



Evaluation of variability of morphological traits of selected caraway (*Carum carvi* L.) genotypes

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ABSTRACT

In the experiments done in 2008 and 2009, 23 selected caraway genotypes originating from European botanical gardens (18), cv. “Kończewicki” and our own breeding strains were tested. The obtained results showed that objects of the caraway collection varied in terms of all the tested morphological traits. The plant height ranged from 71.5 cm (Reykjavik) to 107.8 cm (cv. “Kończewicki”). The number of branches on the main stem was from 5.3 (Reykjavik) to 10.0 (Jena). The number of lateral shoots ranged from 9.8 (Reykjavik) to 21.5 (strain 9/10). The leaf length was from 11.9 cm (Lousanne) to 29.1 cm (cv. “Kończewicki”). The number of umbels per plant varied from 91.4 (Reykjavik) to 251.9 (strain 9/10). The fruit yield ranged from 14.2 g (Reykjavik) to 48.5 g (cv. “Kończewicki”). The weight of 1000 seeds was from 1.81 g (Salzburg) to 3.31 g (strain 9/1). The following morphological traits such as the number of umbels per plant, the number of lateral shoots per plant and weight of a thousand seeds had positive effect on fruit yield. The multidimensional analysis of the tested traits compared caraway objects in respect of eight morphological traits and yield simultaneously. These valuation of caraway genotypes will make it possible to choose the appropriate genotypes for further breeding program.

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1. Introduction

Caraway (*Carum carvi* L.), one of the most important medicinal plants cultivated in Poland, covers an area of 8000 ha. Caraway fruit (*Carvi fructus*) is used as a component of herbal mixtures recommended as digestive, carminative and lactogenic drugs. Caraway essential oil (*Carvi oleum*) obtained from fruit by hydro-distilling consists mainly of monoterpenes such as carvone and limonene, which usually make up 95% of all the oil (Kallio et al., 1994; Ruskowska, 1998; Sedláková et al., 2001).

The investigations carried out by many scientists (Heine, 1998; Okoniewska, 1974; Petraitytė et al., 2001; Puschmann et al., 1992; Šmirous and Kocourková, 2006) showed a great variability of morphological traits within different caraway genotypes. Morphological traits such as the number of branches and lateral shoots, the number of umbel per plant or the seed size have a great influence on fruit crop. The examination of morphological traits and their interaction indicated stability of the analyzed traits with years. Therefore, the multidirectional evaluation of morphological traits of caraway genotypes helps to choose the appropriate genotypes for further breeding program.

2. Materials and methods

The investigated caraway collection consisted of 23 objects: 18 populations originated from botanical gardens of: Bayreuth, Berlin, Bonn, Cluj, Göttingen, Jena, Cracow, Lousanne, Nantes, Poznań, Prague, Reykjavik, Riga, Salzburg, Ulm, Warsaw, Wisley, Wrocław. Moreover, cultivar “Kończewicki” was represented by two strains (VI, VII) and three strains 9/1, 9/10, and 60/8, which were obtained in the Institute of Medicinal Plants of Poznań. Two strains of cultivar “Kończewicki” originated from the maintenance breeding which is done in Institute. Two collections were established on the experimental field in 2007 and 2008. However, in 2008 the seeds of the following genotypes: Warsaw, Cracow, Wisley, strains 9/7, 60/8 and strain no. 7 of cv. “Kończewicki” did not germinate, which resulted in lack of these genotypes in the collection that year. Every year the collections were established in a randomized complete block design in ten repetitions. The number of plants in the investigated objects oscillated from 20 to 100. In April, caraway seeds were sown in the greenhouse and then 5–10-leave plantlets were planted out in 45 cm × 45 cm spacing.

In the second year of the experiment the measurements of the following morphological traits were taken: the plant height, the number of lateral shoots, the number of branches on the main stem, the number of leaves on the main stem, the leaf length, the diameter of the main umbel, the diameter of the primary umbel, the number of umbelets in the main umbel, the number of umbels per

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plant, the fruit weight per plant, the weight of a thousand seeds. The measurements of 10 plants randomly selected in each replication of the collection were taken. Fruit was collected at the phase of their ripeness, dried in shady, well ventilated place, then threshed and cleaned.

The normality of the distribution of the traits was tested using Shapiro-Wilk's normality test (Shapiro and Wilk, 1965). Two-way fixed model analysis of variance was carried out to determine the effects of years, objects and years \times objects interaction on the variability of the plant height, the diameter of the main umbel, the number of umbelets in the main umbel, the diameter of the primary umbel, the number of branches on the main stem, the number of lateral shoots, the leaf length, the number of umbels per plant, the fruit weight per plant and the weight of a thousand seeds. The Tukey's honestly significant differences (HSD) of each trait were calculated, and on this basis homogeneous groups (not significantly different from each other) were determined. The coefficient of variation for each trait was calculated. The relationship between all morphological traits and yield was estimated on the basis of correlation coefficients (Kozak et al., 2010). Mahalanobis' distance (Mahalanobis, 1936) was suggested as a measure of "polytrait" object similarity, whose significance was verified by means of critical value D_α called "the least significant distance". A possibility of graphic distribution of caraway collection described by morphological traits and yield was obtained with the use of the analysis of canonical varieties (Morrison, 1976).

3. Results

The results of the analysis of variance indicated that the main effects of object as well as year \times object interaction were significant for all the morphological traits and yield (Table 1). This analysis proved that the tested traits are not stable and could be modified by year \times object interaction. The main effects of year were significant for all the traits of the study, except for the leaf length and the number of umbelets in the main umbel (Table 1). The coefficient of variation of individual features was differentiated. Low value of the coefficient of variation characterized the height of the plant (16.2%), the weight of a thousand seeds (19.4%) and the diameter of the primary umbel (19.7%), while the following traits: fruit yield (50.7%), the number of umbels per plant (38.9%) and the number of lateral shoots (35.7%) performed high variation (Table 1).

The lowest plants grew in the populations from Reykjavik and Riga (71.05 cm), while the highest plants occurred in cv. "Kończewicki" VI (107.28 cm) and in the population from Bayreuth (107.12 cm) (Table 2). Also, plants of cv. "Kończewicki" VI had the longest leaves (29.12 cm), while plants from Riga had the shortest ones (11.90 cm). Plants of the lowest number of branches on the main stem (Reykjavik – 5.30 and Riga – 5.40) also had the lowest number of lateral shoots (Reykjavik – 9.80 and Riga – 10.35), while plants from the populations from Jena and Wisley (10.0) had the highest number of branches on the main stem and plants of strain 9/10 (20.45) had the highest number of lateral shoots. Both main and primary umbels were the smallest on plants of the population from Berlin (6.38 cm and 6.80 cm, respectively). The diameter of the main umbel reached over 9 cm in plants of 10 objects: Cluj – 9.88 cm, Göttingen – 9.88 cm, cv. "Kończewicki" VI – 9.43 cm, Prague – 9.42 cm, Lusanne – 9.40 cm, strain 60/8 – 9.38 cm, Bayreuth – 9.35 cm, cv. "Kończewicki" VII – 9.30 cm, Bonn – 9.25 cm, Warsaw – 9.23 cm (Table 2), whereas only cv. "Kończewicki" VI was characterized by plants that had the largest diameter of the primary umbel – 9.13 cm (Table 2). Strain 9/10 had the highest number of umbels per plant – 252.0, but over 200 umbels were present on plants from: Bayreuth, Cluj, Jena, Krakow, Nantes, cv. "Kończewicki" VI, cv. "Kończewicki" VII and strain 60/8.

Plants of the population from Reykjavik were characterized by the lowest number of all the umbels per plant (92.4) (Table 2).

Plants of cv. "Kończewicki" (48.46 g) and strain 60/8 (46.9 g) performed the highest yield of fruit, whereas the lowest yield was noted for plants of the population from Reykjavik (14.17 g) and Salzburg (19.85 g). Also, seeds from Salzburg were the smallest (1.81 g), while seeds of strain 9/1 were the biggest (3.32 g) (Table 2).

Table 3 shows a correlation matrix for the analysed traits. A significant positive correlations were observed between:

1. the plant height and the diameter of the main and primary umbels, the number of branches on the main stem and the leaf length,
2. the diameter of the main umbel and: the number of umbelets in the main umbel and the diameter of the primary umbel,
3. the number of branches on the main stem and: the leaf length, the number of umbels per plant and the weight of a thousand seeds,
4. the number of lateral shoots per plant and the number of umbels per plant,
5. fruit yield and the number of umbels per plant, the number of lateral shoots per plant and the weight of a thousand seeds.

The multidimensional analysis of the tested traits compared caraway objects in respect of eight morphological traits and yield simultaneously (Fig. 1). The first and second canonical varieties elucidated 33.55% and 21.03%, respectively, of multivariate variability of objects (Fig. 1). In both years of the experiment plants originating from Prague were mostly differentiated compared with plants from Salzburg, which was measured by Mahalanobis distance (4.72). Plants originating from Prague were also different from plants from Bayreuth (4.50), Ulm (4.29) and strain 9/7 (4.22), while the most similar plants originated from Berlin and Riga (1.08). Also, strain 9/7 was similar to the populations from Warsaw (1.133), Nantes (1.379), Cracow (1.401) and to cv. "Kończewicki" VI (1.265).

4. Discussion

Our statistical analysis of the results of morphological traits and yield showed that the tested objects of caraway collection were different (the coefficient of variation varied from 16.2% to 50.7%).

In our experiment the height of caraway plants varied from 71.05 cm to 107.28 cm, and plants of bred cultivars were not different compared with populations. Similar results were reported by Heine (1998), who tested nine caraway cultivars. He reported the height of the plant from 98 cm (cv. "Niederdeutscher") to 110 cm (cv. "Kończewicki"). Also, Dachler (1992), who tested the yield of six caraway cultivars, obtained the height of the plant ranging from 83 cm (cv. "Rekord") to 92 cm (cv. "Mansholts"). While Okoniewska (1974) in her collection noted the smallest caraway plants (50.2–96.1 cm). Also Petraitytė et al. (2001) presented a lower value of this trait: 33.0–65.5 cm, while the coefficient of variation of this trait was similar to our result (14.6%). The range of the plant height obtained by El-Ballal (1983a) was: 84.75–102.27 cm. Šmirous and Kocourková (2006), who studied eight caraway genotypes, also showed differentiated plant height that ranged from 79.88 to 87.22 cm. Even the study of one cultivar (cv. 'Kepron') showed different plant height oscillating from 68 to 107 cm (Šmirous and Smýkalová, 2006). In our experiment the leaf reached from 11.90 to 29.12 cm in length. Okoniewska (1977) presented the similar results of this trait: 13.6–29.5 cm. Also, Seidler-Łożykowska (2008) obtained the similar length of caraway leaves (13.8–25.7 cm).

Caraway plants from Jena and Wisley characterized by the highest number of branches on the main stem (10), whereas plants

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