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Correlation between the Agronomical Characteristics and Essential Oil Content of *Origanum onites* L. and *Melissa officinalis* L.[#]

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ABSTRACT

Due to their widespread use in the pharmaceutical, cosmetic and food industries, medicinal and aromatic plants have gained importance with an increasing number of studies being conducted concerning the yield and quality characteristics of these plants. In breeding studies, selection is successful when there a correlation is established between the essential oil content, composition, and morphological and agronomic characteristics. The aim of this study was to address the correlation between the yield and quality of medicinal and aromatic plants to present a different perspective for breeding studies. Therefore, in this study, the relationship among the characteristics and the essential oil content of Izmir oregano (*Origanum onites* L.) and lemon balm (*Melissa officinalis* L.) plants were investigated, and correlation and path analyses were performed. There was a significant negative correlation between the essential oil content and fresh herb (-0.279*), dry herb (-0.281*), and dry stem yield (-0.283*) of Izmir oregano. However, no significant correlation was found between the essential oil content and these agronomic characteristics in lemon balm. Fresh herb yield had a significant positive correlation with dry herb (0.661**), dry leaf (0.690**), and dry stem yield (0.610**). Dry herb yield was significantly and positively correlated with dry leaf (0.510*) and dry stem (0.461*) yields. A significant positive correlation was also observed between dry leaf and dry stem (0.688**) yields. According to the results of the path analysis, while the maximum negative effect on the essential oil content of Izmir oregano was provided by dry herb (-48.05%) yield, the highest direct positive effect belonged to dry leaf (21.69%) and dry stem (15.13%) yields. Dry leaf yield (-51.61%) and plant height (-45.71%) were the parameters that had the highest direct negative effect on the essential oil content of lemon balm while fresh herb (33.50%) and dry herb (30.27%) yields were the source of the highest direct positive effect.

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Introduction

Medicinal and aromatic plants have widespread usage in pharmaceutical, cosmetic and food industries. Izmir oregano *(Origanum onites* L.), belonging to the Lamiaceae family, is a widespread perennial plant in the West and South parts of Turkey (Tanker et al., 2007). It is one of the most important export plant collected from natural flora and cultivated in Turkey. The *Origanum* genus is widely used as spices and for the flavouring of food products in addition to being utilised as ingredients in cosmetic and cleaning products. Furthermore, the essential oils of *Origanum* species are used as natural food preservatives due to their antioxidant and antimicrobial activities (Avci, 2017). The major component of *Origanum* essential oil is mostly carvacrol with its content ranging from 51.0% to 84.5% (Ninou et al., 2017). Lemon balm (*Melissa officinalis* L.) belongs to the Lamiaceae family and is a perennial plant widespread in the coastal areas of Turkey, especially in the Mediterranean Region (Avci and Giachino, 2016). There are three subspecies of *M. officinalis*: subsp. *officinalis*, subsp. *inodora*, and subsp. *altissima*; however, only subsp. *officinalis* has commercial value and the characteristic lemony odour of lemon balm (Zeybek and Haksel, 2011).

Medicinal and aromatic plants are collected from flora, and a small amount is obtained by cultivation in many countries. Collecting suppressed the plant species and creates quality and standardisation problems in medicinal and aromatic plant products. This emphasises the necessity of further plant breeding work to be undertaken. In breeding studies, selection is successful when there is a

correlation between essential oil content, composition and morphological and agronomic characteristics. Essential oil is one of the important quality criteria in medicinal plants. The essential oil content of medicinal and aromatic plants is a complex characteristic to which many factors, such as environmental conditions, harvest time, maturity, and genotype contribute by changing the content and composition of essential oil. Therefore, it is considered to be more advantageous to investigate the morphological and agronomical properties that affect the content of essential oil, rather than directly increasing the content of essential oil in medicinal and aromatic plants.

Correlation and path analyses are important statistical methods for evaluating yield and quality criteria in plant breeding. Correlation coefficients basically indicate the relationships between independent variables and their linear relations among the variables. However, correlation coefficients cannot adequately define the complex relationship between variables. For this reason, the direct and indirect effects of various characteristics on both yield and quality should be determined in breeding programs. Accordingly, path coefficient analyses are used to determine the amounts as the percent of direct and indirect effects of the independent variables on the dependent variable (Harman 1976; Neter et al 1983; Kara and Baydar, 2017).

The aim of this study was to determine the relationships between some morphological and agronomical properties of *O. onites* and *M. officinalis* which have direct and indirect effects on the essential oil content using correlation and path analyses and to identify the best selection criteria for the essential oil content of these plants.

Material and Method

Izmir oregano and lemon balm plants were used as the material. The average data from two-year field trials (2014 and 2015 years for oregano; 2013 and 2014 years for lemon) were analysed. For Izmir oregano, plant height was measured in cm from the soil level to the highest point on ten plants from each parcel. For fresh herb yield, after removing the marginal effects, the remaining plants were harvested 10 cm above the soil surface and weighed; then, the parcel yield was converted to hectare yield (ha^{-1}). Dry leaf yield was obtained by weighing 500 g of fresh plant samples from each parcel after drying them for 72 hours at 30 °C in a drying chamber. The leaves of the samples were then removed from the stem and weighed. Dry leaf yield was calculated per hectare. The essential oil content was measured in 20 g of dried samples harvested from each parcel as described by Wichtl (1971). The plant height, fresh herb yield, dry herb yield, dry leaf yield, dry stem yield and essential oil content of lemon balm were calculated as in Izmir oregano. The data obtained from the study were analysed using SPSS (v. 11.0) statistical package program.

Results and Discussion

The correlations between plant height, fresh herb, dry herb, dry leaf and dry stem yields, and essential oil content of *Origanum onites* L are given in Table 1. The results showed a significant positive correlation between plant height and all investigated plant characteristics except essential oil content at the P<0.01 level. The correlation coefficients of the plant height were calculated as 0.469 ** with fresh herb yield, 0.485 ** with dry herb yield, 0.516 ** with dry leaf yield, and 0.485 ** with dry stem yield. Fresh herb, dry herb and dry stem yields were significantly correlated with all the investigated plant traits. Fresh herb yield had a very significant positive correlation with the yields of dry herb (r = 0.984**), dry leaf (r = 0.940**) and dry stem (r = 0.955**) at the P<0.01 level, and it had a significant negative correlation with the essential oil content (r = -0.279*) at the P<0.05 level. Dry herb yield was significantly negatively correlated with fresh herb, dry leaf and dry stem yields with high correlation coefficients (r = 0.984**, 0.948** and 0.952**, respectively). Dry herb yield had a significant negative relationship with the essential oil content (r = -0.281*) and a significant positive correlation with plant height and fresh herb, dry herb and dry stem yields (r = 0.516**, 0.940**, 0.948** and 0.853**, respectively; P<0.01). Dry stem yield was very significantly positively correlated with plant height (r = 0.485**), fresh herb yield (r = 0.955**), dry herb yield (r = 0.952**), and dry leaf yield (r = 0.853**) at the P<0.01 level, but it had a significant negative correlation with the essential oil content (P<0.05).

When examined the essential oil content, it had a negative correlation with all the plant properties investigated, and this negative correlation was significant only with fresh herb, dry herb and dry stem yields at the P<0.05 level (r=-0.279*, -0.281* and r=-0.283*, respectively). Similarly, in their study on 14 accessions of *O. vulgare* L. Venkatesha et al. (2018) reported a very significant negative correlation between essential oil content and the leaf/stem ratio of the essential oil yield (-0,55** and -0,58**, respectively), and as expected there was a significant positive correlation between the essential oil content and essential oil yield (0.92**). Gupta et al. (2017) reported that the essential oil yield of *Mentha* species was highly significantly and positively correlated with the oil content (0.87**) whereas a positive genetic correlation was found between the oil content and the thickness of sucker (0.43*) and number of internodes (0.43*).

Table 1 Correlation coefficients between the investigated properties of *Origanum onites* L. and their significance

Characteristics	Plant Height	Fresh Herb Yield	Dry Herb Yield	Dry Leaf Yield	Dry Stem Yield
Fresh Herb Yield	0.469**	1.000			
Dry Herb Yield	0.485**	0.984**	1.000		
Dry Leaf Yield	0.516**	0.940**	0.948**	1.000	
Dry Stem Yield	0.485**	0.955**	0.952**	0.853**	1.000
Essential Oil Content %	-0.109ns	-0.279*	-0.281*	-0.224ns	-0.283*

**: significant at the 0.01 probability level; *: significant at the 0.05 probability level; ns: non-significant

Table 2 Correlation coefficients between the investigated properties of *Melissa officinalis* L. and their significance

Characteristics	Plant Height	Fresh Herb Yield	Dry Herb Yield	Dry Leaf Yield	Dry Stem Yield
Fresh Herb Yield	0.100ns	1.000			
Dry Herb Yield	0.218ns	0.661**	1.000		
Dry Leaf Yield	0.019ns	0.690**	0.510*	1.000	
Dry Stem Yield	0.273ns	0.610**	0.461*	0.688**	1.000
Essential Oil Content %	-0.030ns	0.093ns	0.287ns	-0.251ns	-0.059ns

**: significant at the 0.01 probability level; *: significant at the 0.05 probability level; ns: non-significant

Table 3 Path coefficient and percentages of the direct and indirect effects of investigated properties on the essential oil content of *Origanum onites* L.

Characteristics	Direct Effects		Indirect Effects									
	Essential oil content		Plant height		Fresh herb yield		Dry herb yield		Dry leaf yield		Dry stem yield	
	PC	P	PC	P	PC	P	PC	P	PC	P	PC	P
Plant height	-0.13	9.35	-	-	0.07	4.76	-0.62	44.08	0.29	20.41	0.19	13.31
Fresh herb yield	0.14	5.42	-0.06	2.34	-	-	-1.25	47.74	0.52	19.84	0.37	13.98
Dry herb yield	-1.27	48.05	-0.06	2.40	0.14	5.28	-	-	0.53	19.81	0.37	13.81
Dry leaf yield	0.55	21.69	-0.07	2.65	0.13	5.23	-1.21	47.23	-	-	0.33	12.82
Dry stem yield	0.38	15.13	-0.06	2.51	0.14	5.35	-1.21	47.76	0.47	18.60	-	-

PC: Path coefficient, P: Path %

Table 4 Path coefficient and percentages of the direct and indirect effects of investigated properties on the essential oil content of *Melissa officinalis* L.

Characteristics	Direct Effects		Indirect Effects									
	Essential oil content		Plant height		Fresh herb yield		Dry herb yield		Dry leaf yield		Dry stem yield	
	PC	P	PC	P	PC	P	PC	P	PC	P	PC	P
Plant height	-0.56	45.71	-	-	0.08	6.63	0.15	12.04	-0.02	1.71	-0.01	0.95
Fresh herb yield	0.81	33.50	-0.06	2.30	-	-	0.45	18.41	-0.74	30.71	-0.03	1.07
Dry herb yield	0.67	30.27	-0.12	5.45	0.54	24.06	-	-	-0.55	24.65	-0.02	0.88
Dry leaf yield	-1.08	51.61	-0.01	0.52	0.56	26.82	0.34	16.48	-	-	-0.03	1.40
Dry stem yield	-0.04	2.05	-0.15	7.30	0.50	23.79	0.31	14.94	-0.74	35.63	-	-

PC: Path coefficient, P: Path %

The correlations between the values obtained from plant height, fresh herb, dry herb, dry leaf and dry stem yields, and essential oil content in *M. officinalis* are given in Table 2. These results revealed that plant height and essential oil content did not have a statistically significant relationship with the remaining properties examined. In contrast, in their study with a lemon balm population, Aharizad et al. (2013) found that essential oil yield was significantly correlated with leaf width, essential oil content, and citral content. In the current study, fresh herb yield had a significant positive relationship with dry herb ($r = 0.661^{**}$), dry leaf ($r = 0.690^{**}$) and dry stem ($r = 0.610^{**}$) yields at the level of $P<0.01$. Dry herb yield was found to be significantly positively correlated with fresh herb yield ($r = 0.661^{**}$; $P<0.01$) and dry leaf ($r = 0.510^{*}$) and stem ($r = 0.461^{*}$) yields ($P<0.05$ for both). Dry leaf yield had a significant positive relationship with fresh herb yield ($r = 0.690^{**}$) and dry stem yield ($r = 0.688^{**}$) at the $P<0.01$ level, and with dry herb yield ($r = 0.510^{*}$) at the $P<0.05$ level. There was a significant positive correlation between dry stem yield and fresh herb yield ($r=0.610^{**}$; $P<0.01$), dry leaf yield ($r=0.688^{**}$) ($P<0.01$), and dry herb yield ($r = 0.461^{*}$; $P<0.05$). Talle et al. (2012), who performed a correlation analysis between plant characteristics in lemon balm accessions, reported a positive correlation between lateral stem and plant height, leaf length and shoot diameter, and between essential oil yield and essential oil content. The authors also observed a significant relationship between plant height and leaf yield, leaf length, leaf width, shoot diameter, essential oil yield, essential oil content, leaf dry weight, and root dry weight.

The direct and indirect effects of plant height and fresh herb, dry herb, dry leaf and dry stem yields on the essential oil content of *O. onites* plant samples were obtained by taking the average of two vegetation years and are presented in Table 3. The path analysis revealed that the direct effect of plant height on essential oil content was negative and low (-9.35%). Dry herb yield had the highest negative indirect effect on essential oil content (-44.08%) and dry leaf yield had the highest positive indirect effect on essential oil content (20.41%) through plant height. Through fresh herb yield, the highest negative indirect effect on essential oil content belonged to dry herb yield (-47.74%) while the highest positive indirect effect was that of dry leaf (19.84%) and dry stem (13.98%) yields (Table 3). Dry herb yield had a direct negative on essential oil content at the highest level (-48.05%). Through this parameter, dry leaf (19.81%) and dry stem (13.81%) yields indirectly positively affected essential oil content. The largest direct effect on essential oil content was that of dry leaf yield, and this effect was positive (21.69%). It was determined that through dry leaf yield, dry herb yield had

the greatest indirect effect on essential oil content (-47.23%) while dry stem yield had an indirect positive effect (12.82%). Dry stem yield directly positively affected essential oil content (15.13%). When the indirect effects through dry stem yield were examined, it was found that the highest indirect negative and positive effects belonged to dry herb yield (-47.76%) dry leaf yield (18.60%), respectively (Table 3). The path analysis results of *O. onites* showed that dry herb yield had the maximum direct negative effect and dry leaf yield had the maximum direct positive effect on essential oil content. It showed that the increasing of the dry leaf yield would also lead to enhancement in the essential oil yield. Therefore, in order to increase the yield of *O. onites* essential oil, dry leaf yield can be used as a selection criterion. Venkatesha et al. (2018) revealed that the highest positive direct effect on the essential oil yield of 14 Oregano accessions were internodes length (0.70), leaf length (0.35), herb yield (0.16), and a number of branches (0.07). The plant height had a negative direct effect (-0.82) followed by the leaf/stem ratio (-0.34) and canopy diameter (-0.25). Gupta et al. (2017) reported that the number of internodes of *Mentha* species might be important for the selection of varieties that indirectly contributed to the essential oil yield, while other characteristics, such as plant height and fresh herb yield were not correlated with oil yield.

In *M. officinalis*, the direct and indirect effects of plant height and fresh herb, dry herb, dry leaf and dry stem yields calculated by taking the average of two vegetation years, and the values are given in Table 4. As a result of path analysis, it was determined that the direct effect of plant height on essential oil content was negative and high (-45.71%). The highest indirect positive and negative effects on essential oil content through plant height belonged to dry herb yield (12.04%) and fresh herb yield (6.63%), respectively.

Fresh herb yield had a high-level positive direct effect on essential oil content (33.50%). Through this parameter, the greatest indirect effects on essential oil content were that of fresh herb yield in a negative direction (-30.71%) dry herb yield (18.41%) in a positive direction. In addition, plant height and dry stem yield indirectly negatively affected essential oil content (Table 4). Dry herb yield had a direct positive effect on essential oil content at a high level (30.27%). Through this parameter, plant height, dry leaf and dry stem yields indirectly negatively affected essential oil content while the indirect effect of fresh herb yield was positive. The maximum indirect effects belonged to fresh herb yield (24.06%) and dry leaf yield (-24.65%). The direct effect of dry leaf yield on essential oil content was found to be negative and at a high rate (-51.61%). Through dry leaf yield, the highest indirect positive effects on essential oil content were exerted by fresh herb yield (26.82%) and dry herb yield (16.48%) while plant height and dry stem yield exhibited indirect negative effects. Dry stem yield had a low-level direct negative effect on essential oil content (-2.05%). The examination of the indirect effects through dry stem yield showed that the maximum indirect effect was produced by dry leaf yield in a negative direction (-35.63%) and fresh herb (23.79%) and dry herb (14.94%) yields in a positive direction (Table 4).

As a result of path analysis performed in *M. officinalis*, the maximum negative effect on essential oil content was obtained from dry leaf yield and plant height, while the highest direct positive effect was seen in fresh herb and dry herb yields. Therefore, short plant height and dry leaf yields can be used as a selection criteria for lemon balm. Aharizad et al. (2013) showed that essential oil content and leaf width respectively had the highest and lowest direct effects on essential oil yield in 11 lemon balm populations evaluated. Talle et al. (2012), who conducted a path analysis on six lemon balm accessions, reported that shoot yield had the highest direct effect on essential oil yield. Furthermore, leaf length, leaf width, and dry stem weight had the lowest direct effects on essential oil yield.

Conclusion

Having knowledge of the direct and indirect effects of various morphological and agronomic characteristics on yield and quality is important for the success of in plant breeding programs. The path analysis revealed that in Izmir oregano, dry herb yield and dry leaf yield had the highest direct negative and positive effects on essential oil content, respectively. Therefore, plants with a low stem ratio but high leaf yield can be considered as selection criteria for the breeding studies of thyme. Similarly, in lemon balm, the highest direct negative effect on essential oil content was obtained from dry leaf yield, followed by plant height. Thus, short plants with low dry leaf yield can be utilised as selection criteria for the breeding of lemon balm.

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