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Evaluation of combining ability in *Cucurbita pepo* L. and *Cucurbita moschata* Duchesne accessions for fruit and seed quantitative traits

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ABSTRACT

A complete diallel cross study of seven Iranian accessions of *Cucurbita*, including five *C. pepo* (four naked seed and one true seed type) and two *C. moschata* accessions, was carried out during two planting seasons at University of Tehran, Karaj, Iran. Investigated traits were fruit number, fruit yield, seed yield, fruit weight, seed weight, ratio of fruit weight/seed weight, 100 seeds weight and seed number. ANOVA for all of the characteristics except fruit number indicated significant differences among the genotypes. Analysis of variance of the diallel data set also revealed high and significant effects of general (GCA) and specific combining ability (SCA) between genotypes in respect of fruit yield, seed yield, seed weight, ratio of fruit weight/seed weight and seed number. The GCA of fruit weight and seed weight and the SCA of 100 seeds weight were significant. The reciprocal effects were significant for all the measured traits. Heritability in broad (h_b^2) and narrow (h_n^2) estimates were generally high for fruit yield, seed yield, seed weight, fruit weight/seed weight and seed number, while they were low for fruit weight and 100 seeds weight. Favourable heterosis over the best parent was found for fruit yield, fruit weight and 100 seeds weight.

1. Introduction

In the genus of *Cucurbita* there are three economically important species, namely, *C. pepo* L., *C. maxima* Duchesne, and *C. moschata* Duchesne, which have different climatic adaptations and are widely distributed in agricultural regions worldwide (Maynard et al., 2002). *Cucurbita pepo* subsp. *pepo* var. *Styriaca* (Styrian oil pumpkin" or "naked seed pumpkin) has been formed by an accidental natural mutation in a single recessive gene that led to a very thin outer hull (naked or hull-less seeds), which highly facilitates the production of a regional specialty oil, and also led to its dark green color (Fruhwirth and Hermetter, 2007). *Cucurbita* seed oil is increasingly esteemed because of its excellent nutritional quality and medicinal value, especially in the prevention and treatment of benign prostate hyperplasia (Kreuter, 2000; Schmidlin and Kreuter, 2003). Pumpkin seed oil has also been implicated in pharmacological activities such as antidiabetic (Li et al., 2003), antifungal (Wang and Ng, 2003), antibacterial and anti-inflammation activities (Fu et al., 2006) and antioxidant effects (Nkosi et al., 2006). The recent increase in the popularity of *Cucurbita* species has stimulated the breeding of new cultivars. The choice of parents for use in a plant breeding program is one of the most important decisions that a breeder makes (Borém and Miranda, 2005) and also knowledge of the mechanisms that control the main agronomic traits of a species is fundamental for the genetic improvement and can be acquired through diallel crosses methodologies such as the one developed by Griffing (1956). Diallel crosses are the most popular mating design used in plant breeding research to obtain information on genetic effects for a set of parental lines or to estimate general combining ability (GCA), specific combining ability (SCA), variance components and heritability for a population. According to Cruz and Vencovsky (1989), the most promising hybrids are those that come from the crossing of divergent parents, which at least one of them presents high GCA. Many studies on pumpkin breeding were focused on the analysis of combining ability and gene action to understand the mode of inheritance of economic traits. Mohanty (2000), Nisha and Veeraragavathatham (2014), Hussien and Hamed (2015) and El-Tahawey et al. (2015) found that general (GCA) and specific combining ability (SCA) variances were highly significant, indicating both additive and non-additive gene effects involved in the expression of most traits of the studied plants. Jha et al. (2009) found that GCA variances were higher than SCA variances in *Cucurbita* for number of nodes to first female flower, number of fruits and average fruit weight, indicating the limited extent of heterosis for

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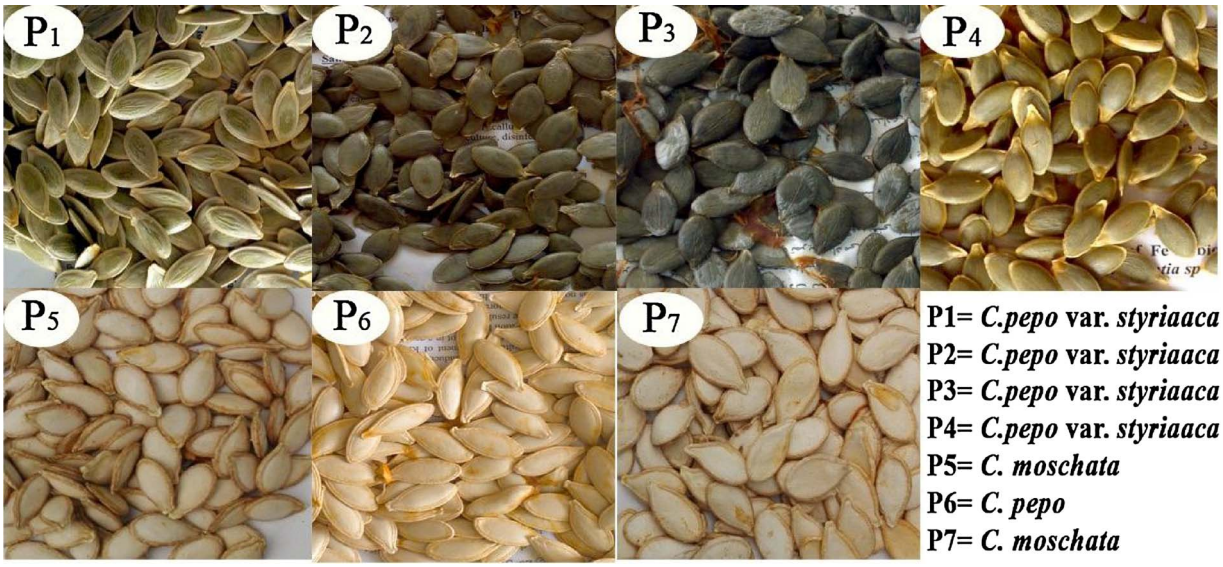

Fig. 1. Different seed types of *Cucurbita* accessions used in this experiment.

these traits. In contrast, GCA variances were lower than SCA for average fruit length, fruit diameter and yield which indicated that due to the predominance of non-additive gene action the improvement of these traits could be achieved by hybridization. Also, Pandey et al. (2010) showed that yield per plant had GCA variances lower than the SCA variances indicating the pre-dominance of non-additive gene effects for yield. There are reports of heterosis as high as to 181.5% and 97.52% for yield, 68.7% for fruit weight and 150% for number of fruits (Mohanty and Mishra, 1999; Pandey et al., 2002). Significant heterosis has been reported in crosses between certain varieties and inbred lines in *Cucurbita* species (Curtis, 1939; Elmstrom, 1978; Firpo et al., 1998; Lopez Anido et al., 2004). Iran is the world's sixth largest producer of squash and pumpkin with more than 600 thousand tons production in 2014, in about 45 thousand ha of growth area (FAOSTST, 2014), but there are no improved cultivars of squash and pumpkin for commercial cultivation. Also, Iranian populations of pumpkin, especially, naked seed pumpkins have low seed and fruit yield. No study has been conducted in order to assess the gene action, heritability and heterosis among these populations. Revealing information regarding this would be of interest for breeding programmes by allocating resources either for improving through hybridization between different populations or along selection of high yielding cultivars. In this research a complete diallel cross analysis was conducted to determine gene action and to estimate components of variance, broad- and narrow-sense heritability and heterosis over the mid- and best parent.

2. Material and methods

2.1. Plant material and experimental design

The study was conducted during two growing seasons of 2015 and 2016 under field conditions at the Research Center of the Department of Horticultural Sciences, University of Tehran, Karaj, Iran. The field located at 35°47′N latitude; 50°56′E longitude and 1312 m elevation. Average precipitation, temperature and humidity were 252 mm, 14.9 °C and 47% respectively. Total annual precipitation was 263 mm in the first year and 275 mm in the second year. Soil characteristics were as below, texture = clay loam, pH value = 8, electrical conductivity = 1.31 ds/m, organic matters = 0.94%, available K2O = 256 mg/kg, available P2O5 = 84.5 mg/kg, total nitrogen = 0.1% and CaCO3 = 6.7%. Sowing and harvesting in the two years were performed on May 10 and the first week of September, respectively. Seeds were planted out directly in the field in both seasons. The plant materials were five open-pollinated accessions of *C. pepo*, including four naked seed types (Styrian oil pumpkin) and one normal seed type (having seed coat), and two open-pollinated accessions of *C. moschata* which have been cultivated in various regions of Iran for many years (Figs. 1 and 2, Table 1). The selected parents were crossed in a diallel scheme to obtain all possible combinations during the summer of 2015 (total of 42 hybrids plus seven parents). Crossings were done using the conventional hybridization method. The female and male flowers that were to be used in manual pollination were identified in the day prior to anthesis by the appearance of a slight touch of yellow at the apex of the corolla tube. They were prevented from opening by tying the tips of the corolla tube to protect the flowers from insect pollination. The following morning, male flowers and all their petals were removed and the stamens containing pollens were transferred into female flowers, then the flowers were closed again (Hazra et al., 2007). After fruit ripening and harvesting, seeds were extracted and stored for using in the next year. In the second season (summer of 2016), the seeds of both the parents and F1 hybrids (in cases that off springs of crossing between *naked seed x normal seed* accessions were normal seeds, naked seeds just were used for sowing) were planted in a randomized complete block design (RCBD) with three replications and five plants per replication. Spacing was 3 m between rows and 1 m between plants. Plots were irrigated every week during the season. Plants were thinned to one plant 15 days after sowing and all plots were weeded manually to maintain proper weed control. It must mention that according to our observations, all the crosses of *C. moschata* x *C. pepo* and *C. pepo* x *C. moschata* were fertile 100% and also we didn't find any male or female sterility in interspecific hybrids.

2.2. Recorded data

Fruits of three plants in each replication were randomly harvested and fruit weight (kg) and fruit yield (kg per plant) were measured by a weighing scale, then the seeds were extracted, washed and air dried. The seed number per fruit was measured by counting all seeds of a fruit. Seed weight (g per fruit), seed yield (g per plant) and 100 seeds weight (g) were recorded by a laboratory scale. The fruit weight (including seeds) to seed weight ratio (fruit weight/seed weight) was also calculated by dividing fruit weight (g) by seed weight (g).

2.3. Statistical analysis

The analysis of variance for GCA, SCA and reciprocal effects was