# EMMER – ANCIENT WHEAT SUITABLE FOR ECOLOGICAL FARMING

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***Abstract.*** *The objective of this study was to evaluate production parameters and selected nutritional compounds of three winter emmer wheat varieties, cultivated under the conditions of ecological farming in the south region of the Slovak Republic during two growing seasons. Field experiments were established on a Haplic Luvisol developed at proluvial sediments mixed with loess. Experimental location has continental climate, belongs to warm agro-climatic region, arid subregion with predominantly mild winter. The average long-term temperature is 9.8°C and for vegetative period it is 16.4°C. Production and nutritional parameters were analyzed in three varieties of winter emmer wheat – Agnone, Molise sel Colli, Guardiaregia in three repetitions. The experimental data were statistically evaluated by STATISTICA 7.0, using multifactorial analysis of variance. The influence of weather conditions on selected production parameters was higher than compared to the effect of tested varieties. Significant differences between varieties were determined in production parameters: weight of grains per spike and TGW. Average weight of grains per spike was 1.63 g; TWG averaging about 47.67 g. Average theoretical yield of emmer varieties was 6.9t.ha$^{-1}$. Nutritional compounds were not influenced by variety; only the crude protein content was affected by weather conditions during two growing seasons. The average content of fat was 0.96%, average crude protein content was 13.6%, and the highest was achieved by variety Agnone (14.17%). The mean soluble fibre content was 0.41%. Soluble fibre is known for its hypocholesterolaemic effect. Starch is the main storage carbohydrate in wheat kernels, accounting for 61 – 68% of the grain. As a primary functional component in cereal grains, its content and characteristics are known to substantially affect the quality of wheat and its end-products. Starch content of three emmer varieties varied from 65.1% to 66.0% without significant influence of weather conditions and variety. Emmer wheat as ancient cereal has a unique composition of secondary components, such as starch, which may play a role as functional food ingredience. Emmer wheat can be suitable and profitable crop when cultivated in marginal areas or under conditions of low-input and ecological agriculture, where modern wheats are unable to develop their full productive potential because they were selected for favourable pedoclimatic and intensive agronomic conditions. Emmer cultivation is justified under low-input, ecological conditions, where its agronomic performance becomes profitable with respect to modern free-threshing wheats.*

***Key words:*** *emmer wheat, ecological farming, production parameters, nutritional parameters*

## INTRODUCTION

Cultivation of cereals and cereal – like grains extends well back into prehistory. Wheat is one of the oldest cultivated crops, grown for food at least as long ago as 8,000 – 10,000 BC. Evidence suggests that the ancient Egyptian, Babylonian, Greek, Cretan, and Roman civilizations were highly dependent on wheat and barley as the principal food. Cereal grains have evolved over the centuries, primarily to enhance yield, disease resistance, and

quality, through traditional breeding programs. With regard to composition and quality, the emphasis has been to improve the key components, protein and starch; much less attention has been paid to secondary substances such as phenolics and dietary fibre. Indeed, some of the secondary constituents, such as polyphenolics, phytates, carotenoids, minerals, and ash show a role in promoting human health, reducing the risk of chronic diseases, and protecting plants against pests and disease. Accordingly, research programs are in progress to identify plant sources such as ancient grains that contain high levels of components that are biologically active and may provide health benefits (ABDEL – AAL, WOOD, 2005).

The existing designation "specialty grains" is usually applied to grains (primitive, alternative, ancient or recently developed) that exhibit some unique characteristic and are currently produce on a marginal scale for a particular end use or market. "Specialty grains" are those which serve the more unusual niche markets or those that may have special health benefits but whose properties and value are not well known (SLOAN, 2002). Emmer wheat is an example of such "specialty grains". Emmer wheat (*Triticum dicoccon* Schrank) as hulled ancient wheat is one of the earliest domesticated plants and has been a staple crop over millennia (NESBITT, SAMUEL, 1996).

The objective of this study was to evaluate production parameters and selected nutritional compounds of three emmer wheat varieties, cultivated under the conditions of ecological farming in the south region of the Slovak Republic during two growing seasons.

## MATERIAL AND METHODS

Field stationary experiments were carried out at the Experimental base of the Faculty of Agrobiology and Food Resources of the Slovak University of Agriculture in Nitra. Experimental base is at Dolná Malanta near Nitra (48°19´N, 18°07´E). Geographically, it is situated in the west side of Žitavská highland with flat surface with a slight slant to the South and East. The territory is characterized by triangular shape which is defined by mountain Tríbeč, rivers Nitra and Žitava. The elevation of this area is 177 – 178 meters above sea level (HANES et al., 1993). Field experiments were established during 2010 – 2011 and 2011 – 2012 growing seasons on a Haplic Luvisol developed at proluvial sediments mixed with loess. The experimental location has continental climate, belongs to warm agro – climatic region, arid subregion with predominantly mild winter with average long – term (1961 – 1990) annual precipitation 532.5 mm. The average long – term temperature is 9. 8°C and for vegetative period it is 16.4°C. The average temperature for 2010 – 2011 vegetation period was 8.61°C; precipitations were 339.10 mm. The average temperature for 2011 – 2012 vegetation period was 9.59°C; precipitations were 305.30 mm (Table 1). Three winter emmer wheat varieties (Agnone, Guardiaregia, Molise sel Colli) were cultivated in ecological farming system without fertilization and chemical treatment. The varieties were grown within the following crop rotation: common pea, emmer wheat, spring barley. Sowing rate of emmer wheat seed (hulled) was 170kg.ha$^{-1}$ with row spacing of 125 mm. The field trial was arranged into randomized blocks (the average plot size was 10m$^2$) in three repetitions.

*Table 1*

Temperature and precipitation characteristics of the Research Experimental Station at Dolná Malanta

| | Month | | | | | | | | | | Mean temp./precipit. in the growing season |
|---|---|---|---|---|---|---|---|---|---|---|---|
| | **10** | **11** | **12** | **1** | **2** | **3** | **4** | **5** | **6** | **7** | |
| **Longterm weather data (1961 - 1990)** | | | | | | | | | | | |
| Temperature (°C) | 10.1 | 4.9 | 0.5 | -1.7 | 0.5 | 4.7 | 10.1 | 14.8 | 18.3 | 19.7 | 8.2 |
| Precipitations (mm) | 41 | 54 | 43 | 31 | 32 | 33 | 43 | 55 | 70 | 64 | 466 |
| **Growing season 2010 – 2011*** | | | | | | | | | | | |
| Temperature (°C) | 6.9 | 7.6 | -2.3 | -0.9 | -0.6 | 5.9 | 12.7 | 15.8 | 19.8 | 21.2 | 8.61 |
| Precipitations (mm) | 22.8 | 72.6 | 52.7 | 5.5 | 3.6 | 0.2 | 13.2 | 48.4 | 91.1 | 29 | 339.1 |
| **Growing season 2011 – 2012*** | | | | | | | | | | | |
| Temperature (°C) | 8.6 | 3.0 | 2.2 | 1.4 | -2.5 | 7.4 | 11.2 | 17.3 | 20.9 | 26.4 | 9.59 |
| Precipitations (mm) | 35.5 | 1.2 | 42 | 61.1 | 23.5 | 2.8 | 36.1 | 19.6 | 70.1 | 13.4 | 305.3 |

***** growing season from October to July

Production (the length of stem, the weight of grains per spike, the weight of thousand grains, theoretical yield) and nutritional (content of fat, starch, soluble fibre and crude protein) parameters were analyzed in three repetitions. Production parameters, the weight of grains per spike and theoretical yield were recalculated to a humidity of 14%. The nutritional quality parameters were determined by the following methods: starch content by the Ewers polarimetric method (STN 461011 – 37); soluble fibre by EXTRACTOR DOSI - FIBER according to Weende; fat content by Soxhlet extraction (ICC 136) by EXTRACTOR DET – GRA. The crude protein content was determined by the Kjeldahl (N x 5.7) method according to AACC 1983.

All achieved data were statistically analyzed by analysis of variance (ANOVA) in STATISTICA 7.0. Significant differences were evaluated by Fisher´s least significant difference (LSD) test at $P < 0.05$.

## RESULTS AND DISCUSSION

Emmer is particularly appreciated for its content of crude protein, resistant starch, fibre, carotenoids, and antioxidant compounds. Unique composition in secondary compounds, such as carotenoids and starch, play a role as functional food ingredients (SERPEN et al., 2008).

In our study the average protein content was 13.67% and varied from 13.26% (Guardiaregia) to 14.17% (Agnone) without significant differences between varieties (Table 2). Protein content was influenced by growing season. Significantly higher protein content (14.62%) was determined in warmer growing season 2011 – 2012 with low precipitations in March, May and July. A selection of data on the crude protein content of emmer wheat available in the literature has shown significant variability. For example, BLANCO et al. (1990) reported high range of protein content from 8.7 – 18.0% db (mean 12.5% db) in 50 accessions, whereas PERRINO et al. (1996) found a range of 14.2 – 20.2% db. Others have confirmed crude protein content variability with values ranging from 7.9% db (GALTERIO et al., 1994) to 19.9%

db, depending on both the genotype and the cultivation environment (GALTERIO et al, 1999, 2003; MARCONI AND CUBADDA, 2005).

The protein content of emmer as hulled wheat was consistently higher than those of modern wheats (*T. aestivum, T. durum*) cultivated under the same agronomic conditions (CASTAGNA et al., 1996; REEDY et al., 1998). However, this does not justify the classification of emmer and hulled wheats in general as protein – rich crops since their high protein level (and high content of other nutrients) could be a consequence of low grain yield. In fact, comparing the protein yields ($g.m^{-2}$), the values for emmer are similar or lower than those for modern wheats (PIERGOVANNI et al., 1996).

Lipids are relatively minor constituents in cereal grains. However, they must be taken into consideration when discussing nutrition, grain storage, and processing. (PIIRONEN et al., 2002). The lipid content of emmer has been reported in very few investigations. MARCONI et al. (2001) found an average lipid content of 2.8% db (range 2.4 – 3.0% db) in nine emmer genotypes, similar to that found in twelve spelt genotypes (mean 2.7% db, range 2.5 – 3% db) and in five varieties of durum wheat (2.8% db) but higher than in three cultivars of soft wheat (2.5% db) (MARCONI, CUBADDA, 2005). Lower lipid values were found by PIERGIOVANNI et al. (1996) in 50 accessions of emmer (average 2.0% db; range 1.4 – 2.8% db). Winter emmer wheat varieties in our experiments were characterized by the lowest fat values. The average fat content was 0.96% and range between 0.91 (Molise sel Colli) and 0.99% (Agnone and Guardiaregia). Differences between varieties and growing seasons were not significant (Table 2). Our results are in agreement with GIACINTUCII et al. (2014) who noted that spring emmer wheat showed higher lipid content of grain (2.33%) than winter emmer wheat (1.52%).

Total starch is the main nutritional component of the emmer kernels, with values ranging from 52.7 to 56.8% db (GALTERIO et al., 2003). These values are similar to those of durum wheat, although the lowest values could be attributed to hulled wheats' minor capacity for starch accumulation compared to that of modern wheats (MARCONI, CUBADDA, 2005).

The content of starch in the investigated verieties was more than 65% in all varieties (Table 2).The highest content of starch was reported in Agnone variety (66%), the lowest content in Molise sel Colli (65.12%). Differences between varieties and growing seasons were not significant. GALTERIO et al. (2003) reported starch content of emmer wheat varieties between 45.7% and 65.1%. New varieties were characterized by lower values of starch (54.3 – 55.6%) than older ones (55.5 – 56.8). According to KONVALINA et al. (2008) lower starch content provided spring emmer wheat varieties (mean 47.7% at locality Prague, 40.9% at locality České Budějovice). MARCONI and CUBADDA (2005) determined content of digestible carbohydrate in whole meal and flour of three emmer wheat varieties grown in Italy. Lower content of starch was found in whole meal (57.2, 58.0, and 60.9%) than in flour (65.9, 67.5, and 68.5%). The highest starch content was in Molise sel Colli. By contrast, spelt whole meal contained 62.2% of starch.

Whole – meal emmer, like all whole – meal cereals, is a good source of dietary fibre and is characterized by a marked predominance of insoluble components, mostly cellulose and hemicelluloses, over soluble components (MARCONI, CUBADDA, 2005). The whole meal of three emmer genotypes had a total dietary fibre content of about 10 – 12% db, mainly insoluble fractions (85 – 88% of total fibre). Lower values of total dietary fibre were found by GALTERIO et al. (1994) in three emmer populations (mean 7.11%), and by GALTERIO et al. (1999) in another seven emmer populations (mean 8.4% db, range 8.04 – 8.94% db), where the soluble dietary fibre (mean 1.69% db, range 1.57 – 1.84% db) was about 20% of the total dietary fibre.

Soluble fibre is known for its hypocholesterolaemic effect (JENKINS et al., 1995). In our study of three winter emmer wheat varieties the content of soluble dietary fibre (SDF) was lower than is reported in foreign literature (Table 2). The content of SDF was not significantly influenced by weather conditions and variety. SDF content was 0.40% in all varieties.

*Table 2*

Statistical evaluation of selected nutritional compounds of three winter emmer wheat varieties

| | Fat (%) | Crude protein (%) | Soluble dietary fibre (%) | Starch (%) |
|---|---|---|---|---|
| **Variety** | | | | |
| Agnone | 0.99 n.s. | 14.17 n.s. | 0.40 n.s. | 66.00 n.s. |
| Guardiaregia | 0.99 n.s. | 13.26 n.s. | 0.40 n.s. | 65.32 n.s. |
| Molise sel Colli | 0.91 n.s. | 13.48 n.s. | 0.41 n.s. | 65.12 n.s. |
| **Growing season*** | | | | |
| 2010 - 2011 | 0.93 n.s. | 12.65 a | 0.40 n.s. | 66.15 n.s. |
| 2011 - 2012 | 0.99 n.s. | 14.62 b | 0.40 n.s. | 64.81 n.s. |
| **Mean** | **0.96 ± 0.091** | **13.64 ±1.301** | **0.40 ± 0.049** | **65.48 ±1.397** |

* growing season from October to July
n.s. no significant difference at alpha 0.05
a/b different letters in the same column mean significant difference at alpha 0.05

The results of two – year evaluation of production parameters (the length of stem, the weight of grains per spike, TGW, and theoretical yield) are shown in Table 3.

*Table 3*

Statistical evaluation of selected production parameters of three winter emmer wheat varieties

| | The length of stem (cm) | The weight of grains per spike (g) | TGW (g) | Theoretical yield ($t.ha^{-1}$) |
|---|---|---|---|---|
| **Variety** | | | | |
| Agnone | 87.65 n.s. | 1.59 a | 45.62 a | 7.40 n.s. |
| Guardiaregia | 84.78 n.s. | 1.88 b | 54.46 b | 7.66 n.s. |
| Molise sel Colli | 86.65 n.s. | 1.50 a | 44.84 a | 6.54 n.s. |
| **Growing season*** | | | | |
| 2010 - 2011 | 88.84 n.s. | 1.74 b | 47.66 n.s. | 8.32 b |
| 2011 - 2012 | 83.88 n.s. | 1.58 a | 48.95 n.s. | 6.07 a |
| **Mean** | **86.36 ± 4.301** | **1.66 ± 0.380** | **48.30 ± 5.101** | **7.20 ± 1.560** |

* growing season from October to July
n.s. no significant difference at alpha 0.05
a/b different letters in the same column mean significant difference at alpha 0.05

The height of plant is an important factor with the impact on lodging resistance. The results of the Germpalsm Institute of Bari showed that the emmer accessions are tall plants. Plant height varied from 69 to 140 cm, the average height was always over 100 cm with low grain yields (0.6 – 4.9 $t.ha^{-1}$) (MARCONI, CUBADDA, 2005). KONVALINA et al. (2010) reported

that the plants of emmer, einkorn and spelt were very long (112.7 cm on average), but 25% of them were longer than 125 cm. The shortest was einkorn – 101 cm, followed by emmer – 107 cm and spelt - 112 cm. The plants were long enough to compete with weeds, but long plants were more susceptible to lodging.

Within more dry conditions of our experiments, the average stem length of emmer varieties was 86.4 cm and ranged from 84.8 cm (Guardiaregia) to 87.6 cm (Agnone). Differences between varieties were not significant; neither the weather conditions had significant effect on this parameter.

The weight of thousand grains (TGW) is an important yield forming parameter. Statistical evaluation of our three tested varieties showed significant influence of the variety. The average TGW was 48.3 g, significantly highest was achieved in Guardiaregia (54.45 g) and the lowest in Molise sel Colli (44.84 g). TGW was not affected by weather conditions. Observations of DE VITA et al. (2006) showed that landraces had lowest TGW (37.5 g), higher TGW was reached by genotypes selected from landraces (39.0 g) and the highest TGW gave modern cultivars as Mosé or Padre Pio (44.2 g). MONDINI et al. (2014) reported significant effects of environment and genotype on TGW, but in contrast to yield, TGW was stable and no serious cross-over interactions were observed.

The weight of grains per spike was significantly influenced by tested varieties (Table 3). The average weight of grains per spike achieved 1.66 g, significantly the highest gave Guardiaregia (1.88 g) and the remaining two varieties reached lower, statistically equal values. The weight of grains per spike is the yield forming component which together with number of productive tillers per square unit are crucial for grain production. In our previous study (LACKO-BARTOSOVA, CURNA, 2015); the average number of productive tillers per $m^2$ achieved 445.6 pc, without significant differences between varieties.

Average theoretical yield in our experiment was 7.2t.$ha^{-1}$, no significant differences between varieties were determined. Significant differences in TGW caused variations in theoretical yield, with the highest achieved by Guardiaregia (7.66 t.$ha^{-1}$) and lowest by Molise sel Colli (6.54 t.$ha^{-1}$). MONDINI et al. (2014) reached the highest yield under higher rate of N fertilization, the lowest yields were observed in the organic and low N input trials. As for the others ancient wheat species, also for emmer are not suitable too high rates of N fertilization, which could result in lodging, poor grain filling and loss of yield.

## CONCLUSIONS

In our study, selected production parameters and nutritional compounds of three emmer wheat varieties cultivated under organic farming conditions were analyzed. Statistical analysis confirmed significant differences between varieties in TGW and weight of grains per spike. Weather conditions during two vegetative periods significantly influenced the weight of grains per spike, theoretical yield and crude protein content. Emmer wheat could be suitable for cultivation in marginal areas, under conditions of low-input or organic farming, where modern soft wheat varieties are unable to develop their full productive potential, because they are selected for favourable pedoclimatic and intensive agronomic conditions.

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