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Agro-morphological and phytochemical diversity of various Iranian fennel landraces

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ABSTRACT

Fennel is used for various purposes in medical, cosmetic and food industries and Iran is one of its main producers. In this study agro-morphological and phytochemical diversities of Iranian fennel landraces were assessed. According to phenological properties, Iranian fennels were classified as early, medium and late maturity. Based on two years data, late and medium maturity fennels had the higher amounts of vegetative and reproductive traits. In term of seed yield, medium maturity fennels had a better performance, and in term of essential oil content medium and late maturity fennels had the highest values. With considering essential oil yield the highest values were related to medium and late maturity landraces. According to GCMS analysis, in essential oil of the studied Iranian fennels, trans anethole content ranges from 1.24 to 88.45, methyl chavicole from 0.22 to 59.1, fenchone from 1.22 to 14.74 and limonene from 5.5 to 15.71%. Trans anethole chemotype landraces were belonged to arid areas of eastern Zagros and southern Alborz; methyl chavicole chemotype landraces to humid areas of western Zagros and northern Alborz; fenchone chemotype landraces to late maturity landraces from humid area of northern Alborz; and he highest limonene contents to landraces from areas with mediocre altitude in north of Iran. Based on path analysis, as morphological markers to improve seed yield, negative selection of days to 50% flowering and positive selection of weight of dry biomass, and to improve essential oil contents positive selection of days to 50% flowering severely are highly recommended.

1. Introduction

The oldest evidence referring to medicinal plants usage traces back to sixty thousands years ago in Shanidar cave in Kurdistan (Lietava, 1992). Among medicinal plants *Foeniculum vulgare* known as fennel from Apiaceae family, is one of the oldest herbs. Bitter fennel subspecies (*F. vulgare* Mill. var. vulgare), possessing appealing flavor and beneficial medicinal effects, is cultivated as source species for the fennel derived drugs (Hornok, 1992). Bitter fennel, hereafter named just as fennel, is native to the Mediterranean areas also has been naturalized in many other regions. Fennel is a biennial or perennial herb up to two meters high and has feathery leaves and golden yellow flowers (Omid baigi, 2009; Guillen and Manzanos, 1994; Hornok, 1992). In human nutrition, every parts of this plant including seeds, foliage and roots can be used in different ways (Edoardo et al., 2010; Barros et al., 2010). Fennel pollen also is known as a popular spice (Kimberly and Jazmine, 2013). Fennel seed with its spicy odor and burning sweet taste has a special usage in condiments, perfumes and liqueurs industrials as flavoring reagent (Edoardo et al., 2010; Barros et al., 2010). In livestock industries, the significant improvement in chicks body weight and feed efficiency were obtained by addition of fennel seed to their feed (Teixeira et al., 2013; Mohammed and Abbas, 2009). From the aspect of medical cares, several studies have shown herbal drugs and essential oil of fennel has valuable antioxidant, anticancer, inflammatory, antibacterial, antifungal and analgesic activities (Diao et al., 2014; El-Awadi and Esmat, 2010; Singh et al., 2006; Lucinewton et al., 2005; Choi and Hwang, 2004; Elagayyar et al., 2001). Fennel essential oil is being added to perfumes, soaps and cosmetics, and several commercial pharmaceuticals are formulated based on it (Edoardo et al., 2010; Elagayyar et al., 2001). The main essential oil components of fennel are trans anethole, methyl chavicole (estragole), fenchone and limonene, and according to Akgiil and Bayrak (1988), the highest values of these components are exist in reproductive organs specially seeds. Trans anethole counts for the anise taste, serves as a pleasing aroma in food and perfumes, as well as an effective antiflatulence agent in herbal medicines (He and Huang, 2011; Pank et al., 2003; Guilled and Manzanons, 1996; Yaylayan, 1991). Methyl chavicole provides sweet taste, is mainly used in the perfume industry while limonene

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is used in resins and solvents, and fenchone is responsible for bitter and spicy taste of fennel and acts as a real antidepressant (Albert Puleo, 1980; Lawless, 1992; Sun, 2007; He and Huang, 2011). According to previous studies about essential oil components of bitter fennel, trans anethole content ranges from 0.1 to 78, methyl chavicole from 0.1 to 58, fenchone from 1 to 14 and limonene from 1 to 22% (Moghtader, 2013; Shahat et al., 2011; Aprotosoaie et al., 2010; Gulfraz et al., 2008; Stefanini et al., 2006; Bowes and Zheljazkov, 2005; Piccaglia and Marotti, 2001). The total world fennel seed production in 2012 was ~830 thousands tones (FAO, 2012), and for use in different industries the demand for fennel seed and its essential oil in today's world market is rapidly raising; this necessitates the need to develop elite cultivars with high yield (Dashora et al., 2003; Reichardt and Pank, 1993). In this way fennel needs more attention of researchers and the first step is gaining the knowledge of present diversity that can guide appropriate selection schemes, breeding programs and germplasm conservation (Judzentiene and Mockute, 2010).

Iran is one of the most important producers of fennel seed in the world (FAO, 2012) and in contrast to commercial cultivation of fennel, Iranian fennel landraces have never been comprehensively studied neither for seed and essential oil production nor for essential oil components. Fennel med quality is associated with seed yield, essential oil content and active components concentration. Fennel populations in Iran are scattered from Chabahar city (25 26°N and 60 61°E) on coastal line of Oman Sea to Mako city (40 39°N and 44 45°E) near Caucasia, from dry areas like Yazd city with 100 mm to humid areas like Talesh city with 2000 mm annual precipitation, from Bandar anzali city with −21 m to Fareydon shahr city with 2600 m altitude, from Zarine obato city with annual mean temperature 7 °C to Ahvaz city with 27 °C (Izadi Darbandi and Bahmani, 2011; www.meteogical.ir), accordingly Iranian fennels occupy very different habitats and due to adaptation to the local environments from long time ago, it is assumed each region has its own specific fennel landrace (Ramırez Valiente et al., 2009; Murray et al., 2004; Heywood, 2002); this subject has been proved morphologically (Bahmani et al., 2012a), genetically (Bahmani et al., 2012b: Bahmani et al., 2013) and cytogenetically (Sheidai et al., 2007). Among this diversity, classical breeding like screening and introduction of elite landraces and also identification of the best criteria as morphological markers to use in future yield improving breeding programs are being mentioned as the fastest, easiest and reliable way to develop elite fennel cultivars (Farsi and Baqheri, 2006; Zeinali Khanaqhah et al., 2004). In the way of having the best criteria to use in future yield improving breeding programs, finding the relationship between yield and its components, and also the relationship among yield components is the first priority (Ali et al., 2003; Choudhry et al., 1986). According to Al-Kordy (2000) in fennel the amounts of heritability for plant height, number of primary branch and seed yield were 0.758, 0.826 and 0.201, respectively. In bitter fennels the broad sense heritability for essential oil content and seed yield were reported as 0.46 and 0.63 by Izadi Darbandi et al. (2013) and 0.81 and 0.93, respectively by Patel et al. (2008). Heritability values of the most of important traits in bitter fennels are high and promising (Izadi Darbandi et al., 2013; Patel et al., 2008). Seed yield in fennel is positively associated with several characters such as plant height, number of branches and umbel number (Singh and Mittal, 2003). Piccaglia and Marotti (2001) explained that the number of inflorescences per plant and the biomass weight were significantly and positively related to the essential oil content ($r = 0.651$ and 0.569, respectively). Contrary to these findings, Cosge et al. (2009) showed that correlations between essential oil content with number of umbels and biological yield were weak ($r = 0.011$ and 0.009, respectively). In addition, Cosge et al. (2009) showed essential oil content was only correlated with thousand seed weight ($r = -0.37$), and seed yield strongly and positively was correlated with biomass weight ($r = 0.91$). Lal (2007) reported the positive and strong correlation between seed yield and essential oil content, also negative correlation between days to 50% flowering with seed yield and essential oil content. The correlation coefficient solely is not informative enough to explain the cause and effect relationships among the variables, because the association between two variables may reliant upon a third variable. The use of path analysis provides a reasonable explanation of observed correlations by modeling the cause and effect relations among the variables. Thus, it is possible to analyze the correlation coefficient of variables in the form of variance and covariance using path analysis (Okut and Orhan, 1993). Path analysis as a statistical method for cause and effect analysis in correlated variables system has been used frequently even in medicinal plants (Dalkani et al., 2011; Cosge et al., 2009; Lal, 2007; Bhandari and Gupta, 1991). Path coefficient is a standardized partial regression coefficient and measures the direct influence of a predictor variable on the dependent variable (Mohammadi et al., 2003; Steel and Torrie, 1980) and will allow separating the correlation coefficient into direct and indirect effects (Mohammadi et al., 2003). Unexplained effects are considered as residual effects. Path analysis is being used by plant breeders to understand the relationship between yield and its components in various crops (Kang et al., 1983). Increases in germplasm collections and availability of agro-biodiversity will decrease the threats of genetic erosion and enhance the probability of finding good landraces for introduction or useful traits as morphological markers for screening programs.

Till now there is no any comprehensive report on Iranian fennels in term of yield production, active composition concentration and identification of criteria for future breeding programs, so we decided to do this. The aims of this study were: (1) evaluation of agro-morphological diversity in Iranian fennels in two successive years, (2) evaluation of phytochemical diversity in Iranian fennels and try to find its diversity pattern, (3) introduction of the elite landraces based on seed yield, essential oil content and active components concentration, (4) identification of relationships between yield and its components, and (5) introduction of the best criteria to use in future yield improving breeding programs. The results of this study are useful for fennel researchers and rearers.

2. Materials and methods

2.1. Plant material

Seeds of 50 landraces of bitter fennels (*F. vulgare* var. *vulgare*) in 2009 from different Iranian locations were collected and stored in refrigerator in 4 °C (Table 1 and Fig. 1).

According to Fig. 1-left, our experiment was including 50 fennel landraces from all over Iran. With closer glance to Fig. 1-right, it is clear that there are two main chain mountains in Iran: one of them known as Alborz Mountains, from northwest to northeast, separating Caspian Sea side from middle side of the country, another one known as Zagros Mountains, from northwest to southeast, separating western margins from middle side of Iran. Alborz and Zagros Mountains like wall against humid winds blowing from Caspian and Mediterranean seas respectively; provide Iran with humid northern and western sides and arid central and eastern sides.

2.2. Agro-morphological assessment

Seeds of these 50 fennel landraces were planted in the experimental site of College of Abouraihan, University of Tehran in spring 2010. The randomized complete block experimental design with three replications was used. Each landrace was sowed in 1 m^2 plots