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EFFECT OF ORGANIC AND MINERAL FERTILIZERS ON ESSENTIAL OIL CONTENT IN CARAWAY, ANISE AND CORIANDER FRUITS

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Abstract. The aim of this study, which was conducted in field conditions on three localities in Serbia during two years, was to investigate the influence of the application of various types of fertilizers on the essential oil content in caraway, anise and coriander fruits. The influence of four organic fertilizers was investigated: two microbiological fertilizers (Slavol and Bactofil B-10), two specific organic fertilizers (Royal Ofert biohumus and vermicompost). Also, the chemical fertilizer was used and there was a control plot without any fertilization. From the results, it can be concluded that the application of different fertilizers has an influence on essential oil content only in case of anise fruits. The application of Royal Ofert biohumus shows the best results, after which follows chemical fertilizer. The use of these two types of fertilizers significantly increased the essential oil content in the anise fruits in comparison with other tested treatments. Although differences in the essential oil content of caraway and coriander were not significant, the two above mentioned fertilizers and vermicompost show the best results.

Key words: *Carum carvi*, *Pimpinella anisum*, *Coriandrum sativum*, weather conditions, locality, fertilizers

INTRODUCTION

Caraway, anise and coriander are well known plants from *Apiaceae* family widely spread in Europe, where they have good climatic and soil conditions for high yield and good quality. Essential oil content is the main criteria for determining the quality of these fruits.

Caraway (*Carum carvi* L.) fruits contain from 1 to 6% of essential oil which gives its characteristic aroma [Sedlakova et al. 2003]. Because of this, *Carvi fructus* is used as

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spice in ice creams, candies, baked goods, meat, cheese, pickles, condiments, soft drinks and alcoholic beverages. Anise (*Pimpinella anisum* L.) fruits contain from 1.5 to 5.0% of essential oil which gives sweet herbaceous odour and taste of this plant [Ullah and Honermeier 2013]. Because of the strong aroma, *Anisi fructus* is often used in pharmaceutical industry for masking the bad taste of remedies, as well as for the preparation of many sweets (chocolate, cookies and candies) and alcoholic beverages. Coriander (*Coriandrum sativum* L.) fruits contain from 0.10 to 1.8% of essential oil [Telci et al. 2006], which has a characteristic aroma similar to a mixture of cinnamon and pepper. *Coriandri fructus* is used as a condiment in pickle spices, seasoning, curry powders, sausages, cakes, pastries, biscuits and buns.

It is known that the amount and composition of essential oil are genetically determined, but it also depends on climatic conditions during stages of fruit formation and ripening [Sedlakova et al. 2003]. Agrotechnique is also very important for the cultivation of these plats, among which are sowing date and rate, fertilization, irrigation and harvest time [Mohamed and Abdu 2004, Rożek et al. 2013, Nurzyńska-Wierdak 2013a].

In the last few years, alternative medicine and organic food production became very popular trends. The application of modern scientific methods on various plants, which were used in traditional medicine for a long time throughout the world, has led to their official approval for the treatment of many disorders. Once more, organic farming ensures safe products for human health as well as for the environment due to the fact that the use of chemical fertilizers and pesticides is not allowed.

From the available literature, only a few papers studied the influence of fertilization on essential oil content in caraway [El-Din et al. 2010, Kozera et al. 2013], anise [Darzi 2012, Jevđović et al. 2012, Faravani et al. 2013, Zand et al. 2013] and coriander fruits [Lenardis et al. 2000, Moosavi et al. 2013]. For this reason, the aim of our study was to investigate the influence of the application of various types of fertilizers on essential oil content in caraway, anise and coriander fruits by applying different types of fertilizer approved for organic farming system, as well as mineral fertilizer.

MATERIAL AND METHODS

Seeds of annual caraway, anise and small seed coriander obtained from local medicinal plant grower were used in this study. The field experiment was carried out during 2011 and 2012, in three localities in Vojvodina Province (south part of Pannonia): Mošorin (latitude 45°18’5’’N; longitude 20°09’32’’E; altitude 111 m), Veliki Radinci (latitude 45°02’26’’E; longitude 19°40’15’’E; altitude 111 m) and Ostojićevo (latitude 45°53’16’’N; longitude 20°09’31’’E; altitude 88 m). The experiment was carried out in fields and under different microclimatic and soil conditions.

Data for meteorological conditions was obtained from the nearest meteorological station for each experimental field (< 30 km), and it is shown in Figure 1. As it can be seen, the values of temperature in each year were almost identical at all three localities, but the values of precipitation were different for both the localities and investigated years. It is visible that the second investigated year (2012) was hotter and dryer in comparison to 2011, especially during June and July.

Soil samples were taken from level of 0–30 cm and analyzed by using standard methods (Soil testing laboratory, Agricultural Extension Service Serbia). For the purpose of determining soil pH a potentiometric method was used, for $CaCO_3$ molar volume of carbon dioxide, humus content was determined by Turin method, total nitrogen by Kjeldahl method, available phosphorous and potassium by Al-method [Van Reeuwijk 2002].

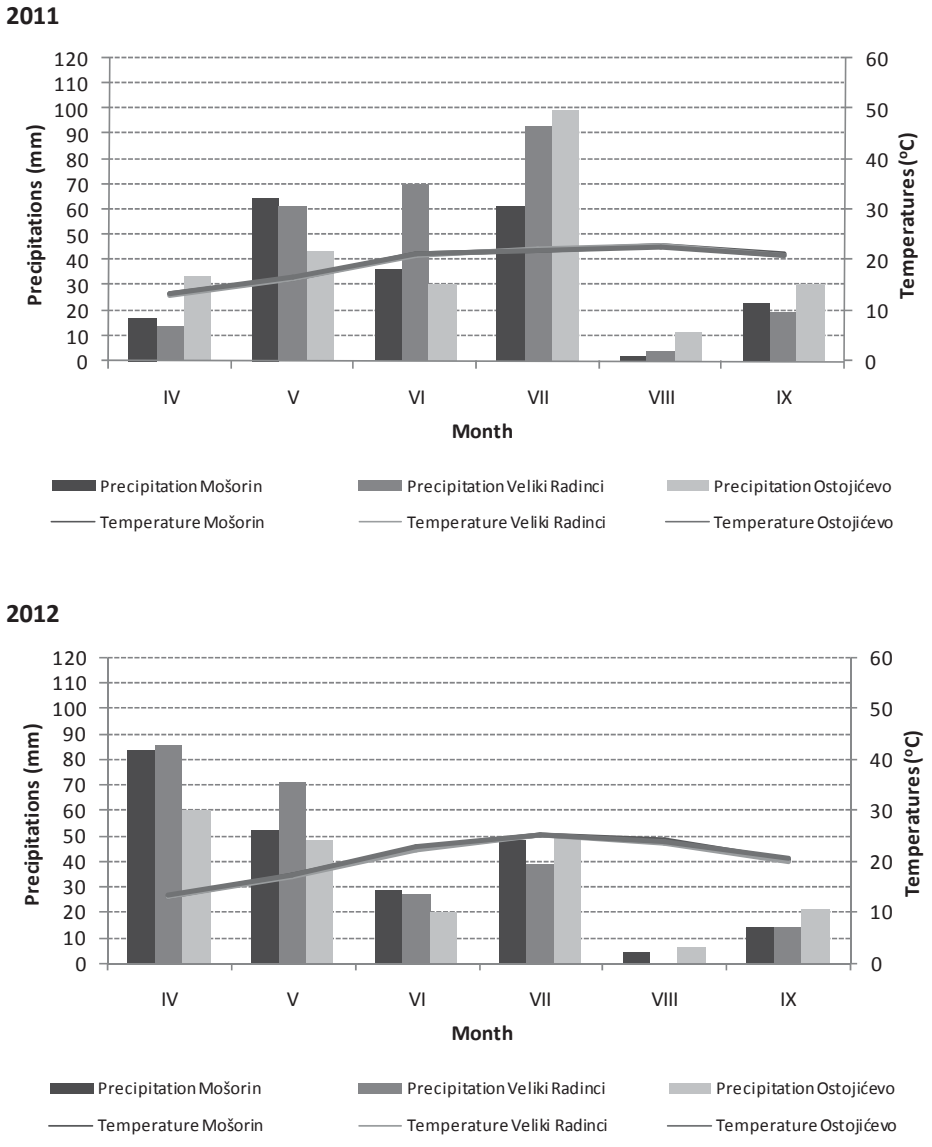

Fig. 1. Average monthly values of precipitations and temperatures for vegetation period (IV–X) in both experimental years for all three localities

Table 1. Agrochemical analysis of soil

	pH (in KCl)	$CaCO_3$ (%)	Humus (%)	Total nitrogen (%)	Al P_2O_5 (mg 100 g^{-1})	Al K_2O (mg 100 g^{-1})
Mošorin	7.3	8.4	2.7	0.18	81.6	75.1
VelikiRadinci	7.1	2.0	2.5	0.16	22.4	21.7
Ostojićevo	7.3	8.8	2.2	0.14	17.6	30.3

The field experiments were set up as a randomized block design with four replications. An experimental plot size was 5 m^2 (consisting of 5 rows 3 m long). Sowing was carried out at optimum time (during April) with a hand seeder. Seeds were sown at row spacing of 0.35 m and by respecting density of 200 plants per m^{-2}. Weeds were controlled by hoeing and weeding when needed.

The influence of six different fertilizer treatments on essential oil content was investigated: two microbiological fertilizers (Slavol and Bactofil B-10), two specific organic fertilizers (Royal Ofert biohumus and vermicompost), one chemical fertilizer (NPK) and control (without fertilization).

Slavol (Agrounik, Serbia) is a microbiological fertilizer containing bacteria from the root system (*Azotobacter chroococcum*, *A. vinelandii*, *Derxia* sp., *Bacillus megaterium*, *B. subtilis*, *B. lichenformis*) which produce natural vitamins, enzymes and growth stimulators. Slavol is applied by spraying the leaves, in the dose of 7 l ha^{-1}, two times during the vegetation period – the first time when the plant was in the stage of 3–4 leaves and the second time after 7 days.

Bactofil B-10 (Agrobio, Hungary) is a microbiological fertilizer containing seven bacterial strains: *A. vinelandii*, *A. lipoferum*, *B. megaterium*, *B. substilis*, *B. circulans*, *Pseudomonas fluorescens* and *Micrococcus roseus*. In addition to bacteria, it contains macro and micro nutrients, as well as enzymes synthesized by microorganisms. This fertilizer directly influences the intensity of humification and mineralisation processes and it is used for treating the soil before sowing by apllying a dose of 1.5 l ha^{-1}.

Royal Ofert biohumus (Altamed, Serbia) is a specific organic fertilizer obtained through the biotechnological processing of organic waste by domestic fly larvae. The larvae live in this organic waste 5–7 days during which time they eat and process the waste. Biohumus is the result of this, with its unique content of nitrogen, phosphorus and potassium, rich in organic matter and humic acids. Royal Ofert is sold in granulated form. The recommended dose is 3 t ha^{-1}.

Vermicompost (Ivić Farm, Serbia) is a complex organic fertilizer obtained by processing miscellaneous organic residues such as cereal straw and other crop residues, animal manure, green weeds and leaves by *Lumbricus terrestris*. Vermicompost is rich in humus, phosphorus, potassium and in micronutrients (Zn, Cu, Fe, Mn), and has high microbiological potential. This fertilizer was applied in our experiment in the quantity of 5 t ha^{-1}.

Complex NPK chemical fertilizer (HIPAzotara, Serbia) in formulation 15:15:15 was used in amount of 400 kg ha^{-1}, i.e. 60 kg per hectare of nitrogen (CAN), phosphorus (MAP) and potassium (KCl). All of the recommended quantities of fertilizers, except Slavol,were applied in pre-sowing by incorporation into soil, on the depth of 5 cm.

The harvest was performed at full ripening stage by hand from the middle of the central row, in order to eliminate marginal effect. Fruits were storaged for three months in paper bags at room temperature. The samples of caraway, anise and coriander were subjected to hydro-distillation using a Clevenger-type apparatus, to extract essential oils, according to the method outlined by the European Pharmacopoeia [2004]. The samples were grinded, homogenized and made into a fine powder. In order to extract the essential oils, 100 g of the powder was placed in 1 litter conical flask and connected to the Clevenger apparatus. 500 ml of distilled water was added to the flask and heated to the boiling point. Steam in combination with the essential oils was distilled into a graduated cylinder for 4 hours and then separated from the aqueous layer.

Statistical analysis was performed by analysis of variance of randomised block system using Statistica 7.0 package.One way ANOVA was done and the source of variations was: years (Y), localities (L) and fertilizers (F). Factorial ANOVA was also performed. Means were compared by LSD test at significancy at 0.05%.

RESULTS

During the dry and hot 2012, the essential oil content in caraway fruits was 4.12%, while in the moderate 2011 it was 3.78%, but this difference was not significant. Locality Ostoićevo is the most favourable for caraway cultivation (4.38%), then Mošorin (3.87%) and the least favourable is Veliki Radinci (3.60%). From this data it can be concluded that the locality strongly influences the essential oil content. Specific organic fertilizers, Royal Ofert biohumus and vermicompost as well as the application of

Table 2. Influence of year, locality and fertilization on essential oil content of caraway, anise and coriander fruits (%)

		Caraway	Anise	Coriander
Year (Y)	2011	3.78	3.93	0.94
	2012	4.12	3.52	0.77
Location (L)	Mošorin	3.87	3.73	0.79
	VelikiRadinci	3.60	3.93	0.91
	Ostojićevo	4.38	3.50	0.86
Fertilization (F)	control	3.79	3.64	0.85
	Slavol	3.92	3.66	0.82
	Bactofil	3.72	3.66	0.84
	Royal Ofertbiohumus	4.09	3.90	0.87
	Vermicompost	4.09	3.63	0.88
	NPK (15:15:15)	4.08	3.85	0.87
$LSD_{0.05}$	Y	ns	0.14	0.07
	L	0.26	0.15	0.08
	F	ns	0.17	ns
	Y*L	0.33	ns	0.08
	Y*F	ns	ns	ns
	L*F	ns	ns	ns
	Y*L*F	ns	ns	ns

ns – not significant

chemical fertilizer gave the highest content in caraway fruits (above 4%), even though the application of different fertilizers did not show significant differences. However, the interaction of year and fertilizer was statistically significant.

Weather conditions during the year had a significant influence on essential oil content of anise. During the vegetation period in 2011, essential oil content was 3.93% which was higher in comparison to 2012 (3.52%). The growing locality significantly influenced the essential oil content in anise fruits. Contrary to caraway, anise plants grown in Ostojićevo accumulated the least essential oil (3.50%) and plants grown in Veliki Radinci the most (3.93%). The application of different fertilizers had a statistically significant influence on essential oil content. Royal Ofert biohumus was most favourable (3.90%), then chemical NPK fertilizer (3.85%). These fertilizers considerably increased the essential oil content in comparison to others.

Essential oil content in coriander was higher in 2011 (0.94%) in comparison to the dry and hot 2012 (0.77%). Moreover, the locality Veliki Radinci was the most favourable for accumulation of essential oil (0.91%). The application of different fertilizers had no significant effect on the essential oil content. In the case of coriander, the application of vermicompost, Royal Ofert biohumus and chemical fertilizer gave the highest content of essential oil as it was the case with caraway fruits. Also, the interaction of year and fertilizer was statistically significant.

DISCUSSION

The years had a strong influence on the content of essential oil in fruits of anise and coriander. These plants originate from the Mediterranean region and favour warm, sunny and dry climate. However, in 2012, stress conditions caused by high temperatures and lack of rainfall were unfavourable for the synthesis of the essential oil.

Water deficit during stem elongation and umbel appearance reduced oil production in anise fruits [Zehtab-Salmasi et al. 2001]. In our experiment during 2012, drought during these phenological phases (June and July) probably caused the decrease in essential oil accumulation in anise fruits.

Drought significantly affects the yield of coriander essential oil, i.e. in drought conditions the amount of essential oil content decreases by half [Sani and Farahani 2010]. It is established that the concentration of essential oils in the fruit decreases at temperatures above 21°C [Luayza et al. 1996]. The reason for the formation of less essential oil during 2012 may be due to the fact that in the course of the year a lot of high mean daily temperatures were recorded, especially during fruit formation and ripening.

In case of caraway, extremely dry 2012 positively influenced the content of essential oil in fruits, although the difference was not statistically significant. Our investigations confirmed that water deficit increased the essential oil yield in caraway fruit, which was previously established [Laribi et al. 2009]. Four varieties of annual caraway grown in Austria (west part of Pannonia), also show variations in essential oil content depending on harvest year and variety. These variations ranged from 2.78 to 3.34% [Bailer et al. 2001].

It was found that the essential oil content in anise fruits varied among the regions in Turkey from 1.85 to 2.38% [Tort and Honermeier 2005] and from 1.3 and 3.7% depend-

ing on the population [Arslan et al. 2004]. Variations in the yield of essential oil in anise fruits from various European countries were also recorded [Orav et al. 2008].

In the case of coriander, growing locality, along with the origin i.e. genotype, has a significant influence on the content of essential oil. In many European countries, where the small seed type of coriander is widespread, essential oil content is mainly around 1%. Coriander fruits from Romania contain 1.87 to 2% of essential oil [Tsagkli et al. 2012], and from Poland 1.15–1.24% [Nowak and Szemplinski 2014], while in countries where the large fruit varieties are spread, the content of essential oil is lower. For example in Turkey the essential oil content is 0.28–0.33% [Kaya et al. 2000] and in Iran from 0.1 to 0.36% [Ebrahimi et al. 2010].

Fertilizers can significantly affect the content of essential oil. They can be supplied to plants by root or by foliar application, in mineral and organic form [Nurzyńska-Wierdak 2013b]. The mean values of caraway essential oil increase gradually by increasing nitrogen [El-Din et al. 2010, Kozera et al. 2013]. The same conclusion is reached for anise [Jevđović et al. 2012] and coriander [Lenardis et al. 2000, Moosavi et al. 2013].

Experiments in Iran show that treatments of anise plants with phosphate solubilising microorganisms had positive effects on essential oil content, especially if they were applied two times during the vegetation period (seed inoculation and spraying at the base of plants at the start of steam elongation phase) [Zand et al. 2013]. Darzi [2012] also recommended the application of phosphate biofertilizer during these phases. The author emphasises that the application of vermicompost also positively influences the essential oil content in anise fruits. Essential oil yield was the highest when vermicompost was applied in experiments conducted by Faravani et al. [2013].

CONCLUSION

The weather conditions during the years had a strong influence on the content of essential oil in fruits of anise and coriander. In the case of caraway, water deficit accompanied by high temperatures positively influenced the content of essential oil in fruits, although the difference was not statistically significant. In the case of anise and coriander, these conditions were unfavourable for the synthesis of essential oil. Localities had a statistically significant influence on essential oil content for all three species. The application of different fertilizers had an influence on anise essential oil content. The application of Royal Ofert biohumus shows the best results, after which is the chemical NPK fertilizer. Using these two types of fertilizers significantly increased the essential oil content in anise fruits in comparison to other tested treatments. Although differences in the essential oil content of caraway and coriander were not significant, the two mentioned fertilizers and vermicompost show the best results.

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WPŁYW NAWOZÓW ORGANICZNYCH I MINERALNYCH NA ZAWARTOŚĆ OLEJKÓW ETERYCZNYCH W OWOCACH KMINKU, ANYŻU I KOLENDRY

Streszczenie. Celem dwuletniego badania przeprowadzonego w warunkach polowych w trzech miejscowościach w Serbii było zbadanie wpływu zastosowania różnych typów nawozów na zawartość olejków eterycznych w owocach kminku, anyżu i kolendry. Zbadano wpływ czterech nawozów organicznych: dwóch nawozów mikrobiologicznych (Slavol i Bactofil B-10) oraz dwóch specyficznych nawozów organicznych (Royal Ofert biohumus i wermikompost). Użyto także nawozu chemicznego. Znajdowało się też poletko bez żadnego nawożenia. Na podstawie otrzymanych rezultatów można wywnioskować, że zastosowanie różnych nawozów ma wpływ na zawartość olejków eterycznych tylko w przypadku owoców anyżu. Zastosowanie Royal Ofert biohumus dało najlepsze wyniki, natomiast użycie nawozu chemicznego było na drugim miejscu. Użycie tych dwóch typów nawozów istotnie zwiększyło zawartość olejków eterycznych w owocach anyżu w porównaniu z pozostałymi zabiegami. Chociaż różnice w zawartości olejków eterycznych w kminku i kolendrze nie były istotne, wyżej wspomniane nawozy oraz wermikompost wykazały najlepsze rezultaty.

Słowa kluczowe: *Carum carvi*, *Pimpinella anisum*, *Coriandrum sativum*, warunki pogodowe, miejscowość, nawozy

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