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ANCIENT WHEATS – AS AN EXAMPLE OF DIVERSIFICATION IN ORGANIC AGRICULTURE

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Abstract: Species diversity is one of the highest in organic agriculture yet arable farming is still characterized by the dominance of a few cereal species. The present work summarizes the results of a 3-year experiment on hulled wheats as potential candidates of food system diversification. 10 winter and 3 spring emmer and 5 winter einkorn accessions, most of them being landraces, were investigated on 10m^2 plots under marginal sandy soil conditions in East-Hungary. Most winter accessions adapted well to these conditions, producing grain yield above 3 t/ha in 3-year average, and some landraces were even ranked higher than registered varieties. Einkorn proved to be resistant to leaf fungal diseases, however, *Fusarium* infected both species similarly. Compared to emmer, einkorn seeds contained higher bound flavonoids and had higher antioxidant activity. Based on our findings on grain yield and quality traits both emmer and einkorn can be a good alternative for organic growers.

Introduction: Modern societies are characterized by a constant, dramatic decrease in diversity, typical for both the nutritional and cultivation habits. In contrast with the hundreds of plants consumed by ancient people, only 30 species provide 95% of global calories and protein demand. Intensification of agriculture resulted in dilutions in the grain macro- and microelements, bioactive components and vitamins. Chronic (non-communicable) diseases are also associated with modern human diet.

Organic agriculture is aimed to provide a more diverse and more sustainable way of food production, however, in some countries like Hungary, and especially in cereal production, it often has to face marginal conditions, low mechanisation and production difficulties. With their special nutritional character and better tolerance to low-input conditions, ancient wheat species could provide an alternative solution to increase both biodiversity and climate adaptation as well as profitability of production.

Material and methods: Regarding health benefits, the rising market demand, and urgent need for diversification of cropping systems in the light of climate change, emmer and einkorn were chosen for the tests. 10 winter and 3 spring

emmer (*Triticum turgidum* subsp. *dicoccum* Schrank*)* and 5 winter einkorn (*Triticum monococcum* L.) accessions were kindly provided by Pro Specie Rara (CH) and Plant Diversity Centre (NöDiK, HU) in the case of landraces, and by the Centre for Agricultural Research Martonvásár (HU) and the Louis Bolk Institute (NL) in the case of registered varieties.
The experiment was sown at the Research Institute of Nyíregyháza in East Hungary in marginal sandy soil on 10 m^2 plots, first in 2015, in 1-4 replications (with respect to the availability of seeds) in an incomplete, and from 2016 in a complete block design, in four replicates. Winter survival (%), disease scores (% of coverage), phenological development (Zadoks et al. 1974), hulled grain yield per plot (harvested with a plot combine harvester), spike number m^{-2}, thousand (hulled) grain weight (TGW) and test weight were recorded each year.
Grain quality of the whole-flour of the grain samples was analysed at the University of Bologna. All determinations were replicated twice and the results expressed on a dry matter (DM) basis assuming 14% water content (Shewry and Hey 2015). Protein content was determined using a Foss Infratec 1229 NIT spectrophotometer. Lipid analysis was carried out according to the standardized methods (AOAC, 1990). Total (TDF), insoluble (IDF) and soluble (SDF) dietary fibre contents were determined following the enzymatic/gravimetric method (Prosky et al. 1988), and the extracts containing free and bound phenolic compounds were analysed for flavonoid content following the spectrophotometric method (Dinelli et al. 2011). The antioxidant activity (DPPH) assay was carried out according to Brand-Williams et al. (1995).
Due to the variation in the number of repetitions in various years, two-way ANOVA without repetitions was applied to compare the three-year performances of different accessions, the two factors being the variety and the year (Microsoft Excel 2010). Wilcoxon signed rank test was used to make comparisons between years on the species level (related samples in pairs), while for comparisons between emmer and einkorn, the data were evaluated using Mann-Whitney U test (IBM SPSS Statistics 25.0).
Results: Under the marginal sandy soil conditions of the experiments, the performance of most landraces in either quantity or quality were not statistically different from registered varieties; the best landraces were even ranked higher in yield in all three years than the commercial varieties. Some accessions produced above 3t/ha in 3-year average, and 4 and 5 t/ha in favourable years in emmer and einkorn, respectively (Figure 1), the top three being GT 143, GT 381 and Mv Hegyes (with 3.44, 3.35, 3.26 t/ha) in emmer and GT 2139, Mv Alkor and Tifi (3.58, 3.16 and 3.08 t/ha) in einkorn. The calculated mean grain yield values for years 2016, 2017 and 2018 were 3.16, 1.76 and 3.58 t/ha for emmer and 4.33, 1.34 and 2.82 t/ha for einkorn, respectively. For both species, the poorest yield values were obtained in 2017 due to the delayed sowing (in November) accompanied by low temperatures during emergence and early development, and damaging sand storms resulting in extreme variations between single plots. Differences between years were significant ($p<0.05$). Einkorn reacted with higher yield fluctuations to the crop year than emmer did. Spring emmer and intensive varieties (like Mv Menket), however, could not be recommended for cultivation under such conditions.
Although emmer and einkorn usually have better disease resistance than modern wheats in general, emmer was susceptible to yellow rust to a varying extent (with 20-70% incidence) depending on the variety, and also to leaf rust to a minor extent. Einkorn had higher disease resistance than emmer; 4 accessions were resistant to all occurring leaf fungal diseases (*Septoria tritici*, *Drechslera graminea*, leaf rust and yellow rust). The most resistant accessions against all diseases were GT 1399 in emmer and Nödik einkorn and Tifi in einkorn. Both species were susceptible to some extent to *Fusarium* depending on the year and variety, however, the emmer GT 1399 and einkorn GT 2139 landraces had no or only a very low level of *Fusarium* infection.
Grain protein content in both species was high, varying between 15.3-19.7% in emmer and 14.8-20.2% in einkorn, with average values around 16.7%. The protein yields were, however, significantly lower in einkorn and in the emmer

accession GT 1402 than in the rest of emmer varieties (p= 0.001). The range was 344-422 and 364-548 kg/ha, with mean values 394 and 512 kg/ha for einkorn and emmer, respectively.
Einkorn seeds contained 277% higher bound and 63% higher total flavonoids, 62% more lipids and had 243% higher antioxidant activity (DPPH) than emmer (p= 0.001). There were, however, no significant differences in the free, bound and total phenolic and free flavonoid contents between the two species.

Figure 1. Grain yield of winter emmer and einkorn and spring emmer accessions in 2016-2018.

Discussion: Most winter accessions of both ancient wheat species exhibited good adaptation abilities to the marginal conditions, producing around 3 t/ha grain yield in three-year average, while the spring types were not well-suited to the circumstances of the experiment. Some landraces even had higher or similar yields than registered varieties. The factors mostly affecting grain yield were freezing out (2016) and germination rate (2017 in emmer). Disease resistance was outstanding in most einkorn accessions which were resistant to all leaf fungal diseases occurring, while yield performance was more stable in emmer. Grain quality was high in both species, while the antioxidant activity, the bound flavonoid and lipid concentrations were the greatest in einkorn.
Based on our findings on grain yield and quality traits, and taking into account the market price of ancient cereals, both winter emmer and einkorn can be good alternatives for organic growers, especially on marginal soils.

Acknowledgements

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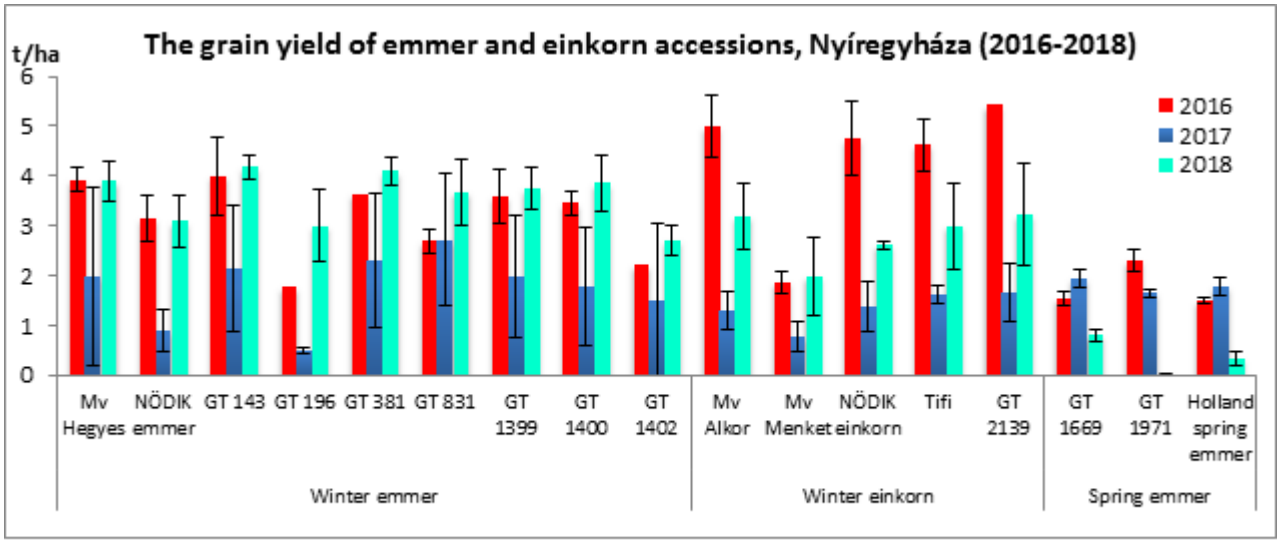

Figure 1. Grain yield of winter emmer and einkorn and spring emmer accessions in 2016-2018.

Disclosure of Interest: None Declared

Keywords: einkorn, emmer, diversity, organic farming, landraces, DIVERSIFOOD