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Ecotype and Foliar Fertilization with Florovit Affect Herbage Yield and Quality of Greenhouse-Grown Basil (*Ocimum basilicum* L.)

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Abstract

Basil is usually grown in 0.5−0.7 dm^3 pots, at 25 plants per pot. However, potted basil plants wilt and die easily due to high plant density, low substrate volume, insufficient moisture and nutrient depletion. The aim of this study was to determine the herbage yield and nutritional value of greenhouse-grown basil. A two-factorial experiment was performed in a randomized block design with three replications, in 2012−2013. A two-factorial experiment was performed in a randomized block design with three replications, in 2012−2013 Six basil (*Ocimum basilicum* L.) ecotypes were analyzed: sweet basil, 'Queen of Siam' basil, purple basil, cinnamon basil, lemon basil and 'Minette' basil. The second experimental factor was foliar fertilization with Florovit at a concentration of 0.5% and 1%. Basil yield was significantly affected by the ecotype and the interaction between the experimental factors. 'Minette' basil fertilized with 1% Florovit solution was characterized by the highest fresh herbage yield. A statistical analysis revealed that Florovit had no significant effect on basil yield. The concentrations of dry matter, total sugars, L-ascorbic acid and nitrates(V) in basil herbage varied across ecotypes. Foliar fertilization had a significant effect on the organic acid content of basil leaves. The accumulation of the analyzed components in basil herbage was significantly affected by the interaction between the experimental factors. Basil yield was significantly affected by the ecotype. 'Minette' and 'Siam Queen' basil was characterized by the highest fresh herbage yield. The fresh herbage of 'Minette' basil contained the lowest concentrations of dry matter, total sugars, L-ascorbic acid, organic acids and nitrates(V).

Keywords: basil, yield, component, quality, nitrates(V)

1. Introduction

Basil is a popular culinary herb that can be grown in pots and containers Fresh potted basil available on the market is characterized by extended post-harvest shelf-life and quality. Greenhouse production ensures a year-round supply of fresh herbs, spices and seasonings (Aharoni et al., 1993; Jadczak et al., 2006; Biesiada & Kus, 2010). Due to regular control and monitoring of the greenhouse environment, plants grown under cover accumulate lower amounts of undesirable compounds such as nitrates(III), nitrates (V) and heavy metals (Wierzchowska-Renke et al., 1995).

Basil is usually grown in 0.5−0.7 dm^3 pots, at 25 plants per pot. However, potted basil plants wilt and die easily due to high plant density, low substrate volume, insufficient moisture and nutrient depletion. In view of the above, research was undertaken to improve greenhouse basil production conditions. Six basil ecotypes were compared in the study. Basil plants were grown in 3.0 dm^3 containers to ensure adequate substrate solution volume. Another important consideration in greenhouse production is the appropriate use of fertilizers to maximize the yield and improve the biological value of potted herb plants. However, fertilizer rates are usually calculated for basil grown in the field (Nurzynska-Wierdak, 2012). Most research studies conducted to date have investigated simple fertilizers, including foliar application of 0.5% urea solution (Nurzynska-Wierdak & Borowski, 2011), fertigation with the use of ammonium nitrate and potassium sulfate (Nurzyńska-Wierdak et al., 2012), and the application of calcium carbonate to neutralize soil acidity (Dzida, 2010a).

The objective of this study was to determine the herbage yield and nutritional value of greenhouse-grown basil fertilized with the compound fertilizer Florovit.

2. Method

A two-factorial experiment was performed in a randomized block design with three replications, in 2012–2013, in a greenhouse in the Experimental Garden of the University of Warmia and Mazury in Olsztyn. The first experimental factor were six basil (*Ocimum basilicum* L.) ecotypes: sweet basil, 'Queen of Siam' basil, purple basil, cinnamon basil, lemon basil and 'Minette' basil. The second experimental factor was foliar fertilization with Florovit at a concentration of 0.5% and 1%. Florovit is a liquid compound fertilizer that can be applied to plant foliage and soil. It has a pH of 3.3−4.3, and contains N : P : K (3.0 : 0.0 : 2.0), copper (70 mg dm^{-3}), iron (400 mg dm^{-3}), manganese (170 mg dm^{-3}), molybdenum (20 mg dm^{-3}), zinc (150 mg dm^{-3}), calcium, magnesium, sulfur and film-forming agents (inco.pl leaflet).

Basil plants were grown in 3.0 dm^3 containers placed on movable flood tables. Experimental unit area was 1 m^2, and each replicate consisted of 25 pots. Each year, in mid-February, basil seeds were sown in containers (four seeds per container) filled with organic substrate with a pH (H_2O) of 6.7, salt concentration of 0.23 g kg^{-1} and the following chemical composition: N-NH_4 – 25 mg dm^{-3}, N-NO_3 – 10 mg dm^{-3}, P – 41 mg dm^{-3}, K – 129 mg dm^{-3}, Ca – 1050 mg dm^{-3}, Mg – 87 mg dm^{-3}. The recommended cultivation practices for basil were applied during the growing season. Fertilization began two weeks after seedling emergence, and it was continued throughout the growing season at 14-day intervals. Basil leaves were harvested at the beginning of flowering. The plants were cut manually, 5 cm above the ground. The chemical composition of basil herbage was determined at harvest. Average samples of basil herbage were collected from the marketable yield in each treatment, according to Polish Standard PN-72/A-75050. The samples were analyzed in the laboratory of the Department of Horticulture, University of Warmia and Mazury in Olsztyn to determine the content of:

- Dry matter - by drying the plant material at 105 ºC to constant weight (PN-90/A-75101/03);
- Total sugars - by the Luff-Schoorl method (PN-90/A-75101/07);
- L-ascorbic acid - by the Tillmans method modified by Pijanowski (PN-90/A-75101/11);
- Organic acids expressed as malic acid equivalents – by titration, as described by Pietersburgski;
- ß-carotene – by column chromatography (PN-90/A-75101/12);
- Nitrates(V) – by the colorimetric method with the use of salicylic acid.

The results were processed statistically by analysis of variance (ANOVA). The significance of differences between means was estimated by Tukey's range test at $\alpha = 0.01$. All calculations were performed using STATISTICA 10 software.

3. Results and Discussion

A significant correlation was noted between the herbage yield and ecotype of basil. 'Minette' basil was characterized by the highest fresh herbage, dried herbage and crumbled herbage yields. 'Siam Queen' basil produced similar herbage yields. High dry herbage and crumbled herbage yields were also attained in sweet basil. Our results are comparable with those reported by Roslon et al. (2011) in whose study the fresh herbage yield of basil reached 1.04 kg m^{-2}. Cinnamon basil and lemon basil were characterized by the lowest fresh herbage, dried herbage and crumbled herbage yields.

Previous research has shown that the herbage yield and quality of basil are significantly affected by fertilization. In a study by Nurzynska-Wierdak et al. (2011a), fresh herbage yield was significantly higher (3.40 kg m^{-2}, two-year average) in basil plants grown in an unheated plastic tunnel and fertilized with nitrogen. In a pot experiment conducted by Biesiada and Kus (2010), the fresh herbage yield of basil ranged from 2.65 to 4.34 kg m^{-2} depending on fertilizer rate. In our study, a statistical analysis of two-year data demonstrated that Florovit had no significant effect on the fresh herbage, dried herbage or crumbled herbage yields of basil (Table 1).

Table 1. The effect of ecotype and foliar fertilization with Florovit on basil yield (kg m^{-2})

Basil ecotype	Fertilizer rate	Fresh herbage yield	Dry herbage yield	Crumbled herbage yield
		(kg m^{-2})		
Sweet basil	I	0.62	0.25	0.04
	II	0.76	0.20	0.08
	III	0.90	0.16	0.10
Mean		0.76	0.21	0.07
'Siam Queen' basil	I	0.78	0.17	0.05
	II	0.94	0.16	0.07
	III	1.09	0.17	0.11
Mean		0.93	0.17	0.08
'Minette' basil	I	0.98	0.19	0.08
	II	1.07	0.20	0.09
	III	1.11	0.22	0.09
Mean		1.05	0.20	0.08
Purple basil	I	0.39	0.06	0.04
	II	0.51	0.09	0.08
	III	0.64	0.15	0.08
Mean		0.51	0.10	0.07
Cinnamon basil	I	0.22	0.05	0.03
	II	0.33	0.04	0.02
	III	0.32	0.04	0.02
Mean		0.29	0.04	0.02
Lemon basil	I	0.26	0.10	0.02
	II	0.22	0.04	0.03
	III	0.20	0.06	0.03
Mean		0.23	0.07	0.03
Mean for fertilizer rate	I	0.54	0.14	0.04
	II	0.64	0.12	0.06
	III	0.71	0.13	0.07
LSDα=0.01				
Basil ecotype		0.16	0.10	0.02
Fertilizer rate		n.s.	n.s.	n.s.
Interaction		0.2	n.s.	0.02

Note. I – control; II – 0.5% fertilizer rate; III – 1.0% fertilizer rate.

An analysis of the interaction between the experimental factors revealed that 'Minette' basil fertilized with 1.0% Florovit solution produced the highest fresh herbage yield (1.11 kg m^{-2}). Sweet basil grown in the control treatment was characterized by the highest dry herbage yield (0.25 kg m^{-2}). Crumbled herbage yield was highest in 'Siam Queen' basil and sweet basil fertilized with 1.0% Florovit solution (0.11 and 0.10 kg m^{-2}, respectively).

Basil is a popular culinary herb widely used in the Mediterranean cuisine. This spice and medicinal plant is rich in biologically active substances that deliver health benefits (Nurzynska-Wierdak, 2012). In the present study, the dry matter content of fresh basil herbage was significantly affected by the ecotype (Table 2). Lemon basil and cinnamon basil had the highest dry matter content (19.30% and 19.14%, respectively). Purple basil and 'Minette' basil were least abundant in dry matter (11.63% and 13.72%, respectively). Foliar fertilization had no significant effect on the dry matter content of basil herbage, which was significantly influenced by the interaction between

the experimental factors. The highest dry matter content was noted in lemon basil grown in the control treatment and in cinnamon basil fertilized with 0.5% Florovit solution. The lowest dry matter content was observed in purple basil, regardless of treatment, and in 'Minette' basil from the control treatment. The highest dry matter content of basil herbage, noted in our study, is similar to the values reported by Dzida (2010b) for basil fertilized with calcium carbonate (28.42% and 29.15%). In experiments carried out by Martyniak-Przybyszewska and Wojciechowski (2004), and Jadczak and Grzeszczuk (2008), the dry matter content of basil herbage reached 12.50% and 12.89%, respectively. In the work of Nurzynska-Wierdak et al. (2011b), basil plants fertilized with various potassium and nitrogen rates had a dry matter content of 13.20%.

Table 2. The effect of ecotype and foliar fertilization with Florovit on the content of dry matter and organic compounds in basil herbage

Basil ecotype	Fertilizer rate	Dry matter	Total sugar	Ascorbic acid	Organic acid	ß-carotene	Nitrate (V)
		(%)	(g $100g^{-1}$ f.m.)	(mg $100g^{-1}$ f.m.)	(mg $100g^{-1}$ f.m.)	(µg·$100g^{-1}$ f.m.)	(mg $NO_3 \cdot kg^{-1}$ f.m.)
Sweet basil	I	15.39	7.54	11.08	2.21	563	1127
	II	15.93	7.20	12.04	2.14	537	1471
	III	18.22	8.22	10.69	2.48	576	1098
Mean		16.51	7.65	11.27	2.28	559	1232
'Siam Queen' basil	I	14.18	8.16	9.68	1.74	579	1320
	II	15.05	8.94	11.56	1.94	538	1089
	III	15.27	11.56	10.16	2.28	537	1029
Mean		14.83	9.55	10.47	1.99	551	1146
'Minette' basil	I	12.80	6.60	9.90	1.88	768	1127
	II	14.90	7.20	9.20	1.94	568	751
	III	13.47	7.44	9.51	2.08	534	615
Mean		13.72	7.08	9.54	1.97	623	831
Purple basil	I	11.91	8.98	18.65	2.35	584	551
	II	10.99	6.48	17.84	1.68	553	633
	III	11.99	7.98	18.09	1.94	505	695
Mean		11.63	7.81	18.19	1.99	547	627
Cinnamon basil	I	19.36	6.00	10.81	2.41	593	1274
	II	22.50	10.30	11.87	1.88	559	743
	III	15.56	8.14	10.94	2.21	562	1137
Mean		19.14	8.15	11.21	2.17	571	1051
Lemon basil	I	22.98	7.37	9.99	2.28	518	1904
	II	15.87	9.75	17.44	2.08	364	1198
	III	19.05	8.75	15.70	2.08	564	1319
Mean		19.30	8.62	14.38	2.14	482	1474
Mean for fertilizer rate	I	16.10	7.44	11.69	2.14	601	1217
	II	15.87	8.20	13.33	1.94	520	981
	III	15.59	8.37	12.52	2.18	546	982
LSDα=0.01							
Basil ecotype		2.63	1.50	1.86	n.s.	n.s.	288
Fertilizer rate		n.s.	n.s.	n.s.	0.19	n.s.	n.s.
Interaction		2,21	0.22	0.32	0.22	221	219

Note. I – control; II – 0.5% fertilizer rate; III – 1.0% fertilizer rate.

The concentrations of total sugars in basil herbage were affected by the ecotype and the ecotype x fertilizer interaction. Total sugar content was highest in 'Siam Queen' basil and lowest in 'Minette' basil. Florovit applied at a concentration of 1% contributed to the accumulation of total sugars in basil herbage (11.56 g 100 g^{-1} fresh weight). A higher total sugar content of basil herbage was reported by Nurzynska-Wierdak (2012).

L-ascorbic acid levels in basil herbage ranged from 9.68 to 18.65 mg 100g^{-1} fresh weight, and they were significantly affected by the ecotype and the ecotype x fertilizer interaction. Purple basil had the highest L-ascorbic acid content, at 18.19 mg 100 g^{-1} fresh weight (mean of 2012-2013). Insignificantly higher concentrations of L-ascorbic acid (19.41 mg 100 g^{-1} fresh weight) were reported by Dzida (2011) for purple basil grown in pots.

A statistical analysis revealed that the organic acid content of basil herbage was significantly affected by foliar fertilization with Florovit and the fertilizer x ecotype interaction. The highest organic acid concentrations (2.48 g 100 g^{-1} fresh weight on average) were noted in sweet basil fertilized with 1% Florovit solution, and the lowest – in 'Siam Queen' basil (1.68 g 100 g^{-1} fresh weight). The effect of Florovit on the organic acid content of basil herbage was significant, but it varied across ecotypes depending on rate.

Herb plants are a rich source of antioxidant compounds, including carotenoids (Nurzynska-Wierdak, 2012, Kopsell et al., 2005). According to Daly et al. (2010), the average ß-carotene content of basil herbage is 258 µg·100 g^{-1}. In our study, ß-carotene concentrations were highest in 'Minette' basil grown in the control treatment (768 µg 100 g^{-1}), and lowest in lemon basil fertilized with 0.5% Florovit solution (364 µg 100 g^{-1}).

The nitrate(V) content of herbage is an important consideration in the greenhouse production of herbs and spices. Nitrate accumulation in plant material can be prevented with the use of liquid organic fertilizers, which are particularly recommended for certified organic plantations (Wierzchowska-Renke i in. 1995). No maximum permissible nitrate(V) levels have been established for herb and spice plants. The results of chemical analyses indicate that the herbage of control lemon basil plants had the highest nitrate(V) content (1904 mg $NO_3 \cdot kg^{-1}$ fresh weight). Foliar fertilization did not increase nitrate concentrations, which reached an average of 981 and 982 mg $NO_3 \cdot kg^{-1}$ fresh weight in basil ecotypes fertilized with 0.5% and 1% Florovit solutions, respectively. In a study by Seidler-Łozykowska et al. (2007, 2009), nitrate(V) levels in organically-grown basil ranged from 306.2 to 5250.0 mg $NO_3 \cdot kg^{-1}$ fresh weight, depending on the region and cultivation method. According to Telesiński et al. (2013), the nitrate(V) content of basil herbage can be as high as 9950 mg $NO_3 \cdot kg^{-1}$ fresh weight.

4. Conclusions

Basil yield was significantly affected by the ecotype. 'Minette' and 'Siam Queen' basil was characterized by the highest fresh herbage yield.

Foliar fertilization with Florovit solution had no statistically significant effect on the herbage yield of greenhouse-grown basil.

The fresh herbage of 'Minette' basil contained the lowest concentrations of dry matter, total sugars, L-ascorbic acid, organic acids and nitrates(V).

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