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DEPARTMENT OF PLANT PRODUCTION

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STUDY ON MAIN UNITS OF THE TECHNOLOGY OF *TRITICUM MONOCOCCUM* L., *TRITICUM DICOCCUM* Sch. AND *TRITICUM SPELTA* L. IN THE CONDITIONS OF ORGANIC AGRICULTURE

THESIS

of a dissertation for the award of educational and scientific degree "Doctor"

Scientific specialty - "Plant Breeding"

Supervisors:

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The study was conducted in the period 2018 - 2021 in the Training - Experimental and Implementation Base of the Agri-Environmental Center at the Agricultural University - Plovdiv.

The dissertation has a volume of 172 pages and contains 86 tables and 12 figures. The cited literature includes 204 sources, of which 16 in Cyrillic and 188 in Latin.

The dissertation was discussed at the Department Council of the Department of Plant prrroduccction at the Faculty of Agriculture at the Agricultural University - Plovdiv.

The presentation of the dissertation will take place on .... 2022 at .... hours in .... of the Faculty of Agriculture at the University of Agriculture - Plovdiv in front of the Specialized Scientific Jury, approved by Order of the Rector № RD -16-149 dated 28. 02. 2022, composed of:

Reviews from:
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Opinions from:
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Assoc. Prof. Dr. Natalia Petrovska
Prof. Dr. Nelly Valkova

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The dissertation materials are available in the library of the Agricultural University - Plovdiv, 12 Mendeleev Blvd.

I. INTRODUCTION

There is evidence that the original bread on the territory of today's Bulgaria was made from wheat called einkorn, emmer and spelt. In recent years, there has been interested in natural and healthy foods in our country and around the world. The attention of modern man returns to the old types of wheat. In Bulgaria there are suitable conditions for the development of organic farming and some suitable crops, whose renaissance in our country has already begun, are einkorn (*Triticum monococcum* L.), emmer (*Triticum dicoccum* Sch.) and spelt (*Triticum spelta* L). The EU's common agricultural policy faces reforms based on the "From farm to fork" strategy for a fair, healthy and environmentally friendly food system. In response to these trends in agricultural policy and increased interest in einkorn, emmer and spelt wheat, it is necessary to optimize their cultivation technology, especially in biological conditions.

II. GOAL AND TASKS

The study's **main goal** is to optimize some elements of the technology - sowing density and fertilization - in three ancient species of wheat - *Triticum monococcum* L., *Triticum dicoccum* Sch. and *Triticum spelta* L., in organic farming.

Tasks:

1. To make a comparative characteristic of the three wheat species' phenological development in the vegetation years' conditions. To trace the dependences between the duration of the interphase periods and the vegetation period with the tested factors.
2. To trace the dynamics of growth, tillering and the formed productive stems and establish the influence on different sowing densities and fertilization.
3. To characterize the photosynthetic activity of the three wheat species and analyze its dependence on the tested factors.
4. To determine the influence of sowing density and fertilization on the productivity of *Triticum monococcum* L., *Triticum. dicoccum* Sch. and *Triticum spelta* L. To establish correlations between yield and spike components.
5. To establish the elements of productivity and their relative impact on yield under the tested factors - year, species, the density of sowing and fertilization.
6. To study the physical qualities of the grain in the tested factors of the study.
7. To study the biochemical composition and the content of some macro- and microelements in the grain of the three species of wheat.

III. MATERIAL AND METHODS

To achieve the goal and tasks of the study, two experiments are set - a field experiment and a pot experiment.

A. Field experiment

1. Location of the study

The study was conducted at the Agro-Environmental Center - Demonstration Center for Organic Agriculture at the Agricultural University - Plovdiv in 2018 - 2021.

2. Method, scheme

To achieve this goal, a field three-factor experiment is set by the method of fractional plots with a size of the reporting plot of 15 m^2 in four replications. The seeds (local forms) are provided by organic crops and by the Institute of Plant Genetic Resources in Sadovo, accompanied by the relevant required documents.

The statistical processing of the experimental data is performed by SPSS V. 9.0 for Microsoft Windows by Duncan, Anova. All values marked with the same letter in the tables do not differ statistically.

3. Factors of the study

Factor A - Wheat species:

A_1 - *Triticum dicoccum* Sch .;

A_2 - *Triticum spelta* L .;

A_3 - *Triticum monococcum* L .;

Factor B - Sowing density

B_1 - 500 g.s./ m^2

B_2 - 700 g.s./ m^2

B_3 - 900 g.s./ m^2

Factor C - Fertilizers for organic farming

C_1 - Control - without fertilization

C_2 - Italpolina - soil fertilizer, at a dose of 0.7 t / ha

C_3 - Haturamin WSP - amino acid product for foliar treatment - three treatments in tillering, stem elongation and heading at a 30 g/ da dose.

4. Survey indicators:

4.1. Number of sprouted plants per m2;

4.2. Phenological development;

4.3. Physiological indicators:

Indicators of leaf gas exchange;

Content of the photosynthetic pigment chlorophyll;

Parameters of chlorophyll fluorescence

4.4. Plant height

4.5. Common and productive tillering

4.6. Productive stems/m^2

4.7. Harvest index

4.8. Structural elements of the head

4.9. Grain yield

4.10. Physical parameters of the grain

4.11. Biochemical parameters of the grain

• Total nitrogen/Crude protein, Crude fiber, Crude ash, Dry matter, Lysine;

• Content of macro- and microelements

5. Mathematical data processing:

- Analyzes: Two-factor analysis of variance, correlation analysis;
- Software products: SPSS for Windows, v 9.00; Duncan’s Multiple Range Test

B. Pot vegetation experience

The experiment was performed according to the following scheme in four replications:

1. Control - unfertilized soil;
2. Soil fertilized with Italpolina (0.03 g / container - 70 kg / da)
3. Foliar fertilization with Naturamin WSP (abundant wetting of plants - 30 g / da)

IV. CLIMATE CHARACTERISTICS

1. Climatic conditions

The City of Plovdiv is located in the Transitional-Continental Climate Sub-District in the Climate Region of Eastern Central Bulgaria. It is significantly milder and with more frequent warming in winter. Spring is warm and short. Summer is dry and hot. The average annual air temperature is 12.0 °C and the annual temperature amplitude is 22.8 °C.

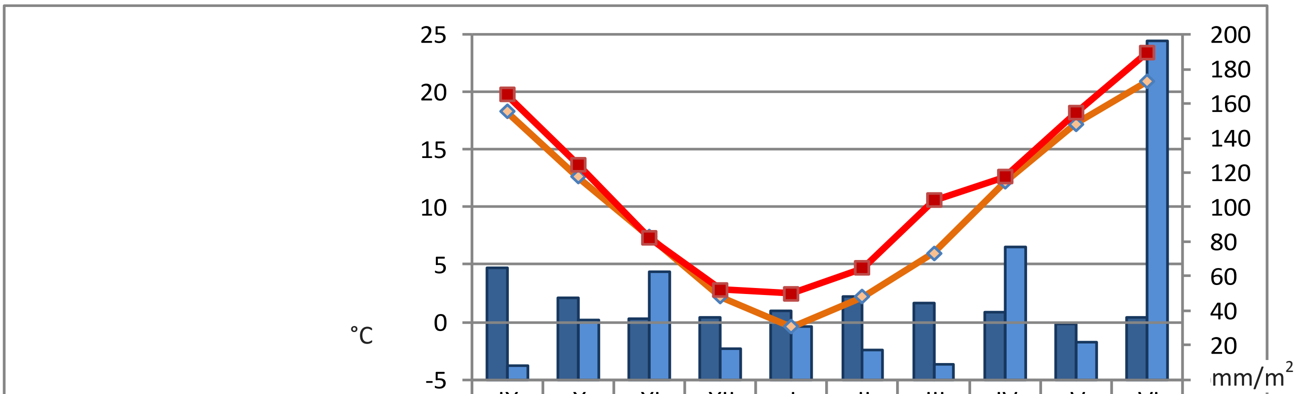
The average precipitation in the Plovdiv region is 512 mm/m^2. It is one of the driest in the country. Rainfall is unevenly distributed.

2. Soil conditions

The soils in the Agroecological Center are alluvial-meadow. They have a low supply of N, a low to the medium of P, and a good supply of K. Alluvial meadow soils are loose, ventilated and warm. Most of these soils are characterized by high fertility.

3. Analysis of agrometeorological conditions in the study period

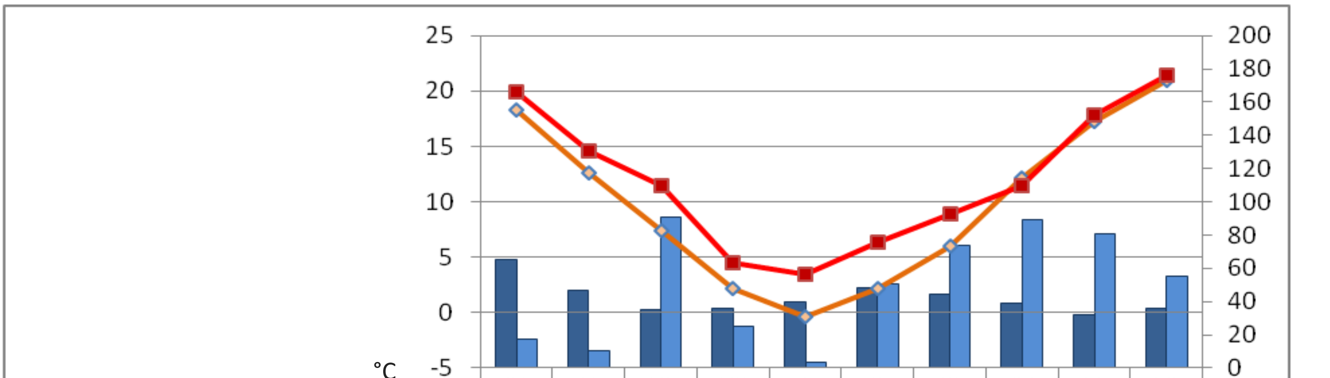
The meteorological situation during the period of preparation for sowing and sowing in the autumn of 2018, and for the first phases of the development of culture, is not very favorable. Autumn is relatively warm, with temperatures in September, October and November higher than the average monthly for the long period (*Fig.* 1). However, rainfall is extremely limited, especially in September, which did not allow timely quality preparation for sowing. Only the rains at the beginning of October, although in insufficient quantities, allowed the final preparation of the fields for sowing.



	IX	X	XI	XII	I	II	III	IV	V	VI
mm/m2 ср. за 1965-1995	65	47	35	36	40	48	44	39	32	36
валежи (mm/m2) за 2018-19г.	8.3	34.3	62.5	17.9	30.9	17.2	8.8	76.5	21.3	196.7
t° C ср. за периода 1965-1995	18.3	12.6	7.4	2.2	-0.4	2.2	6	12.2	17.2	20.9
t° C за 2018-19г.	19.8	13.7	7.3	2.8	2.5	4.7	10.6	12.6	18.2	23.4

***Fig. 1*. Agrometeorological conditions for the development of *Tr. dicoccum* Sch., *Tr. spelta* L. and *Tr. monococcum* L. in the region of Plovdiv (2018/2019)**

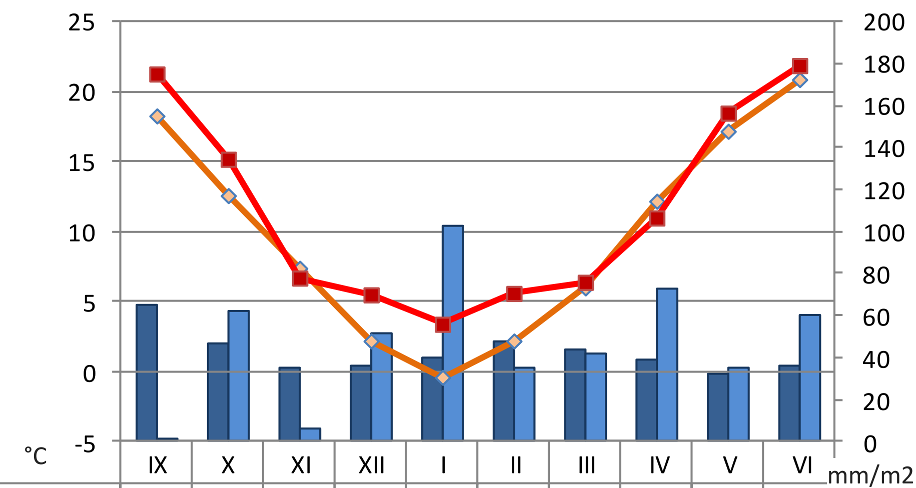
The month of September 2019 (*Fig.* 2) is more favorable for quality pre-sowing treatments. The complex agrometeorological conditions in the coming months ensure the normal transition of the third leaf phase and entering the tillering phase. The winter of 2019-2020 is mild, with temperatures much higher than normal. The crops are provided with sufficient amounts of moisture. These conditions predetermine trouble-free overwintering and the course of the tillering phase. The next phases (until ripening) also take place in optimal agrometeorological conditions.



	IX	X	XI	XII	I	II	III	IV	V	VI
mm/m2 ср. за 1965-1995	65	47	35	36	40	48	44	39	32	36
валежи (mm/m2) за 2019-20г.	17,4	10,2	90,4	25,3	3	50,7	74,1	89,1	80,7	55,4
t° C ср. за периода 1965-1995	18,3	12,6	7,4	2,2	-0,4	2,2	6	12,2	17,2	20,9
t° C за 2019-20г.	19,9	14,6	11,4	4,5	3,5	6,4	8,9	11,5	17,8	21,4

***Fig. 2*. Agrometeorological conditions for the development of *Tr. dicoccum* Sch., *Tr. spelta* L. and *Tr. monococcum* L. in the region of Plovdiv (2019/2020)**

The third experimental year (*Fig.* 3) started with temperatures above the norm and limited humidity. The lack of precipitation in September makes it difficult to carry out pre-sowing tillage, but the rainfall in October (62.3 mm / m2) favors their timely implementation and sowing. Temperatures in the coming months outline a warm and mild winter for developing the three types of wheat. Temperatures and precipitation in the third experimental year contribute to the common germination and successful overwintering of plants. Until the end of the vegetation, the phenophases take place in favorable agrometeorological conditions.



	IX	X	XI	XII	I	II	III	IV	V	VI
mm/m2 ср. за 1965-1995	65	47	35	36	40	48	44	39	32	36
валежи (mm/m2) за 2020-21г.	1,3	62,3	5,7	51,8	103	34,6	42,2	72,9	34,9	60
t° C ср. за периода 1965-1995	18,3	12,6	7,4	2,2	-0,4	2,2	6	12,2	17,2	20,9
t° C за 2020-21г.	21,3	15,2	6,7	5,5	3,4	5,6	6,4	11	18,5	21,9

***Fig. 3*. Agrometeorological conditions for the development of *Tr. dicoccum* Sch., *Tr. spelta* L. and *Tr. monococcum* L. in the region of Plovdiv (2020/2021)**

The three years of research appear to be significantly warmer than the norm, which is in absolute unison with global trends in climate change. For a 6-month vegetation period, the average monthly temperature is 1.7 ° C higher than the norm for 2018-2019 (X to VI), 3.2 ° C higher for the same period in 2019-2020. and by 1,7 ° C in the last year of the study. Precipitation is 52, 74 and 47 liters more per m2 for the 6-month growing season in the first, second and third experimental years. However, the vegetation period is accompanied by shortages and excessive rainfall in certain phenophases, reflecting the duration of the interphase periods, the height reached and the manifestations of lodging at the end of the vegetation.

V. RESULTS AND DISCUSSION

1. Phenological development

The three species of wheat, despite the different sowing dates (from 12 to 27 October) (Table 1), different conditions and duration of germination, quickly managed to adapt. They start tillering between December 18 and 23 and successfully overwinter. The spring phases are similar in the three years, with only the emmer standing out more clearly with a shorter growing season. In some of the phases, the einkorn also enters 1-2 days earlier than the spelt catching up with the emmer reaches full maturity at the same time as the spelt.

***Table* 2. Phenological development of the tested species**

Species	**Phenological phases**							
	Germi-nating	Third leaf	Tillering	Stem elongation	Heading	Milk ripening	Vox ripening	Full ripening
	(BBCH 11)	**(BBC18)**	**(BBCH 28)**	**(BBCH 38)**	**(BBCH 59)**	**(BBCH 78)**	**(BBCH 89)**	**(BBCH 99)**
	Sowing 24.10.2018 г.			**2018/ 2019**				
***Triticum dicoccum* Sch.**	08.11.18	14.12.18	23.12.18	22.04.19	16.05.19	02.06.19	13.06.19	25.06.19
***Triticum spelta* L.**	08.11.18	14.12.18	23.12.18	24.04.19	19.05.19	08.06.19	19.06.19	26.06.19
***Triticum monococcum*L.**	08.11.18	14.12.18	23.12.18	25.04.19	16.05.19	08.06.19	19.06.19	26.06.19
	Sowing 12.10.2019 г.			**2019/ 2020**				
***Triticum dicoccum* Sch.**	10.11.19	07.12.19	18.12.19	19.04.20	14.05.20	05.06.20	15.06.20	26.06.20
***Triticum spelta* L.**	10.11.19	07.12.19	18.12.19	19.04.20	15.05.20	07.06.20	16.06.20	27.06.20
***Triticum monococcum*L.**	10.11.19	07.12.19	23.12.19	21.04.20	15.05.20	08.06.20	17.06.20	27.06.20
	Sowing 27.10.2020 г.			**2020/ 2021**				
***Triticum dicoccum* Sch.**	05.11.20	15.12.20	22.12.20	22.04.21	16.05.21	05.06.21	16.06.21	25.06.21
***Triticum spelta* L.**	05.11.20	15.12.20	22.12.20	22.04.21	17.05.21	07.06.21	17.06.21	26.06.21
***Triticum monococcum*L.**	05.11.20	15.12.20	22.12.20	21.04.21	15.05.21	07.06.21	18.06.21	26.06.21

Tabl. 2,3 and 4 present data on the duration of the interphase periods and the amounts of active temperatures that the plants collected in each of them - by species, for the three years.

Plants of emmer (*Table* 2) have a duration of the interphase period from germination to the third leaf 34 days on average. They accumulate an effective temperature sum of 209.5 °C (> 0 °C) for this period. The shortest is the interphase period from the third leaf to tillering - only 9 days, which requires a 41 °C temperature sum (> 0 °C). The interphase period from tillering to stem elonagtion is the longest, as all three species are grown as winter crops - with sowing in October. Plants accumulate an amount of 328 ° C (> 5 °C) during this period. The stem elongation phase until the beginning of heading lasts for 24 days and amounts to 273 °C. Another 42 days with a total temperature of 647.7 °C are needed until full ripening. The duration of the vegetation period for emmer is on average 230 days, in which period it accumulates 1499 °C active temperature sum.

***Table* 2. Duration of the interphase periods and sum of active temperatures by phases in *Triticum dicoccum* Sch., 2018-2021**

Interphase period	Duration of the interphase period, number of days				Sum of active temperatures - °C			
Year	**2018-2019**	**2019-2020**	**2020-2021**	Average	**2018-2019**	**2019-2020**	**2020-2021**	**Average**
Germinating Third leaf	**36**	**27**	**40**	**34**	**160,6**	**240,5**	**227,5**	**209,5**
Third leaf Tillering	**9**	**11**	**7**	**9**	**26,2**	**62,2**	**34,4**	**40,9**
Tillering Stem elongation	**120**	**123**	**121**	**121**	**362,4**	**351,8**	**269,0**	**327,7**
Stem elongation Heading	**24**	**25**	**24**	**24**	**269,2**	**260,3**	**288,4**	**272,6**
Heading Milk ripening	**17**	**22**	**20**	**20**	**263,9**	**290,4**	**273,7**	**276,0**
Milk ripening Vox ripening	**11**	**10**	**11**	**11**	**192,0**	**159,6**	**161,5**	**171,0**
Vox ripening Full ripening	**12**	**11**	**9**	**11**	**239,2**	**185,0**	**177,9**	**200,7**
Vegetation period	**229**	**229**	**232**	**230**	**1513,5**	**1549,8**	**1432,4**	**1498,6**

Spelt has an almost similar duration of its interphase periods (*Table* 3). The total length of the vegetation period is one day longer due to the slightly longer interphase periods "tillering – stem elongation“ and "stem elongation – heading". The total temperature collected for the whole vegetation period on average for the three years is 1513 °C. The vegetation ends in the last experimental year with the lowest accumulated effective temperature, similar to the first year - 2020-2021 - 1451 °C.

***Table* 3. Duration of the interphase periods and sum of active temperatures by phases in *Triticum spelta* L., 2018-2021**

Interphase period	Duration of the interphase period, number of days				Sum of active temperatures - °C			
Year	**2018-2019**	**2019-2020**	**2020-2021**	**Average**	**2018-2019**	**2019-2020**	**2020-2021**	**Average**
Germinating Third leaf	**36**	**27**	**40**	**34**	**160,6**	**240,5**	**227,5**	**209,5**
Third leaf Tillering	**9**	**11**	**7**	**9**	**26,2**	**62,2**	**34,4**	**40,9**
Tillering Stem elongation	**122**	**123**	**121**	**122**	**378,2**	**351,8**	**269,0**	**333,0**
Stem elongation Heading	**25**	**26**	**25**	**25**	**298,3**	**280,3**	**299,7**	**292,8**
Heading Milk ripening	**20**	**23**	**21**	**21**	**302,2**	**302,1**	**292,3**	**298,9**
Milk ripening Vox ripening	**11**	**9**	**10**	**10**	**216,4**	**141,2**	**149,1**	**168,9**
Vox ripening Full ripening	**7**	**11**	**9**	**9**	**137,8**	**189,2**	**179,0**	**168,7**
Vegetation period	**230**	**230**	**233**	**231**	**1519,7**	**1567,3**	**1451,0**	**1512,7**

The einkorn develops its vegetation period for the same number of days as spelt, but differs in the duration of some of its interphase periods (*Table* 4).

***Table* 4. Duration of the interphase periods and sum of active temperatures by phases in *Triticum monococcum* L., 2018-2021**

Interphase period	Duration of the interphase period, number of days				Sum of active temperatures - °C			
Year	**2018-2019**	**2019-2020**	**2020-2021**	**Average**	**2018-2019**	**2019-2020**	**2020-2021**	**Average**
Germinating Third leaf	**36**	**27**	**40**	**34**	**160,6**	**240,5**	**227,5**	**209,5**
Third leaf Tillering	**9**	**16**	**7**	**11**	**26,2**	**88,7**	**34,4**	**49,8**
Tillering Stem elongation	**123**	**120**	**120**	**121**	**389,4**	**354,0**	**260,1**	**334,5**
Stem elongation Heading	**21**	**24**	**24**	**21**	**242,2**	**270,1**	**264,9**	**259,1**
Heading Milk ripening	**23**	**24**	**23**	**23**	**347,1**	**319,4**	**316,1**	**327,5**
Milk ripening Vox ripening	**11**	**9**	**11**	**10**	**216,4**	**138,6**	**165,0**	**173,3**
Vox ripening Full ripening	**7**	**10**	**8**	**8**	**137,8**	**174,5**	**163,1**	**158,5**
Vegetation period	**230**	**230**	**233**	**231**	**1519,7**	**1585,8**	**1431,1**	**1512,2**

As a result of the observations and calculations, the following summaries can be made:

In the conditions of the experimental years 2018-2021, during autumn sowing in the region of Plovdiv, the wheat *Triticum dicoccum* Sch., *Triticum spelta* L. and *Triticum monococcum* L. develop their vegetation within 230 to 231 days. Einkorn has relatively shorter vegetation. Until the stem elongation phase, the interphase periods are equalized. Some differences have been identified in the further development of the species. The shortest is the period of stem elongation - heading in einkorn, and the longest is the period of ripening in emmer. During the growing season (from germination to full maturity), the species needs an average of 1499 to 1512 °C effective temperature. With the least accumulated effective temperature (1431-1451 °C), all three species end their vegetation in 2020-2021, and with the most in 2019-2020 (1550 -1586 °C). These data are evidence of the exceptional adaptability of the species in years with different agrometeorological conditions.

2. Germination

The degree of germination of plants in the crop is crucial in forming optimal productive stems. In the case of tested ancient wheat, this indicator depends not only on the combination of favorable agro-climatic conditions but also on the genetically determined husk of the grain, the time of sowing and other factors. In the organic cultivation of wheat after autumn sowing and in need to control weeds without the use of herbicides, ensuring optimal crop density is extremely important.

In the case of **emmer** in the first experimental year emerge from 322 (at 500 g. s. /m^2 and Naturamin) to 672 plants /m^2 (at 900 g. s./ m^2, control). In the second year (2019/2020) the variants with 700 g. s./ m^2 and 900 g. s./m^2 garnish the plots better again, with 422 to 510 plants growing in them. The same trend continues in the third year. Statistical analysis of the independent influence of the tested factors (*Table* 5) for the three years shows that the year has been shown to influence the rate of germination in emmer.

***Table* 5. Influence of year, sowing density and fertilization on number of sprouted plants / m^2 at *Tr. dicoccum* Sch., average for the period**

Influence of a factor **Year**			Influence of a factor **Sowing density**			Influence of a factor **Fertilization**		
2018-2019	479,4	a	500 g.s./m^2	366,9	c	Control	469,2	a
2019-2020	429,0	b	700 g.s./m^2	452,1	b	Italpolina	441,4	a
2020-2021	437,1	a b	900 g.s./m^2	526,6	a	Naturamine WSP	434,8	a

The crops are best garnished under the conditions of the first experimental year 2018/2019. With close values, the third and second experimental years follow. It has been proven that the lower values in 2019/2020 are related to the already described stressful conditions after sowing, related to the lack of soil moisture.

Sowing density has also been shown to affect the number of plants sprouted in einkorn, with the best-garnished plots on average for the period at the highest tested sowing rate - 900 g.s. /m^2, followed by 700 g.s./m^2 and 500 g.s./m^2. Fertilization does not affect this test indicator.

The second tested species - **spelt wheat** (*Table* 6), with used sowing rates of 500 to 900 g.s. / m^2, in field conditions, sprout only 285 to 449 plants /m^2 in the first experimental year, 359 to 528 plants /m^2 in the second year and 351 to 490 plants /m^2 in the third year. In the first year of testing with the most proven plants (410 pieces /m^2), variants with the maximum tested sowing rate are formed. With proven differences between them, 700 and 500 g.s. /m^2 follow in descending order.

In the second and third years tested, the two larger sowing rates did not differ statistically but exceeded 500 g.s. /m^2.

When summarizing the results for the whole three-year period in spelt wheat, (*Table* 6) it is established that in the conditions of 2018/2019, the crops are less well-garnished (average 371 plants /m^2), while in the next two years, more plants sprout. There is no proven difference between the two higher sowing rates, but in crops with 500 g.s. /m^2, there are proven to be fewer plants. Variants with different fertilization at this stage do not affect.

The third tested species - **eincorn** - germinates better than spelt in the first year (*Table* 7), with the increase of the sowing rate from 500 to 900 g.s. / m^2, the number of sprouted plants has been proven to increase. At the maximum sowing rate, an average of 538 plants grow. In the second year, fewer plants sprout - between 321 (500 g.s. / m_2) to 475 (700 g.s. / m^2). Further increase of the sowing rate this year does not lead to proven differences in germination. In the last year of the experiment, most plants grow again at the highest sowing rate.

***Table* 6. Influence of year, sowing density and fertilization on number of sprouted plants / m^2 at *Tr. spelta* L., average for the period**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	371,1 b	500 g.s./m^2	359,3 b	Control	421,4 a
2019-2020	451,8 a	700 g.s./m^2	438,9 a	Italpolina	409,3 a
2020-2021	426,4 a	900 g.s./m^2	451,1 a	Naturamine WSP	418,6 a

***Table* 7. Influence of year, sowing density and fertilization on number of sprouted plants / m^2 at *Tr. monococcum* L., average for the period**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	459,3 a	500 g.s./m^2	365,3 c	Control	452,7 a
2019-2020	421,1 b	700 g.s./m^2	452,8 b	Italpolina	430,1 a
2020-2021	443,2 a b	900 g.s./m^2	505,6 a	Naturamine WSP	440,9 a

When testing the independent influence of the year, on average for the period, (*Table* 7) it is established that einkorn germinates best in the conditions of 2018/2019, followed by 2020/2021 and proven less in 2019/2020, with an increase in sowing rate from 500 to 900 g.s. /m^2 proven the number of sprouted plants per m^2 also increases.

Table. 8 presents data on the complex influence of the 4 factors (year, species, sowing rate and fertilization) on germination on average for the three-year period. Proven differences between the species are established. The Tr. dicoccum Sch. and Tr. monococcum L. plants (441 to 448 plants /m^2) are better garnished with the crops, while the spelt has proven to be inferior - with sprouted 416 plants/ m^2 on average for the period. The influence of the sowing rate and the fertilization follows the same dependencies, which are proved for each species separately. In conclusion, it can be summarized that the three types of wheat react differently to the specific agrometeorological conditions of the years. The tendency for the positive influence of the growing up to 900 g.s. /m^2 sowing norms on germination is definitely proved in the complex assessment of the factors.

Table 8. **Influence of the year, wheat species, sowing density and fertilization on plant germination, average for the period 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	436,6 a	**Tr. dicoccum Sch.**	448,5 a	**500 g.s./m2**	363,9 c	**Control**	447,8 a
2019/2020	434,0 a	**Tr. spelta L.**	416,4 b	**700 g.s./m2**	447,9 b	**Italpolina**	427,0 a
2020/2021	435,6 a	**Tr.monococcumL.**	441,2 a	**900 g.s./m2**	494,4 a	**Naturamine WSP**	431,4 a

3. Dynamics of tillering

The analysis of the data from the multi-year period in **emmer**, taking into account the influence of the year (*Table* 9), clearly marks some dependencies. Most tillers form plants in the first experimental year, forming an average of 3.1 productive tillers per plant, followed by 2.9 tillers from the second year. Productive tillering in the third year has been shown to be lower than the first two. Most tillers develop the variants with the lowest sowing rate - 500 g.s. / m^2 followed without a statistically significant difference from the variants with 700 g.s. /m^2. It has been proven that fewer brothers form the variants with the highest sowing rate.

Spelt wheat under the same conditions develops fewer tillers. The independent influence of the year, the density of sowing and fertilization is reflected in *Table* 10. The proven strong influence of the year is established. 2019/2020 provides conditions for the best course of the phase in this species, followed by 2018/2019 and 2020/2021.

For the formation of the maximum number of productive tillers, the optimal density is 700 g.s./m^2. Soil fertilization with Italpolina also slightly increases productive tillering.

Einkorn *(Table 11)* forms the highest productive tillers of the three tested wheat species. The summary analysis shows proven differences in the impact of the year. The second and third experimental years provided proven better conditions for tillering than the first year. The plants reach a maximum productive tiller of 4.6 productive tillers per plant in the third year. As the sowing rate increases, the productive tillering decreases from 4.1 to 3.9 productive tillers per plant. Soil fertilizer Italpolina leads to a slight increase in productive brotherhood, and Naturamin has no effect.

***Table* 9. Influence of the year, sowing density and fertilization on the number of productive tillers at the end of the growing season in *Triticum dicoccum* Sch., 2018-2021**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	3,1 a	500 g. s./m^2	2,9 a b	Control	2,8 a
2019-2020	2,9 a	700 g. s./m^2	3,0 a	Italpolina	2,9 a
2020-2021	2,5 b	900 g. s../m^2	2,7 b	Naturamin WSP	2,8 a

Table 10.* Influence of the year, sowing density and fertilization on the number of productive tillers at the end of the growing season in *Triticum spelta* L., *2018-2021

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	1,8 b	500 g. s./m^2	1,8 a	Control	1,8 A
2019-2020	2,1 a	700 g. s./m^2	1,9 a	Italpolina	1,9 A
2020-2021	1,5 c	900 g. s../m^2	1,8 a	Naturamin WSP	1,8 A

***Table* 11. Influence of the year, sowing density and fertilization on the number of productive tillers at the end of the growing season in *Triticum monococcum* L., 2018-2021**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	2,9 b	500 g. s./m^2	4,1 a	Control	4,0 A
2019-2020	4,4 a	700 g. s./m^2	4,0 a	Italpolina	4,1 A
2020-2021	4,6 a	900 g. s./m^2	3,9 a	Naturamin WSP	3,9 A

From the summarized statistics of the data from the complex three-factor experience *(Table 12)* it is established that the year has been proven to influence the formation of productive tillering. The most favorable is 2019/2020 when the plants form 12.5 to 18.7% more tillers. The species also has a proven statistical impact. The einkorn has the most tillers - 4.0 productive tillers/ plant, followed by the emmer - 2.9 productive tillers/ plant (27% less), and the least tillers form spelt - 1.8 productive tillers/ plant (55% less than einkorn).

The influence of sowing density on productive tillering is weaker and the differences are not proven statistically, but the variants with 700 g. s. / m^2 are best developed, followed by 500 and 900 g. s./m^2. Of the tested variants with fertilization, this indicator is best influenced by the application of soil fertilizer Italpolina.

Table 12. **Influence of the year, wheat species, sowing density and fertilization on the number of tillers, average for the period 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	2,6 b	***Tr. dicoccum* Sch.**	2,9 b	**500 g. s./m^2**	2,9 a	**Control**	2,9 a
2019/2020	3,2 a	***Tr. spelta* L.**	1,8 c	**700 g. s./m^2**	3,0 a	**Italpolina**	3,0 a
2020/2021	2,8 b	***Tr. monococcum* L.**	4,0 a	**900 g. s../m^2**	2,8 a	**Naturamin WSP**	2,8 a

4. Dynamics of increase in height

Table 13 presents the summarized average results for the independent influence of the year, the density of sowing and fertilizing in **emmer.** We have proven differences when considering the impact of the year. The highest plants are in 2019/2020, 2020/2021 and 2018/2019. Sowing density has less effect. The plants of the 700 g.s./ m^2 and 900 g.s./ m^2 variants develop 1.9 cm and 1.7 cm higher heights compared to the lowest sowing rate. Italpolina leads to 4.9 cm taller plants and Naturamin - 2.4 cm taller plant.

Table 13. **Influence of year, sowing density and fertilization on plant height in *Triticum dicoccum* Sch.,** ***2018-2021, cm***

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	78,4 b	500 g. s./m^2	91,3 a	Control	90,1 a
2019-2020	100,5 a	700 g. s./m^2	93,2 a	Italpolina	95,0 a
2020-2021	98,6 a	900 g. s./m^2	93,0 a	Naturamin WSP	92,5 a

When analyzing the average results of complex experience, including the influence of the year in **spelt**, it is found that it strongly influences this indicator. In the first year, the plants remained 28.8 cm to 27.7 cm lower than in 2019/2020 and 2020/2021. These differences are statistically proven. Density does not affect height. Fertilization with Italpolina soil fertilizer has been proven to lead to higher plant heights.

The summarized statistical processing for the three years in **einkorn** shows the strong influence of the year. Densities have minimal effect on this indicator and it is not proven. Fertilization has a more significant effect on heights. Italpolina increases growth by 2.9 cm and Naturamin by 3.5 cm.

Table 14.* Influence of year, sowing density and fertilization on plant height in *Triticum spelta* L., *2018-2021, cm

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	80,3 b	500 g. s./m^2	99,1 a	Control	96,1 b
2019-2020	109,1 a	700 g. s./m^2	98,9 a	Italpolina	104,7 a
2020-2021	108,0 a	900 g. s./m^2	99,3 a	Naturamin WSP	96,6 b

Table 15.* Influence of year, sowing density and fertilization on plant height in *Triticum monococcum* L., *2018-2021, cm

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	82,2 b	500 g. s./m^2	101,4 a	Control	99,5 a
2019-2020	113,2 a	700 g. s./m^2	102,4 a	Italpolina	102,4 a
2020-2021	109,4 a	900 g. s./m^2	101,1 a	Naturamin WSP	103,0 a

More conclusions can be drawn in the complex assessment of the data with the influence of year, species, density and fertilization included (*Table* 16). The clear differences between the first and the other two years are confirmed. *Triticum monococcum* L. develops the highest, followed by *Triticum spelta* L. and *Triticum dicoccum* Sch. The differences between the einkorn and emmer reach nearly 10%, and between the emmer and spelt - 7.1% and are proven statistically. There are no significant differences between the variants with different sowing rates. Fertilization with soil fertilizer has been shown to affect plant height, while foliar fertilizer has a lesser effect.

***Table* 16. Influence of the year, wheat species, sowing density and fertilization on the height of plants, 2018-2021, cm**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	80,3 b	***Tr. dicoccum* Sch.**	92,5 b	**500 g. s./m^2**	97,3 a	**Control**	95,2 b
2019/2020	107,6 a	***Tr. spelta* L.**	99,1 a	**700 g. s./m^2**	98,2 a	**Italpolina**	100,7 a
2020/2021	105,3 a	***Tr.monococcum L.***	101,6 a	**900 g. s./m^2**	97,8 a	**Naturamin WSP**	97,4 ab

5. Foliar gas exchange of plants from emmer, spelt and einkorn when fertilizing with soil and foliar fertilizer

Studies have shown (Table 17) that in spelt applied soil and foliar fertilization increases the rate of photosynthesis of plants. The effect is more pronounced in foliar treatment with Naturamin at higher crop densities. In this variant, the intensity of transpiration is also higher. Improved foliar gas exchange (P_N and E) corresponds to the better stomatal conductivity (g_s) found in plants treated with foliar fertilizer. This proves that the oral factor leads to the rate of photosynthesis (increased conductivity of CO2). Significant differences between the variants have been found in the soil application of Italpolina fertilizer, as the P_N values decrease with an increasing number of plants per m^2. Data on transpiration intensity and stomatal conductivity follow the trends in photosynthesis. Elevated E and g_s lead to higher intercellular concentrations of CO_2, which is probably one of the main reasons for greater photosynthesis.

In the case of emmer and einkorn, the results differ from those obtained in spelt. The highest rate of photosynthesis was found in control. In all variants studied, higher crop density leads to lower P_N. In both species, the intensity of transpiration is highest in foliar plant nutrition. In principle, changes in the leaf gas exchange of plants depend stomatal and mesophilic factors. Since the values of the stomatal conductivity of emmer and einkorn vary within narrow limits, it can be assumed that mesophilic factors (pigment content, light, biochemical processes of photosynthesis) affect the leaf gas exchange of these plants.

***Table* 17. Influence of fertilization on the intensity of photosynthesis in the leaves of spelt, emmer and einkorn plants**

Variants	P_N [μmol $m^{-2}s^{-1}$]					
	500 бр. m^{-2}		700 бр. m^{-2}		900 бр. m^{-2}	
***Triticum spelta* L.**						
Control	13,12	100,0%	13,14	100,0%	13,45	100,0%
Italpolina	17,51	133,5%	13,65	103,9%	14,57	108,3%
Naturamin WSP	16,18	123,3%	17,41	132,5%	19,46	144,7%
LSD α=0.05	1,778		1,215		2,041	
***Triticum monococcum* L.**						
Control	9,24	100,0%	8,92	100,0%	7,59	100,0%
Italpolina	6,77	73,3%	7,11	79,8%	7,77	102,4%
Naturamin WSP	8,51	92,1%	8,41	94,3%	7,42	97,8%
LSD α=0.05	0,935		1,778		1,472	
***Triticum dicoccum* Sch.**						
Control	13,24	100,0%	11,99	100,0%	11,70	100,0%
Italpolina	11,90	89,9%	11,12	92,7%	10,00	85,5%
Naturamin WSP	12,35	93,3%	11,75	98,0%	10,10	86,3%
LSD α=0.05	1,583		1,467		1,148	

6. Productive stems

The dynamics of productive stem formation give us information about what productivity can be expected from a crop that has started its vegetation with a certain number of plants and developed a certain number of tillers of each plant - unproductive and productive.

The summarized results within the **emmer** species show the strong influence of the year in favor of the more favorable ones (2019/2020 and 2020/2021). Although with unproven differences, increasing the sowing density increases the number of productive stems. Both tested fertilizers - soil and foliar- also positively affect the indicator, with a more significant predominance of soil fertilizer.

Table 18. Influence of the year, sowing density and fertilization on the productive stems in *Triticum dicoccum* Sch., 2018-2021, number per m^2

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	526 b	500 g. s./m^2	715 a	Control	718 a
2019-2020	892 a	700 g. s./m^2	772 a	Italpolina	796 a
2020-2021	866 a	900 g. s./m^2	796 a	Naturamin WSP	771 a

The summarized information on the independent influence of the density of sowing and fertilization in *Table* 19 shows that **spelt** is much more sensitive to sowing density than emmer. In all three years, with the increase of the sowing rate, the number of productive stems has increased. Fertilization does not have the expected effect. Taking into account the independent influence of this factor for spelt, it is established that the control variant (without fertilization) has the highest number of productive stems/ m^2.

Table 19. Influence of the year, sowing density and fertilization on the productive stems in *Triticum spelta* L., 2018-2021, number per m^2

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	433 b	500 g. s./m^2	368 C	Control	514 a
2019-2020	537 A	700 g. s./m^2	518 b	Italpolina	506 a
2020-2021	517 A	900 g. s./m^2	601 a	Naturamin WSP	467 a

The summary data for the three years in **einkorn** confirm the strong influence of the year. The optimum sowing density for this indicator is 700 g. s./ m^2. Both types of fertilization have a positive effect, but it is stronger in soil fertilizer (*Table* 20).

***Table* 20. Influence of the year, sowing density and fertilization on the productive stems in *Triticum monococcum* L., 2018-2021, number per m^2**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	819 B	500 g. s./m^2	902 a	Control	903 a
2019-2020	1009 a	700 g. s./m^2	968 a	Italpolina	977 a
2020-2021	996 a	900 g. s./m^2	954 a	Naturamin WSP	943 a

When included in the statistical analysis and the species, as a major factor in the multifactorial study (*Table* 21*),* it is established that there are also significant differences between the three species in terms of this indicator. The largest number of productive stems in m^2 are developed at *Tr. monococcum* L., followed by *Tr. dicoccum* Sch., and finally *Tr. spelta* L. These results are explained by the different degrees of productive tillering reported in the three species.

Sowing density has also been shown to affect this indicator. The smallest sowing rate forms a proven smaller number of productive stems. We have the most number in the variant with the highest sowing rate, but the differences between 700 and 900 g.s./ m^2 are not proven.

The strongest influence of the variants with different fertilization has the soil fertilizer and less foliar fertilizer.

***Table* 21. Influence of the year, wheat species, sowing density and fertilization on productive stems, 2018-2021, number/ m^2**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	592 b	***Tr. dicoccum* Sch.**	761 b	**500 g. s./m^2**	661 b	**Control**	711 a
2019/2020	812 a	***Tr. spelta* L.**	495 c	**700 g. s./m^2**	752 a	**Italpolina**	760 a
2020/2021	793 a	***Tr.monococcum* L.**	941 a	**900 g. s./m^2**	784 a	**Naturamin WSP**	727 a

7. Harvest index (HI)

The harvest index is considered an important component of yield. It shows the set productive potential of the genotype and its realization under different agro-ecological conditions and the influence of the factors of agrotechnics.

The summarized information about the independent influence in the complex experience of the 4 main factors of the study - year, wheat species, sowing density and fertilization, on average for the period 2018-2021, is presented in *Table* 22. The highest harvest index is the first growing year - 0.36, followed by the third year -

2020/2021 - 0.33, and the lowest is 2019/2020 - 0.32. The differences are statistically proven. Of the three species with the highest harvest index, spelt is 0.36. It is followed by emmer and einkorn. Sowing density has less effect. With a slight difference, at the highest sowing rate of 900 g.s. /m^2, the harvest index is higher. On average, fertilization does not positively affect the index for the period.

***Table* 22. Influence of the year, wheat species, sowing density and fertilization on the harvest index, 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	0,36 a	***Tr. dicoccum* Sch.**	0,33 b	**500 g. s./m^2**	0,33 a	**Control**	0,34 a
2019/2020	*0,32 c*	***Tr. spelta* L.**	0,36 a	**700 g. s./m^2**	0,33 a	**Italpolina**	0,33 a
2020/2021	0,33 b	***Tr. monococcum* L.**	0,31 c	**900 g. s./m^2**	0,34 a	**Naturamin WSP**	0,34 a

8. Yield

Yield is a resultant value that is a function of several factors and elements of productivity described so far.

8.1. *Triticum dicoccum* Sch.

In the statistical processing for the multi-year period, including the influence of the year, the strong influence of the agro-meteorological conditions of the year is confirmed with proof of the differences. The tendency to increase the yield with increasing the sowing rate to 900 g.s./m^2 is confirmed, as the difference with the lowest sowing rate reaches 19,1%.

Of the types of fertilization, only soil fertilization is of interest, which leads to an increase in yield by 11%.

Table 23.* Influence of year, sowing density and fertilization on grain yield in *Triticum dicoccum* Sch., *2018-2021, kg/da

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	134,5 c	500 g. s./m^2	208,7 a	Control	217,0 a
2019-2020	290,8 a	700 g. s./m^2	223,3 a	Italpolina	240,8 a
2020-2021	255,0 b	900 g. s./m^2	248,5 a	Naturamin WSP	222,6 a

8.2. *Triticum spelta* L.

With the inclusion of the year as a surveyed factor for the yield variation, it is established that the most favorable year for obtaining the maximum yield is 2019/2020. With proven differences after this year and with each other, follow 2020/2021 and 2018/2019 as the optimal sowing rate stands out 700 g.s./ m2, after which the yield begins to decrease. It has been proven that Italpolina alone affects increasing the yield compared to unfertilized control (*Table* 24).

Table 24.* Influence of year, sowing density and fertilization on grain yield in *Triticum spelta* L., *2018-2021, kg/da

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	185,1 c	500 g. s./m^2	266,5 a	Control	278,2 b
2019-2020	364,7 a	700 g. s./m^2	307,4 a	Italpolina	330,5 a
2020-2021	322,1 b	900 g. s./m^2	298,0 a	Naturamin WSP	263,2 b

8.3. *Triticum monococcum* L.

The summarized results and the statistical processing of the obtained results for the yield of einkorn for the three years, including the influence of the year, confirm our conclusions from each year separately. The second year has proven to be the most favorable for high yields. Sowing density does not affect yield. Soil fertilizer Italpolina leads to a slight increase in yield (6.3%) (*Table* 25).

***Table* 25. Influence of year, sowing density and fertilization on grain yield in *Triticum monococcum* L., 2018-2021, kg/da**

Influence of a factor **Year**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018-2019	227,6 b	500 g. s./m^2	265,7 a	Control	259,1 A
2019-2020	329,5 a	700 g. s./m^2	264,9 a	Italpolina	275,5 A
2020-2021	240,9 b	900 g. s./m^2	267,3 a	Naturamin WSP	263,3 A

The summarized data processing in the complex experiment, including the influence of the species, is presented in *Table* 26. The conclusions made about the influence of the year on the individual species are reaffirmed. The highest yield is obtained in the second year (2019/2020) - 328.3 kg/ da, which is 54.8% more than the first (most unfavorable year). The third year is also more favorable than the first and less favorable than the second year.

Of the three species, *Triticum spelta* L. has the highest productive potential - 290.6 kg/ da grain yield, followed by *Triticum monococcum* L. - 266 kg/da and *Triticum dicoccum* Sch. - 226.8 kg/day. The differences between the three species are statistically proven.

On average for the three species, our hypothesis is confirmed that the increase in sowing density leads to an increase in yield, compared to the traditionally used in our country 500 g.s./ m^2 - by 7.4% in the second tested sowing rate - 700 g.s./ m^2 and by 9.8% at the highest sowing rate - 900 g.s./ m^2.

Italpolina soil fertilizer has been proven to increase yields by approx. 12% compared to the unfertilized control.

Table* 26. Influence of the year, wheat species, sowing density and fertilization on grail yield, 2018-2021, *kg/da

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	182,4 c	***Tr. dicoccum* Sch.**	226,8 c	500 g. s./m^2	247,0 a	**Control**	251,4 b
2019/2020	328,3 a	***Tr. spelta* L.**	290,6 a	700 g. s./m^2	265,2 a	**Italpolina**	282,3 a
2020/2021	272,7 b	***Tr.monococcum* L.**	266, 0 b	900 g. s./m^2	271,3 a	**Naturamin WSP**	24-9,7 b

9. Structural elements of the spike

9.1. *Triticum dicoccum* Sch.

Emmer develops a small spike, regardless of the year and other factors tested. The length of the spike is between 2,9 and 3,4 cm in the most unfavorable 2018/2019. In the next year, which we define as the most favorable, the maximum length reaches 4.2 cm. According to this indicator - spike length, there is a tendency to decrease the values with increasing sowing rate from 500 to 900 g.s./m^2. The influence of fertilization is more visible only in the second experimental year, which we define as the most favorable. This year, soil and foliar fertilization led to an extension of the spike. The statistical analysis of the data from the three years proves the strong, proven influence of the year on this indicator.

The number of spikelets in a spike ranges between 9 and 10,3 in the first year, from 9 to 11,5 in the second and 9.5 to 11,5 in the third year. This indicator follows the same dependencies as the length of the spike. Most spikelets on average for the period – 10,3 number, are formed at the lowest sowing rate - 500 g.s./m^2. The number decreases to 900 g.s./m^2 and reaches 9,7 units. Fertilization has a little positive effect on this trait (up to 3% for Italpolina). Naturamine shows a somewhat corrective effect in the first unfavorable year, slightly increasing the number of spikelets. It has been proven that fewer spikelets in a spike develop only in the first experimental year.

Each spike of emmer develops from 12,3 to 15 grains in the first year, from 10 to 14,3 in the second and from 11,3 to 14 in the third year. The analysis of the influence of sowing density on the indicator by years proves that the number of grains in a spike decreases with increasing sowing density. On average for the three years, the differences are confirmed statistically. Fertilization has a positive effect on the number of grains. In the first two years the influence of foliar fertilizer Naturamin is stronger. On average for the period there are from 3,9 to 7% differences in favor of soil and foliar fertilization compared to the control, respectively. The analysis of the influence of the year shows the opposite trend in the number of spikes and the length of the spike. Most grains are formed in the first year of the study. In the second and third year, the number of grains was 10,6 to 9.2% lower.

The grain mass of a spike is the final result value closest to the harvested yield. There is a slight tendency to decrease the values of the indicator with increasing sowing rate, more pronounced between 700 and 900 g.s./m^2 in the first year and in the average results for the period. Fertilization effects in different ways and to different degrees in the years of testing. In the first two years, soil fertilization negatively affects the grain mass, while in the third year, it has a positive effect. However, foliar fertilization has a positive effect in all three years. In terms of this indicator, the year has a strong proven impact. The heaviest grain is formed in the third experimental year.

9.2. *Triticum spelta* L.

Spelt wheat has significantly longer spikes than emmer. In all three years, with an increasing sowing rate, the length of the spike decreases. In the second and third years and for the whole experimental period, the differences are proved statistically. Fertilization, although less, also affects the length of the spike. The differences are better expressed in soil fertilizer but are not proven. The year also affects this indicator. The spikes in the first year have proven to be shorter.

The number of spikelets in the spike is more dependent on the interaction of the tested factors - sowing density and fertilization - in the second and third years. In both years, more spikelets in the spike have been proven to develop at the lowest sowing rate of 500 g.s./m^2, followed successively by higher sowing rates. The Fertilizer factor is less important in the formation of this indicator. Only in the more favorable 2019/2020 and 2020/2021 soil fertilization has some positive impact, increasing the number by 13,6 and 4.4%, respectively. Naturamine has no effect. The influence of the Year factor in relation to this indicator is also not taken into account.

In all three years, at the lowest sowing rate, the number of grains in a spike is the largest, and these differences are greater under the more favorable conditions of 2019/2020. On average for the period, the differences are also proven. Both fertilization variants have a positive effect on the indicator, but the influence of Italpolina fertilizer is stronger and is statistically proven.

The grain mass of one spike is from 1,23 to 1,74 g in the first year, and with more varying values in the second (0,79 to 1,34) and third (0,73 to 1,82) years. In all three years and on average for the period, the heaviest grain is formed at the lowest sowing rate. Soil fertilization has a stronger influence than foliar fertilization, and there are proven differences between the results on average for the period. The grain is also the largest in this species in the first experimental year.

9.3. *Triticum monococcum* L.

According to the length of the spike, the einkorn occupies an intermediate position between the emmer and the spelt. There is no statistical difference between the established spike lengths within each year. Quite naturally, the density affects the indicator in one direction. In all three years and the average for the period, with increasing sowing rate, the length of the spike decreases. The differences are not proven, but the trend is the same in all three years. Fertilization definitely does not affect the length of the spike. The most favorable conditions for the development of a longer spike is 2019/2020. In the first year, it is formed with approx. 33%. Shorter spike.

The number of spikelets is between 14,3 and 17 in the spike in the first year and between 19 and 25,3 in the other two years. Sowing density does not significantly affect this indicator. There are no differences on average for the period between the first two densities, while at the highest density, the number of spikelets decreases slightly. The impact of fertilization is diverse in the three years. In the first year, the highest number was reported with Naturamin, which is more noticeable in the year with more stressful conditions for the culture. These data once again confirm the corrective function of foliar fertilizer in drought conditions. In the second year soil fertilization has a negative impact, and in the third year - a weak positive impact. In the second and third years, Naturamin did not affect the studied indicator. The influence of the year is also strong for this wheat. The first year has proven lower indicator values than the other two.

The number of developed grains is narrow - from 13 to 16,3 in the first year, from 13,8 to 17,3 in the second and from 14 to 16,8 in the third. There are also minimal differences between the tested densities, but they favor the lowest sowing rate for the three-year study period. Fertilization with foliar fertilizer again positively impacts this indicator only in the first year. Soil fertilizer has a very small effect on the indicator, on average for the period. The year has no significant impact.

The grain mass in the spike varies within narrow limits within each year individually. A larger grain is formed with a very slight predominance at the smallest sowing rate. Slightly negative effect is observed in soil fertilization, and foliar fertilization affects the grain mass in the spike, mainly in the first and third years. The first experimental year, 2018/2019, turned out to be the most favorable for forming larger grain.

9.4. Comprehensive assessment of the influence of the year, wheat species, sowing density and fertilization on the main structural components of the spike

The results of the variance analysis of the data related to the main structural components of the class in the three ancient species, taking into account the influence of the year, are presented in *Table* 27.

Within the experimental period, the year proved to be the strongest factor, influencing the main components of the spike in different ways. Proven longer spike length and a larger number of spikelets in the spike developed in the second and third experimental years. However, the number of grains, as well as the mass of grain in a spike, is highest in the first (2018/2019) year, followed by the third (2020/2021) and second (2019/2020) years.

The three species also differ significantly in terms of spike components. *Triticum spelta* L. is the leader in terms of spike length, number of grains in the spike and grain mass in the spike. *Triticum monococcum* L. forms the longest spike, but with the smallest grain mass in it. *Triticum dicoccum* Sch. has the shortest spike, with the fewest spikelets in it and with the fewest number of grains per spike. Regarding the mass of the grain in the class, *Triticum dicoccum* Sch. proven to be superior to *Triticum monococcum* L., but proven to be inferior to *Triticum spelta* L.

Sowing density affects the different parameters of the spike in a specific way. The length of the spike and the number of spikelets in the spike decrease with increasing sowing rate from 500 to 900 g.s./m^2, although the trend is not statistically proven in the complex statistical analysis. However, it is proved that the larger number of grains and their greater mass at the lowest sowing rate - 500 g.s./m^2, compared to the other two.

***Table* 27. Influence of the year, wheat species, sowing density and fertilization on the main structural components of the spike, 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
Spike lenght, cm							
2018/2019	4,9 b	***Tr. dicoccum* Sch.**	3,5 c	**500 g. s./m^2**	5,7 a	**Control**	5,4 a
2019/2020	5,8 a	***Tr. spelta* L.**	8,2 a	**700 g. s./m^2**	5,4 a	**Italpolina**	5,5 a
2020/2021	5,7 a	***Tr. moncoccum* L.**	4,7 b	**900 g. s./m^2**	5,3 a	**Naturamin WSP**	5,5 a
Spikelets number per spike							
2018/2019	12,9b	***Tr. dicoccum* Sch.**	10,1 c	**500 g. s./m^2**	14,8a	**Control**	14,1a
2019/2020	15,0a	***Tr. spelta* L.**	13,6 b	**700 g. s./m^2**	14,3a	**Italpolina**	14,6a
2020/2021	14,9a	***Tr. moncoccum* L.**	19,2 a	**900 g. s./m^2**	13,7a	**Naturamin WSP**	14,1a
Grain number per spike							
2018/2019	16,5a	***Tr. dicoccum* Sch.**	13,2 c	**500 g. s./m^2**	16,9a	**Control**	15,3a
2019/2020	15,3b	***Tr. spelta* L.**	19,5 a	**700 g. s./m^2**	15,7b	**Italpolina**	16,3a
2020/2021	15,9ab	***Tr. moncoccum* L.**	15,1 b	**900 g. s./m^2**	15,1b	**Naturamin WSP**	16,1a
Grain mass per spike, g							
2018/2019	0,83 a	***Tr. dicoccum* Sch.**	0,58 b	**500 g. s./m^2**	0,86 a	**Control**	0,72 a
2019/2020	0,69 b	***Tr. spelta* L.**	1,23 a	**700 g. s./m^2**	0,74 b	**Italpolina**	0,81 a
2020/2021	0,80 ab	***Tr. moncoccum* L.**	0,50 c	**900 g. s./m^2**	0,72 b	**Naturamin WSP**	0,78 a

In the conditions of the stronger influence of the year, the wheat species and the sowing density, the fertilization does not have a significant influence on average for the period within the experimental 2018-2021. However, there is a trend for a positive effect of Italpolina soil fertilizer on the number of spikelets (within 3.5%), the number of grains (within 6.5%) and the mass of grains in the spike (within 12.5 %). Naturamine has an even weaker effect, mainly on the number of grain and grain mass in the spike.

10. Correlation dependencies between basic elements of productivity

Correlation analysis was used to establish the strength and dependence between the main elements of the spike, as well as between yield and some basic productive components. In our study, the correlation coefficient (R) introduced by Carl Pearson was used, based on the fundamental assumption that the two variables studied are linearly dependent.

In the analysis, we also used the coefficient of determination ($D = R^2$), also called the coefficient of certainty. This coefficient shows what% (R^2x100) of the changes in the factor value will lead to changes in the result variable.

10.1. Correlation dependencies between the elements of the spike

The grain mass in the spike of emmer is in a medium-strong positive correlation with the number of grains, the number of spikelets, and the spike's length (*Table* 28).

***Table* 28. Correlation dependencies between basic spike parameters of *Tritium dicoccum* Sch. (Correlation coefficient - R; Determination coefficient - D)**

Spike parameter	Grain mass per spike, g		Grain number per spike		Number of spikelets per spike		Spike lnght, cm	
	R	D	R	D	R	D	R	D
Grain mass per spike, g	**1,000**		0,423**	18	0,417**	17	0,471**	22
Grain number per spike			**1,000**		0,625**	39	0,495**	25
Number of spikelets per spike					**1,000**		0,735**	54
Spike lnght, cm							**1,000**	

** The correlation is significant at the level of P≤0.01;

The variation of the productivity of the spike is influenced almost in the same way (in 17-22%) by the variation of these productive elements of the spike. The number of spikelets very much depends on the formed length of the spike, and the number of grains in 39% of cases is determined by this number. In emmer there is a close and always proven relationship between all elements of the spike, but the strongest relationship is between the number of spikelets in the spike and the length of the spike.

In **spelt** wheat (*Table* 29), all successively formed elements are indirect and very strong positive correlation. For example, the length of the spike very strongly (in 54% of cases) determines the number of developed spikelets in the spike, and the number of spikelets is in a very strong and proven correlation (R = 0.719 **) with the number of formed grains. The most direct relationship is between the number of grains and their mass, and the dependence, in this case, is very strong (R = 0.679 **).

In **einkorn**, not all correlations have been proven (*Table* 30). Direct and proven dependencies are found between the mass of the grain and the number of grains (R = 0.514 **), slightly stronger between the number of grains and the number of spikelets (R = 0.665 **), and even stronger between the number of spikelets and spike length (R = 0.870 **). There is no direct relationship between the weight of the grain in the spike and the number of spikelets in the spike, as well as between the grain mass in the spike and the length of the spike.

***Table* 29. Correlation dependencies between basic spike parameters of *Tritium spelta* L. (Correlation coefficient - R; Determination coefficient - D)**

Spike parameter	**Grain mass per spike, g**		**Grain number per spike**		**Number of spikelets per spike**		**Spike lnght, cm**	
	R	D	R	D	R	D	R	D
Grain mass per spike, g	**1,000**		0,679**	46	0,464**	22	0,316**	10
Grain number per spike			**1,000**		0,719**	52	0,616**	38
Number of spikelets per spike					**1,000**		0,734**	54
Spike lnght, cm							**1,000**	

***Table* 30. Correlation dependencies between basic spike parameters of *Tritium monococcum* L. (Correlation coefficient - R; Determination coefficient - D)**

Spike parameter	**Grain mass per spike, g**		**Grain number per spike**		**Number of spikelets per spike**		**Spike lnght, cm**	
	R	D	R	D	R	D	R	D
Grain mass per spike, g	**1,000**		0,514**	26	0,130	2	0,110	1
Grain number per spike			**1,000**		0,665**	44	0,661**	44
Number of spikelets per spike					**1,000**		0,870**	76
Spike lnght, cm							**1,000**	

The correlation analysis shows that the three species have different strong correlations. They are most stable in *Triticum spelta* L.. In einkorn, not all dependencies have been proven, which suggests that these traits are not genetically stable.

10.2. Correlation dependencies between grain yield and productivity elements

Table 31 shows the correlation coefficients between the yield and some of the examined elements of productivity in emmer. Of all the observed dependences, the strongest is between the yield and the productive stems (R = 0.759 **). The coefficient of determination shows that in 58% of the cases the variation of the yield is due to the variation of the productive stems. The relationship between yield and grain mass in the spike has been proven, but is weaker (R = 0.278 **). The other established dependencies show the insignificant influence of the respective element on the yield.

***Table* 31. Correlation dependencies between the yield and productivity parameters of *Tritium dicoccum* Sch. (Correlation coefficient - R; Determination coefficient - D)**

Productivity parameters	**Yield kg/da**	**Germinated seeds/ m^2**		**Productive tillering, number of tillers /m^2**		**Productive stems, Number spikes /m^2**		**Grain mass in spike, g**	
		R	D	R	D	R	D	R	D
Yield kg/da	**1,000**	-0,094	1	0,005	0	0,759**	58	0,278**	8
Germinated seeds/ m^2		**1,000**		-0,139	2	-0,114	1	-0,039	0
Productive tillering, number of tillers /m^2				**1,000**		-0,108	1	-0,077	1
Productive stems, Number spikes /m^2						**1,000**		0,196*	4
Grain mass in spike, g								**1,000**	

** The correlation is significant at the level of P≤0.01;

Yield in **spelt wheat** (*Table* 32) is in the average proven positive correlation with the number of germinated seeds and the productive stem formation. Productive stems are directly dependent on the number of germinated seeds (R = 0.503 **). The dependence of the grain mass in the spike and the productive stems is negative (R = -0.323 **), which predetermines the dominant importance of the productive stems for the formation of the final yield.

***Table* 32. Correlation dependencies between the yield and productivity parameters of *Tritium spelta* L. (Correlation coefficient - R; Determination coefficient - D)**

Productivity parameters	Yield kg/da	Germinated seeds/ m^2		Productive tillering, number of tillers /m^2		Productive stems, Number spikes /m^2		Grain mass in spike, g	
		R	D	R	D	R	D	R	D
Yield kg/da	**1,000**	0,347**	12	0,035	0	0,410**	17	-0,005	0
Germinated seeds/ m^2		**1,000**		0,095	1	0,503**	25	-0,409**	17
Productive tillering, number of tillers /m^2				**1,000**		0,161	3	-0,329**	11
Productive stems, Number spikes /m^2						**1,000**		-0,323**	10
Grain mass in spike, g								**1,000**	

** The correlation is significant at the level of P≤0.01;

The **einkorn** (Table 33) forms its yield under the proven influence of its productive tillering and less under the influence of its productive stems. Productive tillering largely determines the variation of productive stems, while the number of germinated seeds does not have a direct impact.

In conclusion, we can summarize that the main factor that has been proven to directly and most strongly affect the yield of the three tested ancient wheat is the productive stems.

The strongest relationship between yield and productive stems is the strongest in emmer (R = 0.759 **). The yield of this species is in a proven but less positive correlation with the grain mass in the spike (R = 0.278 **).

In spelt, the yield is positively dependent on the productive stems (R = 0.410 **) and the number of germinated seeds (R = 0.347 **).

In the case of einkorn, the productive tillering is the factor that strongly influences the productive stem (R = 0.419 **). Both elements of productivity are in proven average correlations with yield (R = 0.422 ** and R = 0.371 **).

***Table* 33. Correlation dependencies between the yield and productivity parameters of *Tritium monococcum* L. (Correlation coefficient - R; Determination coefficient - D)**

Productivity parameters	**Yield kg/da**	**Germinated seeds/ m^2**		**Productive tillering, number of tillers /m^2**		**Productive stems, Number spikes /m^2**		**Grain mass in spike, g**	
		R	D	R	D	R	D	R	D
Yield kg/da	**1,000**	-0,121	1	0,422**	18	0,371**	14	-0,048	0
Germinated seeds/ m^2		**1,000**		-0,180	3	0,058	0	-0,034	0
Productive tillering, number of tillers /m^2				**1,000**		0,419**	18	-0,055	0
Productive stems, Number spikes /m^2						**1,000**		-0,002	0
Grain mass in spike, g								**1,000**	

** The correlation is significant at the level of P≤0.01;

11. Grain quality indicators

1. Physical qualities

1.1. 1000-grain weight

The complex analysis of the influence of all factors (year, wheat species, sowing rate and fertilization) on average for the three-year study period is presented in Table 34. This indicator is strongly influenced by the year with its agro-climatic features. The three species have also been shown to differ.

Spelt wheat has the highest potential for large grains. Her grain is approx. 20% heavier than that of the emmer and with approx. 34% of that of einkorn. The differences are statistically proven. Against the background of the strong influence of these two factors, the sowing density is weakly reflected and the differences are not proven. Still, there is a tendency - with increasing density, the 1000-grain weight to decrease. Fertilization has an even lesser effect.

Table 34. **Influence of the year, wheat species, sowing density and fertilization on 1000-grain weight, average for the period 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	38,4 a	***Tr. dicoccum* Sch.**	33,8 b	**500 к.с./m²**	35,4 a	**Control**	34,5 a
2019/2020	32,7 b	***Tr. spelta* L.**	42,1 a	**700 к.с./m²**	34,4 a	**Italpolina**	34,7 a
2020/2021	32,5 b	***Tr.monococcum* L.**	27,7 c	**900 к.с./m²**	33,8 a	**Naturamin WSP**	34,4 a

1.2. Hectoliter mass

The complex assessment and analysis of variance for the influence of the year, wheat species, sowing density and fertilization are presented in *Table* 35. Within the experimental period 2018-2021, the most favorable conditions for this indicator are in the second 2019/2020, followed by 2020/2021 and 2018/2019 with proven differences. The emmer accumulates the highest hectolitre mass, followed by the einkorn and spelt. The differences are statistically significant. There are no strong trends in the impact of sowing density and fertilization. The highest values of the indicator are reported at 900 g.s. /m^2, and fertilization with Italpolina has a rather negative effect.

Table 35. **Influence of the year, wheat species, sowing density and fertilization on hectoliter mass, average for the period 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	43,8 b	***Tr. dicoccum* Sch.**	50,0 a	**500 к.с./m²**	45,1 a	**Control**	45,7 a
2019/2020	46,7 a	***Tr. spelta* L.**	41,6 c	**700 к.с./m²**	45,2 a	**Italpolina**	45,1 a
2020/2021	45,8 a	***Tr.monococcum* L.**	44,7 b	**900 к.с./m²**	45,9 a	**Naturamin WSP**	45,5 a

1.3. Grain husk

Grain husk is a specific indicator of primitive (wild) wheat. The grain is tightly wrapped with flower husks. The presence of husk protects the species from fungal diseases, but is also a factor that affects some specifics in agricultural technology and the initial development of plants.

Table 36 presents the generalized statistical processing of data in a complex 4-factor experience - taking into account the independent influence of each factor - year, species, sowing density and fertilization. We have more favorable conditions for a low% of the formed husk in the first and third years of the experiment. Of the three species with a high % of husk is *Triticum spelta* L., followed by *Triticum monococcum* L. and *Triticum dicoccum* Sch. The differences are significant and are proven statistically. Minimal reduction of the share of chaff is reported by increasing the sowing rate of 500 to 900 g.s./ m^2 and the use of Italpolina.

Table 36. **Influence of the year, wheat species, sowing density and fertilization on grain husk, average for the period 2018-2021**

Influence of a factor **Year**		Influence of a factor **Wheat species**		Influence of a factor **Sowing density**		Influence of a factor **Fertilization**	
2018/2019	26,1 b	***Tr. dicoccum* Sch.**	22,4 c	**500 к.с./m^2**	27,5 a	**Control**	27,3 a
2019/2020	29,3 a	***Tr. spelta* L.**	31,5 a	**700 к.с./m^2**	27,0 a	**Italpolina**	27,0 a
2020/2021	26,0 b	***Tr.monococcum* L.**	27,5 b	**900 к.с./m^2**	26,9 a	**Naturamin WSP**	27,2 a

2. Biochemical parameters of the grain

2.1. *Triticum dicoccum* Sch.

Emmer is characterized by a higher crude protein content than durum and bread wheat. The amount of protein depends on the genotype, environment and growing conditions. Many authors report strong variations in protein content depending on genotype. Protein content can reach 20%, but it is usually about 18% (Kyosev, 2018; Konvalina et al, 2013; Stolickova, 2014).

Table 37 presents average data on basic biochemical parameters in emmer.

***Table* 37. Content of crude protein, lysine, crude fiber and crude ash in *Triticum dicoccum* Sch., %**

Parameters	N	Min	Max	Mean	Std. Error	Std. Deviation	VC, %
Crude protein, %	9	12,74	14,84	**13,37**	0,23	0,70	**5,22**
Lysine, %	9	0,33	0,43	**0,37**	0,01	0,03	**9,35**
% lisine in % protein, %	9	2,36	3,29	**2,75**	0,10	0,31	**11,30**
Crude fiber, %	9	0,15	1,54	**0,95**	0,14	0,42	**44,38**
Crude ash, %	9	1,46	1,84	**1,61**	0,03	0,10	**6,48**

The content of crude protein in the studied variants of emmer is in the range of 12,74% (in the variant with foliar fertilizer and sowing rate 900 g.s./m^2) to 14,84% (in the control and 500 g.s. /m), the average content of the studied indicator 13,37%.

The average lysine content of the 9 variants studied was 0,37%.

With the indicator % lysine in% protein, the variant with soil fertilizer and 500 g.s./ m^2 – 3,19% has the highest content.

It was found that the content of crude fiber in the grain of emmer is higher than that of durum wheat. The studied indicator varies from 0,15% to 1,54% in the analyzed variants, with an average value of 0,95%.

The content of raw ash in the grain of the analyzed variants varies from 1,46% to 1,84%.

2.2. *Triticum spelta* L.

The crude protein content of spelt wheat under the experimental conditions is presented in *Table* 38. It ranges from 16,41% (control and 900 g.s./ m^2) to 19,79% (leaf fertilizer and 700 g.s./ m^2), average content of the studied indicator 17,78%.

With the indicator % lysine in% protein, the variant with foliar fertilizer and 900 g.s. / m^2 has the highest content – 2,05%. The content of raw ash in the grain of the analyzed variants varies from 1,45% to 1,98%.

***Table* 38. Content of crude protein, lysine, crude fiber and crude ash in *Triticum spelta* L., %**

Parameters	N	Min	Max	Mean	Std. Error	Std. Deviation	VC, %
Crude protein, %	9	16,41	19,79	**17,78**	0,42	1,27	**7.14**
Lysine, %	9	0,27	0,36	**0,32**	0,01	0,03	**9,52**
% lisine in % protein, %	9	1,60	2,05	**1,78**	0,04	0,13	**7,42**
Crude fiber, %	9	0,00	1,99	**0,87**	0,25	0,76	**86,92**
Crude ash, %	9	1,45	1,98	**1,68**	0,07	0,22	**13,08**

2.3. *Triticum monococcum* L.

From the point of view of the usability of einkorn in the selection, the greatest interest is the high yield of grain protein per da compared to many modern wheat varieties. It was found that the content of crude protein in the grain varies from 17% to 22,5%. The amino acid composition is similar to that of wheat, varying on a wide scale in the amount of total protein.

The content of crude protein in the test specie under the conditions of the experiment (*Table* 39) is in the range from 12,40% (for the variant with foliar fertilizer and 900 g.s./m^2) to 17,04% (for the control and 500 g.s./m^2), the average content of the studied indicator is 15,24%.

The average lysine content of the 9 variants studied was 0,37%.

With the indicator % lysine in % protein, the variant with foliar fertilizer and 900 g.s./m^2 – 3,14% has the highest content.

It was found that the content of crude fiber in the grain of einkorn is higher than that of durum wheat. In the studied variants, the studied indicator varies from 0,00% to 1,64%, with an average value of 0,40%.

The content of raw ash in the grain of the analyzed variants varies from 1,44% to 1,95%.

***Table* 39. Content of crude protein, lysine, crude fiber and crude ash in *Triticum monococcum* L., %**

Parameters	N	Min	Max	Mean	Std. Error	Std. Deviation	VC, %
Crude protein, %	9	12,40	17,04	**15,24**	0,47	1,42	**9,30**
Lysine, %	9	0,34	0,42	**0,37**	0,01	0,03	**7,33**
% lisine in % protein, %	9	2,05	3,14	**2,47**	0,11	0,34	**13,62**
Crude fiber, %	9	0,00	1,64	**0,40**	0,17	0,50	**123,17**
Crude ash, %	9	1,44	1,95	**1,63**	0,06	0,18	**10,91**

3. Content of macro- and microelements in the grain

Macro- and micronutrients are minerals that are essential for human health. Magnesium is included in our study as a macronutrient, and copper, iron, manganese and zinc are micronutrients. They are necessary for the normal life of man. They are part of enzymes, vitamins and hormones and affect growth, reproduction, blood formation, *etc*. Their deficiency or excess leads to metabolic disorders.

In our study (*Table* 40), the three ancient wheat- emmer, spelt and einkorn, were compared in terms of the content of **magnesium** in naked grain. The emmer has the highest content - 866 mg/kg grain. It is followed by spelt (812 mg/kg) and at least einkorn (768 mg/kg).

The same table shows the **iron** content (mg/kg) in the naked grain (hulled). This trace element is characterized by the largest share in the blood, therefore it is associated with the proper function of the immune system and good energy production in the body. The spelt grain has the highest iron content – 35,35 mg/kg. This makes it a leader in terms of this trace element as well.

The chemical trace element **zinc** is extremely important for the growth and development of reproductive organs. Through it, the levels of vitamin E in the blood are maintained. Einkorn may be recommended to overcome zinc deficiency. It contains 42 mg/ kg of zinc in its grain, 38.6% superior to emmer and 32.4% spelt.

Manganese is involved in the metabolism of proteins and fats, and also supports the immune and nervous systems. It is necessary for the growth and development of bones. *Triticum monococcum* L. has the highest manganese content – 35,87 mg/kg, followed by *Triticum dicoccum* Sch. and *Triticum spelta* L.

Table 40. **Content of magnesium, copper, iron, zinc and manganese in different types of ancient wheat, mg / kg**

Elements	***Triticum dicoccum* Sch.**	***Triticum spelta* L.**	***Triticum monococcum* L.**
Magnesium	866,90±1,44	812,51 ± 1,23	768,81 ± 1,14
Copper	5,48 ± 0,18	8,46 ± 0,25	6,48 ± 0,20
Iron	24,43 ± 0,27	35,35 ± 0,24	26,41 ± 0,27
Zinc	30,91 ± 0,04	32,36 ± 0,04	42,85 ± 0,06
Manganese	29,41 ± 0,02	29,37 ± 0,02	35,87 ± 0,02

We can summarize that emmer stands out with the highest content of magnesium. Spelt wheat is a leader in the trace elements copper and iron, and einkorn is superior to the other two species in its content of zinc and manganese.

B. Pot vegetation experience

The experiment was set up in order to establish the influence of fertilization on some biometric and physiological indicators of *Tr. dicoccum* Sch., *Tr. spelta* L. and *Tr. monococcum* L. in the conditions of pot experience.

The study results show that the soil fertilizer Italpolina and foliar Naturamin - WSP improve the photosynthetic activity of spelt plants, einkorn and emmer. Their positive effect is manifested by improving the leaf gas exchange, increasing the photosynthetic pigment chlorophyll content, and improving the chlorophyll fluorescence parameters. Soil fertilization with Italpolina has a more pronounced effect on the physiological status of plants.

VIII. CONCLUSIONS

1.Wheat *Triticum dicoccum* Sch., *Triticum spelta* L. and *Triticum monococcum* L. develop their vegetation within 230-231 days. Some differences in the length of the interphase periods were found after the stem elongation phase. Emmer has relatively shorter vegetation. In the course of the vegetation, the species need, on average from, 1499 to 1512 °C an effective temperature sum.

2. With increasing sowing density, the crops have been proven to develop more plants per m^2, garnished with 366 to 588 plants in emmer, 332 to 484 plants in spelt and 335 to 538 plants in einkorn. Of the three species, *Tr. dicoccum* Sch., followed by *Tr. monococcum* L. and *Tr. spelta* L., with significant differences between them.

3. The year strongly influences the productive tillering of the three tested species. In the most the favorable year 2019/2020, the plants from 12,5 to 18,7% more tillers than in the first, less favorable year. The strongest tillering are einkorn - 4.0 productive tillers/ plant, followed by emmer – 2,9 productive tillers/ plant, and spelt – 1,8 productive tillers/ plant. The influence of sowing density and fertilization on productive tillering is weaker and the differences are not proven statistically. Still, the best options are developed with 700 g.s./m^2 and Italpolina soil fertilizer.

4. The agro-meteorological conditions mainly influence the growth of the tested species over the years. In the first year, they reach a height of 80,3 cm on average, while in the second and third years, they are 107,6 and 105,3 cm, respectively. *Triticum monococcum* L. (101,6 cm) develops the highest, followed by *Triticum spelta* L. (99,1 cm) and *Triticum dicoccum* Sch. (92,5 cm). The differences are nearly 10% and are proven statistically. There are no proven differences between the variants with different sowing densities. Fertilization with soil fertilizer Italpolina has been shown to affect plant height, and foliar fertilizer Naturamin has a weaker effect.

5. The applied soil and foliar fertilization improve the photosynthetic activity of spelt, eincorn and emmer plants. The effect of fertilization is manifested by increasing the photosynthetic pigment chlorophyll content and improving the chlorophyll fluorescence parameters. The observed positive changes in leaf gas exchange in spelt and einkorn were not found in emmer. This may be due to the different photosynthetic sensitivity of the studied species to the applied preparations.

6. The influence of the year is decisive for the formation of the productive stem. The experiment proved to be more favorable in 2019/2020 and 2020/2021, when plants form 812 and 793 productive stems/m^2, respectively. The most significant number of spikes in m^2 developed in *Triticum monococcum* L. (941 pieces / m^2), followed by *Triticum dicoccum* Sch. (761 pieces/ m^2), and *Triticum spelta* L. (495 pieces/m^2). Most spikes develop at the highest sowing density, but between 700 and 900 g.s./m^2, the differences are not proven. Soil fertilizer has a more significant effect, and foliar fertilizer less.

7. The grain yield of the three tested species is most strongly influenced by the agro-meteorological conditions of the years. The highest yield is obtained in the second year (2019/2020) - 328.3 kg/ da, 54,8% more than the first (most unfavorable

year). Of the three species, *Triticum spelta* L. has the highest productive potential – 290,6 kg/da grain yield, followed by *Triticum monococcum* L. - 266 kg/da and Triticum dicoccum Sch. – 226,8 kg/da. The differences between the three types are statistically proven.

8. *Triticum dicoccum* Sch. realizes its best productive potential at a sowing density of 900 g.s./m^2, as the difference with the lowest sowing density is 19,1%. Soil fertilization with Italpolina leads to an increase in yield by 11%. Of all the observed correlations, the strongest is between yield and productive stem (R = 0,759**). The relationship between yield and grain mass in the spike has been proven, but is weaker (R = 0,278**).

9. In the case of *Triticum spelta* L., the optimum density for maximum yield is 700 g.s./m^2. Fertilization with soil fertilizer Italpolina has increased yields by 18,8%. The yield is in the average proven positive correlation with the number of germinated seeds (R = 0.503**) and the formed productive stem (R = 0,410**).

10. The yield of *Tririicum monococcum* L. is not affected by sowing density. Italpolina soil fertilizer leads to a slight increase in grain productivity (6,3%). The yield is in proven average positive correlations with the productive tillering and the productive stems/m^2 (R = 0.422** and R = 0.371**).

11. The three tested species have differently proven correlations between the structural elements of their spikes. The grain mass in the class of emmer has a moderately positive correlation with the number of grains, the number of spikelets, and the spike's length. In spelt wheat, all successively formed elements of the spike are in a direct and very strong positive correlation. Not all addictions have been proven in einkorn, which means that these traits are not genetically stable.

12. The indicator "1000-grain weight" is strongly influenced by the agro-meteorological conditions in the years of the experiment. The largest grain is formed in the first year, the most unfavorable for high yield. The weight of 1000 naked grains in spelt is 42,1 g, which is approx. 20% heavier than that of the emmer and with approx. 34% of that of einkorn. The differences are statistically proven. There is a clear tendency to reduce the weight of the grain with increasing sowing density. The effect of fertilization is less pronounced.

13. Within the experimental period, the most favorable conditions for forming the hectoliter mass of the three tested species are in the second 2019/2020, followed by 2020/2021 and 2018/2019 with proven differences. The highest hectoliter mass accumulates emmer (50,0 kg), followed by einkorn (44,7 kg) and spelt (41,6 kg). The differences are statistically significant. There are no strong trends in the impact of sowing rate and fertilization.

14. The highest content of crude protein was found in spelt (17,78%), followed by eincorn (15,24%) and emmer (13,37%). The lysine in einkorn and emmer is 0,37%, which is superior to spelt (0,32%). The most fiber was reported in *Tr. dicoccum* Sch. (0,95%), followed by *Tr. spelta* L. (0,87%) and *Tr. monococcum* L. (0,0%).

15. Emmer has the highest magnesium content (866,9 mg/ kg). Spelt wheat is a leader in the micronutrients copper (8,46 mg/kg) and iron (35,35 mg/kg), and einkorn

is superior to the other two species in its content of zinc (42.85 mg/kg) and manganese. (35.87 mg/kg).

IX. SCIENTIFIC AND APPLIED CONTRIBUTIONS

1. It has been established for the first time the influence of increased sowing rate and fertilization in local forms of the three ancient wheat species - *Triticum dicoccum* Sch., *Triticum spelta* L. and *Triticum monococcum* L. in a complex multifactorial experiment

2. It has been established the influence of the growing sowing density from 500 to 900 g.s./ m^2, in combination with two fertilizer products - soil fertilizer Italpolina and foliar fertilizer Naturamin WSP, on the growth, development and formation of productivity of local forms of emmer, spelt and einkorn, in the conditions of the biological system of agriculture.

3. Specific conclusions and recommendations have been made for the individual species related to sowing density and fertilization, based on their comparative evaluation in the experiment, analysis of variance and the established correlations.

4. A set of physiological parameters has shown that the applied soil and foliar fertilization improves the photosynthetic activity of spelt, emmer and emmer plants.

5. A comparative assessment of the grain's physical, biochemical qualities and mineral composition (naked and chaff) in the conditions of the tested factors and the biological system of agriculture has been made.