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INFLUENCE OF SOWING DATE ON YIELD AND FRUIT QUALITY OF CORIANDER (*Coriandrum sativum* L.)

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Abstract. Coriander (*Coriandrum sativum* L.) is known as a herbal plant all over the world. The yield of coriander fruit is influenced by weather conditions, agronomic and genetic factors. This paper discusses the impact of the year of research and date of sowing and their mutual interactions on yield and yield components of coriander and on the content and chemical profile of essential oil in coriander fruit. It has been demonstrated that air temperature and precipitation during each season had a determining effect on coriander fruit yields and yield their component. The weather conditions in 2007 were most favourable for the growth and development of coriander, which then produced the highest fruit yield (1.54 $t \cdot ha^{-1}$). The date of sowing did not differentiate yields of coriander. However, yields of coriander were determined by interaction of sowing date with years of research. In north-eastern Poland, a date of sowing which falls between April 10 and 20 seems to ensure best coriander yields (1.40 $t \cdot ha^{-1}$). When coriander was sown later, the yield tended to be lower. Coriander yielding was positively correlated with the weight of fruit per plant. The content of essential oil in coriander fruits was distinctly different between the years of the experiment. The content of oil in coriander fruits was slightly raised by a later sowing date. The main component of coriander essential oil was linalool, which made up 65–67% of its chemical composition. The year of the experiment rather than the date of sowing differentiated the composition of coriander oil.

Key words: medicinal plants, *Coriandri fructus*, yield components, essential oil, linalool

INTRODUCTION

Success of growing coriander for seeds depends on many factors. Yields of coriander can be affected, for example, by genetic traits of cultivars, weather conditions in each season and agronomic factors. Thus, coriander fruit yields reported from different experiments are unstable and highly varied, from very high (over 3 $t \cdot ha^{-1}$) to very low

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(less than 0.5 t·ha^{-1}) [Luayza et al. 1996, Angelini et al. 1997, Carrubba et al. 2006, 2009, Kucharski and Mordalski 2008, Zheljazkov et al. 2008, Ghobadi and Ghobadi 2010, Moosavi et al. 2012].

Coriander is a native to dry and warm climates, but has adapted itself to more temperate weather. Regarding the length of daytime, coriander's photoperiodic response is neutral, although longer daylight after sowing is beneficial to its growth and development [Weiss 2002]. The date of sowing, an agronomic factor, affects the photoperiodic response of plants and determines yields. Obviously, the sowing date influences the early stage of plant growth but it also affects results of fertilization and other treatments carried out during later stages of plant development. A delayed date of sowing accelerates subsequent development stages and shortens the whole plant growing period [Carrubba et al. 2006], thus reducing yields [Luayza 1997, Carrubba et al. 2006, Zheljazkov et al. 2008]. Lower yields of coriander plants from delayed sowing are due to inferior development of shoots and reduced yield components [Carrubba et al. 2006], which depend on plants' response to sunlight and length of daytime [Diederichsen 1996, Weiss 2002]. Particularly strong adverse consequences are caused by shortage of rainfall during the growing season [Carrubba et al. 2006]. Thus, irrespective of what species of plant is cultivated, the date of sowing is considered to be a cost-free element in any plant production technology. It can be suspected that in north-eastern Poland, where spring comes later, temperatures are lower and there is less sunlight than in other parts of the country, coriander will experience worse conditions for its onthogenetic development.

The purpose of this study has been to determine the effect of year and sowing date as well as their interaction on coriander yield and yield components and on the content and chemical composition of essential oil in coriander fruits.

MATERIAL AND METHODS

The study has been based on the results of an experiment on coriander designed at the Department of Agrotechnology and Crop Management, the University of Warmia and Mazury in Olsztyn. Field trials were carried out in 2006–2008, on a field at the Experimental Station in Bałcyny near Ostróda (N – 53º35'; E – 19º51'). The experiment was set up on proper grey-brown podzolic soil developed from light and medium loam, which in the Polish soil valuation classification belonged to class IIIa. The soil was highly abundant in available phosphorus (173–194 mg P·kg^{-1}) and potassium (160–169 mg K·kg^{-1}), moderately rich in magnesium (58–85 mg Mg·kg^{-1}), and slightly acid in reaction (pH 6.1–6.5).

The research relied on a strict multi-factorial experiment set up in a fractional replication design of the s^{k-p} type, where k stands for the number of agronomic treatments tested on s levels in p replications [Załuski and Gołaszewski 2006, Załuski et al. 2006]. Five agronomic factors were tested on 3 different levels of input intensity: 0 – the lowest level, 1 – moderate level and 2 – the highest level (tab. 1). In order to exclude effects of soil-related variability, two replications were run. The date of sowing was considered to be the key factor responsible for variability of the analyzed characteristics. For the

Table 1. Agronomic factors and their levels

	Agronomic factor	Level 0	Level 1	Level 2
A	sowing date	14 day delayed	7 day delayed	early
B	P and K fertilization	no fertilization	17.5 kg P+ 41.5 kg K·ha^{-1}	35.0 kg P + 83.0 kg K·ha^{-1}
C	S, Mg and microelements fertilization	no fertilization	20 kg S+ 15 kg Mg·ha^{-1}	20 kg S + 15 kg Mg·ha^{-1} + microelements
D	weed control	no control	mechanical	chemical
E	diesease control	no control	seed dressing	seed dressing + foliar fungicide

evaluation of the experimental results, $1/3^p$ of combinations of factors out of 234 possible ones were chosen, and a set of 27 combinations was obtained, which was then divided into three blocks (tab. 2). With the 2 replications, the experiment was run on a total of 54 plots. The evaluation of the results excluded other combinations of factors, considered less interesting, as well as effects of higher order interactions, which were included into the evaluation of experimental error [Oktaba 1971, Gołaszewski and Szempliński 1998]. Thus, the experiment was performed to evaluate primarily the main effects and the effects of the first order interaction which were not aggregates of assessed effects of the blocks or higher order interactions [Załuski et al. 2006]. The area of a plot for harvest was 12.6 m^2 (for combinations with D_0 and D_2 factors) or 14.0 m^2 (for combinations D_1).

Table 2. 3^{5-2} factorial design plan

2	0	2	2	0*	1	0	1	1	0	0	2	2	1	0
2	0	1	1	2	1	1	0	1	1	0	0	2	2	2
2	2	0	2	2	1	2	0	2	0	0	2	0	2	1
2	2	1	0	0	1	2	2	1	2	0	1	1	2	0
2	0	0	0	1	1	0	0	0	2	0	0	0	0	0
2	1	1	2	1	1	2	1	0	1	0	0	1	1	1
2	1	2	0	2	1	1	1	2	2	0	1	2	0	1
2	2	2	1	1	1	1	2	0	0	0	1	0	1	2
2	1	0	1	0	1	0	2	2	1	0	2	1	0	2

* 20220 is factor A on level 2, B on level 0, C on level 2, D on level 2 and E on level 0

In 2006 and 2008, the preceding crop before coriander was spring barley harvested on grain, and in 2007 coriander was preceded by a cereal and legume mix harvested on green matter. Post-harvest and pre-sowing soil tillage treatments were carried out according to principles of good agricultural practice. During the whole experiment, nitrogen fertilization was applied in a rate of 80 kg N·ha^{-1} (ammonium nitrate 34%) split into two doses: 50 kg before sowing and 30 kg in the early leaf rosette stage (which coincided with the mechanical weed control treatment in combination D_1). Alternatively, boron in a dose of 5.0 kg B·ha^{-1} (Solubor $Na_2B_8O_{13}\cdot 4H_2O$) was applied. Phosphorus (triple superphosphate 46%) and potassium fertilizers (potassium salt 60%) in combinations B_1 and B_2 were applied in spring before sowing. In combinations with factors C_1 and C_2, pre-sowing fertilization with sulphur and magnesium (magnesium sulphate $MgSO_4\cdot 7H_2O$) was applied additionally. Micronutrients in combination C_2 were sprayed over plants (Insol Mikro in a dose of 2.0 l·ha^{-1}) during the generative shoot full formation phase. The fertilizer contained 0.41% of boron, 0.17% of copper, 2.33% of iron, 0.92% of manganese, 0.08% of molybdenum, 0.41% of zinc, and Cu, Fe, Mn and Zn were in the chelated form [INS 2010].

Coriander was sown on three dates: first date (A_2) was the earliest possible in a given year [Rumińska 1983] (2006 – 14 April, 2007 – 20 April, 2008 – 5 April); the second date (A_1) was delayed by 7 days (2006 – 21 April, 2007 – 27 April, 2008 – 12 April), and the third one (A_0) was postponed by 14 days (2006 – 28 April, 2007 – 4 May, 2008 – 19 April) (tab. 3). A Polish cultivar of coriander called Ursynowska was tested. The cultivar has the following characteristics: the 1000-fruit weight of 7 g and the content of essential oil in fruit between 0.9 and 1.0% [Rumińska 1979]. Fifteen kg·ha^{-1} of fruits were sown in rows spaced at 20 cm (combinations D_0 and D_2) and 40 cm (D_1), at a depth of 1–1.5 cm [Rumińska 1983]. Plant protection treatments in combination D_1 consisted of mechanical weed control (once removing weeds between rows) and chemical weed control in combination D_2 (post-sowing application of the herbicide Patoran 500 SC, s.a., metabromuron, dose 3.0 l·ha^{-1}). No weed control was performed in combination D_0.

Disease control treatments in combinations E_1 and E_2 consisted of pre-sowing seed dressing with the preparation Oxafun T, s.a. (carboxin + tiuram, dose 3.0 g·kg^{-1}). In E_2, fungicide was applied before flowering (Penncozeb 80 WP, s.a., mancozeb, dose 2.5 kg·ha^{-1}). No pathogen control was carried out in combination E_0. Coriander plants were harvested at the full fruit ripeness stage with a field combine.

During the whole growing season of coriander, the plant's major development phases were monitored (tab. 3). Yield structure components were determined: number of plants (per 1 m^2), weight of fruits per plant (from 10 plants randomly chosen from each plot) and weight of 1000 fruits (based on the combine harvested yield). The quality assays, that is the content and chemical composition of coriander essential oil, were performed only on fruits grown in 2007 and 2008 and sown on the extreme dates of sowing (A_0 and A_2). It was assumed that a 7-day difference between sowing dates would differentiate the quality of herbal produce almost negligibly. The content of coriander oil was determined with the direct method [Farmakopea Polska 2008] via distillation of plant raw material in a Deryng apparatus with water recirculation [PN-R-87019:1991]. The chemical profile of oil was determined by gas chromatography coupled with a mass detector (a Varian 4000GC/MS chromatographer).

For statistical elaboration of the results, analysis of variance for a fractional factorial experiment type 3^{k-2} (k = 5) with replications was used [Oktaba 1971, Gołaszewski and Szempliński 1998, Załuski et al. 2006]. Significance of differences of the main and

Table 3. Course of phenological phases of coriander on the meteorological conditions

	Fenological period	Number of vegetation days			Mean daily temperature (ºC)			Rainfall (mm)		
		2006	2007	2008	2006	2007	2008	2006	2007	2008
1st sowing date (2006 – 14.04, 2007 – 20.04, 2008 – 5.04)	sowing – emergence	23	20	24	10.4	8.6	7.6	24.5	25.9	32.2
	emergence – shoot elongation	39	34	36	12.6	16.7	12.9	94.2	62.8	48.4
	shoot elongation – flowering	13	11	14	19.1	18.2	15.6	73.5	21.3	11.2
	flowering – fruits forming	10	10	10	19.6	15.9	17.1	3.0	51.0	15.6
	fruits forming – full maturity	36	52	48	20.0	18.3	18.5	93.5	236.8	92.8
	full maturity – harvest	4	5	6	16.8	15.3	17.5	7.0	0.2	24.2
	vegetation season	125	132	138	16.4	15.5	14.9	295.7	398.0	224.4
2nd sowing date (2006 – 21.04, 2007 – 27.04, 2008 – 12.04)	sowing – emergence	21	18	24	11.7	9.1	9.4	22.6	47.3	52.7
	emergence – shoot elongation	39	32	36	13.2	17.6	13.9	118.8	53.4	6.6
	shoot elongation – flowering	11	12	11	19.2	17.1	15.1	51.9	32.9	15.6
	flowering – fruits forming	19	7	9	21.8	15.8	17.0	8.0	55.0	12.2
	fruits forming – full maturity	39	53	47	19.4	18.4	18.5	95.5	209.2	101.0
	full maturity – harvest	6	3	4	17.6	13.1	18.2	22.6	0.2	15.0
	vegetation season	135	125	131	17.1	15.2	15.4	319.4	398.0	203.1
3rd sowing date (2006 – 28.04, 2007 – 4.05, 2008 – 9.04)	sowing – emergence	18	22	21	12.9	13.4	10.2	33.0	67.1	42.8
	emergence – shoot elongation	36	26	34	13.3	18.7	14.4	105.8	40.8	6.6
	shoot elongation – flowering	16	15	15	19.6	16.1	15.9	51.9	95.7	26.8
	flowering – fruits forming	11	8	8	21.0	14.7	17.6	14.0	47.9	1.0
	fruits forming – full maturity	35	51	45	19.3	18.3	18.5	95.0	150.0	116.0
	full maturity – harvest	3	5	1	16.7	12.0	20.3	17.1	23.8	0.0
	vegetation season	119	127	124	17.1	15.5	16.2	316.8	425.3	193.2
	mean for 3 years	126	128	131	16.9	15.4	15.5	310.6	407.1	206.9

interaction effects was assessed with the F (*Fisher-Snedecor's*) test. The analysis comprised 6 main effects (years + 5 variables), 9 two-factor interactions (5 – years with particular variables, 4 – variable A with the other variables) and 4 three-factor interactions (years × variable A × variables B, C, D, E). Effects of the other two-factor interactions and higher order interactions were included into the variation of error. The analyzed characteristics generating similar mean values were put into homogenous groups according to Duncan's test (level of significance $\alpha = 0.05$) and assigned small letters in the tables. For evaluation of the relationships between yield and yield structure components, Pearson's simple correlation coefficient (*r*) was applied. Statistical calculations included ANOVA analysis of variance for multi-factorial experiments, using a STATISTICA 8.0® software package. The remaining calculations were performed in EXCEL® spreadsheets.

Table 4. Analysis of variance for fruits yield and fruits yield components of coriander

Source of variation	Fruit field	Plant number per 1 m^2 at harvest time	1000-fruit weight	Fruit weight per plant
Year (L)	*	*	*	*
Sowing date (A)	n.s.	*	*	n.s.
L × A	*	*	*	n.s.

* – significant with the F (Fisher-Snedecor's) test at 0.05 probability level; n.s. – non-significant

This paper contains an interpretation of the results pertaining to years and dates of sowing as well as their interactions. Results of our analysis of variance for fruit yields and yield structure components are set in table 4.

RESULTS AND DISCUSSION

The yields of coriander fruits during the experiment were varied between the years, which was verified statistically (tab. 4). Two homogenous groups were distinguished with respect to the fruit yield: *a* comprising yields from the year 2007 and *b* composed of yields from 2006 and 2008 (tab. 5). This shows that coriander yields in 2007 could be the result of preceding crop and weather conditions influence (tab. 3). The temperatures and rainfall in 2007 were most favourable for this plant (length of the vegetative season was 128 days, the average daily air temperature reached 15.4°C, and the rainfall was 407.1 mm). The fruit yields obtained in that year were the highest (on average 1.54 t·ha^{-1}). In the other years (in 2006: vegetative growth season 126 days, average daily temperature 16.9°C, precipitation 310.6 mm; in 2008: vegetative growth season 131 days, average daily air temperature 15.5°C, rainfall 206.9 mm) coriander produced significantly lower yields, statistically similar in both seasons (1.25 in 2006 and 1.24 t·ha^{-1} in 2008) (tab. 5). Weiss [2002] underlines that low rainfall during the growing season demonstrably inhibits the vegetative growth and reduces yields of coriander. Significant influence of years of field experiments on coriander yields has also been revealed by Carrubba et al. [2006], who proved a highly significant dependence of coriander yields on precipitation during the plant's growth (linear correlation coefficient r = 0.93). When rainfall was deficient during the growing season (200 mm), coriander fruit yields were very low (0.87 t·ha^{-1}). In years with the rainfalls reaching 420 and 505 mm, fruit yields were 1.71 and 2.13 t·ha^{-1}, respectively, which was 97 and 145% higher than in the dry year. Positive effect of rainfall supplemented by irrigation up to 350–450 mm during the growing season on coriander fruit yields has also been demonstrated by Rzekanowski et al. [2008].

Table 5. Fruits yield of coriander (t·ha^{-1})

Sowing date	Year of investigation			Mean*
	2006	2007	2008	
Early	1.39^{b}	1.60^{a}	1.21^{bc}	1.40
7 day delayed	1.08^{d}	1.67^{a}	1.15^{c}	1.30
14 day delayed	1.29^{bc}	1.36^{b}	1.37^{b}	1.34
Mean	1.25^{b}	1.54^{a}	1.24^{b}	–

a-d – homogeneous groups for Duncan's test (0.05 significance level)
* – with the F (Fisher-Snedecor's) test (0.05 significance level)

The three-year averaged results of the present experiment have shown that 7-day intervals between dates of sowing in north-eastern Poland did not differentiate significantly coriander yields (tab. 5). A tendency towards higher yields (1.40 t·ha^{-1}) has only been noticed when the earliest date of sowing was tested. The date of sowing postponed by 7 and 14 days led to a decrease in fruit yields by 7.1 and 4.3%, respectively. However, a significant dependence has been demonstrated between fruit yields and the year of experiments and date of sowing (tab. 4). In 2007, which was most favourable for stimulating the coriander yielding potential, the lowest yields were obtained from plots seeded on the latest date (4 May). Fruit yields from plants sown on the early date and 7 days later (20 and 27 April) were significantly higher and statistically similar. In 2006, the highest fruit yield was obtained from plants sown on the early date (14 April) but in 2008 plants sown on the latest date (19 April) gave the highest fruit yield. All these results related to dates of sowing suggest that an optimum sowing date in north-eastern Poland, considering fruit yields, falls on the second decade of April (tab. 5). Although Weiss (2002) claims that coriander is photoperiodically neutral to the length of daytime, an early sowing date has a better effect on the plant's growth and yield than delayed sowing. The fact that coriander tends to yield lower when sown later has also been implied by other researchers, e.g. Luayza [1996], Carrubba et al. [2006], Zheljazkov et al. [2008], Moosavi et al. [2012]. However, contrary relationships were reported by Ghobadi and Ghobadi [2010] in their experiment conducted in Iran.

Yields of coriander in the subsequent years of the research depended to a different degree on particular yield structure components (tab. 4). Differences in the number of plants per 1 m^2 before harvest were most probably caused by the changeable weather conditions. In 2007, when the fruit yield was the highest, the pre-harvest number of plants was the lowest (130.0 plants·m^{-2}), and the weight of fruits per plant was the highest (2.41 g). In the other two years (2006 and 2008), when respective fruit yields were 18.8 and 19.5% lower than in 2007, the number of plants per m^2 was 22 and 46% higher respectively, but the weight of fruits per plant was significantly lower: by 38% and 48% (tab. 6). Significant differences in the weight of fruits per coriander plant between years have also been demonstrated by Angelini et al. [1997] or Carrubba et al. [2006]. In our experiment, another trait that varied between the years was the 1000-fruit weight (tab. 4), analogously to a study reported by Angelini et al. [1997]. The most robust fruits (10.6 g) were produced by coriander in 2006. Fruits were significantly smaller in 2008 but the smallest ones grew in 2007. The linear correlation coefficient shows that the fruit yield was negatively correlated with the 1000-fruit weight (tab. 7). In 2007, in which statistically the highest yield was harvested, the 1000-fruit weight was statistically the lowest (9.6 g).

Table 6. Components of fruits yield of coriander

	Sowing date	Year of investigation			Mean
		2006	2007	2008	
Plant number per 1 m^2 at harvest time	early	162.1^{bc}	151.3^{c}	186.4^{b}	166.6
	7 day delayed	142.1^{c}	147.9^{c}	203.3^{a}	164.4
	14 day delayed	171.2^{bc}	90.9^{d}	181.7^{b}	147.9
	mean	158.5^{b}	130.0^{c}	190.5^{a}	–
Fruit weight per plant (g)	early	1.78	2.13	1.36	1.76
	7 day delayed	1.36	2.61	1.17	1.71
	14 day delayed	1.35	2.49	1.26	1.65
	mean	1.50^{b}	2.41^{a}	1.26^{b}	–
1000-fruit weight (g)	early	11.1^{a}	9.5^{c}	10.1^{b}	10.2^{a}
	7 day delayed	10.3^{b}	9.3^{c}	10.4^{b}	10.0^{b}
	14 day delayed	10.4^{b}	10.1^{b}	10.4^{b}	10.3^{a}
	mean	10.6^{a}	9.6^{c}	10.3^{b}	–

a–d – homogeneous groups for Duncan's test (0.05 significance level)

The date of sowing did not differentiate number of plants or weight of fruits per plant, and consequently did not vary the yield of coriander per field area unit. The pre-harvest number of plants was significantly dependent on the year of research and date of sowing. Statistically the smallest number of plants (90.9 indiv.·m^{-2}) was produced by coriander in the second year of the experiment (2007) when sown on a date 14 days after the earliest one, which coincided with the smallest yield of fruits. The highest number of plants (203.3 indiv.·m^{-2}) was produced by coriander sown in the third year (2008) on a date 7 days after the earliest one. Also in this combination, the coriander yield was the lowest. The weight of fruits per plant proved to be that yield structure component which was strongly correlated with coriander yields (tab. 7), the fact indicated by a high linear correlation coefficient (r = 0.49). This may explain significant differences in coriander yields between the years of the research.

Table 7. Dependence of coriander yielding on yield components

Variable	Correlation coefficients (r)
Number of plants per 1 m^2 at harvest time	0.070
Fruit weight per plant (g)	0.490
1000-fruit weight (g)	-0.080

The date of sowing significantly differentiated the 1000-fruit weight. The smallest fruits (10.0 g) were produced by coriander sown on a 7-day delayed date. Significantly more robust fruits were grown when coriander had been sown on the earliest and the latest dates and the 1000-fruit weight was statistically similar. This trait was differentiated by the date of sowing also between the years of the experiment (year × sowing date interaction). In 2006, the biggest fruits (11.1 g) were formed by coriander sown on the earliest date, which also generated the highest yield; when sowing was postponed, the 1000-fruit weight was significantly lower. In 2007, the highest 1000-fruit weight was attained by coriander sown on the last date of sowing, but in 2008 the numerical value of this trait, irrespective of the sowing date, was statistically similar (tab. 6). Other authors [Luayza et al. 1996, Carrubba et al. 2006] concluded that early sowing had a more beneficial effect on the size of fruits and therefore ensured higher yields.

The content of essential oil in coriander fruits was different between the years (tab. 8). In 2007, when the average air temperature during the plant growing season was 15.4°C and the rainfall reached 407.1 mm, the coriander fruits contained 1.02% of oil, which was much less than in 2008, when the mean daily temperature was 15.5^{o}C and the rainfall equaled 206.9 mm, but the content of oil in coriander fruits was 1.36%. The literature indicates that the content of essential oil in coriander fruits depends the plant's botanic form, cultivar, location of a plantation and agronomic and technical conditions. In a study reported by Stoyanova et al. [2002], coriander fruits were found to contain 0.8–1.8% of oil, but other authors determined it at 1.32–1.44% [Kucharski and Mordalski 2008], 0.65–2.20% [Zheljazkov et al. 2008] 0.14–0.21% [Telci et al., 2006] or 0.14–0.50% [Moosavi et al. 2012]. Among the factors which modify the content of essential oil in coriander fruits is the weather during the plants' growing season [Misharina 2001, Telci et al. 2006, Carrubba et al. 2009] This is also confirmed by an experiment conducted by Zawiślak [2011] in Poland, where the concentration of oil in coriander fruits was distinctly different in two consecutive years (1.87% in 2007 and 2.33% in 2006).

Table 8. Essential oil content (%) in fruits of coriander

Sowing date	Year of investigation		Mean
	2007	2008	
Early	0.98	1.31	1.15
14 day delayed	1.05	1.42	1.24
Mean	1.02	1.36	–

The date of sowing in our experiment, similarly to the trials reported by Ghobadi and Ghobadi [2012] as well as Moosavi et al. [2012], did not induce substantial differences in the content of oil in coriander fruits (tab. 8). Coriander fruits originating from the earlier date of sowing contained slightly less oil than the ones produced by plants sown 2 weeks later. In a study completed under the climatic conditions of Canada, Zheljazkov et al. [2008] showed an opposite response of coriander to the sowing date than observed in the present experiment. In Canada, fruits from an early date of sowing, irrespective of the location of a plantation or a cultivar tested, contained more coriander oil than fruits harvested from plants sown two weeks later.

The composition of coriander oil, in which a profile of over 20 chemical compounds was determined, was dominated by linalool (tab. 9). This is the major constituent of essential oil in coriander fruits, responsible for their typical aroma [Carrubba et al. 2006]. The references emphasize that the content of essential oil and linalool in fruits defines potential usage of coriander fruits as raw herbal material [Diederichsen 1996, Carrubba et al. 2006]. In the present experiment, the concentration of linalool was 67.1% in 2007 and 65.3% in 2008. Many authors report similar percentages of linalool in coriander essential oil. For example, Zawiślak [2011] determined the concentration of linalool in coriander oil at 69.9 and 72.5% from plants harvested in Poland in two seasons. Coriander fruits grown in Sicily and tested by Carrubba et al. [2009] were found to have from 64.6 to 71.6% of this constituent in essential oil. In Turkey, the percentage determined by Telci et al. [2006] ranged from 33.7 to 70.8%, while in Canada the results obtained by Zheljazkov et al. [2008] revealed from 64.0 to 84.6% of linalool in coriander essential oil. Other dominant constituents of coriander essential oil, apart from linalool, were α-pinene, γ-terpinene, camphor, cymene and limonene, although these compounds occurred in much smaller quantities, each forming less than 10% of the total oil composition (tab. 9). Other researchers [Diederichsen 1996, Misharina 2001, Stoyanova et al. 2002, Kocourkova et al. 2005, Zheljazkov et al. 2008, Carrubba et al. 2009, Zawiślak 2011] mention the same compounds as predominant constituents, apart from linalool, in coriander oil. Carrubba et al. [2009] showed that years of the experiment do not generate significant differences in the content of the major constituents of coriander essential oil.

The sowing date did not differentiate the chemical profile of coriander oil (tab. 9). Lack of distinct differences in the chemical composition of coriander oil or else modifications of just single constituents of oil in response to the date of sowing have also been verified by other authors. In their experiment conducted under arid climatic conditions

Table 9. Participation of main identified coriander essential oil compounds (mean for 2 years)

Chemical compounds	2007			2008			Mean for sowing date (%)		Mean
	retention index	percentage(%) sowing date		retention index	percentage(%) sowing date				
		early	14 day delayed		early	14 day delayed	early	14 day delayed	
Pentanol	(–)	tr	tr	–	–	–	–	–	tr
Tricyclene	–	–	–	1002	tr	tr	tr	tr	tr
Hexane 2,2,4-trimethyl	(–)	0.14	0.11	–	–	–	0.07	0.05	0.06
α-thujene	928	0.10	0.07	1005	0.13	tr	0.11	tr	0.05
α-pinene	936	9.28	9.36	1011	7.18	7.60	8.23	8.48	8.35
Camphene	954	1.15	1.07	1026	1.29	1.35	1.22	1.21	1.21
Sabinene	976	0.48	0.45	1046	0.40	0.42	0.44	0.43	0.43
β-pinene	983	0.69	0.58	1051	0.48	0.46	0.58	0.52	0.55
Myrcene	991	0.82	0.68	1060	0.65	0.84	0.73	0.76	0.74
ρ-cymen	1029	3.50	3.40	1094	3.86	3.48	3.68	3.44	3.56
Limonene	1033	2.80	2.86	1098	3.09	3.26	2.94	3.06	3.00
γ-terpinene	1062	7.13	7.12	1123	6.26	7.25	6.69	7.18	6.93
trans-linalol oxide	1076	0.15	0.12	1134	0.28	0.21	0.21	0.16	0.18
Terpinolene	1090	0.74	0.56	1146	0.42	0.58	0.58	0.57	0.57
cis-linalool oxide	–	–	–	1147	tr	0.09	tr	tr	tr
Linalool	1103	67.23	67.19	1159	66.95	63.49	67.09	65.34	66.21
Camphor	1157	4.69	4.63	1202	5.73	5.98	5.21	5.30	5.25
Borneol	1182	0.07	0.08	1223	tr	0.09	tr	0.08	tr
Terpinen-4-ol	1189	0.11	0.12	1224	0.09	0.23	0.10	0.17	0.13
α-terpineol	1205	0.18	0.21	1244	0.11	–	0.14	0.10	0.12
Nerol	1258	0.20	0.30	1284	0.76	1.52	0.48	0.91	0.69
Myrtenyl acetate	–	–	–	1342	0.33	0.07	0.16	tr	0.08
Neryl acetate	1381	0.33	0.75	1382	1.79	1.67	1.06	1.21	1.13
E-caryophyllene	1426	0.11	0.12	1417	0.06	0.86	0.08	0.49	0.28
Tridecene-1-al	–	–	–	1606	tr	0.07	tr	tr	tr
Total	–	99.90	99.78	–	99.86	99.52	99.80	99.46	99.52

tr – trace (<0.05%)
(–) – values were not calculated

of Sicily, Carrubba et al. [2009] did not show that the date of sowing had much influence on the content of major chemical compounds in coriander oil, and significant changes were only observed in the case of α-pinene. Zheljazkov et al. [2008] showed that a delayed date of sowing depressed the content of linalool and camphor in coriander oil.

CONCLUSIONS

1. The thermal and moisture conditions during the years when the trials were conducted had a major effect on coriander fruit yield and yield components. The weather conditions during the growing season in 2007 were most favourable to the growth and development of coriander, which produced the highest yield (1.54 $t \cdot ha^{-1}$) in that season.

2. The date of sowing did not differentiate yields of coriander. However, yields of coriander were determined by interaction of sowing date with years of research. In the climatic conditions prevalent in north-eastern Poland, the date of sowing falling on the second decade of April proved to be optimal with respect to the yields obtained (1.40 $t \cdot ha^{-1}$). Any delay in sowing led to depressed yields.

3. Yields of coriander were positively correlated with the weight of fruit per plant.

4. The content of essential oil in coriander fruit was distinctly different between the years. When the sowing date was postponed, the content of essential oil in coriander fruits increased only very slightly. The major constituent of coriander oil was linalool, which made up 65–67% of its total chemical composition. Years of the research rather than date of sowing differentiated the composition of coriander essential oil.

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WPŁYW TERMINU SIEWU NA PLON I JAKOŚĆ OWOCÓW KOLENDRY SIEWNEJ (*Coriandrum sativum* L.)

Streszczenie. Kolendra siewna (*Coriandrum sativum* L.) jest znaną na całym świecie rośliną zielarską. Plon owoców kolendry podlega wpływom warunków pogodowych oraz czynników agronomicznych i genetycznych. W pracy przedstawiono wpływ lat badań i terminu siewu oraz ich interakcji na plonowanie i cechy plonu oraz zawartość i profil chemiczny olejku eterycznego w owocach kolendry siewnej. Wykazano, że warunki termiczno-wilgotnościowe w latach badań determinowały plon owoców kolendry i jego elementy składowe. Najbardziej korzystne dla jej wzrostu i rozwoju były warunki pogodowe w 2007 r., w którym uzyskano największy plon owoców (1,54 $t \cdot ha^{-1}$). Termin siewu nie różnicował plonowania kolendry siewnej. W plonowaniu wykazano jednak interakcję terminu siewu z latami badań. W warunkach północno-wschodniej Polski termin siewu przypadający na II dekadę kwietnia był optymalny pod względem plonowania kolendry (1,40 $t \cdot ha^{-1}$). Opóźnianie terminu siewu powodowało tendencję spadku plonu. Plonowanie kolendry było dodatnio skorelowane z masą owoców z rośliny. Zawartość olejku eterycznego w owocach kolendry wyraźnie różnicowały lata badań. Opóźnianie terminu siewu nieznacznie zwiększało zawartość olejku w owocach. Głównym komponentem olejku kolendrowego był linalol stanowiący 65–67% jego składu chemicznego. Lata badań bardziej niż termin siewu różnicowały skład olejku kolendrowego.

Słowa kluczowe: rośliny lecznicze, *Coriandri fructus*, cechy plonu, olejek eteryczny, linalol

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