yield parameters of potatoes with coloured flesh
Short Communication

Wpływ preparatów biodynamicznych na wzrost i plonowanie bulw ziemniaków o kolorowym miąższu
Komunikat

Biodynamic agriculture is one of the organic agricultural farming methods. Different from organic farmers, biodynamic farmers add eight specific preparations (made from cow manure, silica, and various plants) to improve crops growth and nutrient composition. In 2012–2013, in organic farm (Prienai district), potato cultivars with coloured flesh were grown for research. The aim of two years' research was to evaluate effects of biodynamic (BD) preparations (500 and 501) on the growth and yield parameters of the coloured fleshed potatoes. An experiment included two factors: I — three potato cultivars (purple fleshed — Vitelotte, Blue Congo and red-fleshed Red Emmalie), II — using of BD preparations in field sprays (four treatments: 1. Control without BD preparations; 2. BD preparation 500; 3. BD preparation 501; 4. complex application of BD preparations (500+501). The individual productivities of potato plants were analyzed in the field experiment (chlorophyll content index values of leaves, tuber weight per plant and tuber number per plant). The results revealed that combination of BD preparations (500 + 501) was the best among all the treatments for most of the growth and yield parameters under study. It was found, that, compared with the control variant, combination of BD preparations (500 + 501) substantially increased the chlorophyll content index in leaves, the weight and number of tubers per plant of cvs. Blue Congo and Red Emmalie. BD preparation 501 substantially increased the chlorophyll content index in leaves of Red Emmalie at 9^{th} (1.07 times) and 13^{th} (1.13 times) week, and of Blue Congo only at 9^{th} (1.07 times) week after planting. However, more research is needed to determine whether the BD preparations affect growth and yield parameters of colour-fleshed potato tubers.

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Key words: biodynamic preparations, coloured fleshed potato, growth and yield parameters

Rolnictwo biodynamiczne jest jedną z metod rolnictwa ekologicznego. W uprawie biodynamicznej, w celu poprawy jakości plonu i kompozycji składników odżywczych w surowcu, wykorzystuje się osiem konkretnych preparatów (z nawozu krowiego, krzemionki i różnych roślin). Materiałem użytym do badań były ziemniaki odmian o kolorowym miąższu uprawiane w gospodarstwie ekologicznym (powiat Prienai) w latach 2012–2013. Celem badań było określenie wpływu preparatów biodynamicznych (BD) 500 i 501 na parametry wzrostu i wydajność plonu ziemniaków o kolorowym miąższu. Eksperyment obejmował dwa czynniki: I — odmiany ziemniaka (dwie odmiany ziemniaków z niebieskim miąższem — Blue Congo i Vitelotte oraz jedna z czerwonym — Red Emmalie), II — wykorzystanie preparatów biodynamicznych do oprysków gleby i roślin (cztery zabiegi: 1. kontrola bez preparatów BD 2. z zastosowaniem preparatu biodynamicznego 500; 3. z zastosowaniem preparatu biodynamicznego 501; 4. z zastosowaniem obu preparatów biodynamicznych (500 + 501). Produktywność roślin ziemniaka oznaczano w doświadczeniu polowym (wartość indeksu zawartości chlorofilu w liściach, masę i liczbę bulw pod krzewem). Najlepsze parametry wzrostu uzyskano przy zastosowaniu kombinacji preparatów biodynamicznych (500 + 501). Stwierdzono, że w porównaniu z wariantem kontrolnym stosowanie obu preparatów (500 + 501), istotnie zwiększyło zawartość chlorofilu w liściach oraz masę i liczbę bulw z jednej rośliny w odmianach ziemniaka Blue Congo i Red Emmalie. Preparat 501 istotnie zwiększał wskaźnik zawartości chlorofilu w liściach odmiany Red Emmalie w 9 (1.07 razy) i 13 (1.13 razy) tygodniu, a Blue Congo tylko w 9 (1.07 razy) tygodniu po posadzeniu. Niezbędne są jednakże dalsze badania, które pozwolą na ustalenie czy preparaty biodynamiczne istotnie wpływają na parametry wzrostu i plonowanie bulw ziemniaka o kolorowym miąższu.

Słowa kluczowe: parametry wzrostu i plonu, preparaty biodynamiczne, ziemniak o kolorowym miąższu

INTRODUCTION

Coloured potatoes (*Solanum tuberosum* L.) have attracted the attention of researchers as well as purchasers because of their antioxidant activities, appearance and taste. The antioxidant activity in these potatoes is related to the presence of anthocyanins, flavonoids, ascorbic acid, tocopherols, alpha-lipoic acid and selenium. Consequently, coloured potatoes have the potential to be one of the most significant sources of antioxidants in the human diet (Lachman et al., 2005; Nayak et al., 2011; Jarienė et al., 2013). In order to preserve the nutritive value of these potatoes, one needs to look for alternative farming methods.

Like organic farming, the products of biodynamic agriculture are nutritionally superior and they taste better than the conventional foods, besides having the potential to mitigate some of the negative effects of chemical agriculture (Steiner, 1996).

Biodynamic agriculture was developed in the 1920 s in response to concerns from farmers about the deteriorating soils and health of their farms (Steiner, 1993). Similar to organic agriculture, biodynamics eliminates synthetic chemical fertilizers and pesticides. A major difference is that biodynamic farmers add eight specific preparations to their soils, crops, and composts to enhance soil and crop quality and to stimulate the composting process (Zaller and Kopke, 2004). In order to promote efficient cycling of nutrients, a series of eight fermented herbal and manure based preparations numbered 500 through 507 are applied regularly, in small quantities to the soil, compost and crops.

Some biodynamic farmers make the preparations themselves while others buy them from certified biodynamic associations or experienced practitioners (Reganold, 1995; Koepf et al., 2001).

The preparation 500 consists of high quality farmyard manure, fresh or aged, put in bovine horns, then buried at autumn and dug up in spring, after that it can be stored under controlled conditions for some months and finally sprayed to the soil (Koepf et al., 2001).

Horn silica (501) is powdered quartz (rock crystal) put in a bovine horn and processed as horn manure. A very small quantity of the 501 is then dissolved in water and sprayed on the standing crop, mostly at flowering stage: it would reinforce the plant against pests and diseases and improve its nutritional properties, flavours and shelf-life (Koepf et al., 2001; Catellani, 2006). These two BD preparations are believed to work synergistically, with preparation 500 mainly improving the overall soil fertility, and preparation 501 being active in enhancing the plant physiological response to the light radiation (Spaccini et al., 2012).

Biodynamic preparations are added to the soil or to composting organic material always in very low doses of a few grams per ton of soil/compost material. Therefore, the primary purpose of these compounds is not to add nutrients, but to stimulate the processes of nutrient and energy cycling, to affect decomposition/building of humus and to improve soil and crop quality (Raupp, 1999).

The main aim of this study was to establish effects of biodynamic (BD) preparations (500 and 501) on the growth and yield parameters of the colour-fleshed potatoes.

MATERIALS AND METHODS

Field experiment was carried out in 2012-2013 in organic farm (Prienai district). When applying biodynamic (BD) preparations, potatoes were grown using the traditional potato growing technology (Ražukas, 2003). They were planted in May, and harvested in September. The field experiment was carried out in four replications. Variants of replications were arranged randomly. The overall field size of potato experiment was 17.5 m^2 whereas the size of the accounting field was 10 m^2.

Agrochemical soil indicators were following: weakly acidic (pH_{KCl} 6.86), phosphorus (166.1 $mg \cdot kg^{-1}$), very high in potassium (248.8 $mg \cdot kg^{-1}$) and low in nitrogen (0.142%).

An experiment of two factors was carried out: I – three potato cultivars with coloured tuber flesh (Vitelotte and Blue Congo — blue and Red Emmalie — red), II — biodynamic (BD) preparations — 500 and 501 — used for potato field spraying. There were four treatments to evaluate the effectiveness of BD preparations: 1. control (BD preparations were not used); 2. application of BD preparation 500 (the soil was sprayed two weeks before the planting of potatoes with 1% solution); 3. application of BD preparation 501 (two times early in the morning potato leaves were sprayed with 0.5% solution in the VIII and IX stages of organogenesis); 4. complex application of BD preparations (500+501) (two weeks before the planting of potatoes the soil was sprayed with 1% solution of BD preparation 500 and two times early in the morning potato leaves

were sprayed with 0.5% solution of BD preparation 501 in the VIII and IX stages of organogenesis).

BD preparations (500 and 501) investigated in the experiment, were purchased in the Biodynamic Preparations Centre, Germany. During experiment it was evaluated values of chlorophyll content index (CCI) in leaves of potatoes (chlorophyll content meter CCM 200 Plius, Opti-Science, Tyngsboro, MA, USA) — in the 9^{th} and 13^{th} week after the planting. Ten plants were randomly selected in each replication. The CCM-200 plus uses absorbance to estimate the chlorophyll content in leaf tissue. Two wavelengths were used for absorbance determinations. One wavelength falls within the chlorophyll absorbance range while the other one serves to compensate for mechanical differences such as tissue thickness. The device measures the absorbance of both wavelengths and calculates a chlorophyll content index (CCI) value that is proportional to the amount of chlorophyll in the sample. The average tuber mass per plant, expressed in $g \cdot plant^{-1}$ and tuber number per plant were also assessed.

Soil analyses were conducted at the Laboratory of Food Raw Materials, Agronomic and Zootechnical Research of Aleksandras Stulginskis University. Soil pH_{KCl} was established by the potentiometric method in 1N KCl extract. The amount of total nitrogen in the soil was established by the Kjeldahl method. The amount of available phosphorus was determined by the CAL method using a spectrophotometer as well available potassium content using a flame photometer.

Statistical analysis was performed using two-way ANOVA (STATISTICA software). Statistical significance was considered at $p<0.05$. Arithmetic means and standard deviations of research data were calculated with EXCEL program.

RESULTS AND DISCUSSION

Values of chlorophyll content index (CCI) are directly proportional to the total content of chlorophyll in leaves. According to the CCI of the foliage, it is possible to predict the yield and to accurately determine its relationship with index values recorded during various stages of growth (Spaner et al., 2005; Gianquinto, 2004; Zebarth et al., 2007; Janušauskaitė, 2009). Results of our research have shown that CCI values in potato leaves depend on the cultivar, BD preparations used and age of plants (Table 1). The highest values of CCI were found in the leaves of cv. Red Emmalie 9 and 13 weeks after planting of potatoes. In all the measurements the lowest CCI values were determined in cv. Vitelotte leaves. It is stated in the literature that the pigment content may be influenced by architectonics of the plant's leaves, leaning angle towards the sun which varies in different varieties (Long et al., 2006).

Our research results have shown that in comparison with control, complex using of BD preparations (500 + 501) substantially increased CCI values in cvs. Blue Congo and Red Emmalie leaves 9 (respectively 1.10 and 1.08 times) and 13 (respectively 1.25 and 1.16 times) weeks after planting whereas the use of preparations in cv. Vitelotte had no significant effect. Comparing with control, BD preparation 501 substantially increased the CCI values in cv. Red Emmalie leaves after 9 (1.07 times) and 13 (1.13 times) weeks

whereas in Blue Congo only 9 (1.07 times) weeks after potato planting (Table 1). Tegethoff and Koepf (1993) also found that horn-silica (BD preparations 501) spray increased chlorophyll content in bush beans. BD preparation 500 did not affect CCI values in the leaves of grown cultivars.

Plant age also had a significant influence on the CCI values. Essentially negative effect on CCI values was established after 13 weeks of potato planting (Table 1). Poljak and others (2008) determined that CCI values significantly decreased when plant got older.

Table 1

Effects of biodynamic (BD) preparations on chlorophyll content index values (CCI) of potato plants during growing season
Wpływ preparatów biodynamicznych na wartości indeksu zawartości chlorofilu (WIK) w liściach roślin ziemniaka podczas wegetacji

Treatment Doświadczenie	Chlorophyll content index values (CCI) Wartość zawartości chlorofilu (CCI)	
	9 weeks after planting 9 tygodni po posadzeniu	13 weeks after planting 13 tygodni po posadzeniu
	Blue Congo	
Control without BD preparations	20.46 ± 0.97 [b]	8.63 ± 1.17 [b]
BD preparation 500	20.68 ± 1.37 [ab]	9.70 ± 0.81 [b]
BD preparation 501	21.99 ± 1.93 [a]	9.36 ± 0.75 [b]
BD preparations 500 + 501	22.47 ± 1.91 [a]	10.80 ± 0.77 [a]
	Vitelotte	
Control without BD preparations	14.93 ± 1.05 [a]	6.76 ± 0,90 [a]
BD preparation 500	14.15 ± 1.94 [a]	7.13 ± 0.80 [a]
BD preparation 501	15.80 ± 0.86 [a]	7.88 ± 1.03 [a]
BD preparations 500 + 501	15.91 ± 1.34 [a]	7.32 ± 1.07 [a]
	Red Emmalie	
Control without BD preparations	32.49 ± 1.91 [b]	19.45 ± 1.38 [b]
BD preparation 500	32.40 ± 1.71 [b]	19.43 ± 1.96 [b]
BD preparation 501	34.92 ± 1.87 [a]	22.10 ± 1.15 [a]
BD preparations 500+ 501	34.99 ± 1.99 [a]	22.50 ± 1.59 [a]

*— Means located on the same column and marked with different letters differ significantly at p<0.05
* — Wyniki znajdujące się w tej samej kolumnie i oznaczone różnymi literami różnią się istotnie, gdy p <0,05

Potato yield is determined by the number and weight of tubers per plant (Čeponienė, 2002). The largest number and weight of tubers per plant were determined in cv. Red Emmalie whereas the smallest — in cv. Blue Congo (Table 2).

It was established that in comparison with control, only the complex of BD preparations (500+501) essentially increased the yield of potato tubers. Average number of tubers per plant in cv. Red Emmalie and Blue Congo increased by 1.12 and 1.13 times respectively, as well average weight of tubers per plant increased by 1.10 and 1.34 times respectively. However, separately used BD preparations 500 and 501 had no influence on tuber yield in these cultivars (Table 2).

The use of BD preparations did not affect the yield of tubers of Vitelotte cultivar either, there were no essential differences among the treatments. There are other authors who mention different effect of BD preparation on various potato cultivars (Granstedt and Kjellenberg, 1997).

Table 2

Effects of biodynamic (BD) preparations on the yield parameters of potato tubers
Wpływ preparatów biodynamicznych na parametry plonu bulw ziemniaków

Treatment Doświadczenie	Number of tubers per plant Liczba bulw na roślinę	Tuber mass per plant (g) Ciężar bulw na roślinę (g)
	Blue Congo	
Control without BD preparations	8.25 ± 0.27 [b]	371.25 ± 17,5 [b]
BD preparation 500	8.31 ± 0.42 [b]	365.13 ± 22.17 [b]
BD preparation 501	8.35 ± 0.37 [b]	377.53 ± 27.95 [b]
BD preparations 500 + 501	9.30 ± 0.65 [a]	496.24 ± 34.97 [a]
	Vitelotte	
Control without BD preparations	15.99 ± 0.43 [a]	473,22 ± 21.17 [a]
BD preparation 500	16.03 ± 0.56 [a]	451.95 ± 38.67 [a]
BD preparation 501	16.15 ± 0.41 [a]	460,42 ± 35.28 [a]
BD preparations 500 + 501	16.46 ± 0.44 [a]	472.95 ± 56.19 [a]
	Red Emmalie	
Control without BD preparations	16,48 ± 0.55 [b]	1045.13 ± 25.90 [b]
BD preparation 500	16.98 ± 0.60 [b]	1037.50 ± 43.49 [b]
BD preparation 501	17.30 ± 0.30 [b]	1085.45 ± 34.16 [ab]
BD preparations 500 + 501	18.41 ± 0.41 [a]	1116.59 ± 42.81 [a]

*— Means located on the same column and marked with different letters differ significantly at p<0.05
* — Wyniki znajdujące się w tej samej kolumnie i oznaczone różnymi literami różnią się istotnie, gdy p <0,05

CONCLUSIONS

The results revealed that combination of BD preparations (500 + 501) was the best among all the treatments for most of the growth and yield parameters under study.

It was found, that compared with the control variant, combination of BD preparations (500 + 501) substantially increased the chlorophyll content index values in leaves of cvs. Red Emmalie and Blue Congo in 9th (respectively 1.10 and 1.08 times) and 13th (respectively 1.25 and 1.16 times) week after planting. BD preparation 501 substantially increased the chlorophyll content index in leaves of cv. Red Emmalie in 9th (1.07 times) and 13th (1.13 times) week, and of cv. 'Blue Congo' only in 9th (1.07 times) week after planting.

Combination of BD preparations (500 + 501), compared with the control variant, substantially increased the weight and number of tubers per plant of cvs. Blue Congo and Red Emmalie.

BD preparations did not affect the growth and yield parameters of cv. Vitelotte.

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