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[1] Department of Industrial and Medicinal Plants, University of Life Sciences in Lublin, Akademicka 15, 20–950 Lublin, Poland
[2] Department of Plant Production Technology and Commodities Science, University of Life Sciences in Lublin, Akademicka 15, 20–950 Lublin, Poland, e-mail: anna.kieltyka-dadasiewicz@up.lublin.pl

BEATA KRÓL[1], ANNA KIEŁTYKA-DADASIEWICZ[2],

Effectiveness of foliar fertilizers in integrated crop production of thyme (*Thymus vulgaris* L.)

Efektywność stosowania nawozów dolistnych w integrowanej uprawie tymianku właściwego (*Thymus vulgaris* L.)

Summary. A field experiment to assess the use of foliar fertilizers in the integrated crop production of thyme, was carried out in 2012–2013. Foliar fertilization with multicomponent preparations matched to the soil abundance according to the principles of integrated production was used twice: 1) Plonvit Kali (3 kg·ha^{-1}); 2) Bormax (1 l·ha^{-1}); 3) Alkalin K+Si (2 l·ha^{-1}); 4) Kendal (1.5 l·ha^{-1}); 5) Fertileader Vital 954 (2.5 l ha^{-1}). The applied preparations positively influenced the growth of plants and resulted in the increase of the raw material yield – the highest was obtained under the influence of Fertileader V. Under the influence of fertilizers, the content of essential oil in the raw material decreased, however due to higher yields, the oil yield per unit area was greater.

Key words: herb yield, essential oil, Plonvit Kali, Bormax, Alkalin K+Si, Kendal, Fertileader Vital

INTRODUCTION

Crop technology is a factor determining the yield-producing effect, but it also interferes with the natural environment. Conventional system assumes intensive production based on maximizing the yields due to the widespread use of plant growth enhancers, such as fertilizers and plant protection products. The opposite ecological system has the main objective to minimize the impact of agricultural production on the natural environment by abandoning the use of synthetic means. Lower yields are obtained then. Integrated crop production is an optimized technology that allows to obtain high yields without

affecting the environment. This is achieved by the use of sustainably technical and biological progress in the cultivation of plants, paying particular attention to environmental protection and human health. Currently, integrated crop production is considered to be the most effective method of producing the food plant materials. Among pro-ecological agrotechnical methods used in integrated cultivation, we can mention: intercrop sowing, mechanical weeding and precise fertilization [Makarewicz et al. 2014, Sosnowska et al. 2016, Jamiołkowska et al. 2017]. Foliar fertilizer preparations are more absorbed by the plant compared to soil fertilization. Foliar feeding is also a method that allows to quickly respond to the first signs of a deficiency of elements in plants, also in the advanced stage of plant growth, where soil fertilization is virtually impossible. This avoids excessive prophylactic fertilization, which is readily used in conventional cultivation. The foliar form of fertilization also allows precise application of deficit micro- and macro-elements on a given soil. Foliar fertilization is recommended in the integrated cultivation of agricultural plants such as potatoes [Jabłoński 2012], cereals [Jarecki et al. 2017, Andruszczak et al. 2017, Rahman et al. 2015] and fruits and vegetables [Mikiciuk and Mikiciuk 2008, Rahman et al. 2015].

Literature data indicate that thyme (*Thymus vulgaris* L.) responds well to foliar fertilization in a conventional cultivation system [Berbeć et al. 2003, Kołodziej 2009, Król 2009a, 2009b], which prompts to accept the research hypothesis assuming a positive effect of the applied foliar preparations on the growth and yield of thyme grown using the integrated method.

The aim of the research was to determine the height of plants, size and structure of yield and the content and yield of essential oil depending on the application of foliar fertilizers.

MATERIAL AND METHODS

The field experiment (2012–2013) was established using the randomized block method in 4 replicates, on plots of 10 m^2 area, separated on the production plantation of thyme (*Thymus vulgaris* L.) located in Trębanów (50°51'06"N, 21°29'10"E) in Świętokrzyskie province. Plants were grown on loess soil with mechanical composition of clay dust, characterized by neutral reaction (pH 6.7–7.4 in 1 M KCl), average phosphorus content (6.52–7.24 mg P · 100 g^{-1}) and magnesium (4.87–5.41 mg Mg · 100 g^{-1}) and low potassium (72.9–78.5 mg K · 100 g^{-1}) and boron (13.5–14.9 mg B · kg^{-1}).

Seeds of thyme of ′Słoneczko′ cultivar were sown directly to the ground at the beginning of April with a garden sowing machine at the row spacing of 30 cm in an amount of 4 kg · ha^{-1}. In all objects, mineral fertilization was applied in the amount of: N – 40 kg · ha^{-1} (at 2 doses – 1/2 before plantation establishment, 1/2 after plant emergence), P – 30 kg · ha^{-1}, K – 60 kg · ha^{-1} (before establishing the plantation). Since the thyme plantation was carried out in the integrated production system, the use of plant protection products was limited. After sowing the seeds, Reglone 200 SL herbicide (1.5 l ha^{-1}) was applied, and further protection against weeds consisted of their mechanical removal in inter-rows (hoe) and

manually in rows. In addition, Miedzian 50 WP was used to reduce the occurrence of fungal diseases.

Experiment factor consisted of foliar preparations, the selection of which was based, according to the recommendations of integrated cultivation, on the analysis of the soil's abundance in minerals. Due to the low supply of potassium and boron in soils, Alkalin K + Si and Bormax, two compound fertilizers: Plonvit Kali and Fertileader Vital, as well as Kendal with an innovative composition containing, in addition to minerals, glutathione, oligosaccharides and saponins, were selected (Table 1). All preparations were applied in the form of sprays on the leaves, twice during the growing season: at the beginning of June (in the vegetative growth stage) and after 4 weeks from the first treatment. With each spray, the following doses of the preparation were delivered:

1) Plonvit Kali (3 kg·ha^{-1})
2) Bormax (1 l·ha^{-1})
3) Alkalin K+Si (2 l·ha^{-1})
4) Kendal (1.5 l·ha^{-1})
5) Fertileader Vital 954 (2.5 l ha^{-1})

In the control object, plants were sprayed with clean water at the same time.

Because the thyme plantation was utilized in the one-year system, the herbal harvest was carried out at the end of September; its fresh mass was determined and dried in a floor dryer at 35 C (± 2°C). Then, the yield of dry herb was determined, and after grating (on sieves with a diameter of 5 mm) the yield of the grated herb. Samples for determination of the essential oil content by the pharmacopoeia method were obtained from this raw material [Poland Farmakopea IX 2011].

The obtained numerical data was analyzed statistically by the analysis of variance and verified by Tukey's test at the significance level of $\alpha = 0.05$.

Table 1. Components of the preparations used in the experiment (g·100 g^{-1})

Name of preparations (producer)	Composition of preparations
Plonvit Kali (Intermag)	NO_3 – 8.5; NH_2–2.5; P_2O_5 – 12; K_2O –38; MgO – 0.1; SO_3 – 1.1; B – 0.03; Co –0.001; Cu_{EDTA} – 0.03; Fe_{EDTA} – 0.15; Mn_{EDTA} – 0.07; Mo – 0.002; Zn_{EDTA} – 0.07; Ti – 0.001
Bormax (Intermag)	organic form of boron – boronethanolamine (11)
Alkalin K+ Si (Intermag)	N – 3; K_2O – 25; SiO_2 – 1.1
Kendal (Valagro SpA)	N – 3.5; K_2O – 15.5; C (org.) – 3; Glutathione, Oligosaccharides, Saponins
Fertileader Vital 954 (Timac Agro Poland)	N – 9; P – 5; K – 4; B – 0.05; Cu – 0.2; Fe – 0.02; Mg – 0.1; Mo – 0.01; Zn – 0.05; Complex SEACTIV® (Glycine-Betaine, Isopentyl-Adenine, Amino acid)

EDTA – chelated by EDTA

Weather conditions in 2012–2013 varied and exerted significant impact on the course of thyme vegetation (Table 2). The growing season 2012 was characterized by low rainfall and high temperatures, which adversely affected the growth and yielding of thyme.

Table 2. Weather conditions in 2012–2013 and in a multiyear period (1971–2010)

Year	Month						
	IV	V	VI	VII	VIII	IX	IV–IX
Air temperature (°C)							Mean
2012	9.9	15.2	17.9	21.2	19.1	14.8	16.4
2013	8.7	14.1	17.7	18.9	18.5	11.6	14.9
1971–2010	8.5	14.0	16.7	18.6	18.0	13.4	14.9
Rainfall (mm)							Total
2012	30	43	78	55	40	41	287
2013	48	134	93	52	47	51	425
1971–2010	40	63	70	83	68	53	377

Weather more favorable for the growth of this species was recorded in 2013. Heavy spring precipitation (the sum of rainfall in April and May was 79 mm higher than the long-term average) facilitated the emergence and growth of plants, while moderate summer precipitation reduced the occurrence of fungal diseases.

RESULTS AND DISCUSSION

Height of plants is a parameter showing their condition and nutrition and it affects the biomass yield directly. The application of foliar fertilizers resulted in a significant increase in plant height, and consequently in herb yield compared to the control object. Comparing the tested preparations, it was observed that the highest increase in fresh and dry mass of aboveground parts was obtained in the objects sprayed with multicomponent preparations: Fertileader V, Plonvit Kali and Kendal (Tables 3 and 4).

Table 3. Height of plants (cm) and mass of fresh herb ($Mg \cdot ha^{-1}$) of thyme depending on the preparations used

Preparations	Height of plants			Mass of fresh herb		
	2012	2013	mean	2012	2013	mean
Plonvit Kali	22.6	29.8	26.2	15.90	17.87	16.89
Bormax	23.3	28.8	26.1	14.90	17.15	16.03
Alkalin K+Si	23.4	28.2	25.8	15.10	17.07	16.09
Kendal	24.1	29.6	26.9	15.95	17.52	16.74
Fertileader V	24.0	30.2	27.1	16.20	17.93	17.07
Control	21.2	26.8	24.0	14.20	15.88	15.04
Mean for years	23.1	28.9	–	15.38	17.24	
$LSD_{(0.05)}$ for:	a – 1.13 b – 1.26 a × b – 1.29			a – 0.647 b – 0.752 a × b – 0.863		

a – preparations; b – years; a × b – interaction

Table 4. The effect of tested preparations on yield (Mg·ha^{-1}) of thyme herbs

Preparations	Yield of air dry herb			Yield of grated herb		
	2012	2013	mean	2012	2013	mean
Plonvit Kali	6.03	7.10	6.57	2.25	3.06	2.66
Bormax	5.73	6.83	6.28	2.09	2.98	2.54
Alkalin K+Si	5.76	6.77	6.27	2.11	2.91	2.51
Kendal	5.98	7.01	6.50	2.19	3.03	2.61
Fertileader V	6.13	7.13	6.63	2.31	3.14	2.73
Control	5.49	6.37	5.93	1.98	2.73	2.36
Mean for years	5.85	6.87	–	2.16	2.98	–
$LSD_{(0.05)}$ for:	a – 0.285 b – 0.308 a × b – 0.317			a – 0.127 b – 0.118 a × b – 0.129		

a – preparations; b – years; a × b – interaction

In the conducted research, the weather conditions prevailing during thyme growing season also influenced the plant growth and biomass formation. In 2013, the plants were higher (by 5.6 cm on average compared to 2012), which also contributed to the increase of fresh and dry herb mass (by 12% and 16.6%, respectively as compared to 2012) (Table 3). In the two-year study period, the average yield of thyme raw material was 2.6 Mg·ha^{-1} and foliar fertilizers had positive impact on its size (Table 3). Plant feeding increased the yield of the raw material (on average from two years) from 0.15 Mg·ha^{-1} to 690 0.37 Mg·ha^{-1} in comparison to the control. The most beneficial effect on yields was obtained after application of Fertileader V (increase of yield by an average of 15.7% compared to the control), slightly lower impact was demonstrated by Plonvit Kali and Kendal (increase by 12.7% and 10.6%, respectively). Analyzing the parameter directly conditioning the yield of the raw material, i.e. the share of grated herb in the yield of thyme, it was found that the tested preparations did not cause a significant increase in the share of leaves in the mass of plants (Fig. 1).Weather conditions exerted the strongest effect on these features and in the rainfall-abundant 2013, the plants were more leafy, which as an effect resulted in a larger share of the grated herb (Fig. 1). Similarly, beneficial effects of foliar fertilizers on the yield of thyme were observed in previous studies in conventional cultivation [Berbeć et al. 2003, Król 2009a, Kołodziej 2009] and other plants from the *Lamiaceae* family, i.e. garden marjoram [Król and Kiełtyka-Dadasiewicz 2017], motherwort [Kiełtyka-Dadasiewicz and Berbeć 2010] and peppermint, both in the conventional and organic farming system [Patrui and Tabara 2011].

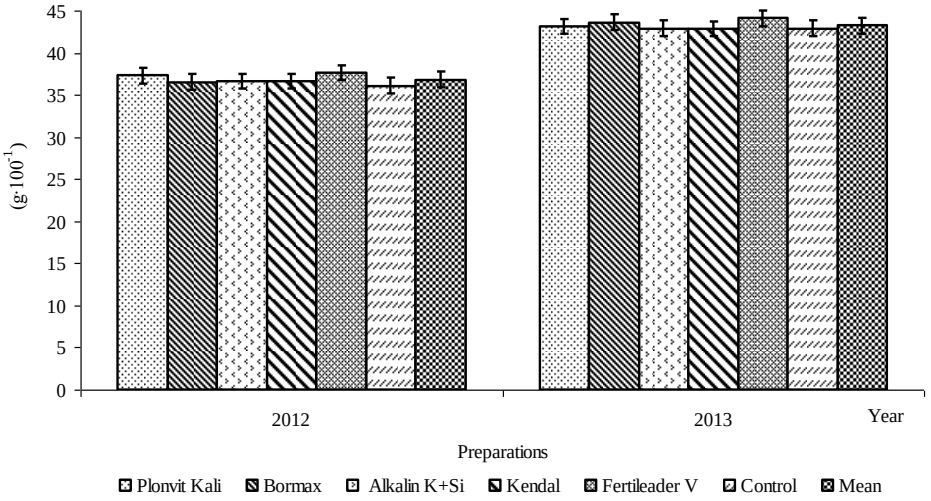

Fig. 1. The effect of tested preparations on the participation (g·100 g^{-1}) of grated herb of thyme; error bars – Least Significant Difference (p = 0.05)

Content of essential oil in the tested raw material is a qualitative feature that determines its usefulness, as it conditions both pharmacological properties and the intensity of the essential scent when used for seasoning. The obtained raw material in both years of research was characterized by a high content of essential oil (2.44–2.74 ml·100 g^{-1}), more than twice the minimum pharmacopoeias requirements (1.2 ml·100 g^{-1}) (Fig. 2). In the literature, there are reports of other authors with much lower oil content in thyme herb [Seidler-Łożykowska 2007, Said-Al et al. 2019], but also values close to our results [Bitarafan et al. 2017].

It was found that foliar fertilizers influenced the percentage of essential oil in the thyme raw material (Fig. 2). Most of this ingredient was recorded in the control object (the average of two years 2.68 ml·100 g^{-1}), and the applied foliar nutrition reduced its share by an average of 0.13 ml·100 g^{-1}. The smallest drop in the oil content was found after the application of Alkalin K + Si (on average from two years by 0.06 ml·100 g^{-1}). The highest decrease in the oil share was noted after the application of Kendal and Fertileader V (respectively by 0.22 ml·100 g^{-1} and 0.21 ml·100 g^{-1}).Considering that the highest yield of raw material was found in these objects, one can presume a negative correlation between the yield and the content of essential oil. A similar effect lowering the concentration of the active substance is observed with increasing the intensity of thyme yielding not only under the influence of foliar preparations [Berbeć et al. 2003, Kołodziej 2009, Król 2009a, 2009b], but also other agrotechnical treatments improving the yield, e.g. irrigation [Said-Al et al. 2019], organic fertilization [Bitarafan et al. 2017], and finally, regulation of the harvest date [Król and Kiełtyka-Dadasiewicz 2015].

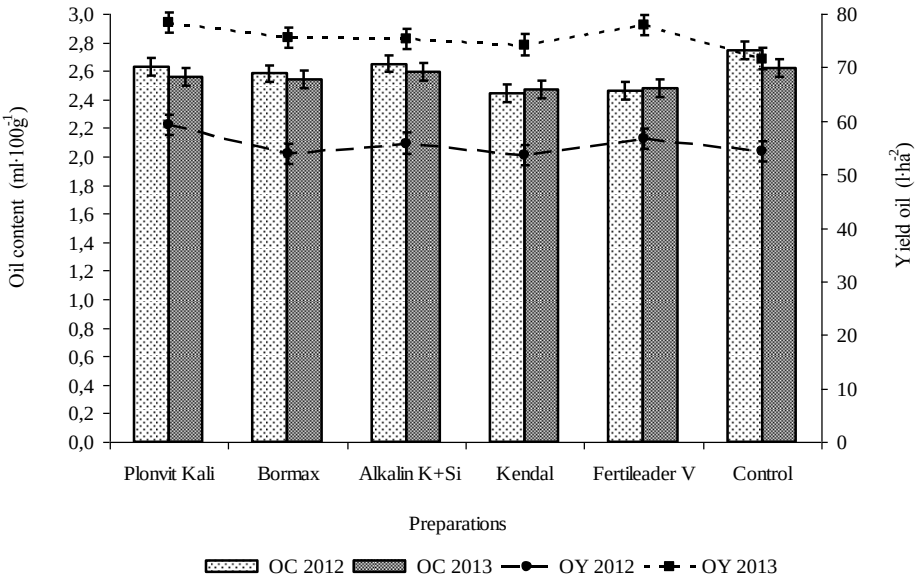

Fig. 2. Essential oil content (OC) (ml·100g^{-1} DW) in raw material of thyme and its yield (OY) (l·ha^{-1})

Therefore, in order to determine the real effect of the test preparations on the production of essential oil by thyme plants, the theoretical yield of oil from the unit area was calculated. Its size is determined by two parameters: the yield of the raw material and the content of essential oil in it. Despite the negative effect on the oil content in the raw material, the applied preparations did not reduce the theoretical oil yield per unit area, and the most yielding multicomponent preparations (Plonvit Kali and Fertileader V) even caused a significant increase in oil yield due to a higher yield increase (Fig. 2).

CONCLUSIONS

1. The applied foliar preparations positively influenced the height of plants, stimulated formation of the aboveground mass of thyme and increased the yield of the raw material.

2. The application of Fertileader V and Plonvit Kali preparations proved to be the most effective among the compared preparations.

3. The applied foliar preparations caused a decrease in the oil content in the raw material. However, considering the yield of oil from the surface unit, its increase was recorded.

4. Atmospheric conditions differentiated the growth and yield of thyme grown using the integrated method, however, they did not affect the share of essential oil in the raw material.

5. In the system of integrated thyme growing, foliar application of nutrients found in the deficit is justified, as it increases both the yield of the raw material and the yield of oil from the surface unit.

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Streszczenie. Eksperyment polowy, mający na celu ocenę stosowania nawozów dolistnych w uprawie integrowanej tymianku właściwego, przeprowadzono w latach 2012–2013. Dwukrotnie stosowano dolistne nawożenie preparatami wieloskładnikowymi dobranymi do zasobności gleby według zasad integrowanej produkcji: 1) Plonvit Kali (3 kg·ha^{-1}); 2) Bormax (1 l·ha^{-1}); 3) Alkalin K+Si (2 l·ha^{-1}); 4) Kendal (1,5 l·ha^{-1}); 5) Fertileader Vital 954 (2,5 l ha^{-1}). Zastosowane preparaty pozytywnie wpłynęły na wzrost roślin oraz spowodowały zwyżkę plonu surowca – największy otrzymano pod wpływem preparatu Fertileader V. Pod wpływem zastosowanych nawozów zmniejszyła się zawartość olejku eterycznego w surowcu, jednak z uwagi na wyższe plony wydajność olejku z jednostki powierzchni była większa.

Słowa kluczowe: plon ziela, olejek eteryczny, Plonvit Kali, Bormax, Alkalin K + Si, Kendal, Fertileader Vital

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