Plant Physiology and Biochemistry 119 (2017) 170–177

Contents lists available at ScienceDirect

Plant Physiology and Biochemistry

journal homepage: www.elsevier.com/locate/plaphy

Research article

Stress-induced changes of growth, yield and bioactive compounds in lemon balm cultivars

Krisztina Szabó [a, *], Péter Radácsi [a], Péter Rajhárt [a], Márta Ladányi [b], Éva Németh [a]

[a] *Department of Medicinal and Aromatic Plants, Faculty of Horticultural Science, Szent István University, Budapest, H-1118 Budapest, Villányi Str. 29-43, Hungary*

[b] *Department of Biometrics and Agricultural Informatics, Faculty of Horticultural Science, Szent István University, Budapest, H-1118 Budapest, Villányi Str. 29-43, Hungary*

ARTICLE INFO

Article history:
Received 30 May 2017
Received in revised form
11 July 2017
Accepted 21 July 2017
Available online 22 July 2017

Keywords:
Melissa officinalis
Drought stress
Essential oil
Total phenolic content
Total flavonoid content
Rosmarinic acid
FRAP antioxidant capacity

ABSTRACT

The aim of the present study was to investigate the impact of water deficiency on five *Melissa officinalis* genotypes. For three months water supply of 70% (control) and 40% (stress) of soil water capacity treatments have been adjusted in a pot experiment. Considering the morphological data, the different genetic potentials of cultivars were manifested only under optimum water regimes while under drought they merged into one homogeneous basic population representing the species. The biomass data decreased for all cultivars under drought stress, but the degree of loss was genotype specific. Genotype dependence of the change in essential oil accumulation was clearly proved by the data. Three of the cultivars (‘Gold Leaf’, ‘Lorelei’ and ‘Quedlinburger Niederliegende’) showed the same essential oil content both in control and stress treatments. Under drought stress the cultivar ‘Lemona’ produced only 35% of its essential oil content, however cv. ‘Soroksár’ reacted with 58% increase of essential oil accumulation to drought treatment. Considering the non-volatile bioactive compounds a unique response of the investigated accessions to drought stress was demonstrated. Cultivar ‘Lorelei’ showed an increased accumulation of total hydroxicinnamic acid derivatives content while cv. ‘Gold Leaf’ and ‘Soroksár’ clearly reacted with higher accumulation of total flavonoid fraction. In the case of cv. ‘Quedlinburger Niederliegende’ the remarkable decline in total flavonoid content is the most obvious stress reaction. The rosmarinic acid content of all genotypes showed lower accumulation level in consequence of lower water supply.

1. Introduction

Optimization of cultivation techniques while adapting to the changing environment (e.g. climate change) and taking into account the consequences of existing methods (e.g. decreasing water resources, soil degradation, etc.) is one of the major challenges in sustainable horticulture (Witcombe et al., 2016). The reaction of plants to environment-induced perturbations – including drought – is thoroughly discussed for several species. Continuously increasing number of publications proves the shift in metabolism due to stress factors, which is specifically important in the cultivation of medicinal and aromatic plants (MAPs). One may have the chance to take advantage of the phenomenon (Kleinwächter et al., 2015) in view of the possibility for increased accumulation of secondary metabolites without sacrificing much of the useful biomass (parts of the plant providing the crude drug). To thoroughly unfold the processes, having discussed the universally present tendencies (Selmar and Kleinwächter, 2013a; 2013b; Ramakrishna and Ravishankar, 2011), new, additional aspects need to be investigated such as specific reactions of intraspecific accessions, characteristics of different secondary compounds, the degree and duration of stress or the margins between stress and adaptation just to list a few among many (Anonymus, 2015).

Some statements in the literature regarding the accumulation of active ingredients of MAPs due to drought stress are summarized in Table 1. Differences among species does not support generalization. It seems that the mechanism through which secondary metabolites are taking part in mediating plant responses to environmental changes is more complex.

Remarkable intraspecific variability was proved for some species when exposed to water deficiency (Table 2). These few examples demonstrate that although natural products in the

* Corresponding author.
E-mail address: szabo.krisztina@kertk.szie.hu (K. Szabó).

http://dx.doi.org/10.1016/j.plaphy.2017.07.019

List of abbreviations

EO	essential oil
THA	total hydroxicinnamic acid derivatives
RA	rosmarinic acid
DW	dry weight
MAPs	medicinal and aromatic plants
cv.	cultivar
FRAP	ferric reducing antioxidant power
TPC	total polyphenolic content
TFC	total flavonoid content
SWC	soil water capacity
QE	isoquercitroside equivalent
GAE	gallic acid equivalent
AAE	ascorbic acid equivalent
ANOVA	analysis of variance
MANOVA	Two-way multivariate ANOVA

phenoloid class are good counterpoints of oxidative stress and frequently studied defence compounds, not all types of phenoloids, not in all species, cultivars or scions, and not in all types of organs will accumulate when exposed to drought. Obviously, tolerance mechanisms other than this may contribute to coping with water deficiency.

The literature background in connection with *Melissa officinalis* – target species of the present study – and its reaction to water deficiency is limited. The studies on the effect of drought stress on the species mainly focused on the essential oil (EO) accumulation in addition to some plant physiological and/or yield characteristics (Munné-Bosch and Alegre, 1999; 2003, Abbaszadeh et al., 2009, Farahani et al., 2009; Ozturk et al., 2004; Shirzadi et al., 2010; Meira et al., 2013). Recently the tests of drought stress were extended also to the response of the accumulation of phenoloids in some reports (Manukyan, 2011; Németh-Zámbori et al., 2016; Radácsi et al., 2016). Based on these results, the accumulation of EO (defined as % of dry weight) increased. Morphological characteristics influencing biomass and yield did not vary significantly when moderate water deficiency was used. Authors generally concluded that moderate water deficiency stress for *Melissa officinalis* can be advantageous when EO yield is calculated (Abbaszadeh et al., 2009, Farahani et al., 2009; Ozturk et al., 2004; Meira et al., 2013). Result for EO content (%) in a report of soilless greenhouse circumstances (Manukyan, 2011) delineated a modified context. Only high drought stress induced a higher EO % while EO yield (ml/plant) decreased step by step parallel to decreased substrate moisture.

As for the non-volatile substances (total polyphenolic content (TPC), total flavonoid content (TFC), rosmarinic acid (RA) content) of lemon balm the outcome of experiments is not so obvious. According to Manukyan (2011) TPC of *Melissa officinalis* shoots

Table 1
Drought stress related changes in various secondary metabolite accumulation.

Plant species	Adjustment of drought stress	Secondary metabolite type	Direction of change in accumulation	Reference
Origanum vulgare	continuous at flowering	essential oil	no change increase	Azizi et al., 2009
Salvia miltiorrhiza	continuous	rosmarinic acid phenolics terpenoids	decrease increase increase	Hongyun et al., 2011
Artemisia annua	continuous	essential oil artemisinin	decrease decrease	Yadav et al., 2014
Matricaria recutita	continuous	essential oil	no change	Baghalian et al., 2011
Mentha piperita	continuous	essential oil	increase	Ghanbari and Ariafar, 2013
Scutellaria baicalensis	continuous	flavonoids	increase	Yuan et al., 2012
Salvia officinalis	continuous	essential oil	increase	Bettaieb et al., 2009
Prunella vulgaris	continuous	phenolic acids	increase	Yuhang et al., 2011
Trachyspermum ammi	continuous	phenoloids	increase	Azhar et al., 2011
Tropaeolum majus	continuous	glucotropaeolin	increase	Bloem et al., 2014
Eucalyptus spp.	continuous	TPC	decrease	McKiernan et al., 2014
Dracocephalum moldavica	continuous	essential oil	decrease	Gholizadeh et al., 2010
Ocimum basilicum	continuous	antocyanin	increase	Alishah et al., 2006
Salvia officinalis	continuous	essential oil	no change	Rioba et al., 2015
Salvia officinalis	continuous (8 weeks)	monoterpenes	increase	Nowak et al., 2010
Ocimum basilicum	continuous	essential oil	increase	Radácsi et al., 2010
Vitis vinifera	8 days	polyphenols	increase	Griesser et al., 2015

Table 2
Examples of intraspecific diversity in manifestation of drought resistance.

Plant species	Adjustment of drought stress	Secondary metabolite type	Variation	Reference
Arachis hypogaea	continuous around generative phase	TPC	different responses in leaf phenolic content among genotypes	Aninbon et al., 2016
Lactuca sativa	continuous for 3 weeks before harvest	TPC	reaction to water deficit depended on the cultivar, for cv. Theodore higher TPC when stressed	Eichholz et al., 2014
Vitis vinifera	continuous	flavonoids	genotype specific increase of rutin and quercetin-3-O-galactoside in cv. Shiraz, but not in cv. Cabernet Sauvignon	Hochberg et al., 2013
Olea europaea	continuous	TPC oleuropein	genotype dependent reaction, cv. Gaidourelia showed higher phenolic concentration after water stress	Petridis et al., 2012