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*Corresponding Author:

Lilian Schmidt
Hochschule Geisenheim University
Department of Soil Science and Plant Nutrition
Von-Lade-Straße 1
65366 Geisenheim
Germany

Email: Lilian.Schmidt@hs-gm.de

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Effects of different glass covering materials on basil and mint quality

Sofia Faliagka[1], Lilian Schmidt[2], Frederik Langner[2], Angeliki Elvanidi[1], Anastasia Papadopoulou[1], Nikolaos Katsoulas[1] and Johannes F.J. Max[2]

[1]University of Thessaly, Dept. of Agriculture Crop Production and Rural Environment, Laboratory of Agricultural Constructions and Environmental Control, Volos, Greece.
[2]Hochschule Geisenheim University, Dept. of Soil Science and Plant Nutrition, Geisenheim, Germany.

1. Introduction, Knowledge, Objectives

The essential oils and herbal extracts produced by peppermint (*Mentha piperita L.*) and basil (*Ocimum basilicum L.*) have attracted scientific interest due to their potential as a source of natural antibiotic and biologically active compounds (Flanigan and Niemeyer, 2014). The composition and quantity of essential oil produced from these species could be markedly affected by climate conditions and agronomic factors, such as nutrient supply. In fact, the micronutrient manganese (Mn) controls various processes like enzymatic and non-enzymatic antioxidant activity, monoterpene biosynthesis and utilization of other mineral elements (Ca, Mg, Fe and P), in order to avoid oxidative stress (Lei et al., 2007). However, excessive Mn supply may result in toxic effects (Ducic and Polle, 2005). Therefore, according to Lange et al. (2011), the Mn concentration in the root zone should not exceed 2 ppm in order to produce the maximum amount of essential oils. In fact, the ability of plants to absorb Mn depends, among other environmental factors, on the light intensity imposed to the plants.

Cultivating peppermint and basil under greenhouse conditions was shown to increase the content of polyphenolic substances and the antioxidative capacity (Yi and Wetzstein, 2010). Indeed, cover materials with low-iron glass may further increase the yield of their essential oil production. Those materials provide increased light scattering so that better light distribution can be achieved within the greenhouse. Consequently, the resulting diffuse light that penetrates deeper into plant canopies, leads to lower plant temperature, better transpiration balances and increased photosynthetic activities (Max et al., 2012; Dueck et al., 2012). In addition, low-iron glass cover materials provide higher essential oil production to the plants, by amplifying the intense response of the plants to excess manganese supply. For this reason, the cover material selection is an important step in crop cultivation in greenhouses (Giacomelli and Roberts, 1993; Max et al., 2012).

The objective of this study was to determine the effect of glass cover material with different iron content to valuable essential oil compounds of peppermint and basil crop. To achieve this, basil and mint plants were cultivated under four different glass cover materials with different iron composition. Measurements of their antioxidant capacity and monoterpene content were performed. Additionally, the ability of the mint plants to absorb manganese under the different glass materials was investigated. This works aims to provide more insight into the modification of the greenhouse claddings and their impact on crop productivity.

2. Material and Methods

The experiment was conducted from September to October of 2017 in a glasshouse at Hochschule Geisenheim University, in Geisenheim, Germany. Basil (*Ocimum basilicum*) and mint (*Mentha piperita*) plants were grown in pots (basil: 30 plants per pot; mint: one plant per pot) filled with either soil (basil: Frühstorfer Topferde Typ T, Einheitserdewerke Patzer, Gebr. Patzer GmbH & Co. KG, Sinntal-Altengronau, Germany) or sand (mint: particle size 0.1- 0.4 mm). Four different cover materials with the same haze factor (80 %) - float glass (F), sina/sina (S/S), yasmin/yasmin (Y/Y) and yasmin/astra (Y/A, all from Interfloat Corporation, Ruggell, Switzerland) - were used in four repetitions. Thus, 16 identical mini greenhouses were chosen for this experiment. Each one of these contained six mint plants and six basil plants that were arranged in randomized block design (4 treatments x 4 repetitions). In order to study the effects of different cover materials on mint crop ability to absorb Mn, manganese(II)-nitrate tetrahydrate (Carl Roth GmbH & Co. KG, Karlsruhe, Germany) was added to the nutrient solution (Calcinit and Kristalon+micro, each 0.5 g/L; YARA GmbH & Co. KG, Dülmen, Germany) for 30 days, yielding 0, 1 and 2 mmol Mn/L. Each mini greenhouse contained two mint plants per each Mn treatment level (totally 8 plants per cover material and Mn treatment). Basil plants were supplied with water and were fertilized (Agriplant 1, PLANTA Düngemittel GmbH, Regenstauf, Germany) during their cultivation period. No environmental data were recorded during the experimental period and the impact of the different cover materials to the yield was estimated through the antioxidant and monoterpenes compound measurements. Harvest was done at 65 days after the transplantation of mint plants, while basil plants were harvested 42 days after seeding. Five random leaves from each basil pot were immediately frozen in liquid nitrogen (6 pots per cover material treatment). The remaining leaves were dried at 60 °C for three days. The leaves of 48 mint plants per Mn and cover material treatment were dried at 60 °C for three days, while the leaves of the rest 48 plants per Mn treatment were sampled in liquid nitrogen (6 plants x 2 Mn x 4 cover material treatment). The frozen leaf material was ground to fine powder and used for determination of the antioxidative capacity (both plant species; photoluminescence method) and the monoterpene content (only mint; extraction in methyl chloride and quantification by GC-MS). The dried leaf material was ground for subsequent determination of leaf nutrients using the Kjeldahl extraction and quantification by ICP-OES. Comparison of means was performed by one-way ANOVA at a confidence level of 95 % ($p \leq 0.05$) using SPSS (IBM, New York, USA).

3. Results

The results of the antioxidative capacity of basil plants under Y/A and S/S material presented a significant increase of 62% and 57% ($p<0.05$), respectively, compared to float glass (Fig. 1a). Meanwhile, the pattern of the antioxidant capacity of the mint plants was different to those of the basil. Indeed, the antioxidant capacity of the mint plants cultivated under S/S glass presented 20 % lower values than those cultivated under F, Y/Y and Y/A cover ($p<0.05$). However, the cover materials did not differ significantly ($p>0.05$). Additionally, only the antioxidative capacity of the mint plants under F and Y/A glasses was affected by the Mn supply (Fig. 1b).

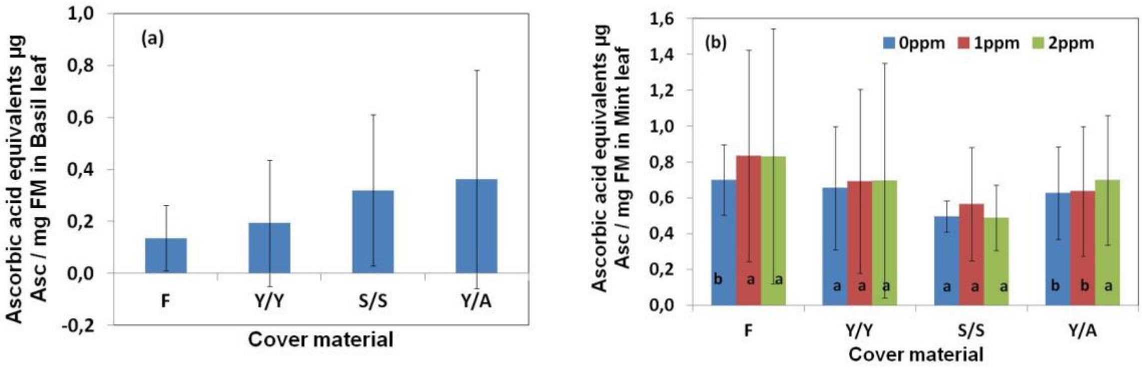

Fig. 1. Antioxidative capacity of (a) basil and (b) mint leaves. Bars show means of n=18-24 (basil) or 3-4 (mint), and SD. Ascorbic acid values with different letters are significantly different (p<0.05).

The nutrient content of basil leaves was little affected by the type of glass cover (Table 1). N, P, K, Ca, Mg and Zn presented the highest values under the float glass, Mn and Cu under the Y/Y, while Fe content was highest under S/S cover material. However, these results did not differ significantly (p>0.05). The only element that presented a statistically significant reduction was Mg. In fact, the Mg concentration reduced by 5.47% when plants were grown under S/S cladding (p<0.05). No significant variation was observed for the other nutrients, unless the Mn supply was increased. The mint plants cultivated under the Y/Y cover glass provided the highest P, K, Zn and Mn concentrations, when the Mn supply was 1or 2 ppm. However, the S/S cover material affected negatively the content of Zn when the Mn treatment increased to 2 ppm (Table 2). The maximum values of most monoterpenes at 0 ppm Mn treatment, such as b-pinene, b-myrcene, eucalyptol, menthone, l-menthone, neomenthol and levomenthol were found under S/S cover glass (Table 3). On the other hand, d-limonene and menthylacetate present higher ability to Y/A cover. No significant difference was performed between S/S and Y/A in case of pulegone. However, for doses from 1 ppm to 2 ppm of Mn supply, the plant produced maximum amounts of b-pinene, b-myrcene, D-limonene, eucalyptol and pulegone under Y/A cover glass. Particularly the D-limonene content in the leaves increased more than twice by applying 2 ppm Mn, while the pulegone content increased by more than 30 % at 1 ppm Mn (p<0.05).

Table 1. Leaf nutrient content of basil plants cultivated under different cover materials. N=24. Maximum values are highlighted in grey. The asterisk indicates the statistically significant differences (p<0.05).

Cover mat/Elements	N %	P %	K %	Ca %	Mg %	Fe ppm	Zn ppm	Mn ppm	Cu ppm
F	4,16	1,51	7,88	3,69	0,769	229	185	129	16,2
Y/Y	4,14	1,5	7,85	3,63	0,737	243	184	130	16,7
S/S	4,13	1,49	7,74	3,58	0,727*	253	182	127	16,4
Y/A	4,15	1,48	7,75	3,54	0,737	219	181	129	16,0

Table 2. Leaf nutrient content in mint plants cultivated under different cover materials and supplied with different Mn doses. N=4. Maximum values are highlighted in grey. The asterisk indicates the statistically significant differences (p<0.05).

Cover mat/	N %			P %			K %			Ca %			Mg %		
Mn supply	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm
F	4,21	4,27	4,31	0,43	0,56	0,51	4,64	4,66	4,44	1,23	1,18	1,11	0,60	0,57	0,50
Y/Y	3,94	4,25	4,60	0,44	0,60*	0,51	3,97	5,08*	4,78	1,03	1,08	1,16	0,50	0,52	0,59
S/S	4,23	4,47	4,66	0,45	0,47	0,56	4,65	4,68	4,69	1,14	1,14	1,18	0,57	0,58	0,52
Y/A	4,35	4,24	4,18	0,38	0,55	0,50	4,49	4,71	4,41	1,09	1,13	1,01	0,58	0,55	0,48

Cover mat/	Fe ppm			Zn ppm			Mn ppm			Cu ppm		
Mn supply	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm	0ppm	1ppm	2ppm
F	459,63	390,68	518,48	63,51	96,35	82,80	251,08	1346*	1809*	36,05	41,19	30,29
Y/Y	534,55	510,33	504,43	59,58	90,70*	91,24*	296,68	1252,43*	1789,75*	31,94	35,73	33,41
S/S	443,50	449,53	426,65	55,71	70,10	74,14*	201,98	754,63*	1431,5*	30,17	35,21	35,20
Y/A	512,48	375,15	532,15	48,82	81,64	89,32	204,78	935,33	2030,75	36,02	33,65	38,97

Table 3. Monoterpenes (in mg/L) of mint plants cultivated under different cover materials and supplied with different Mn doses. N=4. Maximum values of each Mn treatment are highlighted in grey. The asterisk indicates the statistically significant differences ($p<0.05$).

Mn conc./	beta-Pinene				beta-Myrcene				D-Limonene				Eucalyptol				Menthone			
cover mat	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A
0ppm	4,24	4,60	4,95	4,13	0,87	0,91	1,05	0,86	0,53	0,61	0,70	0,90	6,11	5,75	7,13	5,34	40,38	47,56	52,07	31,04
1ppm	4,41	4,19	4,52	4,79	0,89	0,84	0,94	0,97	0,63	0,69	0,71	0,96	6,61	5,85	6,74	6,69	45,78	37,09	39,20	44,83
2ppm	4,09	3,97	3,93	4,55	0,79	0,78	0,77	0,94	0,47	0,44	0,61	0,98	5,37	5,55	4,56	6,13	35,03	34,81	35,81	34,53
Mn conc.	l-Menthone				Menthylacetate				Neomenthol				Levomenthol				Pulegone			
cover mat	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A	F	Y/Y	S/S	Y/A
0ppm	2,34	2,44	2,88	1,82	3,80	3,75	4,35	4,53	3,08	3,14	3,77	2,53	22,43	22,48	29,01	17,48	87,72	97,18	101,25	100,67
1ppm	2,75	1,86	2,09	2,48	3,81	3,60	3,45	3,10	2,63	2,42	3,07	2,81	28,49	18,23	22,75	19,50	80,17	94,38	100,8202	107,59*
2ppm	2,01	2,31	1,87	2,27	4,62	4,02	4,13	4,25	2,89	2,70	2,48	2,94	19,08	18,63	17,61	20,24	81,89	91,43	81,80	98,31

4. Discussion

In the current research similar to Farzadfar et al. (2017), it was confirmed that the monoterpene biosynthesis is strongly correlated to the Mn supply. It was shown that the monoterpene components of mint oil varied under different cover materials, with mostly lower values for Y/A, Y/Y and S/S at 0 ppm, 1 ppm and 2 ppm respectively. Overall, however, it was found that the highest content of monoterpenes occurred under S/S without extra Mn supply. Additionally, the mint monoterpene biosynthesis varied with the Mn concentration in the root zone. The results showed that most of the monoterpene compounds increased when the Mn concentration was 1 ppm, while higher Mn concentrations in the root zone (2 ppm) affected negatively the monoterpene production. These findings are in agreement with the study of Ghannadniaa et al. (2014) in which the monoterpene content of cumin increased by supplementary application of Mn during both blooming and vegetative phase. The antioxidative capacity of mint plants cultivated under F and Y/A cover glass increased once the Mn supply raised to 1 ppm and 2 ppm, respectively. On the other hand the antioxidative activity of basil plants presented maximum values under S/S and Y/A treatment. The Mg leaf content in basil plants seems to be negatively affected by the S/S cover material. The contents of P, K, Zn and Mn of mint increased once the Mn treatment was 1 mmol/L, while the plants were grown under the Y/Y glass. The highest Mn dose (2 mmol/L) combined with the S/S materials decreased significantly the Zn content.

5. Conclusions

The diffuse light generated glass cover material with low iron content provides optimization of the antioxidative capacity, nutrient absorption and monoterpene content in the leaves of mint and basil plants. However, glass covers with different iron content affect differently the aforementioned factors. Particularly, the Y/A glass cover increased the antioxidative capacity in the basil plants and produced high concentrations of pulegone in mint leaves. The optimum Mn threshold to produce maximum amounts of monoterpenes in mint varied from 0 to 1 ppm in S/S and Y/A respectively. Meanwhile, the Y/Y glass cover provides highest P, K and Zn concentrations in the leaf, by applying 1 ppm Mn to the root zone.

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