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Agrobiological assessment of wild *Carum carvi* L. cenopopulation biodiversity *ex situ*

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In 2000–2004, collections of 107 wild caraway samples were grown and field trials were established at the trial station of the LUA. The earliness of the study cenopopulations had an impact on their morphological and productivity parameters. The hierarchic-cluster analysis was performed according to phenological data as well as petal and leaf colour. Early-season caraway forms showed the lowest height, fruit weight and total yield, but had the highest carvone content in fruit essential oil. Pink petals are characteristic of early-season caraway cenopopulations. White petal colour, higher leaf pigmentation and fruit productivity, as well as essential oil and carvone output characterize medium-late and late forms. According to qualitative and quantitative traits, cenopopulations with an extra high fruit essential oil content, high carvone content in essential oil, fruit weight and one plant yield as well as early and late highly productive cenopopulations were selected.

Key words: essential oil, carvone, productivity, ex situ, biodiversity, Carum carvi

INTRODUCTION

Common caraway (*Carum carvi* L.) is one of the most widely used plants owing to its ability to accumulate essential oils in fruits [1]. Its fruits are used in pharmacy, perfumery and food industry. Presently, in many American and European countries caraway (*fructis carvi*) is an official medicine [2]. It has antiseptic, pain sedative, antispasmodic, depletive, antimicrobic and antioxidant properties [3, 4]. Caraway is the most widely grown medicinal and aromatic plant in Lithuania; its fruits are exported to the EU [5].

Caraway essential oil and its compound carvone hold a high economic potential [6]. Amongst monoterpenes, carvone as a potato sprouts inhibitor is most important and holds forth a hope to use it in practice [7, 8].

In Lithuania, together with the decline of natural meadows, caraway habitats shrink, and its species biodiversity and genetic resources become sparse. Wild plant populations are still being formed by such evolution forces as natural selection, mutation, migration and hybridization. A more stable survival potential is shown by wild plant populations with more individuals because this provides a better chance to form genotype combinations adapted to the changing environment. Therefore, species genetic diversity is a guarantee of its survival. To preserve a species genetic fund, it is important to accumulate and investigate the intraspecific diversity, to assess and select the most valuable samples suitable for registering in national genefund registers and utilize them in breeding [9].

The aim of the present work was to assess the diversity and stability of morphological and productivity traits of wild *Carum carvi* L. cenopopulations *ex situ*. The study object was caraway (*Carum carvi* L.) cenopopulations from various geographic places of Lithuania.

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MATERIALS AND METHODS

In 2000–2004, collections of 107 wild caraway samples were grown and field trials were established at the trial station of the LUA. Analysis of the collected material (biometric parameters) and distillation of essential oils were carried out at the Genetics and Biotechnology Laboratory of the LUA. For plant assessment, we used biometric traits such as stalk height, branching height, inflorescences number, 1000 seeds weight, seed yield per plant, and the biochemical parameters – essential oil content in fruit, carvone content in essential oil (2000–2004), leaf pigments (in 2001) – chlorophylls a and b and carotenoid content. Visual coloration estimations of petals and leaves were carried out. Evaluation of qualitative parameters were defined (2001) by five points: colour of petals (5 – fuchsia; 4 – dark rose, 3 – rose, 2 – pink, 1 – white), colour of leaves (5 – blue green, 4 – grey green, 3 – dark green, 2 – green; 1 – light green), earliness of cenopopulations (5 – ultra early, 4 – early, 3 – average early, 2 – late, 1 – ultra late).

Phytochemical analyses – essentials oil content in caraway fruits (distillation by water steam method) and essential oil composition (by FISONC GC gas chromotographer) were carried out at the Biochemistry Laboratory of the KTU. Chlorophyll and carotenoid contents were established by the colorimetric method in a 100% extract of acetone according to Wetshtein [10] with a Beckman DU-40 spectrophotometer at the "Tempus" laboratory of the LUA. Data were processed mathematically and statistically according to G. Zaitsev (1984) [11] and V. Sakalauskas (1998) [12], computing using the Excel and STATISTIKA pack-

age. Hierarchic cluster analysis was carried out, the connection criterion being the mean distance between group indices, and the measure of distance square Euclid distance.

Meteorological conditions in the study years. Thermal and humidity conditions at caraway development stages were characterized by Selianinov's hydrothermal coefficient – the ratio of precipitation and the sum of temperatures above zero [13]. The hydrothermal coefficient (HTC) of vegetation period (April I – July I–II)) was calculated to show meteorological conditions from the beginning of caraway vegetation till the ripening stage. When HTC is up to 0.3, years or stages are very dry, 0.4–0.5 – dry, 0.6–0.7 – arid, 0.8–1.0 – insufficiently wet, 1–1.5 – sufficiently wet, 1.5 and more – wet.

Meteorological conditions varied (Table). 2004 was the wettest year, 2001 and 2003 being wet, 2002 sufficiently wet; 2000 was insufficiently wet, with a draughty spring and summer.

Table. **Hydrothermal coefficient (HTC) of caraway vegetation period (2000–2004)**

Investigation year	HTC
2000	1.0
2001	1.7
2002	1.4
2003	1.7
2004	2.0
Multiannual value	1.8

RESULTS AND DISCUSSION

The study results showed a high variation of *Carum carvi* L. cenopopulations in morphological, productivity and biochemical parameters. The average height of caraway stalks was 76.5 cm, variation of stem heights being 14.6%. The maximal height of caraway stalk was 1.9 times higher than the minimal. Stalk height was affected by meteorological conditions. A week positive dependence of stalk height on the ratio of precipitation and air temperature (hydrothermal coefficient (HTC) was estimated (r = 0.3638)). The average number of inflorescences was 68.6 pct. A high variation of inflorescence number was established (74.6%). The maximal height of caraway stalk was 21.1 times higher than the minimal. The average weight of 1000 caraway fruits was 2.1 g. The weight of 1000 caraway fruits showed a low variation (5%), although the difference between the minimal and the maximal values was 1.7 times. A negative linear correlation was found between this parameter and inflorescences number (r = –0.5398). In *ex situ* conditions, on average caraway gave 3.7 g fruit yield, and in favorable years some populations gave a 5-fold higher yield (19.1 g) than the average of the study years. The variation of this parameter was among the highest ones (86.6%). The average essential oil content in caraway fruits was 4.8% (3.2–7.0%). An average negative correlation was established between caraway essential oil content and precipitation and air temperature (HTC) (r = –0.6553). The most favorable year for essential oil synthesis was the dry and hot weather of

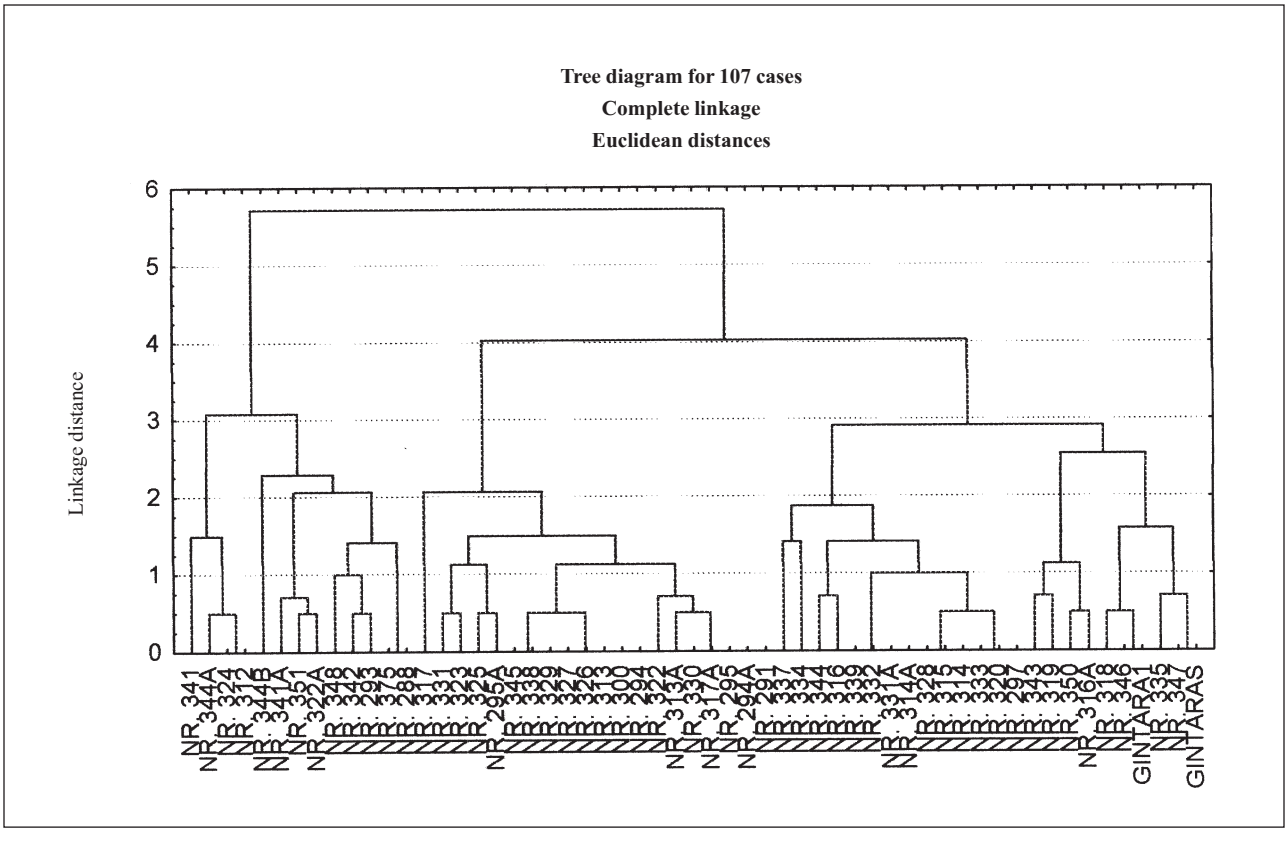

Fig. 1. Dendrogram indicating similarities among wild caraway cenopopulations by petals, leaf colour and phenological dates

2000 summer, and most unfavorable was the wet and cool year 2004. Essential oil dependence on environmental conditions is acknowledged by other authors as well [14]. Carvone amount in essential oil ranged from 49.6 to 60.7% (mean, 52.9%). There was no correlation between carvone content in essential oil and HTC.

The most liable parameters were inflorescences and fruit yield, and the most stable were the weight of 1000 fruits and the biochemical composition of essential oil.

Various plant species are differently adapted to low above zero temperatures and frost stresses [15]. Such stress arises various gene expression changes [16] such as increased leaf hairiness [17], content of anthocyanins [18] and carotenoids [19]. Temperature is the main climatic factor that allows revealing the diversity of leaf colors [20]. It is supposed that the different coloration of the same species petals is related to resistance to low temperatures [21].

In the study years, visual estimations of caraway petals and coloration in the collection revealed that petal coloration of the same cenopopulations varied in different years. Caraway with pink flowers was more abundant in the years with changeable weather in spring when cold spells interchanged with warm

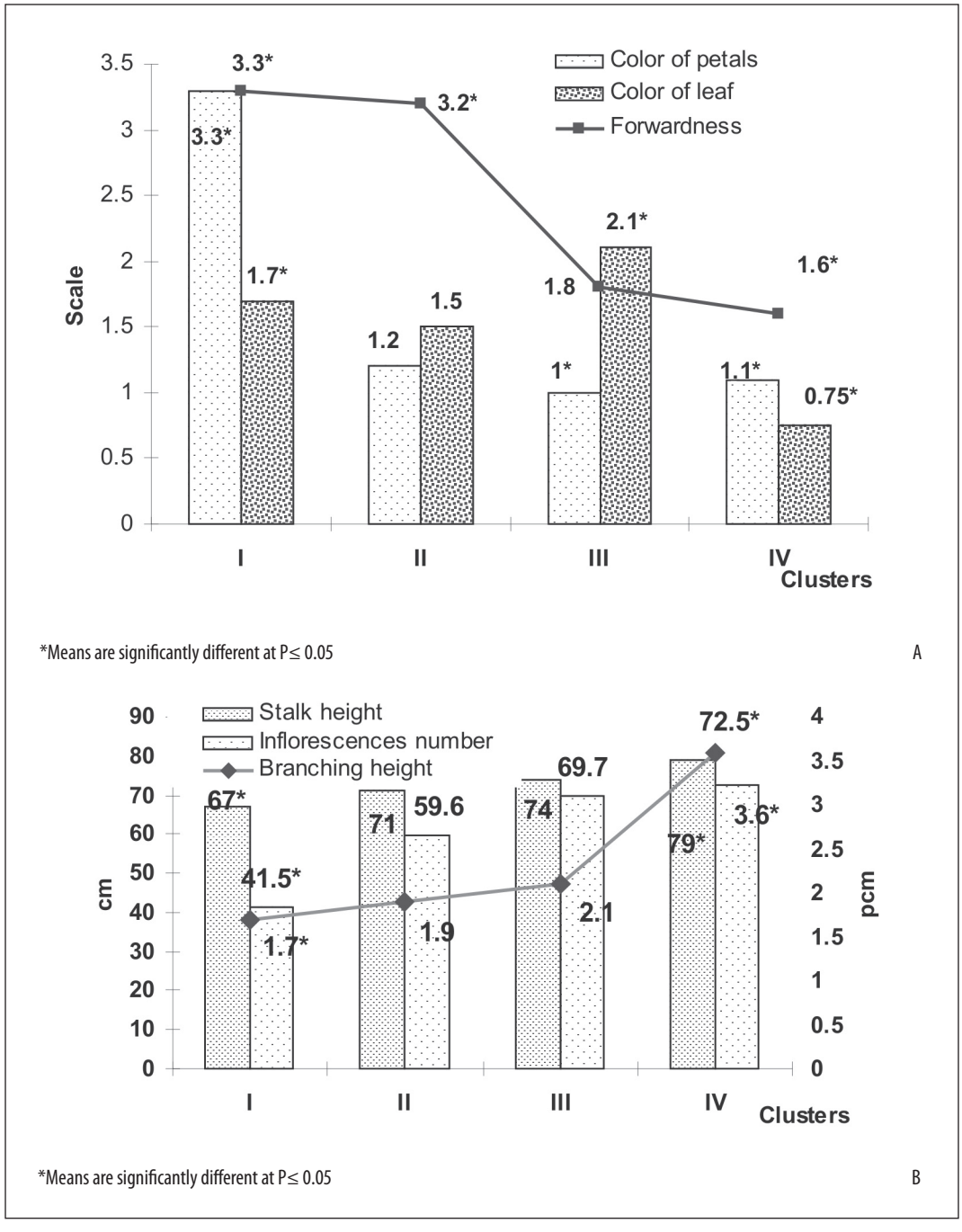

Fig. 2. Phenological and phenotypical traits characteristics of different caraway cenopopulations clusters. A – earliness, petal and leaf colour; B – height of stalks and branching, inflorescence number

spells and late frosts were more frequent. A particularly strong caraway petal coloration was found in 2001 when in April, after a rather warm period (in the first decade the temperature at the soil surface in certain days reached 28.3 °C), followed a cold spell and for nearly a week each night frosts occurred (in the second decade to –3.4 °C at the soil surface). In 2001, 90% of cenopopulations had coloured petals. The diversity of leaf colors was also more frequent.

To summarize the research data on *ex situ* caraway, a hierarchic-cluster analysis was performed according to phenological (2000–2004) as well as petal and leaf colour research data (2001). The cenopopulations were grouped into four clusters (Fig. 1) which varied in the morphological and biochemical parameters.

The earliness of the cenopopulations had an impact on their morphological and productivity parameters. To early cluster I belonged cenopopulations with the most intensive petal colour and the darkest leaf colour (Fig. 2). Cenopopulations of this cluster were behind cenopopulations of other clusters in all morphological and productivity parameters, whereas in fruit essential oil content and carvone content in essential oil they exceeded the others (Fig. 3). Caraway of medium early cenopopulations of cluster II and medium late cenopopulations of cluster III had medium morphological and productivity parameters in comparison to clusters I and IV.

Caraway of late cenopopulations of cluster IV had the highest plant and branching height, the greatest number of flowers,

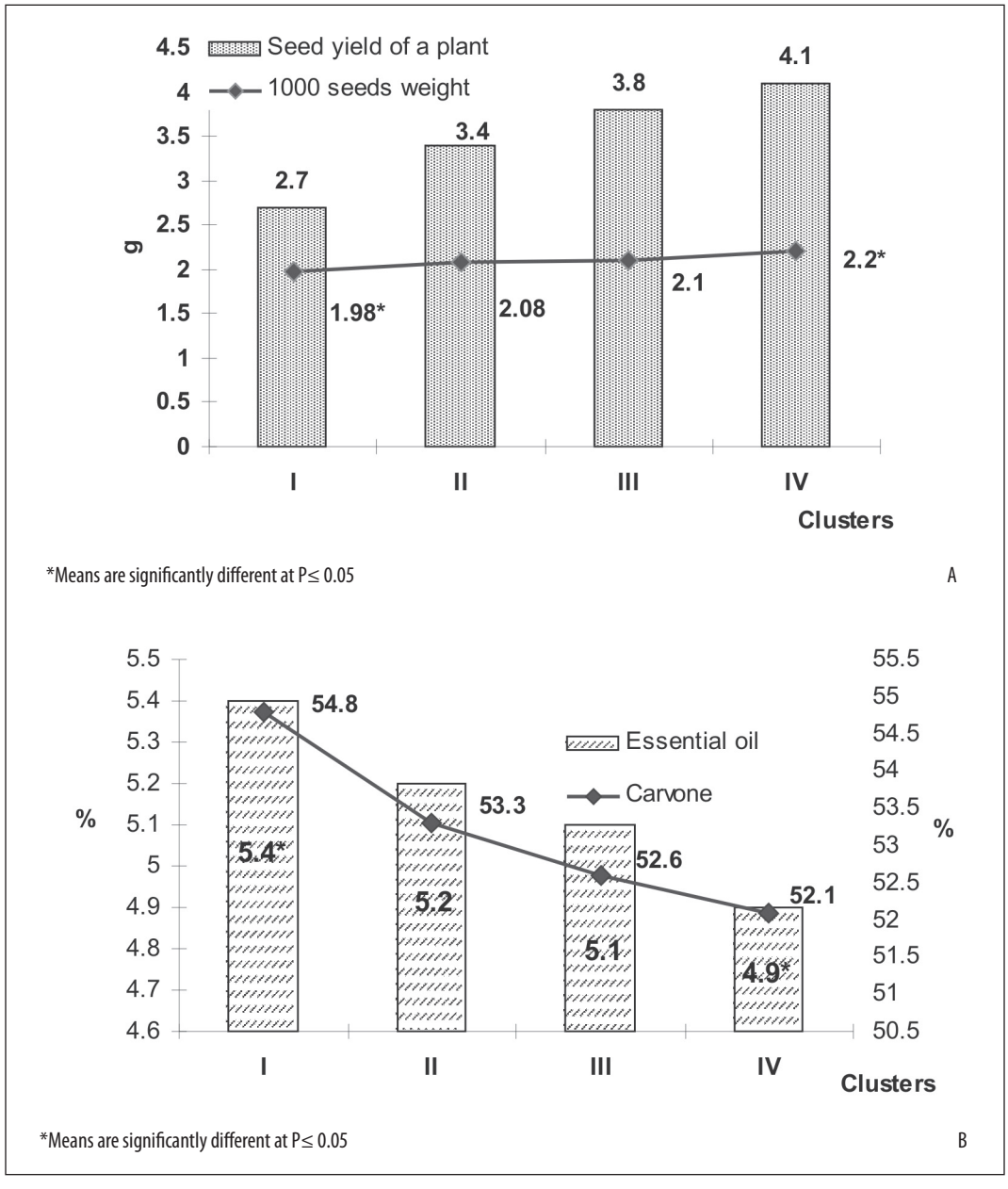

Fig. 3. Productivity traits characteristic of different caraway cenopopulation cluster. A – seeds weight and yield of one plant; B – content of essential oil and carvone

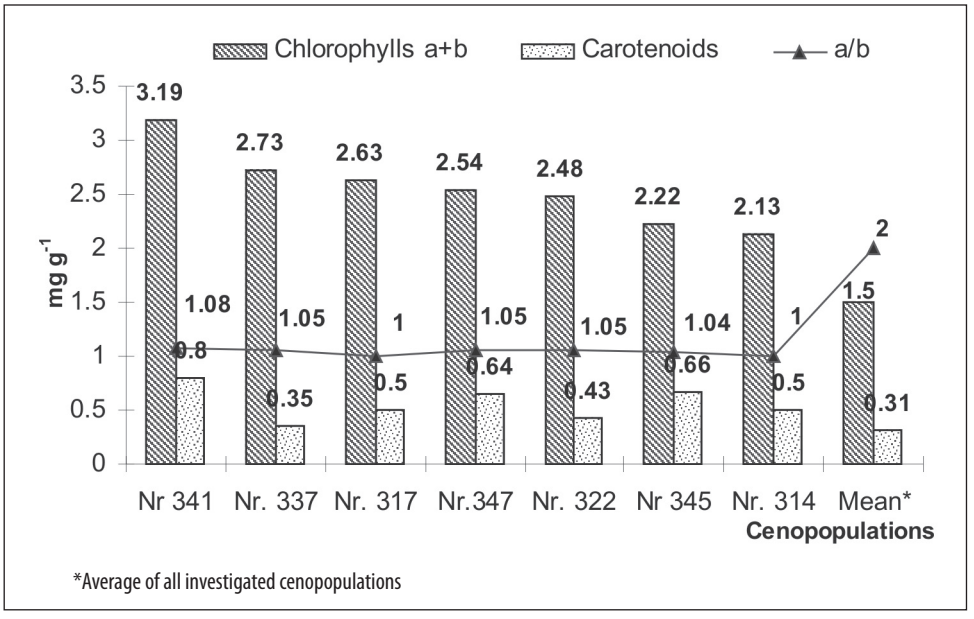

Fig. 4. Chlorophyll and carotenoid content, chlorophylls *a* and *b* ratio of some wild caraway cenopopulations

weight of 1000 fruit and one fruit yield, though it had the highest content of essential oils and carvone.

The most important productivity parameters of caraway are essential oil content and carvone content in essential oil [21]. According to these two parameters, most productive were medium late and late cenopopulations of clusters III and IV (Fig. 3).

Some cenopopulations showed a particularly high content of chlorophylls and carotenoides and a higher ratio of chlorophylls a and b (Fig. 4). Ultra-early cenopopulations with coloured petals and ultra-late cenopopulations with white petals had higher levels of leaf pigments. According to literature data, such ecotypes have a higher cold resistantce [19]. According to data of other authors, high chlorophyll content directly correlates with high plant productivity [22]. There was no correlation between leaf colour and chlorophyll ratio. Leaf colour, pigment amount and composition show a biochemical diversity within the plant genus or species as well as adaptivity to intensive lighting and shade tolerance [23–26].

Early-season caraway forms showed the lowest height, fruit weight and total yield, but had the highest carvone content in fruit essential oil. Pink petals are characteristic of early-season caraway cenopopulations. White petal colour, a higher pigment content in leaves, a higher fruit productivity and as essential oil output characterize medium-late and late forms. According to qualitative and quantitative traits, we selected cenopopulations outstanding for fruit essential oil content, high carvone content in essential oil, fruit weight and one plant yield as well as early and late highly productive cenopopulations.

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AGROBIOLOGINIS LAUKINIŲ *CARUM CARVI* L. CENOPOPULIACIJŲ BIOĮVAIROVĖS ĮVERTINIMAS *EX SITU*

S a n t r a u k a

Įvairių geografinių Lietuvos vietų (107) laukinės paprastojo kmyno (*Carum carvi* L.) cenopopuliacijos 2000–2004 m. buvo auginamos *ex situ* LŽŪU bandymų stotyje vienodos agrotechnikos sąlygomis siekiant įvertinti jas agronominiu požiūriu ir nustatyti galimą ryšį tarp atskirų fenologinių, fenotipinių ir produktyvumo požymių. Apibendrinant laukinių kmynų cenopopuliacijų tyrimų rezultatus, atlikta hierarchinė-klasterinė analizė. Tirtos cenopopuliacijos sugrupuotos į keturis klasterius, kurie skyrėsi ankstyvumu, žiedų ir lapų spalva, morfologiniais parametrais, produktyvumu. Ankstyvosios paprastojo kmyno formos, lyginant su kitomis, išsiskyrė mažiausiu aukščiu, vaisių mase ir bendru derliumi, tačiau jų vaisių eterinio aliejaus sudėtyje buvo daugiausiai karvono. Ankstyvoms paprastojo kmyno cenopopuliacijoms būdinga rausva, vidutinio vėlyvumo ir vėlyvoms formoms – balta vainiklapių spalva, didesnis nei ankstyvų cenopopuliacijų lapų pigmentų kiekis, vaisių produktyvumas, eterinio aliejaus išeiga.