Scientific Papers. Series A. Agronomy, Vol. LXVI, No. 2, 2023
ISSN 2285-5785; ISSN CD-ROM 2285-5793; ISSN Online 2285-5807; ISSN-L 2285-5785

INFLUENCE OF THE SEEDING RATE ON SOME PARAMETERS OF THE GROWTH AND DEVELOPMENT OF *Triticum monococcum* L. IN THE CONDITIONS OF ORGANIC PRODUCTION IN BULGARIA

Tonya GEORGIEVA, Yordan YORDANOV, Malgozhata BEROVA

Agricultural University of Plovdiv, 12 Mendeleev Blvd, Plovdiv, Bulgaria

Corresponding author email: tonia@au-plovdiv.bg

Abstract

The purpose of the study is to establish the growth and development of Triticum monococcum L. in organic farming conditions. The main factors of the study were: year (2018-2019; 2019-2020 and 2020-2021) and seeding rate (500, 700 and 900 germinated seeds/m²). A three-year field experiment was conducted at the Agricultural University - Plovdiv, using the block method, with a plot of 15 m², in 4 repetitions. Phenological development was analysed. Vegetation takes place for 230-233 days. With increasing seeding rate, the number of sprouted plants/m² has been proven to increase, reaching up to 506 plants/m² at 900 germinated seeds (g.s.)/m². The plants develop a height of up to 102.4 cm at a seeding rate of 700 g.s./m². With an increase in the seeding rate from 500 to 900 g. s./m², the productive tillering decreases from 4.1 to 3.9 number of tillers/plant. The number of productive stems/m² varies from 902 (at 500 g.s./m²) to 968 numbers/m² (at 700 g.s./m²). The year affects all tested factors, as proven - with worse conditions for developing Triticum monococcum L., 2018-2019 stands out.

Key words: *Triticum monococcum L., growth, phenophases, seeding rate.*

INTRODUCTION

Einkorn (*Triticum monococcum* L.) is a type of wheat that has both wild and domesticated forms. It is assumed that this is the most ancient species and belongs to the group of diploid wheat (2n = 14).

The stability and unpretentiousness of this culture make it possible to obtain acceptable yields from it on weak soils with low agrotechnics in semi-mountainous and mountainous regions. The crop is suitable for scientific research as an alternative food source with the growing interest in organic farming and healthy eating.

Triticum monococcum L. is among the earliest cereals domesticated by man (Feldman, 1976). The abandonment and decline in its production are due (Nesbitt, 1996; Heun et al., 1997) to changes in people's dietary habits, economic conditions and the introduction into production of *Triticum aestivum* L. and *Triticum durum* Desf., which are higher yielding and can easily to be threshed. Interest in this ancient species has also been renewed due to the search for traditional crops suitable for growing in poor and disadvantaged areas, as well as the need to preserve the genetic diversity of field crops (Stagnari et al., 2008; Konvalina et al., 2014; Glamočlija et al., 2015).

Triticum monococcum L. is known to be one of the first cultivated wheat (Salamini et al., 2002). Wheat grains have been found in Fertile Crescent sites. Einkorn has first domesticated in Southwest Asia at approximately 10 500 BC. The exact locality is mentioned by Heun et al. (1997) and Weiss and Zohary (2011), and it is near the Karakadag Mountains in present-day southeastern Turkey. Grains of einkorn have also been found in the region of the Near East. In the years of the Bronze Age, it significantly reduced its area. In Bulgaria, einkorn is a little wider.

There is a renewed interest in this crop due to the nutritional qualities of the grain, its adaptation to economic cultivation and the high resistance to enemies and diseases, which is an advantage for organic farming. Cultivated einkorn is also a valuable source of genes for the breeding improvement of modern wheat (Zaharieva and Monneveux, 2014).

Sowing density is one of the main agrotechnical factors that have been studied in various places around the world. In Italy, for example, Castagna et al. (1995) studied six different seeding rates (from 100 to 600 germinated seeds (g.s./m^2) in 21 wheat lines. The authors recommend the optimal seeding rate of 300 g.s./m^2, at which they get the highest yield.

In an experiment conducted in Croatia in 2015-2018, the influence of increasing seeding rates (100, 150, 200 and 250 g.s./m^2) on yield and its components were studied (Pospilis et al., 2020). An increase in yield with an increase in seeding rate was found, but differences above 150 g. s./m^2 were not statistically proven.

In southern Italy, Trocoli and Codianni (2005) made a complex study of the influence of the seeding rate on the productivity of three types of wheat, including the einkorn. Unlike emmer and spelt, einkorn realizes the highest yield at the seeding rate at the smallest tested rate - 100 g. s./m^2. However, the authors specify that further studies are needed.

The literature review shows the existence of conflicting and insufficient scientific data related to the influence of the seeding rate on the growth, development and formation of some productive components of the yield. With the present study, we set ourselves the goal - to optimize the seeding rate for local forms of einkorn in the conditions of organic production in Bulgaria.

MATERIALS AND METHODS

In 2018-2021, a field experiment was conducted on the field of the first organically certified farm in Bulgaria - the Agroecological Center of the Agricultural University - Plovdiv, which is also a member of the International Federation for Organic Agriculture since 1993.

The seeds of the local form *Triticum monococcum* L. used were biologically produced by the Institute of Plant Genetic Resources "K. Malkov". They are provided with the necessary documents corresponding to Regulation 848/2018.

The experiment is two-factorial; it is laid out in a block method, in four repetitions, after a predecessor common vetch (*Vicia sativa* L. ssp. *sativa*), sown in spring. The main tested factor (A) is the seeding rate with three levels: A1 - 500 germinated seed (g.s.)/m^2, A2 - 700 g.s./m^2 and A3 - 900 g.s./m^2. The reporting area of each plot is 15 m^2. In the statistical processing of the data, the year was also analyzed as a second factor in the three-year experiment.

After harvesting the selected predecessor - spring vetch, a shallow plowing (18-20 cm) and a single disking at a depth of 10-12 cm was carried out. During the monitoring of the crop, no attacks of diseases and enemies were reported, as a result of which plant protection was not required. In early spring, as soon as possible, harrowing is carried out against late-autumn and early-spring weeding in the plots, even when the weeds are in their initial stages and the einkorn is at the end of the tillering phase.

The indicators that are reported are: emergence, phenological development, dynamics of growth in height, dynamics of tillering and productive stems.

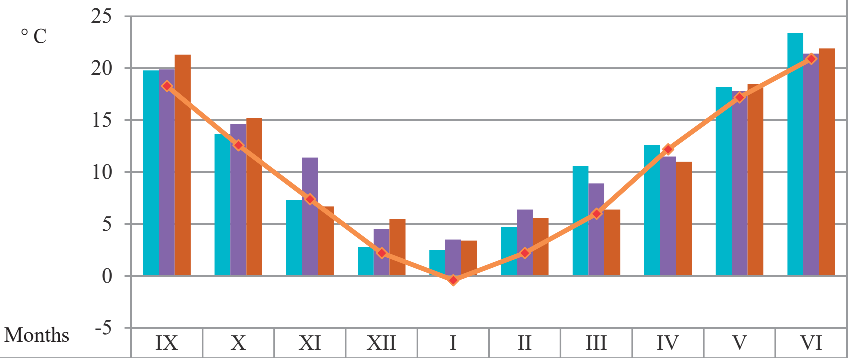
Statistical data processing was performed with SPSS V. 9.0 for the Microsoft Windows program, using Duncan's method, Anova.

The agroecological center is located on alluvial-meadow soils (Mollic Fulvisols) (FAO, 1988). Nitrogen availability is weak; it is good with potassium and weak to medium with phosphorus (Popova and Sevov, 2010). The analyzed soil reaction is neutral to slightly alkaline and has a low percentage of organic matter.

In the autumn of the first year (2018), the weather conditions were not particularly favorable for the timely preparation of the soil for sowing (Figure 1). Temperatures in autumn are relatively high, but rainfall is extremely low. Later in the growing season, this deficit is compensated by rainfall peaks in November, April and especially June.

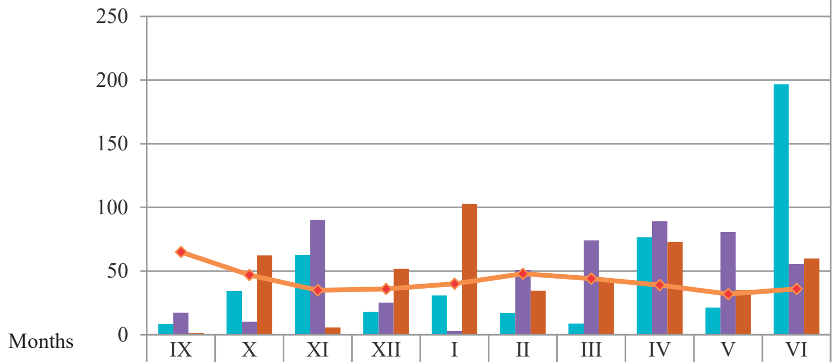
The growing year 2019/2020 is more favorable, which has been taken into account since autumn. The complex agrometeorological conditions ensure normal preparation for sowing and optimal conditions for the phenophases.

In the third experimental year, 2020/2021, conditions were also unfavorable for timely sowing. In October, however, heavy rainfall (62.3 mm/m^2) falls, stimulating rapid germination (Figure 2). By the end of December, the plants enter the tillering phase. In the next phenological phases in the spring, the plants go through the same periods in the three years.



	IX	X	XI	XII	I	II	III	IV	V	VI
t C° for 2018-2019	19,8	13,7	7,3	2,8	2,5	4,7	10,6	12,6	18,2	23,4
t C° for 2019-2020	19,9	14,6	11,4	4,5	3,5	6,4	8,9	11,5	17,8	21,4
t C° for 2020-2021	21,3	15,2	6,7	5,5	3,4	5,6	6,4	11	18,5	21,9
t C° Average for the period 1981-2010	18,3	12,6	7,4	2,2	-0,4	2,2	6	12,2	17,2	20,9

Figure 1. Average monthly temperatures (t°C) during the growing season of *Triticum monococcum* L. in 2018/2019, 2019/2020 and 2020/2021



	IX	X	XI	XII	I	II	III	IV	V	VI
Precipitation, 2018-2019	8,3	34,3	62,5	17,9	30,9	17,2	8,8	76,5	21,3	196,7
Precipitation, 2019-2020	17,4	10,2	90,4	25,3	3	50,7	74,1	89,1	80,7	55,4
Precipitation, 2020-2021	1,3	62,3	5,7	51,8	103	34,6	42,2	72,9	34,9	60
Precipitation, average for the period 1981-2010	65	47	35	36	40	48	44	39	32	36

Figure 2. Amount of precipitation (mm/m^2) during the growing season of *Triticum monococcum* L. in 2018/2019, 2019/2020 and 2020/2021

RESULTS AND DISCUSSIONS

Germination. The presence of chaff in einkorn seeds affects the speed and degree of germination due to the strength with which they cover them. Ehsanzadeh (1998) spoke in his study about this predetermined genetic specificity of the grain in einkorn and its negative influence on seed germination and subsequent development.

This indicator is also influenced by agro-meteorological conditions, the sowing time, and the seeding rate.

Simultaneous sprouting is extremely important for the good and harmonious development of the crop. Weed control becomes difficult when this wheat is grown organically (without chemical plant protection) and sowing is done in autumn. Therefore, it is very important to ensure the optimal density of sprouted plants. This ensures a better and uniform absorption of nutrients from the soil. Moreover, in winter, it is possible to reduce the sprouted plants to 50%, according to some authors (Jablonskytė-Raščė et al., 2013). They have found that if 320-360 plants per m^2 have sprouted, 45-46% of the plants survive the winter, which significantly reduces density.

Our results also show such a large percentage reduction in germination (Table 1). The data in the table 1 shows that in the first year of the study (2018/2019), the sprouted plants were from 395 to 538 per m^2, which is 59.7% to 79.0% of the seeding rate. Although a greater number of sprouted plants was reported with an increase in the seeding rate, a trend was found for a lower percentage of sprouted plants at the higher seeding rate (900 g.s./m^2).

The established smaller % of sprouted plants at the highest seeding rate was also confirmed in the second and third experimental years.

We can also add that the soil's non-uniform distribution of moisture causes einkorn's non-uniform germination and, accordingly, the different number of sprouted plants.

Table 1. Influence of seeding rate on the number of sprouted plants/m^2 of *Triticum monococcum* L., by years

Variant	2018/2019	2019/2020	2020/2021
500 g.s./m^2	395 c	335 b	366 c
700 g.s./m^2	445 b	458 a	455 b
900 g.s./m^2	538 a	470 a	508 a

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

When testing the independent influence of the year factor on average over the three-year study period, it was found that the most favorable conditions for germination were in 2018. In 2019, plants germinated with a proven smaller number per m^2, followed by 2020. Regarding the influence of the seeding rate, it is found that with an increase in the seeding rate from 500 to 900 g.s./m^2, the number of sprouted plants per m^2 is proven to increase. We can summarize that by increasing the seeding rate by up to 80% (from 500 to 900 g.s./m^2), the number of sprouted plants increases by up to 38.4%.

Table 2. Influence of year and seeding rate on the number of sprouted plants/m^2 of *Titicum monococcum* L., average for the period

Influence of factor Year			Influence of factor Seeding rate		
Variant	Number/ m^2	%	Variant	Number/ m^2	%
2018-2019	459.3 a	100.0	500 g.s./m^2	365.3 c	100.0
2019-2020	421.1 b	91.7	700 g.s./m^2	452.8 b	124.0
2020-2021	443.2 a	96.5	900 g.s./m^2	505.6 a	138.4

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

Phenological development. Despite the difficult and slightly delayed tillage of the soil, sowing in all three years was carried out in October, which for the conditions of Bulgaria, is perceived as an optimal time (Table 3). The plants germinate quite irregularly in the period 5-10 November. The reason is the need for sufficient moisture and its uneven distribution in the soil. This negative effect on germinating was commented on in a publication by other Bulgarian authors, too (Stamatov et al., 2017a).

Table 3. Phenological development of *Triticum monococcum* L.

Phenological phases	Phases	Sowing		
		24.10.2018	12.10.2019	27.10.2020
Germination	BBCH 11	8.11.2018	10.11.2019	5.11.2020
Third leaf	BBCH 18	14.12.2018	7.12.2019	15.12.2020
Tillering	BBCH 28	23.12.2018	23.12.2019	22.12.2020
Stem elongation	BBCH 38	25.04.2019	21.04.2020	21.04.2021
Heading	BBCH 59	16.05.2019	15.05.2020	15.05.2021
Milk maturity	BBCH 78	8.06.2019	8.06.2020	7.06.2021
Wax maturity	BBCH 89	19.06.2019	17.06.2020	18.06.2021
Full maturity	BBCH 99	26.06.2019	27.06.2020	26.06.2021

Germination also affects the varying duration of the interphase period until entering the 3rd leaf phase - from 27 (2019) to 40 days (2020). The plants enter approximately the same period in tillering - from December 22 to 23. The subsequent phases, up to ripening, proceed normally in all three years, despite certain differences in agro-meteorological conditions. The growing season ends on June 26-27 for 230 to 233 days. All this shows the great adaptability of the species, which successfully overcomes specific meteorological differences in the experiment period. Our conclusions confirm the results of a study done earlier **by** Zorovski et al. (2018).

Dynamics of tillering. Tillering is a biological specificity in cereal crops, which is highly dependent on the genotype, but can also be controlled by agrotechnical factors. Figure 3 presents the dynamics of tillering of *Triticum monococcum* L. during the three years of the experiment, respectively by phases – tillering, stem elongation and heading.

The tillering phase begins on December 22-23 in experimental years and continues until April 21-25 in subsequent years. Within these months in 2018/2019, the plants form a total of up to 4.5 tillers/plant, which by the end of the growing season are reduced by about 36% - to 2.9 tillers/plant.

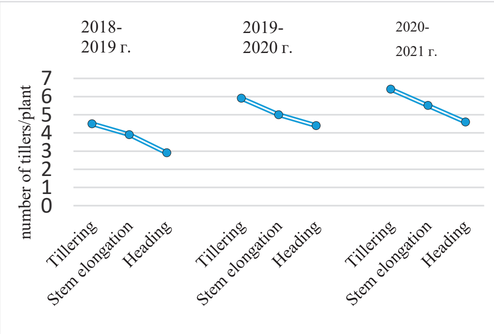


Figure 3. Dynamics of tillering of *Triticum monococcum* L, number of tillers/plant, by phases and by years

In the second experimental year, the maximum number of tillers was much higher - up to 5.9 number/plant, which we explain by the better combination of temperatures and more precipitation in March and April (2020) compared to the first year. Within the further development of the einkorn, the crop self-regulates its density, with only 3.6 productive tillers remaining by the end of the growing season. Thus, 61% of the tillers formed at the beginning of the growing season remain in the crop.

In the third year, the trend is the same. At the end of the growing season, the plants remain with 4.6 productive tillers/plant, 71.9% of the previously formed total number of tillers.

When analyzing the influence of the seeding rate by year, it is found that in the first year, there is no difference between the 500 and 700 g.s./m^2 variants in terms of this indicator (Table 4). As the seeding rate increases to 900 g.s./m^2, the productive tillering decreases. In the third year, the trend is the same - with an increase in the seeding rate, it has been proven that productive tillering decreases. In the second year, the results are mixed. We can summarize that plants form the most productive tillers at 500 g.s./m^2, followed by 700 and 900 g.s./m^2.

Table 4. Influence of seeding rate on the number of productive tillers/plant of *Triticum monococcum* L, at the end of the growing season in., by years

Variant	2018/2019	2019/2020	2020/2021
500 g.s./m^2	3.0 a	4.4 a	4.8 a
700 g.s./m^2	3.0 a	4.3 a	4.6 ab
900 g.s./m^2	2.7 a	4.5 a	4.4 b

*Means followed by the same letter are not statistically different (P<0,05) by Duncan's multiple range test

Table 5. Influence of year and seeding rate on the number of productive tillers/ plant of *Triticum monococcum* L., average for the period

Influence of factor Year			Influence of factor Seeding rate		
Variant	Number/ m^2	%	Variant	Number/ m^2	%
2018-2019	2.9 a	100.0	500 g.s./m^2	4.1 a	100.0
2019-2020	4.4 a	151.7	700 g.s./m^2	4.0 a	97.6
2020-2021	4.6 a	158.6	900 g.s./m^2	3.9 a	95.1

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

The summary analysis of the effect of year and seeding rate for the study period is presented in Table 5. The second and third experimental years provided proven better conditions for tillering than the first year. In the third year, the plants reach a maximum productive tillering of 4.6 productive tillers per plant. With an increase in the seeding rate from 500 to 900 g.s./m^2, productive tillering decreases from 4.1 to 3.9 tillers/plant.

Plant height. Growth in height is an indicator of active growth processes and biomass accumulation. The data in Table 6 shows that the plants reached their highest height in 2020, which we define as the year with the most favorable conditions. Plants reached a height of 112 to 114.8 cm, and no significant differences

were found between the seeding rates tested. The plants remained the lowest in 2019.
The summarized statistical processing for the three years shows a strong influence of the year on this indicator. The differences reach 33.1 to 37.7% and are statistically proven. The seeding rate had a minor effect on plant height and this was not statistically proven (Table 7).

Table 6. Influence of seeding rate on plant height of *Triticum monococcum* L., cm, by years

Variant	2018/2019	2019/2020	2020/2021
500 g.s./m^2	79.9 a	114.8 a	109.4 a
700 g.s./m^2	84.9 a	112.9 a	109.3 a
900 g.s./m^2	81.9 a	112.0 a	109.4 b

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

Table 7. Influence of year and seeding rate on plant height of *Triticum monococcum* L., cm, average for the period

Influence of factor Year			Influence of factor Seeding rate		
Variant	Plant height, cm	%	Variant	Plant height, cm	%
2018-2019	82.2 b	100.0	500 g.s./m^2	101.4 a	100.0
2019-2020	113.2 a	137.7	700 g.s./m^2	102.4 a	101.0
2020-2021	109.4 a	133.1	900 g.s./m^2	101.1 a	100.0

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

Productive stems. The productive stem is a function of the number of plants germinated and productive tillering. The accumulation of biomass in the crop and the processes of self-regulation in terms of tillering are prerequisites for developing more productive stems. The study of these reactions gives valuable information about the potential of the crop to form a high yield under certain agrometeorological conditions.
Einkorn formed many productive stems even in the unfavourable 2018/2019 year (Figure 4) - 782 to 850 spike-bearing stems, which is most likely due to the higher degree of productive tillering. This year, the tendency to increase the number of productive stems with an increase in the seeding rate to 900 g.s./m^2 is taken into account. In the following two years, the most formed spike-bearing stems were the variants with 700 g.s./m^2.
The summary data for the three years confirms the strong influence of the year. The optimal seeding rate for this indicator is 700 g.s./m^2 (Table 8).

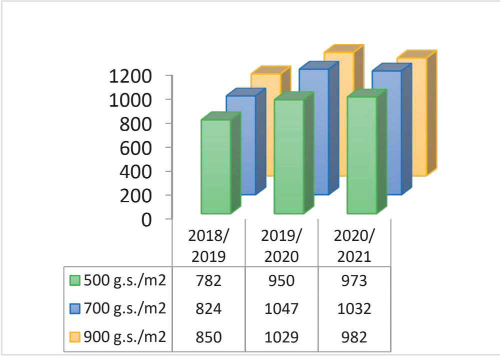


Figure. 4. Influence of seeding rate on the formation of the productive stems, number/m^2, by years

Table 8. Influence of year and seeding rate on the number of productive stems of *Triticum monococcum* L./m^2, the average for the period

Influence of factor Year			Influence of factor Seeding rate		
Variant	Number/ m^2	%	Variant	Number /m^2	%
2018-2019	819 b	100.0	500 g.s./m^2	902 a	100.0
2019-2020	1009 a	123.2	700 g.s./m^2	968 a	107.3
2020-2021	996 a	121.6	900 g.s./m^2	954 a	105.8

*Means followed by the same letter are not statistically different (P<0.05) by Duncan's multiple range test

CONCLUSIONS

When sowing in an optimal period (October) and a seeding rate of 500 to 900 g.s./m^2, 395 to 538 plants germinate, respectively, constituting 79 to 59.7% of the sown seeds. As the seeding rate increases, the germination percentage decreases.
Depending on weather conditions, plants go through germination and third leaf phases at different times. They enter the tillering phase between December 18 and 23 in all three years, regardless of the differences in the duration of the past phases. Despite the specifics in the agrometeorological conditions in the three years, the following phases - stem elongation, heading and ripening, proceed approximately identically. Vegetation ends in 230 to 233 days.
For the growing season, einkorn formed 4.4 to 4.6 productive tillers per plant in the more favorable second and third experimental years, 51.7 to 58.6% more than the first year. With an

increase in the seeding rate from 500 to 900 g.s./m^2, the productive tillering decreases by nearly 5%.

The agrometeorological conditions of the year have a proven influence on the height of the plants. In the more favorable second and third years, the plants reached a height of 109.4 and 113.2 cm, which exceeded the values of the first year by 33.1 to 37.7%. The seeding rate does not significantly affect plant height.

The number of formed productive stems reached 1009/m^2 in 2020 and 996 in 2021, 21.6 to 23.2% more than the less favorable year 2019. The most productive stems were formed at a seeding rate of 700 g.s./m^2.

REFERENCES

Castagna, R., Borghi, B., Di Fonzo, N., Heun, M., & Salamini, F. (1995). Yield and related traits of einkorn (*T. monococcum* ssp. *monococcum)* in different environments. *European Journal of Agronomy*, *4*(3), 371–378.

Ehsanzadeh, P. (1998). for the Degree of Doctor of Philosophy in the Department of Plant Sciences (Doctoral dissertation, University of Saskatchewan Saskatoon).

Glamočlija, Đ., Jankovic, S., Popovic, V., Filipović, V., Ugrenovic, V., Kuzevski, J. (2015). Alternative crops in conventional and organic cropping system.

FAO-UNESCO, I. S. R. T. C. (1988). Soil map of the world, revised legend. *World Soil Resources Report* 60, 119.

Feldman, M. (1976). Wheats. In: Simonds, N.W., Longman (Eds.), Evolution of Crop Plants, London, p. 121.

Heun, M., Schafer-Pregl, R., Klawan, D., Castagna, R., Accerbi, M., Borghi, B., Salamini, F. (1997). Site of einkorn wheat domestication identified by DNA fingerprinting. *Science*, *278*(5341), 1312–1314.

Jablonskytė-Raščė, D., Maikštėnienė, S., & Mankevičienė, A. (2013). Evaluation of productivity and quality of common wheat (*Triticum aestivum* L.) and spelt (*Triticum spelta* L.) in relation to nutrition conditions. *Zemdirbyste-Agriculture, 100*(1), 45–56.

Konvalina, P., Suchý, K., Stehno, Z., Capouchová, I., Moudrý, J. (2014). Drought tolerance of different wheat species (*Triticum* L.). In *Vulnerability of Agriculture, Water and Fisheries to Climate Change* (pp. 207-216). Springer, Dordrecht.

Nesbitt, M. (1996). From staple crop to extinction? The archaeology and history of hulled wheat. *Hulled Wheat: Promoting the Conservation and Use of Underutilized and Neglected Crops*, 41–100.

Popova, R, Sevov, A. (2010). Soil characteristic of experimental field of crop production department as a result of the cultivation of grain, technical and forage crops, Agricultural university-Plovdiv, *Scientific Works*, LV(book1), pp 151-156 (in Bulgarian).

Pospisil, A., Pospisil, M., Brcic, M. (2020). Agronomic traits of einkorn and emmer under different seeding rates and topdressing with organic fertilizers. *Turkish Journal of Agriculture and Forestry*, *44*(1), 95–102.

Salamini, F., Özkan, H., Brandolini, A., Schäfer-Pregl, R., Martin, W. (2002). Genetics and geography of wild cereal domestication in the near east. *Nature Reviews Genetics*, *3*(6), 429–441.

Stagnari, F., Codianni, P., Pisante, M. (2008). Agronomic and kernel quality of ancient wheats grown in central and southern Italy. *Cereal Research Communications*, *36*(2), 313–326.

Stamatov, S., Valchinova, E., Desheva, G., Uzundzhalieva, K., Chavdarov, P., Cholakov, T., Kyosev, B., Ruseva, R., Velcheva, N. (2017a). Length of the growing season and yield in *Triticum monococcum* L., in accordance with the growing conditions. *Agricultural Science and Technology, 9*(4), 296–300.

Troccoli, A., Codianni, P. (2005). Appropriate seeding rate for einkorn, emmer, and spelt grown under rainfed condition in southern Italy. *European Journal of Agronomy*, *22*(3), 293–300

Weiss, E., Zohary, D. (2011). The Neolithic Southwest Asian founder crops: their biology and archaeobotany. *Current Anthropology*, *52*(S4), S237-S254.

Zaharieva, M., Monneveux, P. (2014). Cultivated einkorn wheat (*Triticum monococcum* L. subsp. *monococcum*): the long life of a founder crop of agriculture. *Genetic Resources and Crop Evolution, 61*(3), 677–706.

Zorovski, P., Popov, V., Georgieva, T. (2018). Growth and development of *Triticum monococcum* L., *Triticum dicoccum* Sch. and *Triticum spelta* L. in organic farming conditions. *Contemporary Agriculture, 67*(1), 45–50.