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Fruit yield, fatty and essential oils content genetics in coriander

Mostafa Khodadadi[a], Hamid Dehghani[a,*], Mokhtar Jalali Javaran[a], Jack T. Christopher[b]

[a] Plant Breeding and Biotechnology Department, Faculty of Agriculture, Tarbiat Modares University, Tehran, P.O. Box 14115-336, Iran
[b] Queensland Alliance for Agriculture and Food Innovation (QAAFI), Leslie Research Facility, The University of Queensland, PO Box 2282, Toowoomba, Qld, 4350, Australia

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ABSTRACT

Some regions of the world suffers of drought which affects plant behavior regarding biochemical and yield responses. This study aimed to estimate the general and specific combining abilities of coriander (*Coriandrum sativum* L.) by analyzing its fruit yield, essential oil content (EOC) and fatty oil content (FOC). To reach this aim, 15 half-diallel hybrids and their six parents, selected for their different response to water stress in fruit yield, essential oil and fatty oil content were evaluated under well-watered, moderate water-stressed and sever water-stressed conditions in the field and in glasshouse cultivation systems. Fruit yield in the field (FYF) and glasshouse (FYG), percent of de-hulled fruit, percent of hulls, EOC, essential oil yield (EOY), de-hulled fruit fatty oil content (DFFOC), hull fatty oil content (HFOC), fatty oil content (FOC) and fatty oil yield (FOY) were examined. Water treatment (WT), genotype and genotype × WT effects were significant ($P \leq 0.01$) for all measured traits. For FYF, gene action was mostly additive while dominance was more important for FYG. Genotypes gained different EOC and FOC in different WTs. Genetic control of the EOC was affected by water stress and the portion of dominance in gene action increased as water stress progressed leading to completely dominant genetic control of EOC under severe water stress. For FOC and FOY genetic control was governed by dominant and over dominant gene nature in all WTs. Parents including P_1, P_4 and P_6 were indicated as promising hybrid contributors for high EOC, DFFOC and FOY. Similar genetic control mechanisms of the EOC, EOY, FOC and FOY suggests that improvement of essential oil content and fatty oil content could be simultaneously achieved in coriander.

1. Introduction

The development of new crop products for industrial applications is an area of significant interest both scientifically and environmentally. While methods are being developed for modifying the fatty acid content and composition of oils produced by established crops such as oilseed rape (*Brassica napus* L.) and soybeans (*Glycine max* L.), another approach is to investigate alternative species as potential sources of specialist essential and fatty oils and pharmacological activities. An example of such a crop is coriander (*Coriandrum sativum* L.), a member of the Apiaceae family (Msaada et al., 2009a). Coriander leaves can be used as a herb and the fruits are a source of oils. Coriander fruits produce both fatty oils and essential oils. The fatty oils and essential oils differ in that composition and stability. The fatty oils are extracted by pressing or extraction and the essential oils are extracted by hydrodistillation.

In the case of fatty oils, fruit contain 19–21% fatty oil (triglyceride), of which petroselinic acid (C18:1Δ6) is the main fatty acid (up to 80%) in the fatty oil (Kleiman and Spencer, 1982). Petroselinic acid, an isomer of oleic acid, can potentially be used to manufacture of medium chain fatty acids, since it can be split into lauric (C12:0) and adipic (C6) acids by oxidative cleavage. Lauric acid is utilized as a raw material for softeners, emulsifiers, detergents, and soaps. Adipic acid is used for the manufacture of a wide range of polymers, including high grade engineering plastics. Methyl esters of coriander fatty oil have excellent fuel properties as a result of its unique fatty acid composition. The methyl esters exhibit high oxidative stability, superior low temperature properties, and lower iodine value than soybean oil methyl esters (Moser and Vaughn, 2010). Fatty oil composition of coriander fruit has been well characterized by Ramadan and Mörsel (2002). The fruit oil extraction process affects oil yield. The oil content of whole coriander fruit oil (17.6 ± 0.1%) was reported to be less than de-hulled fruit oil (37.6 ± 0.1%). Because, the hulls absorb a considerable amount of oil (Evangelista et al., 2015).

In the case of essential oils, the fruit contain 0.3–1.2% essential oil, of which 60–70% is linalool, the compound that gives the

* Corresponding author.
E-mail addresses: dehghanr@modares.ac.ir, dehghanr@modares.ac.ir (H. Dehghani).

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pleasant characteristic odor. Essential oil production in quantities exceeding one ton per year is limited to less than 60 cultivated taxa including 21 Apiaceae which includes coriander (Lubbe and Verpoorte, 2011). Of the 60 crops producing essential oils coriander had the most annual production volume (710 t) and value (49,700,000 US$) among 21 commercially established Apiaceae taxa EOs producing crops in 2005 (Evergetis and Haroutounian, 2014). Coriander essential oil composition has been characterized in a number of previous studies (Msaada et al., 2007; Msaada et al., 2009b; Neffati et al., 2011).

In additions to the importance of coriander for numerous oleochemistry and aromatic purposes, pharmacological uses resulted in wide research on coriander. Reported pharmacological properties include anti-microbial, anti-oxidant, anti-diabetic, anxiolytic, anti-epileptic, anti-depressant, anti-mutagenic, anti-inflammatory, anti-dyslipidemic, anti-hypertensive, neuroprotective and diuretic activities (Ullagaddi and Bondada, 2011; Sahib et al., 2013). Addition of coriander to food can increase the antioxidant content and may thus inhibit unwanted oxidation processes (Wangensteen et al., 2004). Rattanachaikunsopon and Phumkhachorn (2010) reported that for bacteria on raw meat the type of meat and temperature did not influence the antimicrobial activity of the coriander oil. They concluded that this indicates the potential of coriander oil to serve as natural antimicrobial compound against *Campylobacter jejuni* in food. Finally, scientific opinion on the safety of coriander fruit fatty oil suggested that coriander fruit fatty oil has potential to be marketed as a novel food ingredient for healthy adults, at a maximum level of 600 mg per day (Agostoni et al., 2013).

Among the different environmental constraints, drought is the abiotic factor most limiting crop productivity, resulting in yield decreases of more than 50% on a worldwide scale (Bettaieb et al., 2011). It was reported that water limiting conditions cause significant changes in essential oil and fatty oil yield of caraway (*Carum carvi* L.) (Laribi et al., 2009) and cumin (*Cuminum cyminum* L.) (Bettaieb et al., 2011; Bettaieb Rebey et al., 2012; Alinian and Razmjoo, 2014). Water stress has several positive effects on the biosynthesis of secondary metabolites (Sangwan et al., 2001).

Improved coriander genotypes with high yield and desirable fruit quality for growth under different water regimes are possible through plant breeding. Selection is the most common breeding procedure used in coriander and despite of the identification of several desirable traits and resistance donors, breeding of varieties is restricted to selection alone due to absence of crossing technique (Giridhar et al., 2016). In this regard, obtained information on genetic control of target traits through crossing is highly essential for planning a suitable breeding strategy to improve coriander. Also, it was reported that knowledge of the mechanisms that control the main agronomic traits of a species can be acquired through diallel cross methodologies (Feyzian et al., 2009). Blank et al. (2012) used the diallel crossing method to estimate general and specific combining ability of yield components and essential oil constituents in basil, for example.

However, we are not aware of any published research on genetic control of coriander fruit yield or its fruit quality related traits. Therefore, the aim of this research was to estimate the general and specific combining abilities of coriander by identifying promising crosses for fruit yield, essential and fatty oils content under different watering conditions.

2. Materials and methods

2.1. Plant material and growth conditions

A preliminary experiment to screen Iranian endemic coriander genotypes for drought tolerance and identify parental genotypes was done in 2013 at agricultural faculty of Tarbiat Modares University, Iran (Khodadadi et al., 2016). Diallel crosses without reciprocals were made between six genotypes in 2014. Parents included the highly drought tolerant but low yielding TN-59-230 (origin: Bushehr), tolerant and relatively high yielding TN-59-160 (origin: Mazandaran) and TN-59-353 (origin: Markazi), susceptible TN-59-80 (origin: Isfahan), highly drought susceptible TN-59-158 (origin: Hamadan) and commercial genotype provided from Mahdasht, Alborz, Iran. Phenotypic differences between the parent lines are shown in Fig. 1. Parents and their 15 F_1 hybrids were evaluated under various conditions in 2015 as described below.

2.2. Glasshouse experiment

2.2.1. Preparation of the lysimeters and growth conditions

The plants were grown in lysimeters, consisting of PVC cylinders (20 cm diameter, 100 cm heigh) which contained a mixture of sandy loam (3:2 v/v basis) and well crushed compost (3:1 v/v basis). Two layers of plastic mesh (1 × 1 mm) were used as end plates of cylinders and allowed water drainage. The initial weights of filled cylinders were measured by Mahak digital scale with 100 kg capacity and an accuracy of 10 g. The cylinders were kept on mesh platforms. Buckets were then attached to bottom of cylinders and junction point of buckets to cylinders were sealed by cellophane to prevent evaporation of drainage water from the buckets. Plant growth was carried out in a glasshouse with 14-h photoperiod, mean irradiance of 250 μmol m^{-2} s^{-1}, 22–31 °C mean temperature (T), 30–55% relative air humidity (RH). Glasshouse air T and RH were recorded three times a day, 07:00 h, 14:00 h and 21:00 h. Air T and RH values were used to calculate atmospheric vapor pressure deficit (VPD) (Fletcher et al., 2007) based on the formula suggested by Jones (2013). Glasshouse VPD status from 15 April, 2015 to 8 July, 2015 is presented in Fig. 2A.

2.2.2. Sowing and crop management

Seeds were surface sterilized for 5 min in 10% sodium hypochlorite solution and then in 96% ethanol for 1 min and thoroughly washed in sterile distilled water. Seeds were treated with fungicide to avoid any seed-borne diseases. Prior to planting, all the cylinders received 2 l of water to bring the soil profile up to field capacity. Then seeds were planted at a rate of three per cylinder and later thinned to one plant per cylinder. To prevent evaporation from soil surface (Ratnakumar and Vadez, 2011), the soil surface of the cylinders was mulched with aluminum foil. A split plot experiment was used based on randomized complete block design with three replications in the glasshouse experiment. The main factor was water treatment which had two levels, well-watered (WW) and severely water stressed (SWS). The sub-factor was a set of genotypes (parents and their hybrids). WW plants were kept at field capacity (FC) moisture for the entire experiment while SWS plants were irrigated similarly to WW plants up until stem elongation, and from stem elongation to the flowering stage kept in 50% FC until the start flowering after which water was withheld. The amount of water (ml) used to irrigation of each cylinder was recorded. For soil fertility improvement, the third, fourth and fifth irrigations were done with 500 ml (2 g l^{-1}) fertilizer solution (Greenline NPK-20-20-20, Germany). Cylinders were immediately weighed after plants were harvested from above the soil surface. Subsequently, transpired water (TW) amount for each genotype was calculated according to Eq. (1). Results are shown in Fig. 3A.

$$TW = TWU - (FWC - IWC) - DW \tag{1}$$

where TWU, FYC, IWC and DW are total water (ml) used, final and initial weight (g) of cylinder and drainage water (ml).