Corvinus University of Budapest
Faculty of Horticultural Sciences

OPTIMIZATION OF CONDITIONS OF GROWING TECHNOLOGY OF ANNUAL CARAWAY (*CARUM CARVI L. VAR. ANNUUM*) ON CHERNOZEM MEADOW SOIL

Ph.D. Thesis Booklet

NOÉMI JÚLIA VALKOVSZKI

Supervisor:

Prof.Dr. Éva Zámbori Németh
Full professor DSc

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Leader:	Prof. Dr. Magdolna Tóth Full professor, DSc Corvinus University of Budapest Faculty of Horticultural Science Department of Pomology
Supervisor:	Prof. Dr. Éva Zámbori Németh Full professor, DSc Corvinus University of Budapest Faculty of Horticultural Science Department of Medicinal and Aromatic Plants

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Prof. Dr. Magdolna Tóth	Prof. Dr. Éva Zámbori Németh
Leader of Doctoral School	Supervisor

Background and aims of research

In Hungary the area utilized for growing of herbs has fluctuated in the recent years. In 2010 the area utilized for growing of herbs was about 20 thousand hectares. The mustard, poppy-seed, sweet fennel, coriander and caraway are still the most significant herbs produced in the farms.

The most successful period of Hungarian production of annual caraway was the middle of 1990s. During these years the sowing area of the annual caraway was much bigger than that of the biennial variety. The success story of *Carum carvi var. annuum* has nearly ended by the turn of the 21st century. The Hungarian growers were disappointed in the annual caraway. However, it was easier to insert it into the crop rotation than the biennial caraway, neither its crop safety, nor its quality reached the expected level. The chances of growers have been decreased further by the world market competition and the low purchase prices.
The cultivation area of annual caraway has decreased from five thousand hectares to about 100 hectares by 2006.

The efficiency of production is decreased further by the fact that the exact nutrient demand of annual caraway is not known among the Hungarian growers, thus the frequent and imperfect application of fertilizer, and especially that of the nitrogen load the environment. The effect of macro-elements on the yield and quality of annual caraway have not been clarified either.

In the future the maintenance, or preferably the increase of sowing area might be realized only by the improvement of profitability (the crop yield should be 1.5-2 t/ha). At present it is possible by two ways: partly by the yield increase of varieties improving the genetic bases, and partly by strict maintenance of varieties. However, besides the increase of crop yield, the issues of environment protection and sustainability should also be taken into consideration.

The aim of my research was the optimization of conditions of production technology of annual caraway (*Carum carvi var. annuum)* on chernozem meadow soil in the South Great Plain.

Taking into account the Hungarian technology of large scale caraway production the influence of row space and fertilizer treatment was studied. The main questions of my study were the following:

1. Which properties of the plant are influenced by the row space?
2. How can the quantity and quality of crop optimized by nutrient supply (with special respect to the N and K demand?
3. To what extent does the influence of these factors depend on the weather conditions of the given years?
4. What is the connection like among the examined properties of plants?

The aim of my study was to facilitate the efficiency of annual caraway production in Hungary as well as to add some more data to the technical literature on annual caraway.

Materials and methods

The observations were carried out at the Model Farm of Horticulture Discipline of Environment Management Institute of Faculty of Water and Environmental Management of Szent István University in Galambos, Szarvas in 2006-2008.

The experiment was carried out on chernozem meadow soil, every year in another plot. The soil of the farm is rich in humus (2.86-3.00%), slightly acidic (pH 5.24-6.52) and medium hard (K_A: 41-42). The salt content was low (0.02-0.05%). In 2006 the mineral NO_3-N content in the cultivated soil layer (30 cm) was 11.43 kg/ha, in 2007 36.50 kg/ha and in 2008 46.40 kg/ha calculated with the method of potassium-chloride extraction. During the experimental period the P_2O_5-content was 405-226 mg/kg, which demonstrates the high P_2O_5 supply of soil. The K_2O content of the plots was 280-216 mg/kg, which can be evaluated as very good and good supply respectively.

The studies were carried out in one dry and in two wet years. Compared to the 50-year-long data series of precipitation (KAKAS, 1957) the average temperature of growing seasons of the experimental period was higher; the accumulated quality of radiation was lower, while the number of days with temperature over 30^o C was also higher. The precipitation during the growing season was lower than the 50 years average only in 2007. The plots were not irrigated during the years of the experiment.

The annual caraway involved in the observations was the Hungarian registered variety "SZK-1". It is a registered variety owned by the Department of Medicinal Plants of University of Horticulture and the Szilasmenti Agricultural Cooperative Farm. The variety has an outstanding essential oil content of 2-2.8%, does not seed even if it is completely ripe, and is resistant to any pathogens (FÜSTÖS et. al. 2002). Unfortunately the variety has been deleted from the National List of Registered Varieties because of high costs of variety maintenance.

The studies were carried out in small plot crop field experiments in 2006–2008, in two different treatments, first in strips, then in split plots, in three repetitions with plot size of 6 m^2 each.

The row spaces in treatment 'A' were the following:

a_1= 24 cm (8 rows/plot, 140 plants/ m^2)
a_2= 24 cm (5 rows/plot, 92 plants/ m^2)
a_3= 48 cm (4 rows/plot, 70 plants/ m^2)

As at the beginning of the experiment, in 2006 no specific nutrient requirement results were owned, in the calculations of nutrient requirement SCHRÖDER's (1972) and HORNOK's (1978) data were used.

The nutrient supplies in treatment 'B' were the following:

b_1= control plot without any nutrient supply
b_2= basic nutrient supply: 0 kg ha-1 N + 80 kg H-1 K + foliar fertilizer: 0 kg ha^{-1} N (hereinafter: N_0K_{80})
b_3= basic nutrient supply: 80 kg ha-1 N + 0 kg H-1 K + foliar fertilizer: 0 kg ha^{-1} N (hereinafter: $N_{80}K_0$)
b_4= basic nutrient supply: 80 kg ha-1 N + 80 kg H-1 K + foliar fertilizer: 0 kg ha^{-1} N (hereinafter: $N_{80}K_{80}$)
b_5= basic nutrient supply: 80 kg ha-1 N + 0 kg H-1 K + foliar fertilizer: 70 kg ha^{-1} N (hereinafter: $N_{80}+_{70}K_{80}$)
b_6= basic nutrient supply: 80 kg ha-1 N + 80 kg H-1 K + foliar fertilizer: 70 kg ha^{-1} N (hereinafter: $N_{80}+_{70}K_{80}$)

As a basic nutrient supply the N supply was applied in the form of calcium-nitrate (15.5% N), while the K was applied in the form of potassium-sulphate (50% K) before the sowing. The N foliar application of fertilizer was carried out with water soluble fertilizer

containing 26% N (which contained only ammonium-nitrate) at the beginning of blooming (with the help of students). Using 10 l of water a solution of 1.6% concentration was applied. The control plots were sprayed only with water (10 l/6 m^2).

The observations and studies covered the efficacy of nutrient supply treatments to the morphological features of plant stand (plant height, number of umbels per plant), the elements influencing the crop yield (thousand seed mass, yield per plant, yield/m^2) and the quality determining factors (essential oil content, composition of essential oil, germinating power).

The quantitative determination of essential oil content was carried out in the Laboratory of Department of Medicinal and Aromatic Plants, Faculty of Horticultural Science, Corvinus University of Budapest based on the Hungarian Pharmacopeia No.8 by applying water distillation in three replications. The main components of essential oils were determined by the method of gas chromatography. One sample of each nutrient supplementation treatment of every row space could be analysed. The identification of components was carried out on the basis of mass spectrum (NIST spectrum library) and retention indexes.

Before the statistical analyses normality and homogeneity examinations were carried out. As a consequence of low number of repetitions it was impossible to apply linear models. The evaluation of basic data was carried out by a two factorial variance analysis in the Microsoft Excel program. The correlations between the different plant features and the relationships among the row space, the nitrogen and potassium fertilizers and the studied plant features were analysed by the Spearman correlation using the IBM SPSS19 version. For detection of influences of row space, nutrient supply treatment and the given year all the result of the whole experimental period were analysed by discriminance and two-step cluster analyses.

Results

Influences of row space

Height of plants

In 2006 the influence of row space on the height of plants could not be verified as an average of nutrient supply treatments. In 2007 the row space slightly increased the plant height, but statistical difference could not be identified. In 2008 statistically supported difference could not be verified between the different row space plots and the plant height.

Number of umbels per plant

In 2006 significant, statistically proved difference was found among the row spaces. The most umbels were found on the plants collected from the 48 cm row space. In 2007 there was no verifiable difference between the two variables of row space taking the average of nutrient supply, but as a tendency it could be observed that the most umbels grew on the plants in the plots with 48 cm row space. In 2008 the biggest number of umbels was found on the plots with the widest row space, however, the significant difference was not found.

Thousand seed mass

In 2006 the bigger was the row space the lower was the thousand seed mass. It might have been connected to the bigger number of umbels, but the differences were not verifiable statistically. In the growing season of 2007 the average thousand seed mass did not reach the 2.5-3 g characteristic to the variety (FÜSTÖS, 2002), its average was only 2.2 g. There was only a very slight difference between the treatments: the differences were not verifiable statistically. The low values might be explained by the drought. In 2008 the growing of

umbels was favourable, and the influence of the treatments showed statistically verifiable differences in the plots of 48 cm row space.

Crop yield per plant

In 2006 the bigger cultivation surface had a positive effect on the crop yield of plants. The average mass of yield has increased proportionally to the increase of row space. In the year of 2007 there is a significant difference between the smallest and the biggest row space. The yields are slightly lower compared to the previous year, which is probably the result of the low precipitation in the growing season. However, the influence of row space as a treatment was similar to that of the previous year. There are significant differences among the three different variations. The highest individual yield was found in the plots of 48 cm row space. In 2008 there was also significant difference among the three different row spaces. The maximum values were reached at the widest row space.

Crop yield per unit surface

In 2006 the achene yield was not influenced by the row spaces taking the average of nutrient supply treatments. As a tendency the highest achene yield was found in the plots with smaller and medium row spaces – in average in the plots with 36 cm row space. In 2007 there were statistically certified differences between the influence of 24 cm and 48 cm row spaces, as treatments. During the growing season of the year 2008 there were statistically certified differences between the yields of the smallest and the biggest row spaces. The highest yield was reached at 24 cm row space. The amount of yield – as an absolute value - was 2-3 times higher than that of the previous year. Probably it can be explained by the precipitation, as there was 310 mm rainfall in 2008, which was 11.2% higher than that of 2006 and 44.2% higher than that of 2007.

Essential oil content

In 2006 there were no significant differences in the essential oil content of seeds between the different row spaces at average nutrient supply. These values can be considered average essential-oil values (2-2.8%) characteristic to the given variety (BERNÁTH and ZÁMBORINÉ-NÉMETH, 2010). In 2007 there were statistical differences between the essential-oil content of achenes harvested from the row space of 24 cm and the row spaces of 36 cm and 48 cm respectively. The essential oil content of achenes harvested from the plots with 24 cm row space was 6.68% higher than that of achenes harvested from the plots with 48 cm row space. The essential oil content of achenes decreased when the row space was increased. In 2008 there was no statistically verifiable difference between the row spaces at the average of nutrient supply treatments.

Essential oil composition

In 2006 the effect of row space on the main component of annual caraway, the d-carvon could not be statistically certified, but considering the average values the ratio of d-carvon decreased if the row space was increased. In 2007 in the analyses of d-carvon content of essential oil, the differences among the row space treatments were found very low at the averages of nutrient supply; practically they were 48-49% in the three variations. The individual minimum was 45%; the maximum was 51%, which is the characteristic interval for the variety (ZÁMBORINÉ- NÉMETH, 2002). In 2008, similarly to the previous year, practically identical values were found in all the experimental samples. The difference does not reach the half per cent. The d-carvon content of the seed oil is slightly lower than the values characteristic to the variety. Even the highest accumulation level was under 50%.

Germinating power

In average the 69.6% of seeds from the 2006 harvest germinated by the 21st day. This value is nearly identical with the standard of the FVM Decree 50/2004 (22.04). From among the row space treatments the seeds from the widest row space plots had significantly better germination than the seeds originating from plots of narrower row spaces. The significant effect of row space could not be detected in 2007. The tendency was identical with that of the previous year i.e. the germination power of plants grown in bigger row space plots was slightly higher. The averages did not reach the 70% specified in the mentioned decree. In 2008 no statistical difference was found in the germination power of the seeds as a function of row space. The values are low, the tendencies of data series are contrary to the previous years, and the dispersion of values is rather big (minimum 54.7%, maximum 74.7%).

Effects of nutrient supply treatment

Height of plants

In 2006 significant difference was found in the plots with 36 cm row space. Besides identical supply of nitrogen the supplementary application of K had a height decreasing effect up to 80 kg nitrogen affective agent/ha, but in case of 80+70 kg nitrogen affective agent the applied potassium resulted in the increase of plant height. In 2007 all the nutrient supply treatments resulted in height increase compared to the control plots. Significant difference was measured between the control and the $N_{80}K_0$, as well as the control and the $N_{80}K_{80}$ treatments. In 2008 the tendency of the data is controversy to those of the previous year. The plant height was decreased by each nutrient supply, but the differences were not significant.

Number of umbels per plant

In the year of 2006 significant differences could be detected in several cases among the different treatments. The significantly lowest number of umbels was found in the N_0K_{80} treatment. Basically the nutrient supplementation had a stimulating effect on the number of umbels, but at identical nitrogen level the elevation of potassium doses had a negative effect. In 2007 significant difference was found only between two variables of nutrient supply, i.e. the $N_{80}K_0$ treatment and the control, where the better result was shown in the plots with the nutrient supply treatment. The potassium, similarly to the results of the previous year, had a decreasing effect of the number of umbels mostly in the treatments with identical N supplementation. This was especially characteristic for the widest row spaces. In 2008 each dose of nutrient supply decreased the number of umbels per plant compared to the control plot. In case of the highest doses the number of umbels was significantly lower, and only about one third of umbels developed on the plants.

Thousand-seed mass

In 2006 besides identical nitrogen supply the applied potassium decreased the mass of crop, however, statistical differences could not be certified between the nutrient supplementation levels. In 2007 the mass of crop of annual caraway was very low because of the drought, and statistically certified difference could not be detected. In 2008 significant differences were found in two treatments: the highest thousand-seed mass was found at the $N_{80}K_{80}$ treatment (3.53 g) , while the increasing nitrogen doses resulted in decreasing of the mass as an average of the row spaces.

Crop yield per plant

In 2006 the nutrient supply did not show significant changes in the individual crop yield of plants taking into account the average of the row space treatments. The K application

has shown a decreasing tendency in crop yield. The highest crop yield per plant was found at the $N_{80}K_0$ treatment. At bigger row spaces the plants did not show any reaction to the elevated amount of N supply. In 2007 each treatment decreased the crop yield compared to the control plots. Besides identical N doses the extra application of K was disadvantageous, except for the plots treated with the highest nutrient supply and top-dressing as well. In the experimental year of 2008 the best result was found at the $N_{80+70}K_0$ treatment. Similarly to the previous years the extra K application at identical N doses was disadvantageous to the individual crop yield.

Crop yield per unit surface

In 2006 there was a statistically certified difference between the treatments N_0K_{80} and $N_{80}K_{80}$ as well as $N_{80}K_0$ and $N_{80}K_{80}$ respectively. In 2007 significant difference (SD5%) was found in several cases in the different combinations. In the smallest row space plots the nutrient supply had a more serious negative effect than in the bigger row space plots. The yield decreasing effect of potassium was not distinct. In 2007 the maximum crop yield per unit surface was found in the plots with 48 cm row space and the $N_{80+70}K_{80}$ treatment (45.8 g/ m^2), although the control showed only slightly lower (41.7 g/ m^2) result. In 2008 the highest crop yields were found in the plots of the highest nutrient supplementation. The K affective agent had an expressed crop increasing effect i.e. this year the supplementation of K resulted in positive effect, however, the potassium content of the plots was high. The crop yield was extremely increased at K supplementation at higher N levels and lower row spaces.

Essential oil content

In the year of 2006 in the plots treated with N there was a decrease in the essential oil content in each case as a result of nutrient supply treatments. Besides an identical N level, the application of K affective agent resulted in increase of essential oil content in each case. The highest essential oil content of seeds was registered at N_0K_{80} treatment at the average of row spaces (2.62%) as well as at every row space individually. In 2008 at identical K_{80} application the negative effect of the higher N dose of the previous year could also be detected, especially on the plots treated with the highest doses and top dressing in 2007. However, the stimulating effect of K on the accumulation of essential oil was lower this year. In 2008 the highest accumulation of essential oil was found in the control plots at the average of row spaces. The essential oil decreasing effect of extra nitrogen supplementation could be statistically certified. The effect of increasing the essential oil content of K was also identified, however, only at the highest N level; but at this level it occurred at each row space.

Essential oil composition

In 2006 the applied K affective agent clearly increased the d-carvon content. Its influence became higher and higher parallel to the increase of the nitrogen doses. At the average of row spaces the highest carvon level was reached at the $N_{80+70}K_{80}$ treatment (66%). Taking into account the row space it was experienced that the effect was the highest on the plots with 24 cm row space. The higher than 60 % internal content values are practically equal to the level of more valuable biennial variety (ZÁMBORINÉ- NÉMETH, 2005).

However, in 2007 the ratio of d-carvon component was under 50% on each plot. The differences between the treatments were lower, which might be caused by the very low precipitation - as it was mentioned in case of row spaces as well. This is confirmed by LARIBI et al. (2009) who claim that the decreasing water supply results in lower d-carvon content. In this vegetative season the favourable influence of potassium was detected at the weaker nitrogen supply N80, and the maximum value was reached at the $N_{80}K_{80}$ treatment (49.2%).

In 2008 the favourable effect of potassium was detected in several combinations at relatively low potassium values which were similar to those of the previous year. The application of N higher than this value influenced the d-carvon content adversely.

Germinating power

In 2006, the first year of the experiments, the best germination power was detected at the treatments $N_{80}K_0$ and $N_{80}K_{80}$. The stimulating effect of nutrient supplementation occurred mainly at the wider row spaces. In 2007 at the average of row spaces statistically certified difference was not found at any of the nutrient treatments either. In 2008 the interrelationship of the two factors was statistically certified. At the widest row space the difference caused by the nutrient supply treatment is the strongest. The best germination power seeds were found in the untreated control plots (66.9%), and the K application without N had an especially negative effect.

Correlation relationships

Correlation relationships between the row spaces and the observed plant features

In our experiments the row space showed the closest correlation with the crop yield of individual plants. In the rainy years the correlation is stronger (in 2006: r = 0.95; in 2008: r = 0.69), while during the total experimental period the correlation decreased slightly (r = 0.54), but it was still significant. In the course of the experimental period the highest individual crop yield was detected on the plots with 48 cm row space, while the highest average yield was found on the plots with 36 cm row space. These values were certified by discriminance and cluster analyses.

Correlation relationships between the nutrient supply doses and the observed parameters of plants

In case of *nitrogen* the correlation analyses were carried out with the results of control-$N_{80}K_0$-$N_{80+70}K_0$ treatments i.e. the relationship with the increasing nitrogen doses was analysed. Based on the analyses it was found that the applied nitrogen supply had been in negative correlation with the essential-oil content of achenes during the experimental period. It could be certified in the two rainy years of the three-year-long experimental period (2006: r = -0.57 and 2008: r = -0.58) and at the average of the years as well.

In case of potassium supply three different variations were taken into consideration for the correlation analyses of increasing K doses, namely the control-N_0K_{80}, $N_{80}K_0$-$N_{80+70}K_{80}$ and $N_{80+70}K_0$ -$N_{80+70}K_{80}$ treatments respectively. According to these analyses the positive influence of potassium on the d-carvon content was manifested in the rainy years of 2006 (r = 0.68) and 2008 (r = 0.49) in the treatment pairs of $N_{80}K_0$ and $N_{80}K_{80}$ (at the same time the limonene content was negatively influenced).

The effect of nutrient supplies was the most expressed in the case of thousand-seed mass and the essential-oil content. This was certified both by discriminance and by cluster analyses. The lowest essential-oil content during the experiment was detected in the treatment $N_{80+70}K_{80}$, while the highest one was found in the control and the N_0K_{80} treatments.

The influence of annual weather on the results

The differences of the annual weather appeared mostly in the plant height and the number of umbels. The highest plants with the lowest number of umbels were found in 2006 when the weather was fairly cool, cloudy and rainy.

Correlation relationships between the studied parameters of plants

The correlation relationships between the parameters of plants were seriously influenced by the weather of the given year. Taking the average of the rainy years, strong positive correlation was detected between the crop yield per unit surface and the d-carvon content ($r = 0.69$). There was a weaker, but positive correlation between the plant height and the essential-oil content ($r = 0.65$), as well as between the crop yield per plant and the d-limonene content ($r = 0.64$). There is a strong negative correlation between the d-carvon and d-limonene ($r = -0.94$), however, there is a weaker, but inverse correlation between the number of umbels per plant and the d-limonene content as well as between the number of umbels per plant and the crop yield per unit surface. Similar negative correlation was found between the d-limonene content, the number of umbels per plant and the d-carvon content as well as between the plant height and the number of umbels per plant respectively. The positive correlation between the crop yield and the d-carvon content might be important for the agricultural practise.

New scientific results

The plant height, the number of umbels per plant, the thousand-seed mass, the essential-oil content and the d-carvon content were proven not to be influenced significantly every year in the plots of 24 and 48 cm row spaces. All the experimental variations offered adequate conditions for the growth of plants, and the competition among the plant individuals was not strong.

It was demonstrated that the uniformity of annual caraway stands became more expressed by the decrease of row space concerning the number of umbels, crop yield and essential-oil content. At the same time the height and the thousand seeds mass proved to be more homogenous at bigger row spaces.

Based on the collected data the bigger row space (between 24 and 48 cm) ensures higher individual crop yield. However, the mass of crop per unit of growing surface did not improve significantly at bigger row spaces, thus basically the mass of crop is determined not by the row space, but by the plant stand density per unit surface.

Based on the results the row spaces between 24 and 48 cm seem to be adequate for the successful production of the annual caraway on chernozem meadow soil.

It was also found that the nutrient supplementation (in doses of 80+70 kg/ha) on the soil of 10 mg/kg AL-NO_3-N content (at 2.6–3.0%humus content) results in height increase or running-up of plants compared to the lower amount of nutrient supply.

The results of the three-year-long studies clearly show that in case of good potassium supply of soil the generative features of the plant can not be improved by further application of potassium. As a symptom of excessive use of potassium the number of umbels decreased, especially on the plots where top dressing had also been applied.

If the potassium supply of soil was adequate, the supplementation of 80 kg/ha doses influenced the thousand-seed mass and the individual crop negatively as a result of exchange of the nitrogen/potassium ratio.

The results of experiments demonstrate that the supplementation of 80 kg/ha and the 80+70 kg/ha nitrogen decreases the mass of crop. The crop size characterized with the thousand-seed mass is sensitive both to the amount of nitrogen and to the amount of potassium.

The essential-oil content and the essential oil composition proved to be influenceable by the regulation of macro-nutrient supply. The high nitrogen level influenced the essential-oil accumulation of seeds negatively, but the high potassium supply stimulated it. The potassium supplementation was favourable for the carvon content of achenes as well. However, the optimum potassium dose depends both on the potassium serving ability of the soil and the nitrogen/potassium ratio.

The result of the experiments demonstrate that the interrelationship of row space and nutrient supplementation (nitrogen and potassium) is very important from point of view of individual crop and the crop per unit surface as well as the germinating power of plants. In the densest plant stand the nitrogen supplementation had a positive effect, however, at a higher nitrogen level the adequate amount of potassium is also needed (80 kg/ha). In the plant stands with bigger row spaces the adequate nutrient supplementation improves the germination power.

Correlation, discriminance and cluster analyses were used to demonstrate that the row space influences mostly the individual and unit surface crops, while the influence of nutrient supplementation (N-supplementation) occurs mainly in the change of essential-oil content and thousand-seed mass.

It was certified that the weather of the given year (mostly the precipitation) influences the results of nutrient supplementation on a high scale on chernozem meadow soil as well.

This could be detected nearly in all plant parameters, but especially in the plant height and the number of umbels per plant.

This is the first time in Hungary that the correlation relationships among eight parameters of annual caraway (plant height, number of umbels per plant, thousand-seed mass, individual crop, crop per unit surface, essential-oil content, d-carvon content and germination power) have been described. It is important for the large-scale cultivation that the individual crop is determined mostly by the individual number of umbels (r = 0.68), while the thousand-seed mass has got a lower role in it (r = 0.24). However, the too big number of umbels per plant might be disadvantageous for the accumulation of essential-oil (r = 0.55), and on its d-carvon ratio (r = - 0.40).

In case of annual caraway it was detected that the crop per unit surface and the d-carvon content were in positive relationship both at the average of rainy years and at the average of the total experimental period.

Conclusions and recommendations

The annual caraway can be successfully grown at the row spaces of 24-48 cm. In the practice the actual row space within the row space interval might be adjusted to the sowing machine, method of growing (traditional, integrated or ecological farming), width of tilling machines (hoe, cultivator, rotary cultivator), relief conditions, soil hardiness and other organizational features.

On those chernozem meadow soils where the estimated nitrogen content of the soil is higher than 40 kg/ha it is not worth applying further 70 kg/ha nitrogen affective agent in top-dressing over the 80 kg/ha basic nitrogen supplementation, as in the rainy years the laying of crop may happen. If it occurs the harvesting by combine harvester is made very difficult, and may cause loss of harvest.

On good nutrient supply chernozem meadow soils the above mentioned nutrient supplementation (150 kg/ha nitrogen affective agent) may cause the serious decrease of crop yield and essential-oil content.

In case of wider row spaces the supplementation of 80 kg of nitrogen and potassium per hectare results in excellent quality seeds (higher than 70% germination power) if the soil contains the needed amount of potassium, and its AL-NO_3-N content is between 2.93-9.36 mg/kg. Consequently in the Hungarian annual caraway cultivation the introduction of slightly different agrotechnical processes would be suggested in the seed production and the commercial production.

Based on the correlation relationships found in the weather conditions it is very useful to irrigate at least once on the growing areas of annual caraway in the middle of June with 40 mm irrigation water, if there has not been at least 300 mm precipitation since the time of sowing till the middle of June. The irrigation would help to avoid the high fluctuation of crop yield and would assist the incorporation of nutrients.

The prerequisite of optimalization of production technology is the detailed knowledge of specific nutrient demand of annual caraway. The future successful and environment-conscious production might be supported mainly by the continuation of experiments of production technology.

Publications directly connected to the Thesis

Proofreading of articles
Article with Impact Factor

1. Valkovszki N. J.- Zámboriné Németh É. (2010): Effects of growing conditions on content and composition of essential oil of annual caraway (Carum carvi L. var. annua) Acta Alimentaria 40. (2) p. 235-246.

Articles without Impact Factor

1. Valkovszki N. J.- Zámboriné Németh É.- Sárosi Sz. (2007): A tápanyag-utánpótlás és a sortávolság optimalizálása az egyéves konyhakömény termesztésében. Debreceni Egyetem Agrártudományi Közlemények 2007/ 27. p. 135-138.

2. Valkovszki N. (2006): Az intenzív konyhakömény (Carum carvi L. var. annua) termesztés biológiai és technológiai feltételeinek optimatizálása. Tessedik Tudományos Közlemények. 2006. HU ISSN 1587-6179 p. 57-69

Proceedings of conferences (in Hungarian, complete)

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