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Plant growth, yield and bioactive compounds of two culinary herbs as affected by substrate type

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ABSTRACT

This study reports on the influence of growing substrates on plant yield, quality, and valuable bioactive compounds of two aromatic leafy vegetables; dill and parsley, grown in net house. The treatments comprised seven substrates; basis substrate (Stender, Germany soil); peat moss; sandy soil; Germany soil + peat moss (1:1 v/v); Germany soil + sandy soil (1:1 v/v); peat moss + sandy soil (1:1 v/v) and Germany soil + peat mass + sandy soil (1:1:1 v/v). Yield traits (stem length and diameter, number of leaves and leaf area), quality (shoot and root fresh and dry weights), as well as spectrophotometric analysis of bioactive components, including chlorophyll content, phenolics and flavonoids, and antioxidant activity based on radical scavenging activity assays DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS [(2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid)], and ferric reducing antioxidant power (FRAP) were measured. The higher yield and quality were observed in dill and parsley grown in Germany soil, followed by that grown in Germany soil + peat, which showed better performance such as greater plant height, number of leaves and leaf areas, thicker stem diameter, and higher shoot and root fresh and dry weights when compared with other substrates. The highest content of chlorophyll, phenolics, flavonoids, DPPH and ABTS radical scavenging activity, and FRAP was found in dill and parsley plants grown in Germany soil. Dill showed higher antioxidant capacity than parsley owing to the lower content of phenolics and flavonoids compounds in parsley.

1. Introduction

Dill (*Anethum graveolens* L.) and parsley (*Petroselinum crispum* Mill.), which belong to the Apiaceae (Umbelliferae), are used worldwide as fresh, dried or frozen vegetables, and aromatic and medicinal herbs (Osińska et al., 2012; Karklelienė et al., 2014; Kılıç and Duyar, 2016). They are described as a vital source of phenolic and flavonoid compounds, which have anti-inflammatory, anti-allergic, anti-microbial, and anti-cancer properties (Hedges and Lister, 2007; Kamel et al., 2013). Many investigators studied the content of phenolic and flavonoid metabolites in medicinal and herb plants, and their findings confirmed the hypothesis that these compounds contribute significantly to the antioxidant activity (Cai et al., 2004; Yao et al., 2004; Katalinic et al., 2006; Brasileiro et al., 2015). Therefore, they could serve as good sources of antioxidant activity (Kaefer and Milner, 2008; El-Zaeddi et al., 2017). There is increasing research interest in antioxidant defense systems because antioxidants can inhibit the free radical reactions and potentially protect from chronic diseases, particularly cancer, and cardiovascular diseases (Ebrahimzadeh et al., 2010; Leahu et al., 2013; El-Zaeddi et al., 2017; Yashin et al., 2017). Antioxidants may exert their effects through different mechanisms, such as scavenging free radicals, shattering peroxides, and chelating metal ions which catalyze the oxidation process (Majewska et al., 2011). Therefore, inhibition of DPPH (1,1-diphenyl-2- picrylhydrazyl) and ABTS [2,2′-azino-bis (3-

Abbreviations: ABTS, 2,2′-azino-bis (3-ethylbenzothiazoline-6-sulphonic acid; *Chl*, chlorophyll; CRD, complete randomized design; DMF, N, N-dimethylformamide; DPPH, 2,2-diphenyl-1-picrylhydrazyl; FRAP, ferric reducing antioxidant power; FW, fresh weight; TF, total flavonoids

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ethylbenzthiazoline-6-sulfonic acid)] and ferric reducing antioxidant power (FRAP) are used to assay antioxidant activities based on different chemical mechanisms (Kulkarni et al., 2004; Kouřimská et al., 2013). To discern the precise mechanisms of antioxidant activity, different assays may be required, as a single antioxidant assay may not reflect the full spectrum of biochemical action (Çam et al., 2009).

The use of growing substrates in vegetable production is increasing worldwide (Barcelos et al., 2016). Growing substrates are materials, other than soils, in which plants can grow. These include organic materials such as peat moss, compost, tree bark, wood shavings, and sawdust, or inorganic materials such as sand, perlite, vermiculite, and rock wool (Butt et al., 2007; Olle et al., 2012), or mixtures such as peat and perlite, and peat and compost (Nair et al., 2011; Sedaghat et al., 2017). Among the agricultural inputs involved in greenhouse crop production, one vital factor is the type of growing substrate used (Sedaghat et al., 2017). Therefore, choosing the best substrate among the numerous available materials is important for vegetable production in a greenhouse environment (Sedaghat et al., 2017). Moreover, there is currently little information available concerning the influence of substrate type on plant growth and quality in many crops, including leafy vegetables (Barcelos et al., 2016). Crop performance (yield and quality) is usually the main factor in developing a growing substrate (Olle et al., 2012). Previous studies indicated that agricultural practices used for dill and parsley affect its yield, quality, and some health-related compounds (Novac, 2011; Najla et al., 2012; Karklelienė et al., 2014; Kılıç and Duyar, 2016; Alan et al., 2017). Nitrogen application, season of cultivation and stage of harvest influenced the yield and composition of dill essential oil (Tsamaidi et al., 2010). A transient high salinity (240 mM NaCl) and high pH (20 mM $KHCO_3$, pH 12) treatments in substrate-based and substrate-free conditions regulated the appearance of culinary herbs including parsley (Beacham et al., 2015).

There are many methods that can be used to evaluate phenolic and flavonoid content and free radical scavenging activity of plant extracts, but a common one is based on spectrophotometric analysis (Roginsky and Lissi, 2005; Stankevičius et al., 2010). Therefore, this study was performed to: (a) investigate the influence of two commercially introduced substrates (basis substrate Stender, known as Germany soil, and peat moss), as well as sandy soil (traditional substrate), and their mixtures, on yield and quality of dill and parsley plants; (b) assess the content of health-related compounds; chlorophyll, phenolics and flavonoids, in addition to determination of the antioxidant activity by DPPH (2,2-diphenyl-1-picrylhydrazyl) and ABTS (2,2′-azino-bis(3-ethylbenzothiazoline-6-sulphonic acid) radical scavenging, and ferric reducing antioxidant power (FRAP) assays in dill and parsley extracts using spectrographic analyses.

2. Materials and methods

2.1. Plant material and growth conditions

This research was conducted in the net house at the College of Food and Agricultural Sciences, King Saud University, Riyadh, Saudi Arabia (longitude: 24° 39′ N, latitude: 46° 44′ E) during two successive seasons of 2016 and 2017 (from February to April). Seeds of two Apiaceous (umbelliferous) leafy vegetables; dill 'local Var.' (*Anethum graveolens* L.), and parsley 'Italian Giant' (*Petroselinum crispum* cv. neapolitanum), which is followed the plain leaf type cultivated for its foliage (Osińska et al., 2012), were purchased from a local market in Riyadh city. The seeds were sown in plastic trays (50 × 50 cm) filled with sandy soil for their germination. The seeds were planted manually as 0.75 g seeds per tray (Kılıç and Duyar, 2016) and watered daily until 3–4 true leaves were appeared. Ten days later, the seedlings transplanted into plastic pots (one seedling per pot). The weather conditions in terms of minimum, maximum and average air temperatures as well as average relative humidity during experiment period are presented in Table 1.

Table 1
Minimum, maximum and average temperatures and relative humidity in the net house location.

Year	Minimum temperature (°C)	Maximum temperature (°C)	Average temperature (°C)	Average relative humidity (%)
2016				
February	14.2	21	17.6	47.6
March	20.6	27.8	24.3	24.4
April	21.9	31.6	26.7	31.6
2017				
February	12	19.7	15.8	36.3
March	18	24.7	21.6	41.3
April	22.3	32.4	27.3	33.1

2.2. Growing substrates treatments

At the stage of 3–4 true leaves, the seedlings were transplanted into plastic pots (10 cm in diameter) containing three different substrates as follows: (1) Stender, Wachstum braucht Wurzeln (Hersteller/Producer, Stender AG, Alte PoststraBe 121, Germany), which is known in the Saudi market as Germany soil, and (2) peat moss (HAWITA) professional, Weisstorf (European Union, EU), in addition to (3) traditional sandy soil, the common medium used for growing vegetables in a greenhouse (Olle et al., 2012). These substrates were added as follows: Germany soil (T1); peat moss (T2); sandy soil (T3); in addition to a volume ratio of Germany soil + peat moss (1:1; v:v) (T4); Germany soil + sandy soil (1:1; v:v) (T5); peat moss + sandy soil (1:1; v:v) (T6) and Germany soil + peat mass + sandy soil (1:1:1; v:v:v) (T7). Soil structure of sandy soil used was: 79.22% sand, 12.05% silt, and 8.73% clay, and with average pH = 7.69, EC 1.70 dS m^{-1} and organic matter (0.34%) following Chapman and Pratt (1978) procedure. Some chemical and physical characteristics of the two introduced substrates; Germany soil and peat moss according to the manufacturer are shown in Table 2.

During cultivation, dill and parsley plants were checked frequently for pests and disease incidence. The nutritional requirements of the plants were provided solely by the substrate treatments alone and no additional fertilizers were applied over the growth period. The plants were hand-irrigated twice per week.

2.3. Harvesting and determination of growth parameters

The plants were harvested after 66 and 60 days of transplanting for dill and parsley, respectively. Since, Italian parsley and foliage dill have short life cycle; they are harvested approximately 69–70 days after transplanting (Mylavarapu and Zinati, 2009). In order to obtain tender and fresh feathery dill and flat leaved parsley, the plants were harvested in the early morning after the dew has dried. According to the plant growth of both species, the foliage of the plant is restricted due to the short growing season (Mylavarapu and Zinati, 2009; Kılıç and Duyar, 2016); harvesting was done when the plants were more than 10 cm in

Table 2
Chemical and physical characteristics of Germany soil and peat moss substrates.

Substrate characteristics	Germany soil	Peat moss
Unit (Liter)	80	250
Organic matter (% weight of dry matter)	93.1	95
Dry matter (%)	34.2	< 75
Moisture content (%)	38.5	40–50
pH	5.9	2.8-6.0
Electrical conductivity (EC)	338.5 mg/l	< 400 mg/l
C/N ratio	50:1	50:1
Total nitrogen (N, mg.L^{-1})	166	< 50
Phosphorous (P_2O_5, mg.L^{-1})	102	< 30
Potassium (K_2O, mg.L^{-1})	232	< 40