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Agronomic traits of einkorn and emmer under different seeding rates and topdressing with organic fertilizers

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Abstract: The goal of this research carried out at the experimental facility of the Faculty of Agriculture of the University of Zagreb in 2015/2016, 2016/2017 and 2017/2018 was to determine the influence of seeding rate and topdressing with organic fertilizers on yield and yield components in einkorn (*Triticum monococcum* subsp. *monococcum*) and emmer (*Triticum dicoccon*) populations collected in the Croatian region of Slavonia. The research comprised four seeding rates: 100, 150, 200, and 250 grains per m^2; topdressing with organic fertilizers (Fertil Supernova 12.5 N and Ilsamin N90); and a control (no topdressing). Einkorn populations achieved a higher yield of hulled grain relative to the emmer population as a result of their higher coefficient of productive tillering. Conversely, the emmer population showed superiority in a greater number of yield components. On average, for both cereals, yield increased with increasing seeding rates; however, increased yields for seeding rates above 150 grains per m^2 were not statistically significant. Einkorn populations showed a yield increase up to the seeding rate of 200 grains per m^2, while in emmer the equivalent cutoff value amounted to 250 grains per m^2. Topdressing with organic fertilizers positively influenced yield and yield components in both einkorn and emmer populations, except for the year marked by inclement weather conditions in June. Topdressing with organic fertilizers increased the number of spikelets and grains per ear, as well as the grain weight per ear, except in the year with lower precipitation.

Key words: Einkorn, emmer, organic fertilizers, seeding rate, topdressing, yield

1. Introduction

Einkorn (*Triticum monococcum* subsp. *monococcum*) and emmer (*Triticum dicoccon*) are modestly represented cereals in Europe, but due to an increased demand for so-called functional food with favorable chemical contents, as well as the need for greater biodiversity, interest in the production of these cereals is increasing.

Einkorn and emmer are classified as hulled cereals whose grains are firmly enclosed by glumes that do not peel off during harvest. Einkorn is an important source of genes for the enhancement of common wheat (Karagöz and Zencirci, 2005; Zaharieva and Monneveux, 2014). The productivity of einkorn and emmer is significantly lower compared to common wheat, but their humble demands in terms of agroecological conditions, fertilization, and protection make them suitable for organic production (Zaharieva and Monneveux, 2014; Čurná and Lacko-Bartošová, 2015). Einkorn and, to a certain extent, emmer are also more resistant to fungal diseases (Pasquini et al., 1989; Moudrý et al., 2011). Konvalina et al. (2010) pointed to the superior resistance to powdery mildew and brown rust in einkorn and emmer relative to spelt and common wheat. The principal limiting factor for yield increase in einkorn and emmer lies in their low harvest index (Konvalina et al., 2010). Einkorn and emmer are suitable for production on marginal soils where more economically profitable cultivars fail to thrive (Troccoli and Codianni, 2005; Konvalina et al., 2010). Hulled wheats are essential genetic resources for resolving problems of stress (Aslan et al., 2016). Renewed interest in the production of these cereals is a result of increased demand for food of higher nutritional value. Einkorn and emmer are both characterized by a very favorable chemical composition in the grain, i.e. the grains are rich in fiber, proteins, minerals, carotenoids, antioxidants, and vitamins (Brandolini et al., 2008; Hidalgo and Brandolini, 2014; Lacko-Bartošová and Čurná, 2015; Nakov et al., 2016; Tekin et al., 2018; Akar et al., 2019). As a result, einkorn flour is recommended for the preparation of special products (Brandolini et al., 2008; Hidalgo and Brandolini, 2014). Einkorn grains are rich in ferulic acid, p-coumaric acid, and total phenolic content. Therefore, einkorn is a rich gene resource for the improvement of modern wheat cultivars (Şahin et al., 2017). Due to their high crude protein, low acid,

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and neutral detergent fiber contents as well as their low methane production, einkorn and emmer can also be used for animal feed (Kaplan et al., 2014).

Troccoli and Codianni (2005) stated that the optimal seeding rate for einkorn in southern Italy is 100 grains per m^2, compared to 200 grains per m^2 for emmer.

Einkorn and emmer do not require large quantities of nitrogen. Marino et al. (2016) obtained positive results in the productive and physiological properties of emmer with the application of 90 kg N ha^{-1}. The same authors stated that, although a lack of nitrogen resulted in lower yields, the physiological properties were only partially affected, which emphasizes the plasticity of emmer and its suitability for low-input farming systems. However, some researchers claimed that the effect of fertilization with nitrogen is less evident (de Giorgio et al., 1995) or that it does not influence seed yield (Castagna et al., 1996).

The goal of this research was to determine the influence of seeding rate and topdressing with organic fertilizers on the yield and yield components of einkorn and emmer.

2. Materials and methods

The trials were carried out at the experimental facility of the Faculty of Agriculture of the University of Zagreb during three growing seasons (2015/2016, 2016/2017, and 2017/2018). The trial included one einkorn and one emmer population collected in the Croatian region of Slavonia. Populations were grown under organic production, sown at four seeding rates (100, 150, 200, and 250 grains per m^2), and topdressed with organic fertilizers; the control was grown without topdressing. During the first topdressing at the beginning of spring vegetation in growth stage 23 (Zadoks et al., 1974), 300 kg ha^{-1} of organic fertilizer was applied (Fertil Supernova 12.5 N). For the second topdressing at growth stage 26 (Zadoks et al., 1974), 3 L ha^{-1} foliar fertilizer (Ilsamin N90) was applied. Fertil Supernova 12.5 N is an organic nitrogen fertilizer, while Ilsamin N90 is a liquid organic fertilizer containing 9% nitrogen. The experiment was set up according to the strip-split plot method in four replications. The basic plot size in seeding was 8.4 m^2 (10 rows × 0.12 m, row distance × 7 m length). Upon emergence, plot length was shortened by 0.5 m, so that the plot size at harvest was 7.8 m^2. The previous crop was rapeseed. Basic fertilization was done before plowing using 400 kg ha^{-1} of organic fertilizer (PROECO 5:10:10). PROECO 5:10:10 is an organic nitrogen:phosphorus:potassium fertilizer based on animal and plant proteins. Seeding was performed on 26 October 2015, 14 October 2016, and 5 October 2017. Upon germination, the number of emerged plants was determined per m^2, and the number of ears per m^2 was determined before harvest. Harvest was carried out with a Wintersteiger Classic plot harvester on 8 July 2016, 4 July 2017, and 20 June 2018. The hulled grain yields of einkorn and emmer were determined after harvest, and the yields were adjusted to 13% moisture content. Samples of ears were taken before harvest, and the following traits were analyzed: hulled grain weight per ear, spikelet number per ear, grain number per ear, and dehulled grain weight per ear. Crude proteins content in 2017/2018 was determined according to Kjeldahl (AOAC, 2002) and expressed as proteins by multiplying total nitrogen by a factor of 6.25. The results obtained were processed by analysis of variance using the MSTAT-C program (https://msu.edu/~freed/disks.htm).

The trials were conducted on anthropogenic, eutric-brown soil, on slightly luvic loam. The upper layer of soil was acidic (pH in 1 M KCl = 5.29), poorly supplied with humus (1.6%), and moderately supplied with nitrogen (0.09%). The soil was well supplied with phosphorus (AL – P_2O_5 = 28.4 mg 100 g^{-1} soil) and potassium (AL – K_2O = 21.0 mg 100 g^{-1} soil).

3. Results and discussion

Due to significant interactions involving years, data from each year were analyzed separately. In all three years of research the einkorn population achieved a higher yield of hulled grain relative to the emmer population (Tables 1–3). The higher yield was the result of a greater number of ears per m^2, i.e. a higher coefficient of tillering in the einkorn population. The coefficient of tillering in einkorn populations varied from 2.88 in 2015/2016 to 4.12 in 2017/2018; in the emmer population the equivalent values were 1.32 and 1.74, respectively. Karagöz and Zencirci (2005) and Karagöz et al. (2006) also obtained a higher number of tillers in einkorn populations collected from different regions of Turkey. Jaradat (2011) stated that wild einkorn is an important source of genes for increased tillering, among other properties. Depending on the research year, the einkorn yield varied from 3.099 to 3.707 t ha^{-1}, which exceeds the results obtained by Moudrý et al. (2011), but coincides with the values found by Vallega (1992). The emmer yield varied, depending on the year, from 2.92 to 3.33 t ha^{-1}, which is in accord with the results obtained by Marino et al. (2016). Kaplan et al. (2014) also obtained a higher grain yield in einkorn populations (4.617 t ha^{-1}) than in emmer populations (2.477 t ha^{-1}).

Relative to the einkorn populations, in all three years of research the emmer populations demonstrated significantly higher weight of hulled grains per ear and a greater number of grains per ear and weight of dehulled grains per ear, while einkorn surpassed emmer in the number of spikelets (Tables 1–3). The greater weight of grains per ear in emmer did not compensate for the lower coefficient of tillering, which resulted in its lower yield (Tables 1–3).

Table 1. Agronomic traits of einkorn and emmer as affected by seeding rate and topdressing during the growing period of 2015/2016.

Treatments			Hulled grain yield	Ear number m^{-2}	Hulled grain weight per ear	Spikelet number per ear	Grain number per ear	Dehulled grain weight per ear	Tillering coefficient
			t ha^{-1}		(g)			(g)	
		Grains m^{-2}							
Interaction	Einkorn	100	3.488	461 c	1.156 c	29.1	25.6 d	0.779 c	3.86 a
Species ×		150	3.682	544 b	1.182 c	29.1	25.6 d	0.827 c	3.45 b
seeding rate		200	3.946	603 a	1.036 c	28.3	24.4 d	0.724 c	2.44 c
		250	3.710	549 b	1.097 c	27.6	24.1 d	0.750 c	1.89 d
	Emmer	100	3.214	196 f	2.841 a	26.8	41.2 a	1.962 a	1.79 d
		150	3.389	232 ef	2.882 a	26.4	40.6 ab	2.002 a	1.28 e
		200	3.449	256 e	2.427 b	26.6	38.0 b	1.703 b	1.11 e
		250	3.269	328 d	2.176 b	25.2	33.6 c	1.507 b	1.11 e
		Topdressing							
Interaction	Einkorn	C	3.431 b	495 b	1.119	28.0	24.8	0.759 c	2.78
Species ×		T	3.982 a	583 a	1.117	29.1	25.1	0.781 c	2.99
topdressing									
	Emmer	C	3.325 b	250 c	2.725	26.2	39.5	1.904 a	1.28
		T	3.335 b	255 c	2.438	26.3	37.2	1.683 b	1.36
Mean	Einkorn		3.707 a	539 a	1.118 b	28.5	24.9 b	0.770 b	2.88 a
Species	Emmer		3.330 b	253 b	2.581 a	26.3	38.3 a	1.793 a	1.32 b
Mean	100		3.351 b	328 c	1.998 a	27.9 a	33.4 a	1.371 a	2.82 a
Seeding	150		3.535 ab	388 b	2.032 a	27.7 a	33.1 a	1.414 a	2.31 b
rate	200		3.697 a	430 ab	1.731 b	27.5 a	31.2 ab	1.214 ab	1.77 c
grains m^{-2}	250		3.490 ab	438 a	1.637 b	26.4 b	28.9 b	1.128 b	1.50 c
Mean	C		3.378 b	373 b	1.922	27.1	32.1	1.332 a	2.03
Topdressing	T		3.658 a	419 a	1.777	27.7	31.2	1.232 b	2.17

C – Control without topdressing.
T – Topdressing.
Values followed by the same letter are not significantly different at the 5% level of probability.

In all three years of research the lowest yield in both cereals was achieved at the seeding rate of 100 grains per m^2. In 2015/2016, an increasing seeding rate resulted in greater grain yield up to the seeding rate of 200 grains per m^2; the yield achieved at the seeding rate of 250 grains per m^2 was similar to the yields achieved at seeding rates of 100 and 150 grains per m^2. In 2016/2017, there was a noticeable tendency towards yield increase when seeding rates increased from 150 to 250 grains per m^2; however, the differences were not statistically significant. In 2017/2018, no significant influence of seeding rate on grain yield was determined, although the highest yield was achieved at the greatest seeding rate. In all three years of research, a discernible growth tendency in the yield of einkorn populations was observed up to the seeding rate of 200 grains per m^2. In emmer populations, the tendency towards yield increases varied from year to year. In 2015/2016, the yield of emmer populations grew up to the seeding rate of 200 grains per m^2, while in the other two years it increased up to the seeding rate of 250 grains per m^2. Codianni et al. (1993) achieved a yield increase in emmer as the seeding rate grew from 200 to 300 grains per m^2, while the highest yield in einkorn was achieved at seeding rates of 300 and 400 grains per m^2. However, Troccoli and Codianni (2005) obtained the highest yield in einkorn at the seeding rate of 100 grains per m^2.

Interaction between species and seeding density was significant only in 2015/2016 when the einkorn population

Table 2. Agronomic traits of einkorn and emmer as affected by seeding rate and topdressing during the growing period of 2016/2017.

Treatments			Hulled grain yield	Ear number m^{-2}	Hulled grain weight per ear	Spikelet number per ear	Grain number per ear	Dehulled grain weight per ear	Tillering coefficient
			t ha^{-1}		(g)			(g)	
		Grains m^{-2}							
Interaction	Einkorn	100	2.944	499	1.009 d	28.5	23.6 d	0.715 c	5.12 a
Species ×		150	3.159	529	1.018 d	29.0	23.8 d	0.727 c	3.92 b
seeding rate		200	3.146	544	1.038 d	28.0	23.8 d	0.733 c	3.26 c
		250	3.147	581	0.917 d	26.5	21.9 d	0.647 c	2.58 d
	Emmer	100	2.624	193	2.606 a	23.1	34.0 a	1.758 a	1.86 e
		150	2.886	207	2.403 b	22.1	32.0 ab	1.637 a	1.37 ef
		200	3.045	238	2.100 c	21.9	29.4 bc	1.425 b	1.18 f
		250	3.125	256	1.958 c	21.4	27.6 c	1.311 b	1.03 f
		Topdressing							
Interaction	Einkorn	C	2.915	515 a	0.958	27.5	22.5	0.679	3.54
Species ×		T	3.283	561 a	1.032	28.5	24.0	0.732	3.89
topdressing									
	Emmer	C	2.742	238 b	2.152	21.8	29.5	1.449	1.37
		T	3.098	209 b	2.382	22.5	32.0	1.617	1.34
Mean	Einkorn		3.099	538 a	0.995 b	28.0 a	23.3 b	0.716 b	3.72 a
Species	Emmer		2.920	223 b	2.267 a	22.1 b	30.8 a	1.533 a	1.36 b
Mean	100		2.784 b	346 b	1.807 a	25.8 a	28.8 a	1.236 a	3.49 a
Seeding	150		3.022 ab	368 ab	1.711 b	25.6 a	27.9 ab	1.182 a	2.64 b
rate	200		3.096 a	391 ab	1.569 c	25.0 ab	26.6 bc	1.079 b	2.22 c
(grains m^{-2})	250		3.136 a	419 a	1.438 d	24.0 b	24.8 c	0.979 c	1.80 d
Mean	C		2.828 b	376	1.555 b	24.6 b	26.0 b	1.064 b	2.46 b
Topdressing	T		3.191 a	385	1.707 a	25.5 a	28.0 a	1.174 a	2.62 a

C – Control without topdressing.
T – Topdressing.
Values followed by the same letter are not significantly different at the 5% level of probability.

achieved the highest number of ears per m^2 at a seeding density of 200 grains per m^2 (Table 1).

As the seeding rate increases, a tendency towards a decrease in the weight of hulled grains per ear, number of spikelets per ear, number of grains, and weight of dehulled grain per ear emerges. In 2015/2016 the emmer population achieved significantly higher hulled grain weights per ear at seeding rates of 100 and 150 grains per m^2 and in 2016/2017 only at 100 grains per m^2 (Tables 1 and 2). Interaction between species and seeding rate was also significant for grain number and dehulled grain weight per ear. Emmer populations achieved the highest values in those traits at 100 and 150 grains per m^2. In all three years of research, considering the significant interaction between species and seeding rate, the einkorn population achieved the highest tillering coefficient at a seeding rate of 100 grains per m^2, and additionally at 150 grains per m^2 in 2017/2018.

In the first two years of research topdressing with organic fertilizers had a significant positive influence on the grain yields of both einkorn and emmer populations, while in 2017/2018 that influence was significantly adverse. The negative impact was the result of heavy rain accompanied by wind in June of 2018, which caused greater lodging of crops. Troccoli and Codianni (2005) also mentioned problems with lodging of einkorn and emmer as well as its negative influence on grain yield. Marino et al. (2016) referenced the positive influence of fertilization

Table 3. Agronomic traits of einkorn and emmer as affected by seeding rate and topdressing during the growing period of 2017/2018.

Treatments			Hulled grain yield	Ear number m^{-2}	Hulled grain weight per ear	Spikelet number per ear	Grain number per ear	Dehulled grain weight per ear	Tillering coefficient	Protein content
			t ha^{-1}		(g)			(g)		(%)
		Grains m^{-2}								
Interaction	Einkorn	100	3.230	517	1.075	33.9 a	28.4 c	0.762	4.95 a	12.6
Species ×		150	3.528	626	0.926	32.8 b	26.3 d	0.657	4.57 a	12.3
seeding rate		200	3.731	699	0.922	31.5 c	25.4 de	0.642	3.58 b	12.7
		250	3.588	776	0.852	29.1 d	23.5 e	0.600	3.37 b	12.7
	Emmer	100	3.165	296	2.375	28.0 e	36.9 a	1.607	2.23 c	13.5
		150	3.038	260	1.995	27.2 e	33.5 b	1.357	1.54 d	13.5
		200	2.764	335	2.167	27.3 e	35.2 ab	1.517	1.66 d	13.9
		250	3.410	349	2.171	27.1 e	34.6 b	1.467	1.55 d	13.6
		Topdressing								
Interaction	Einkorn	C	3.788	691	0.982	32.3	26.4	0.694	4.37	12.4 d
Species ×		T	3.250	618	0.906	31.3	25.4	0.636	3.86	12.8 c
topdressing										
	Emmer	C	3.308	339	2.147	27.4	34.8	1.475	1.91	13.2 b
		T	2.881	281	2.207	27.4	35.3	1.499	1.58	14.1 a
Mean	Einkorn		3.519	654 a	0.944 b	31.8 a	25.9 b	0.665 b	4.12 a	12.6 b
Species	Emmer		3.094	310 b	2.177 a	27.4 b	35.0 a	1.487 a	1.74 b	13.6 a
Mean	100		3.198	406 c	1.725 a	31.0 a	32.7 a	1.185	3.59 a	13.0
Seeding	150		3.283	443 c	1.460 b	30.0 b	30.0 b	1.007	3.05 b	12.9
rate	200		3.248	517 b	1.545 b	29.4 b	30.3 b	1.080	2.62 c	13.4
(grains m^{-2})	250		3.499	563 a	1.511 b	28.1 c	29.1 b	1.033	2.46 c	13.1
Mean	C		3.548 a	515 a	1.564	29.9	30.6	1.084	3.14 a	12.8 b
Topdressing	T		3.066 b	449 b	1.556	29.4	30.4	1.068	2.72 b	13.4 a

C – Control without topdressing.
T – Topdressing.
Values followed by the same letter are not significantly different at the 5% level of probability.

on grain yield and biomass as well as protein content in emmer grain. Fertilization with nitrogen resulted in the concurrent increase of plant height and lodging. Iannucci et al. (2018) obtained positive effects from nitrogen fertilization in emmer and durum grain yield and quality under an organic farming system.

In 2015/2016 and 2017/2018, topdressing with organic fertilizers did not have a significant influence on yield components, while in 2016/2017 it positively affected all yield components. In 2016/2017, lower precipitation was recorded during the vegetation seasons of einkorn and emmer relative to the other two vegetation seasons (Table 4). During March, April, and May, 34.3, 15.2, and 33.4 mm less precipitation was recorded, respectively, relative to the long-term average. Simultaneously, the average monthly air temperatures in 2016/2017 exceeded the long-term average (Table 5). In dry conditions, topdressing with organic fertilizers that contain nitrogen positively influenced the values of cited yield components. Abid et al. (2016) and Agami et al. (2018) also referenced the positive impact of fertilization with nitrogen on the yield of wheat in dry conditions.

In 2017/2018, the emmer population achieved a significantly higher grain protein content relative to the einkorn population (13.6% versus 12.6%; Table 3). Significant interactions between species and topdressing showed that topdressing with organic fertilizers had a positive influence on protein content in the grains of both cereals. The obtained values coincide with the results of Iannucci et al. (2018) and Lacko-Bartošova and Čurna

Table 4. Total month precipitation (mm) during the 2015/2016, 2016/2017, and 2017/2018 growing seasons and long-term average (1981–2010) in Zagreb–Maksimir.

Month	Growing season			Long-term average 1981-2010
	2015/2016	2016/2017	2017/2018	
October	174.9	107.9	72.0	80.0
November	39.1	96.2	113.2	76.0
December	0.7	1.9	92.3	62.7
January	60.5	34.3	56.7	45.5
February	126.8	41.4	87.5	39.6
March	54.3	19.8	72.2	54.1
April	49.5	44.3	65.8	59.5
May	94.7	35.2	68.7	68.6
June	130.5	107.8	127.8	97.4
July	46.8	58.0	85.2	71.4
Total	777.8	546.8	841.4	654.8

Table 5. Mean monthly air temperature (°C) during the 2015/2016, 2016/2017, and 2017/2018 growing seasons and long-term average (1981–2010) in Zagreb–Maksimir.

Month	Growing season			Long-term average 1981–2010
	2015/2016	2016/2017	2017/2018	
October	11.2	10.4	11.9	11.3
November	8.2	6.8	7.3	5.8
December	3.2	–0.4	4.0	1.6
January	1.3	–3.2	5.2	0.5
February	6.9	5.2	0.2	2.2
March	8.0	10.0	5.2	6.8
April	13.0	12.4	16.1	11.4
May	16.1	17.7	19.5	16.5
June	21.1	22.5	21.4	19.6
July	23.4	24.0	22.5	21.5
Average	11.2	10.5	11.3	9.7

(2015), but they are slightly lower than those of researchers who found that grain protein content varied from 15.8% to 21.3% in einkorn (Brandolini et al., 2008; Sachambula et al., 2015; Akar et al., 2019) and from 13.7% to 18.8% in emmer (Piergiovanni et al., 1996; Brandolini et al., 2008; Akar et al., 2019). Marino et al. (2009) also reported that fertilization with nitrogen had a positive influence on grain protein content in emmer; however, lodging also increased.

In conclusion, compared to einkorn populations, emmer populations showed superiority in a greater number of yield components and grain protein content; however, due to the larger coefficient of tillering, einkorn achieved a higher yield. In both cereals, the yield tended to grow as the seeding rate increased, although the yield increase was not statistically significant when the seeding rate exceeded 150 grains per m^2. Topdressing with organic fertilizers had a significant positive effect on the yields of both einkorn and emmer populations. However, in unfavorable weather conditions (heavy rain and wind), topdressing with organic fertilizers negatively influenced the yield and lodging of both cereals increased. Topdressing with organic fertilizers also led to an increase in grain protein content in both einkorn and emmer populations.

References

Abid M, Tian Z, Ata-Ul-Karim ST, Cui Y, Liu Y et al. (2016). Nitrogen nutrition improves the potential of wheat (*Triticum aestivum* L.) to alleviate the effects of drought stress during vegetative growth periods. Frontiers in Plant Science 7: 981. doi: 10.3389/fpls.2016.00981

Agami RA, Alamri SAM, Abd El-Mageed TA, Abousekken MSM, Hashem M (2018). Role of exogenous nitrogen supply in alleviating the deficit irrigation stress in wheat plants. Agricultural Water Management 210: 261-270. doi: 10.1016/j.agwat.2018.08.034

Akar T, Cengiz MF, Tekin M (2019). A comparative study of protein and free amino acid contents in some important ancient wheat lines. Quality Assurance and Safety of Crops & Foods 11 (2): 191-200. doi: 10.3920/QAS2018.1382

AOAC (2015). Official Methods of Analysis. Gaithersburg, MD, USA: AOAC International.

Aslan D, Zencirci N, Etöz M, Ordu B, Bataw S (2016). Bread wheat responds salt stress better than einkorn wheat does during germination. Turkish Journal of Agriculture and Forestry 40 (5): 783-794. doi: 10.3906/tar-1604-59

Brandolini A, Hidalgo A, Moscaritolo S (2008). Chemical composition and pasting properties of einkorn (*Triticum monococcum* L. subsp. *monococcum*) whole meal flour. Journal of Cereal Science 47 (3): 599-609. doi: 10.1016/j.jcs.2007.07.005

Castagna R, Minoia C, Porfiri O, Rocchetti G (1996). Nitrogen level and seeding rate effects on the performance of hulled wheats (*Triticum monococcum* L., T. *dicoccum* Schubler and *T. spelta* L.) evaluated in contrasting agronomic environments. Journal of Agronomy and Crop Science 176 (3): 173-181. doi: 10.1111/j.1439-037X.1996.tb00461.x

Codianni P, Paoletta G, Castagna R, Li Destri Nicosia O, Di Fonzo N (1993). Agronomical performance of farro in southern Italy environments. L'Informatore Agrario 38: 45-48 (in Italian).

Čurná V, Lacko-Bartošová M (2015). Emmer wheat—production parameters. Acta Fytotechnica et Zootechnica 18: 4-6. doi: 10.15414/afz.2015.18.si.04-06

De Giorgio D, Maiorana M, Rizzo V, Ferri D, Convertini G (1995). Evaluation of the main bio-agronomic and qualitative characteristics of emmer (*Triticum dicoccum* Shübler) at different sowing times and nitrogen fertilizing levels. Cahiers Options Méditerranéennes 12: 75-78.

Hidalgo A, Brandolini A (2014). Nutritional properties of einkorn wheat (*Triticum monococcum* L.). Journal of the Science of Food and Agriculture 94: 601-612. doi: 10.1002/jsfa.6382

Iannucci A, Fares C, Codianni P (2018). Influence of nitrogen levels on bio-agronomic and quality traits of tetraploid wheats under organic farming. Annals of Applied Biology 173: 1-15. doi: 10.1111/aab.12429

Jaradat AA (2011). Ecogeography, genetic diversity, and breeding value of wild emmer wheat (*Triticum dicoccoides* Körn ex Asch. & Graebn.) Thell. Australian Journal of Crop Science 5 (9): 1072-1086.

Kaplan M, Akar T, Kamalak A, Bulut S (2014). Use of diploid and tetraploid hulled wheat genotypes for animal feeding. Turkish Journal of Agriculture and Forestry 38 (6): 838-846. doi: 10.3906/tar-1401-20

Karagöz A, Pilanali N, Polat T (2006). Agro-morphological characterization of some wild wheat (*Aegilops* L. and *Triticum* L.) species. Turkish Journal of Agriculture and Forestry 30 (6): 387-398.

Karagöz A, Zencirci N (2005). Variation in wheat (*Triticum* spp.) landraces from different altitudes of three regions of Turkey. Genetic Resources and Crop Evolution 52: 775-785. doi: 10.1007/s10722-004-3556-3

Konvalina P, Capouchová I, Stehno Z, Moudrý J (2010). Agronomic characteristics of the spring forms of the wheat landraces (einkorn, emmer, spelt, intermediate bread wheat) grown in organic farming. Journal of Agrobiology 27 (1): 9-17. doi: 10.2478/s10146-009-0002-3

Lacko-Bartošová M, Čurná V (2015). Nutritional characteristics of emmer wheat varieties. Journal of Microbiology, Biotechnology and Food Sciences 4: 95-98. doi: 10.15414/jmbfs.2015.4.special3.95-98

Marino S, Cocozza C, Tognetti R, Alvino A (2016). Nitrogen supply effect on emmer (*Triticum dicoccum* Schübler) ecophysiological and yield performance. International Journal of Plant Production 10 (4): 457-468.

Marino S, Tognetti R, Alvino A (2009). Crop yield and grain quality of emmer populations grown in central Italy, as affected by nitrogen fertilization. European Journal of Agronomy 31: 233-240. doi: 10.1016/j.eja.2009.08.002

Moudrý J, Konvalina P, Stehno Z, Capouchova I, Moudrý J Jr (2011). Ancient wheat species can extend biodiversity of cultivated crops. Scientific Research and Essays 6 (20): 4273-4280.

Nakov G, Stamatovska V, Necinova Lj, Ivanova N, Damyanova S (2016). Nutritional properties of einkorn wheat (*Triticum monococcum* L.)—review. In: Proceedings of the 55th Science Conference of Ruse University; Ruse, Bulgaria. pp. 381-384.

Pasquini M, Corazza L, Perrino P (1989). Evaluation of *Triticum monococcum* and *Triticum dicoccum* accessions for resistance to rusts and powdery mildew. Phytopathologia Mediterranea 28 (3): 195-198.

Piergiovanni AR, Laghetti G, Perrino P (1996). Characteristics of meal from hulled wheats (*Triticum dicoccon* Schrank and *T. spelta* L.): an evaluation of selected accessions. Cereal Chemistry 73 (6): 732-435.

Sachambula L, Hartman I, Psota V (2015). Einkorn wheat malting quality. Kvasný Průmysl 61 (10-11): 320-325. doi: 10.18832/kp2015030

Şahin Y, Yildirim A, Yücesan B, Zencirci N, Erbayram Ş et al. (2017). Phytochemical content and antioxidant activity of einkorn (*Triticum monococcum* ssp. *monococcum*), bread (*Triticum aestivum* L.), and durum (*Triticum durum* Desf.) wheat. Progress in Nutrition 19 (4): 450-459. doi: 10.23751/pn.v19i4.5847

Tekin M, Cengiz MF, Abbasov M, Aksoy A, Canci H et al. (2018). Comparison of some mineral nutrients and vitamins in advanced hulled wheat lines. Cereal Chemistry 95 (3): 436-444. doi: 10.1002/cche.10045

Troccoli A, Codiani P (2005). Appropriate seeding rate for einkorn, emmer, and spelt grown under rainfed condition in southern Italy. European Journal of Agronomy 22: 293-300. doi: 10.1016/j.eja.2004.04.003

Vallega V (1992). Agronomical performance and breeding value of selected strains of diploid wheat, *Triticum monococcum*. Euphytica 61 (1): 13-23.

Zadoks JC, Chang TT, Konzak CF (1974). A decimal code for growth stages of cereals. Weed Research 14: 415-421. doi: 10.1111/j.1365-3180.1974.tb01084.x

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. doi: 10.1007/s10722-014-0084-7