The effect of growth stimulators and forecrop on raw material quality and yield of garden thyme (*Thymus vulgaris L.*)

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S u m m a r y

A field experiment in growing garden thyme was carried out in Jaroszewice (the central Lublin region) in 2008–2010. Three growth biostimulators (Asahi SL, Bio-algeen S 90, and Tytanit) were used in the study. Plots with no foliar application of these growth stimulators established the control group. Carrot, faba bean, and spring wheat forecrops were the other experimental factors. The present study showed that the best quantitative parameters of thyme raw material were observed after the application of the growth simulators. The root forecrop (carrot) also had a beneficial effect on thyme yield. Thyme crop protection without the application of the growth simulators resulted in the deterioration of the biometric traits and yields of this crop. The treatment with no application of the growth simulators was the most beneficial for the chemical composition of thyme raw material.

Key words: *garden thyme, growth stimulators, forecrop, yield, thymol content, macronutrient content*

INTRODUCTION

Garden thyme (*Thymus vulgaris* L.) yield depends on the genetic, climatic, soil and agrotechnical factors [1, 2]. In this age of concern for environmental protection, new methods of plant growth stimulation are sought, among others, by selecting an optimal forecrop [3, 4], inoculation with mycorrhizal fungi [5], the application of foliar fertilization with macro- and micronutrients as well as by foliar application of various growth biostimulators [6-8]. The latter method has been successfully used in agricultural practices in growing some vegetables as well as herbal and industrial plants in several West European countries for over a decade [9, 10], and also recently in national experiments [11, 12]. Non-chemical methods of plant growth stimulation are of great importance in the case of garden thyme. It is one of the most important herbal species in Poland; herbal raw material consists of the thyme herb (*Herba Thymi*), collected at full blooming, which is used both as valued spice and medicine [3, 13]. It seems justified to introduce biological stimulators that biodegrade quickly in agricultural practice. The example of such stimulators is Asahi SL (Atonik) – containing sodium salts of 5-nitroguaiacolate as well as ortho- and paranitrophenolates, Tytanit (Ti 0.8%), and Bio-algeen S 90 (a natural extract from sea algae from the group of brown algae) [12, 14].

In present study, a hypothesis was made that growth stimulation of garden thyme plants by the application of the biostimulators would produce better and higher yields, in terms of quality and quantity, as compared to the method with no foliar fertilization. It was also assumed that differentiation in the forecrops (various plant groups) in garden thyme cultivation would allow the determination of an optimal stand for this herbal crop, as an ecology-oriented method of influencing the yield volume and quality. The aim of the study was to analyse some biometric and qualitative traits as well as yield and weed infestation of garden thyme as a result of the application of various growth stimulators and three forecrops.

MATERIALS AND METHODS

The field experiment was carried out in Jaroszewice (the central Lublin region) in 2008–2010. The experiment was set up as a split-plot design, with 3 replicates, in 12 m^2 plots. Garden thyme (cv. Słoneczko) was grown on incomplete podzolic soil (pH in 1 mol KCl = 6.4), classified as good wheat complex and characterized by high availability of essential macronutrients (P=86.4; K=99.7; Mg=34.6 mg kg^{-1}). The soil humus content was 1.46%.

The experimental design included the following factors:

I. Growth stimulators:
A – no biostimulators application (control treatment),
B – foliar spraying with Asahi SL – Atonik (0.1%),
C – foliar spraying with Bio-algeen S 90 (1.0%),
D – foliar spraying with Tytanit (0.05%).

II. Forecrops:
1. root plant (carrot),
2. leguminous plants (faba bean),
3. cereal plant (spring wheat).

Each year, garden thyme seeds were sown directly into soil in the third decade of March. Seeding was done using a seed drill with a press wheel at a rate of 3 kg ha^{-1}, with a row spacing of 40 cm. Mineral fertilization was the same for all the treatments. Taking into account soil nutrient availability, calculated per 1 ha, fertilization was applied at the following rates: N – 80 kg (in 2 doses – 1/2 before plantation establishment and 1/2 after emergence), P – 20 kg (before plantation establishment), K – 80 kg (before plantation establishment). Mineral N fertilization was applied in the form of 34% ammonium nitrate, P in the form of 46% granulated triple superphosphate, whereas K in the form of 50% potassium salt.

Weed control in the thyme plantation was carried out using a mechanical and chemical weed management method common in the Lublin region and consistent with the recommendations of Plant Protection Institute Calendar [15] (a spike tooth harrow before emergence + herbicide Reglone Turbo 200 SL – diquat – 3 l ha^{-1} as well as mechanical weed control in interrows – a hand hoe). Mechanical weed removal was done three times: 1) hoeing at the 3-leaf stage; 2) weeding at the 6-8-leaf stage; 3) weeding before row closure.

Conventional tillage was used, adapted to the specificity of the herbal plant in question and the forecrop plants. The growth stimulators (treatments B-D) were applied using a field sprayer (Kwazar RS/30, 10 l) under a pressure of 0.25 MPa. These biostimulators were applied twice: in the second decade of June and in the first decade of July.

Before harvest, crop weed infestation was evaluated (air-dry weight of weeds) in randomly selected sampling areas (1 m^2) marked out with a wooden frame. Several days before thyme harvest, plant height and number of branches per plant were estimated based on 30 randomly selected plants from each plot.

Garden thyme was harvested in the mid August (beginning of flowering stage), by cutting the herb with a sickle bar mower at a height of about 5 cm. After harvest, the herb was dried in a belt dryer at a temperature of ca. 35°C, and then threshed with a Warmianka threshing machine. Specific determinations of the following traits were made: dry herb yield (threshed material) expressed in t ha^{-1}, thymol content in essential oil (oil distillation with a water pump according to Polish Pharmacopoeia VIII [16], thymol content by the GC/MS method). Furthermore, the total content of the following elements was determined in air-dried plant material after its homogenisation and mineralization:

N – by Kjeldahl's method in the Parnas-Wagner apparatus, P – colourimetrically with ammonium molybdate according to Shillak, K, Ca – by the flame photometry method [17].

The study results were statistically verified, determining the significance of differences using Tukey's test, with 5% risk of error.

RESULTS AND DISCUSSION

Foliar application of the growth stimulators had a significant effect on garden thyme plant height (tab. 1). Spraying the garden thyme plantation with Asahi SL and Tytanit resulted in a ca. 13% increase in the height (5.5–5.9 cm) of this plant, whereas in the case of spraying with Bio-algeen this increase was ca. 9% (4.0 cm), as compared to the control treatment. The forecrops did not differentiate thyme plant height significantly.

Table 1.

Garden thyme plant height [cm] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	39.3	45.2	43.6	44.5	43.1
faba bean	38.9	44.9	42.7	44.0	42.6
spring wheat	37.5	43.3	41.6	43.8	41.5
mean	38.6	44.5	42.6	44.1	-

$LSD_{0.05}$ for:
foliar fertilization methods = 3.07
forecrop = non-significant

All the applied growth regulators had a significant effect on the increase in the number of shoots per plant relative to the control plots, on average by 27.3% (Asahi), 23.1% (Tytanit), and 20.9% (Bio-algeen). Moreover, foliar spraying with Asahi SL resulted in a significantly higher number of thyme shoots (by 8.1% on average) relative to the treatments in which Bio-algeen was applied. The stands in which thyme was grown after the root plant (carrot) and the leguminous plant (faba bean) resulted in a significantly higher number of branches per thyme plant (by 19.8-21.0%) in comparison to the number of shoots found in the treatments with the cereal forecrop (tab. 2).

Table 2.

Number of shoots (lateral branches) per garden thyme plant [pcs.] – mean for 2008-2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	27.6	35.2	33.1	33.7	32.4
faba bean	26.9	34.5	32.8	33.5	31.9
spring wheat	18.3	30,4	26.2	27.7	25.6
Mean	24.3	33.4	30.7	31.6	–

$LSD_{0.05}$ for:
foliar fertilization methods = 2.65
forecrop = 2.83

The growth stimulators investigated in the present experiment had an impact on the increase of garden thyme raw material yield compared to the control treatment (tab. 3). Significantly higher yields were found as a result of the application of Asahi SL (by 12.6% on average) and Tytanit (by 9.7%). Growing garden thyme in the stand after carrot produced raw material yield at a level of 2.19 t ha^{-1}, higher by 24.0% than that obtained in the stand in which thyme was grown after the leguminous forecrop and by nearly 28.0% compared to that found in the treatments with the cereal forecrop.

Table 3.

Air-dry yield of garden thyme raw material [t ha^{-1}] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	2.01	2.35	2.16	2.24	2.19
faba bean	1.59	1.72	1.65	1.69	1.66
spring wheat	1.42	1.67	1.59	1.63	1.58
mean	1.67	1.91	1.80	1.85	-

$LSD_{0.05}$ for:
foliar fertilization methods = 0.176
forecrop = 0.234

Thymol content in garden thyme dry mass depended significantly on both experimental factors (tab. 4). Foliar fertilization with Asahi SL and Tytanit resulted in lower thymol accumulation, on average by 0.25% of air-dry weight (ADW) compared to the control treatment, and a lower content of this component in comparison with the application of Bio-algeen (on average by 0.15% ADW). The highest thymol content, irrespective of the growth stimulators, was found in the treatment where garden thyme was grown after the root forecrop. Thymol content determined under such conditions was significantly higher by 0.13% ADW compared to its value found in the raw material obtained from the treatments in which thyme was grown after the cereal forecrop.

Table 4.

Thymol content in air-dry weight of garden thyme [%] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	1.46	1.21	1.37	1.19	1.31
faba bean	1.32	1.17	1.21	1.22	1.23
spring wheat	1.40	1.06	1.28	0.98	1.18
mean	1.39	1.15	1.29	1.13	

$LSD_{0.05}$ for:
foliar fertilization methods = 0.126
forecrop = 0.122

Under the control conditions and as a result of the application of Tytanit, significantly higher nitrogen content was found in garden thyme raw material (on average by 0.17% ADW) than after foliar application of Asahi SL and Bio-algeen (tab. 5). Regardless of the applied growth stimulators, the faba bean forecrop contributed to a significant increase in nitrogen content (by 0.82% ADW) in garden thyme raw material in comparison with the stand after spring wheat as well as relative to the treatments with the root forecrop (by 0.22% ADW). At the same time, nitrogen content in the raw material harvested from the plots in which thyme was grown after the cereal forecrop was significantly lower (by 0.60% ADW) than that recorded in the stand after carrot.

Table 5.

Nitrogen (N) content in garden thyme raw material [%] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	1.79	1.59	1.68	1.80	1.71
faba bean	1.99	1.88	1.84	2.02	1.93
spring wheat	1.26	1.02	0.99	1.19	1.11
mean	1.68	1.50	1.50	1.67	-

$LSD_{0.05}$ for:
foliar fertilization methods = 0.138
forecrop = 0.145

Phosphorus content in air-dry weight of garden thyme raw material showed correlations similar to those observed for nitrogen content (tab. 6). The highest concentration of this component was found in the samples collected from the control treatment and from the plot sprayed with Tytanit. The application of the Asahi SL and Bio-algeen biostimulators resulted in a significantly lower content of phosphorus, by 0.05% ADW, on average. The ploughing-in of post-harvest residues of the carrot and faba bean crops was translated into a significantly higher content of phosphorus in thyme raw material, by 0.02–0.03% ADW, compared to that obtained in the treatment with the cereal forecrop.

Table 6.

Phosphorus (P) content in garden thyme raw material [%] – mean for 2008-2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	0.17	0.12	0.12	0.17	0.14
faba bean	0.16	0.10	0.11	0.15	0.13
spring wheat	0.14	0.08	0.09	0.12	0.11
mean	0.16	0.10	0.11	0.15	

$LSD_{0.05}$ for:
foliar fertilization methods = 0.029
forecrop = 0.018

The controlled experimental factors significantly modified potassium content in garden thyme raw material (tab. 7). A higher content of this macroelement was recorded in the herb collected from the control plots compared with the treatments where Asahi and Bio-algeen were applied. The highest potassium accumulation, irrespective of the growth stimulators, was noted in garden thyme raw material collected from the plots in which garden thyme was grown after the carrot forecrop, whereas this accumulation was the lowest in the samples obtained from the stand after spring wheat. The difference in the content of this element between the abovementioned treatments averaged 0.27% of ADW. The cultivation of garden thyme in the stand after carrot also gave significantly higher phosphorus content in the dried herb, as confronted with its cultivation after the leguminous forecrop.

Table 7.

Potassium (K) content in garden thyme raw material [%] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	1.53	1.42	1.34	1.46	1.44
faba bean	1.35	1.21	1.19	1.26	1.25
spring wheat	1.23	1.16	1.12	1.18	1.17
mean	1.37	1.26	1.22	1.30	-

$LSD_{0.05}$ for:
foliar fertilization methods = 0.097
forecrop = 0.091

The application of the growth stimulators did not affect significantly calcium accumulation in garden thyme raw material. But the forecrop plants produced a statistically proven difference in the content of this macronutrient (tab. 8). Growing garden thyme in the stand after the root plant yielded the highest calcium. The cereal forecrop resulted in a decrease in calcium content by 0.28% ADW.

Table 8.

Calcium (Ca) content in garden thyme raw material [%] – mean for 2008–2010

specification	foliar fertilization				
forecrop	control	Asahi SL	Bio-algeen	Tytanit	mean
carrot	2.41	2.38	2.35	2.39	2.38
faba bean	2.23	2.21	2.21	2.24	2.22
spring wheat	2.11	2.09	2.07	2.14	2.10
mean	2.25	2.23	2.21	2.26	-

$LSD_{0.05}$ for:
foliar fertilization methods = not significant
forecrop = 0.132

The growth regulators applied in the garden thyme plantation stimulated plant growth, as a consequence contributing to increased herb yield per unit area. The most beneficial effect was noted in the case of the Asahi SL (Atonik) biostimulator followed by Tytanit. Many authors draw attention to the positive effect of foliar application of growth stimulators [6, 10, 18]. Compounds contained in the growth stimulator Asahi SL are natural plant constituents found in small amounts; when they are applied exogenously, they have an intense impact on growth processes and productivity. Atonik accelerates electron transport in plant photosynthesis and the flow of assimilates from leaves to the place of their storage. In addition, it stimulates the cellular accumulation of the so-called polyols that enable plants to quick adaptation to variable environmental conditions [11, 19]. In turn, Bio-algeen S 90 is defined as a biological growth stimulator that affects root system development, thereby increase plant resistance to adverse environmental conditions, e.g. water deficit, too low or too high temperatures. Its composition contains many natural chemical compounds, including amino acids, vitamins, alginic acid, and other components of sea algae [14]. Tytanit is a preparation that contains titanium. It has a beneficial effect on plant growth and development by activating metabolic processes. Furthermore, it stimulates pollination, seed and fruit setting, increases resistance to fungal and bacterial diseases as well as accelerates leaf growth and development. Titanium is also a catalyst through which plants use nutrients better [10]. Berbeć et al. [6] obtained a 24% increase in thyme herb yield in the case of foliar application of the Asahi SL biostimulator. In the study of Król [12], the application of Asahi SL, along with Mikosol (foliar fertilizer), also resulted in increased productivity of garden thyme by 13.6%. Wojdyła and Orlikowski [20] note the positive effect of the application of Atonik (Asahi SL), in particular under the conditions of impeded nutrient uptake. The positive influence of Atonik on yields of hop, pepper, root plants (sugar beets and potatoes), and cherry was found in the studies of other authors [11, 19, 21, 22].

The beneficial effect of foliar application of titanium was shown in the study of Pais [9] who obtained an increase in berry fruit yields reaching up to 26%. Szewczuk and Juszczak [22] also observed a 30% growth in bean yield under the influence of Tytanit. A 10-20% increase in yield after the application of titanium was found in other experiments involving apple, maize, sugar beets, and yellow lupin [24, 25]. In the experiments of Cholewiński [26], higher strawberry yields were obtained after the application of Bio-algeen compared to the use of Asahi SL. The positive impact of Bio-algeen was also shown in some experiments on potato and hop [27, 28].

There are few studies relating to the effect of forecrop on yield and quality of herbal plants. Likewise in the present study, Kwiatkowski and Kołodziej [3] proved that the most beneficial forecrop for garden thyme was a root plant (potato), followed by a mixture of leguminous plants (pea and spring vetch). These authors recorded the lowest productivity of garden thyme in the treatments where winter wheat was the forecrop for this herbal plant. In another experiment on agricultural practices in growing garden thyme, Kwiatkowski [4] reached similar conclusions.

The content of thymol and macronutrients in garden thyme raw material was similar to the results of national studies [4, 5] and the results of foreign studies [1, 29]. In the study of Król [12], foliar-applied biostimulators caused a slight decrease of essential oil content in garden thyme raw material. Other authors note that the content of reserve substances is at a similar or slightly lower level under the influence of the application of growth stimulators. However, due to increased raw material yield, a higher yield of a desired component is obtained, e.g. oil in garden thyme or ginsenocides in ginseng roots, compared to the treatments without growth stimulators [6, 7].

CONCLUSIONS

1. The growth stimulators applied in the present experiment (Asahi SL, Bioalgeen, Tytanit) had a positive effect on some biometric traits of garden thyme plants (plant height, number of lateral branches).

2. Carrot proved to be the most beneficial forecrop for garden thyme, followed by faba bean. The abovementioned forecrops stimulated higher productivity of this herbal plant.

3. The best qualitative parameters of garden thyme raw material (thymol, N, P, K, Ca content) were guaranteed by the cultivation of thyme in the stand in which this plant was grown after carrot and after faba bean.

4. In general, the growth stimulators contributed to the deterioration of the chemical composition of garden thyme raw material compared to the control treatment.

5. The growth stimulators of the most beneficial effect on garden thyme productivity were Asahi SL (Atonik) and Tytanit.

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WPŁYW STYMULATORÓW WZROSTU ORAZ PRZEDPLONU NA JAKOŚĆ SUROWCA I PLONOWANIE TYMIANKU WŁAŚCIWEGO (*THYMUS VULGARIS* L.)

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S t r e s z c z e n i e

Eksperyment polowy z uprawą tymianku właściwego prowadzono w latach 2008-2010 w Jaroszewicach (środkowa Lubelszczyzna). W badaniach zastosowano trzy biostymulatory wzrostu (Asahi SL, Bio-algeen S 90 i Tytanit). Obiektem kontrolnym były poletka bez dolistnego stosowania stymulatorów wzrostu. Drugi czynnik badany w doświadczeniu stanowiły przedplony: marchew, bobik i pszenica jara. Badania dowiodły, że najkorzystniejsze parametry ilościowe surowca tymianku obserwowano po aplikacji stymulatorów wzrostu. Korzystne oddziaływanie na plonowanie tymianku posiadał także przedplon z rośliny okopowej (marchew). Metoda pielęgnacji zasiewów tymianku bez aplikacji stymulatorów wzrostu, wpływała na pogorszenie cech biometrycznych i plonu rośliny. Brak aplikacji stymulatorów wzrostu był korzystniejszy dla składu chemicznego surowca tymianku.

Słowa kluczowe: *tymianek właściwy, stymulatory wzrostu, przedplon, plonowanie, zawartość tymolu, zawartość makroelementów*