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MATHEMATICAL EVALUATION OF TECHNOLOGICAL APPROACHES FOR CORIANDER PRODUCTION

Velika KUNEVA[1], Vanya DELIBALTOVA[1], Svetlana MANHART[1], Manol DALLEV[1], Ivan MITKOV[1], Dimitar RAZPOPOV[1], Galya HRISTOVA[2]

[1]Agriculture University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria
[2]Trakia University, Stud. Grad., Stara Zagora, Bulgaria

Corresponding author email: manol_dallev@abv.bg

Abstract

Recently, the cultivation of essential oil and aromatic crops is becoming more and more popular. A typical representative of such a culture is coriander. The article presents real data from the coriander production process, using two different technological approaches. By using a mathematical, dispersion analysis and T-test, the technology is evaluated. The obtained results are adequate and easy to interpret, they reflect the entire process, but they are valid only under the specific conditions. However, it can be clearly emphasized that sowing term affects yield when cultivate coriander.

Key words*: coriander, technology for production, sowing term, dispersion analysis.*

INTRODUCTION

Coriander is one of the main essential oil crops cultivated in Bulgaria. They are mainly used for fruits (seeds) with an annual production of about 20,000 t, which are mainly exported to Sri Lanka, Indonesia, Singapore, Malaysia and Great Britain. Under the current market conditions, one of the main ways to increase yield and improve the quality of coriander production is the development and application of effective technologies for its cultivation. Sowing data is one of the most important agronomic factors, playing an important role in the expression of plant genetic endowments (Diederichsen, 1996). This key agronomic factor is determined depending on the direction of production and the specific soil and climatic conditions of the area (Ghobadi and Ghobadi, 2010).

The time of sowing has a significant impact on the seed yield of coriander and the determination of the optimum time determines the productivity. In India, the highest seed yield was obtained in coriander sown from mid to late October, but the highest essential oil content was obtained when sown from early to mid-October (Gujar et al., 2005; Khah, 2009). However, sowing beyond the optimum time seriously reduced yield as well as essential oil content.

A study by Sudeep et al. (2005) showed that October sowing compared to December sowing is more suitable for coriander because higher values of structural elements and seed yield are obtained. Other authors have identified the climatic conditions of the year as the determinant in terms of coriander seed yield and essential oil content. The year with the highest amount of rainfall produces the highest seed yield but lower essential oil content (Kuri et al., 2015).

Zheljazkov et al. (2008) conducted a study in Canada with two coriander cultivars (Jantar, Alekseevski) to determine the effect of two sowing data (May 24 and June 8) on seed and essential oil yield. The results showed that the highest seed and essential oil yields for both cultivars were obtained when sown on 24 May, with insignificant differences between Jantar and Alekseevski varieties.

According to Luayza et al. (1996), in Argentina, autumn-winter sowing of coriander is optimal to achieve the highest yield. Another study conducted in Italy (Carruba et al., 2006) found that December sowing provided over 90% higher yield compared to January, February, March and April sowings. Sharangi and A. Roychowdhury (2014) found that late sowing reduces plant height, number of tillers per plant, while sowing at optimum times results in increased yield and productivity elements. Bhadkariya et al. (2007) investigated the effect of several sowing dates (October 25, November 5, November 25 and December 5) on structural elements of yield, yield and seed quality. Maximum values of all the parameters studied were obtained when coriander was sown in early November (5 November). Some authors recommend sowing no later than 30 March (Zareie et al., 2012). Sowing coriander between 30 March and 29 April significantly reduces seed yield (Moosavi, 2012). A study in Poland by Nowak, & Szempliński (2014), showed that early sowing increased seed yield.

In a study conducted in the Karnobat region of southeastern Bulgaria, they investigated the effect of sowing time on coriander productivity and found that sowing in April provided 30-35% lower seed yields and essential oil content compared to February and March sowing (Gramatikov et al., 2005).

For Dobrudzha conditions, Tonev and Gramatikov (2008) recommend sowing coriander in March, while in the Karnobat region the highest seed yield is obtained when sowing in February (Gramatikov et al., 2005).

MATERIALS AND METHODS

Good precursors for coriander with crops that release the area early. Most suitable are winter cereals and grain legumes, suitable are vegetable crops and early maize hybrids, and less suitable are sunflowers, cotton and tobacco. Unsuitable for coriander with sorghum and sugar beet. On the same field to return no earlier than 2-3 years. Coriander is a good precursor for all winter-cereals and other crops sown in autumn.

Annually on the coriander farm is found after the wheat precursor.

Company "Agro Impulse" Ltd. Voyvodinovo, grows coriander, variety "Local small-fruited". This variety was created in the conditions of Bulgaria and is distinguished by thin, upright, light green stems, about 65-70 cm tall. The flowers are clustered in sparse and small umbels of 3-6 rays. Fruits are brown to yellow, small, 1.5-2.0 mm in diameter and 5-6 g per 1000 fruits. Its ripeness at full maturity at harvest is not high. The variety is relatively early maturing, with a growing period of 100-105 days and an essential oil content of 1.25%.

During the period 2020-2022 in the village of. Voyvodinovo, Maritsa municipality, three annual field trials were conducted using the fractional plot method in 4 replications with a harvest plot size of 15 m^2. Precursor - wheat. The tillage depending on the sowing period included:

In autumn sowing of coriander

After wheat harvest - July-August, summer ploughing is carried out at 18-20 cm. In the period August-September - disking at 13-15 cm and immediately before sowing - September-October - cultivation at 6-8 cm.

For spring sowing of coriander

After harvesting the precursor, July-August deep ploughing at 22-25 cm is carried out. During the period October-November - disking at 13-15 cm, at the first opportunity to enter the block in spring cultivate at 8-10 cm (early February) and immediately before sowing - cultivation with harrowing at 6-8 cm (late February - early March).

Coriander is sown at a seed rate of 1.5-2.0 kg/da, at a spacing of 12-15 cm, at a depth of 3-4 cm. Mandatory post-sowing rainfall.

Application of nitrogen fertiliser at a rate of 5-6 kg/da N is carried out after germination. In the case of coriander sown in autumn - February-March, and in the case of those with spring - March-April.

Praxim herbicide (500 g/l Metobromuron) - 220 ml/da applied in March-April was used for weed control.

At the end of the budding phase of coriander plants - May foliar fertilization with Masterblad was applied at a rate of 250 ml/da.

Harvesting was carried out in July with a single-phase combine harvester at the full maturity stage with recorded seed moisture not higher than 9%.

For 100 kg of fruit the coriander extracts 3-3.5 kg N, 3.5 kg K_20, 1.1 kg P_20_5 fertilization is carried out with 1-3 t/da manure. Depending on the soil fertiliser content, mineral fertiliser is applied - 10-15 kg N/day, 8-10 kg/day P_2O_5, 6-8 kg/day K_2O on lightly fertilised soils and 8-10 kg N/day, 6-8 kg/day P_2O_5, 4-6 kg/day K_2O on medium fertilised soils. Manure, phosphorus and potassium fertilisers are applied with ploughing and nitrogen fertilisers just before sowing.

The results of the soil analysis made by the Laboratory Complex at AU - Plovdiv, after harvesting the precursor on the farm are presented in Table 1.

The data showed that the total nitrogen content before sowing of coriander was 9.71 mg/kg soil in the 0-20 cm layer and 9.20 mg/kg soil in the 20-40 cm layer. According to Gorbanov St. et al. (1990), soils are poorly stocked and the application of nitrogen fertilizers is necessary for the optimal development of coriander.

The uptake phosphorus content in the 0-20 cm layer was 19.00 mg/100 g soil and in the 20-40 cm layer was 24.68 mg/100 g soil. According to the methodologies of Truog, Olsen and Egner Reim (Gorbanov St. et al., 1990) the stock is good.

The uptake potassium content determined in the extract with 2N HCI was good 25.40 and 31.79 mg/100 g soil at 0-20 cm and 20-40 cm, respectively.

Due to the good soil phosphorus and potassium availability, no application of these trace elements is required.

The economically important diseases of coriander are bacteriosis, cercosporosis, ramulariosis, leaf spot and bacterial blackening of the fruit, and of the pests, coriander seed weevil, coriander aphid and meadow weevil. The control is carried out with registered fungicides and insecticides, as well as with agrotechnical means - observing crop rotation, selecting a suitable precursor, bulking and ploughing of crop residues, and sowing a weed-free area.

RESULTS AND DISCUSSIONS

Technological maps have been developed from the presented technological solutions for growing coriander (Photo 1).

Photo 1. Trial fields of coriander

Table 1. Technological map for spring sowing of coriander, after predecessor wheat

№	Technological operations	Agrotechnical requirements	Volume of work - V p , (ha, t, t.km, pcs.)	Agrotechnical period	Planned timeline from .... to	Number of working days - Dr	Duration of the working day - Td	Number of mechanics - nmex	Number of support workers - npr	Hourly productivity - Wh	Daily productivity - Wдн	Productivity for the planned period - W pl
1	Ploughing	20-25 cm	100 ha	VII-VIII	1-10.VIII	11	8	1	0	1.18	9.4	103.4
2	Discus	13-15 cm	100 ha	X-XI	1-3.X	3	8	1	0	0.5	38.4	115.2
3	Cultivation	8-10 cm	100 ha	II	1-3.II	3	8	1	0	5.04	40.3	120.9
4	Cultivation + harrowing	6-8 cm	100 ha	II	26-28.II	3	8	1	0	5.04	40.3	120.9
5	Sowing	15-20 kg/ha	2 t	II-III	1-3.III	3	8	1	0	4.69	37.5	112.5
6	Fortified		100 ha	II-III	1-3.III	3	8	1	0	6.75	54	162
7	Fertilization	150 kg/ha (N)	15 t	III-IV	1.IV	1	8	1	1	24.38	195	195
8	Spraying with herbicide (Praxim)	2.2 l/ha	220 l	III-IV	5.IV	1	6	1	1	25	150	150
9	Foliar feeding (Masterblad)	2.5 l/ha	250 l	V	10.V	1	6	1	1	25	150	150
10	Harvesting	2105 kg/ha	210.5 t	VII	6-9.VII	4	8	1	0	3.36	26.9	107.6

Table 2. Technological map for autumn sowing of coriander, after predecessor wheat

№	Technological operations	Agrotechnical requirements	Volume of work - V p , (ha, t, t.km, pcs.)	Agrotechnical period	Planned timeline from .... to	Number of working days - Dr	Duration of the working day - Td	Number of mechanics - nmex	Number of support workers - npr	Hourly productivity - Wh	Daily productivity - Wдн	Productivity for the planned period - W pl
1	Ploughing	18-20 cm	100 ha	VII-VIII	1-10.VIII	11	8	1	0	1.18	9.4	103.4
2	Discus	13-15 cm	100 ha	VIII-IX	1-3.IX	3	8	1	0	0.5	38.4	115.2
3	Cultivation	6-8 cm	100 ha	IX-X	25-27.IX	3	8	1	0	5.04	40.3	120.9
4	Sowing	15-20 kg/ha	2 t	IX-X	1-3.X	3	8	1	0	4.69	37.5	112.5
5	Fortified		100 ha	IX-X	1-3.X	3	8	1	0	6.75	54	162
6	Fertilization	150 kg/ha (N)	15 t	II-III	1.III	1	8	1	1	24.38	195	195
7	Spraying with herbicide (Praxim)	2.2 l/ha	220 l	III-IV	5.IV	1	6	1	1	25	150	150
8	Foliar feeding (Masterblad)	2.5 l/ha	250 l	V	10.V	1	6	1	1	25	150	150
9	Harvesting	2284 kg/ha	228.4 t	VII	6-9.VII	4	8	1	0	3.36	26,9	107.6

In 2020, 2021, 2022 on the Company's farm "Agro Impulse" Ltd. Voyvodinovo coriander yield - 2250-2130 kg/ha for autumn and spring sowing, respectively:
2500-2230 kg/ha
2100-1956 kg/ha

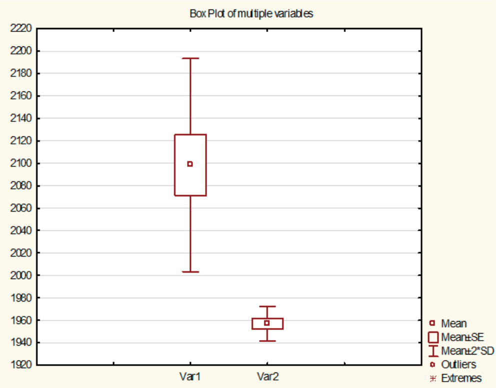

Figure 1. Multitiple variance

Mathematical analyses of both technologies will be performed with specialized data processing software.
When applying one-factor variance analysis, the influence of the factor (sowing term) on the parameter (yield) is established. The main idea in the application of this method is to see the reasons that cause a change in the parameter and in the decomposition of the general change in yield into two constituents - one caused by the factor of sowing time and the other by random and unreported factors.
With these two constituents, two independent estimates of the variance σ2 [ε] of the total disturbance effect are calculated ε (Mitkov et al., 1993)
By comparing these two estimates using Fisher's test, it is established whether the factor (sowing term) has a significant influence on the yield parameter or not.
Let the factor A be the time of sowing, and its levels are respectively A1 - autumn sowing and A2 - spring sowing, and let for both levels of the factor, three-year trials were conducted, which cause a change in the parameter Y - yield.
The data is entered in the following tabular form Table 3.

Table 3. Coriander yield at different sowing times

N of study	Factor levels	
	A1	A2
1	2250	2130
2	2500	2230
3	2100	1956
yi=∑yij	6850	6316
Ȳi	2283.3	2105.3

yi - Sums of all study;
Ȳi - average value.

Analysis of variance will be conducted at the significance level α = 0.05 (Table 4) (Figure 2)

Table 4. Univariate Test of Significance

Effect	Univariate Tests of Significance for Var2 (Spreadsheet1) Sigma-restricted parameterization Effective hypothesis decomposition SS	Degr. of Freedom	MS	F	p
Intercept	55646440	1	55646440	2672,558	0,000000
Var1	121807	1	121807	5,850	0,036142
Error	208214	10	20821		

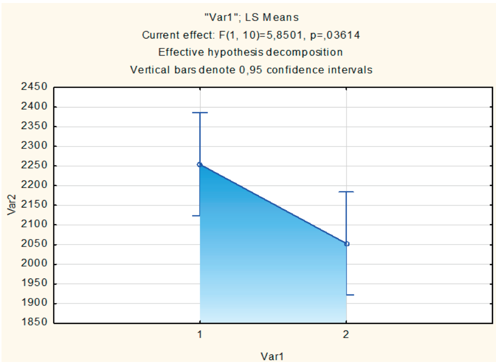

Figure 2. Efective hypothesis decomposition

The analysis shows that the sums of squares considered above and their respective degrees of freedom and variances are (Table 4):
SSA = 121807;
SSE = 208214;
SS = 121807+208214 = 330021.
Fisher's criterion F = 5.850 and its corresponding probability p = 0.0361 << 0.05 indicate that the factor A (sowing term) has a significant effect on the yield of coriander Y.
A T-test (Student's test) was also conducted to test the hypothesis of the samples (Table 5).
From the conducted inspection, it can be seen that there is a proven difference in yields depending on the applied cultivation technology.

Table 5. T-test for Independent Samples

Group 1 vs. Group 2	T-test for Independent Samples (2020) Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Var1 vs. Var2	2245,000	2126,667	3,197679	4	0,032974	3	3	32,78719	55,07571	2,821705	0,523327

Group 1 vs. Group 2	T-test for Independent Samples (2021) Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Var1 vs. Var2	2496,667	2220,000	5,187500	4	0,006572	3	3	65,06407	65,57439	1,015748	0,992187

Group 1 vs. Group 2	T-test for Independent Samples (2022) Note: Variables were treated as independent samples										
	Mean Group 1	Mean Group 2	t-value	df	p	Valid N Group 1	Valid N Group 2	Std.Dev. Group 1	Std.Dev. Group 2	F-ratio Variances	p Variances
Var1 vs. Var2	2098,333	1957,000	5,087430	4	0,007044	3	3	47,52192	7,549834	39,61988	0,049237

CONCLUSIONS

From the mathematical processing of the results obtained from the field tests, we can draw the following conclusions:

Through the use of analysis of variance and t-test to test the hypotheses of two independent samples at the level of significance, it was found that there is a proven difference in yields when growing coriander by the two technologies and the yield directly depends on the term of sowing.

The technology of autumn sowing of coriander gives proven higher yields compared to that of spring sowing.

Although spring sowing has higher production costs related to the preparation of the field for sowing and statistically proven lower yields of coriander, this sowing is recommended in a dry autumn.

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REFERENCES

Bhadkariya, K., Gupta, A., Bobade, A., Kasana, B., Tomar, S. (2007). Effect of different times of sowing on growth, yield and seed quality of coriander (*Coriandrum sativum*). *Indian Journals, 22*(3), 268–275.

Carrubba, A., Torre, R., Saiano, F, Alonzo, G. (2006). Effect of sowing time on coriander performance in a semiarid Mediterranean environment. *Crop Sci., 46*. 437–447.

Diederichsen, A. (1996). Coriander (Coriandrum sativum). *International Plant Genetic Resources Institute (IPGRI)*, Rome, Italy

Gramatikov, B., Koteva V., Penchev P., Atanasova D. (2005). *Tenologiya za otglezhdane na koriandŭr,* 5-36.

Gramatikov, B., Koteva V., Penchev, P., Atanasova, D. (2005). *Coriander Cultivation Technology.* 5–36.

Ghobadi, E., Ghobadi, M. (2010). The effects of sowing dates and densities on yield and yield components of coriander (*Coriandrum sativum*). *Engineering and Technology, 70*. 81–84.

Gujar, S., Warade, A., Mohariya, A., Paithankar, D. (2005). Effect of dates of sowing and nitrogen levels on growth, seed yield and quality of coriander. *Crop Res. 29*(2), 288–291.

Khah, E. (2009). Effect of sowing date and cultivar on leaf yield and seed production of coriander. *(Coriandrum sativum). Journal of Food Agriculture & Environment, 7*(2), 332–334.

Kuri, B. R., Jat, N. L., Shivran, A. C., Saharawat, Y. S., Bana, R. S., & Dadarwal, R. S. (2015). Effect of sowing time, varieties and plant growth regulators on growth, physiological indices and productivity of coriander (*Coriandrum sativum*). *Indian Journal of Agronomy, 60*(3), 464–470.

Luayza, G., Brevedan, R., Palomo, R. (1996). Coriander under irrigation in Argentina. *ASHS Pres, VA*, 590–594.

Mitkov, A., Minkov, D. (1993). *Statistical methods for research and optimization Part II*. Zemizdat, Sofia.

Moosavi, S. R. (2012). Effects of sowing date and plant density on some traits of *Coriandrum sativum L. Technical Journal of Engineering and Applied Sciences, 2*(1), 11–16.

Nowak, J., & Szempliński, W. (2014). Influence of sowing date on yield and fruit quality of coriander (*Coriandrum sativum* L.). *Acta Scientiarum Polonorum Hortorum Cultus, 13*(2), 83–96.

Sudeep, S., Buttar, G. S., Singh, S. P., & Brar, D. S. (2005). Effect of different sowing dates and row spacings on yield of coriander (*Coriandrum sativum*).

Journal Of Medicinal and Aromatic Plant Sciences, 27(2), 301–302.

Sharangi, A. B., & Roychowdhury, A. (2014). Phenology and yield of coriander as influenced by sowing dates and irrigation. *The Bioscan, 9*(4), 1513–1520.

Tonev, T., Gramatikov, B. (2008). Vliyanie na azotnata i na posevnata norma vŭrkhu dobiva na semena ot koriandŭr v usloviyata na Dobrudzha. *Res. Commun. of U.S.B. branch Dobrich*, *10*. 30–34.

Tonev, T., Gramatikov, B. (2008). Influence of nitrogen and sowing rates on the yield of coriander seeds in the conditions of Dobruja. *Res. Commun. of U.S.B. branch Dobrich, 10*. 30–34.

Zareie, M. H., Moosavi, S. R., Javad, M. M., & Seghatoleslami. (2012*).* Effects of sowing date and plant density on yield and yield components of *Coriandrum sativum* L. *International Journal of Agriculture: Research and Review, 2*(5), 555–563.

Zheljazkov, V., Pickett, K., Caldwell, C. (2008). Cultivar and sowing date effects on seed yield and oil composition of coriander in Atlantic Canada. *Industrial Crops and Products, 28*. 88–94.