GENETIC RESOURCES OF EMMER WHEAT AND THEIR PROSPECTIVE USE IN ORGANIC FARMING

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Abstract

Emmer wheat [*Triticum diccocum* (Schrank) Schuebl] is an example of a crop which has been largely grown in less favourable farming areas (i. e. less fertile montane lands, arid areas, etc.). Our paper work aims at a description of an availability of the wheat genetic resources within Europe and an evaluation of the particular agronomically significant parameters and the elementary qualitative parameters of the emmer wheat genetic resources within the Czech Republic. Data for the evaluation of a structure and availability of the wheat genetic resources were drawn from the European Wheat Database and evaluated. Precise small-plot trials were established on the certified organic parcel of the University of South Bohemia in České Budějovice and used between 2009 and 2011. Eight emmer wheat genetic resources and two bread wheat control varieties were involved in the trials. Selected agronomic and elementary qualitative parameters were studied. The accessions were resistant to the common wheat diseases and competitive to weed plants. The mean yield rate achieved 2.03 $t.ha^{-1}$. A reduced resistance to lodging, just as a reduced spike productivity, were two most significant disadvantages of the wheat growing. The protein proportion achieved almost 17 per cent. On the other hand, the emmer wheat proteins usually swell less than the protein of bread wheat (low values of Zeleny test). The emmer wheat is not, therefore, suitable for the traditional baking and processing but for other types of processing, i.e. a production of pasta, biscuits, etc. As for the yield formation, a legally protected variety Rudico was considered as the most prospective of all the tested emmer wheat accessions.

Key words: genetics resources, wheat, emmer, organic farming

Nowadays, the world collections of plant genetic resources include approximately 7.5 milion samples. The collections of *Triticum* and *Aegilops* species involve approximately 900 thousand samples (Börner A. *et al.*, *2011*). Wheat (*Triticum* spp.) is a self-pollinating annual crop belonging to the *Poaceae* family, and the *Triticum* genus too (Šrámková Z. *et al.*, *2009*). The amount of species belonging to the *Triticum* L. genus varies from five to twenty seven, depending on the various classification methods (Merezhko A.F., *1998*). All the *Triticum* species are divided into three different categories, according to the amount of chromosomes. The elementary category includes seven, fourteen or twenty one chromosomes (Šrámková Z. *et al*., *2009*), making duplications in the vegetative cells. Diploid, tetraploid, and hexaploid species contain the amounts of chromosomes as follows: 2x7=14; 4x7=28; 6x7=42 (Belderok B. *et al.*, *2000*). The currently grown wheat species are divided into three different categories/subspecies (Hammer K., *2000*; Feldman M., *2001*): a diploid species (einkorn), a tetraploid species (hard wheat, emmer wheat, Polish and Persian wheat), a hexaploid species (bread wheat, spelt wheat, club wheat and Indian wheat). Farmers respecting the principles of organic or low-input farming systems are searching for the varieties being characterised by a higher diversity level, which are able to adapt to the particular land and climatic conditions. The wider the genetic base is, the more adaptable the variety is to unexpected environmental conditions (Becker H.C. and Leon J., *1988*; Ceccarelli S. *et al.*, *2001*; Finckh M., *2008*). Emmer wheat [*Triticum dicoccum* (Schrank) Schuebl] is a hulled wheat species, which has been traditionally grown and used as a part of the human diet (Marconi M. and Cubadda R., *2005*). A domestication of emmer wheat started after a primitive farming activity had emerged (Zaharieva M. *et al.*, *2010*). As the varieties having firm spike cobs were extending (Marconi M. and Cubadda R., *2005*), the emmer wheat has become a dominating species and it has been the dominating species for seven thousand years (Feldman M., *2001*). It has extended to the

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Middle East and the Far East, Europe and the northern part of Africa. It has been grown together with barley (Zaharieva M. *et al.*, *2010*). The ancient Romans made mush, groats and bread of the emmer wheat (Braun T., *1995*). It is still grown as a minor crop in Ethiopia, India, Italy (Marino S. *et al.*, *2009*) and Turkey (Giuliani A. *et al.*, *2009*). As the requirements for a diversity and a good quality of food have been increasing, the emmer wheat becomes more and more interesting crop (Zaharieva M. *et al.*, *2010*). Our paper aims at: a) a description of an availability of the wheat genetic resources within Europe; b) an evaluation of agronomically important parameters and elementary qualitative parameters of the emmer wheat genetic resources within the Czech Republic.

MATERIAL AND METHOD

A) Genetics resources of emmer wheat

List of the emmer wheat genetic resources grown within Europe is available in the European Wheat Database (http://genbank.vurv.cz/ewdb/).

B) Field trials and evaluation

Tested varieties: The varieties came from the Gene bank of the Crop Research Institute in Prague-Ruzyně. The genetic resources of emmer wheat [*Triticum dicoccum* (Schrank) Schuebl] and two bread wheat varieties (*Triticum aestivum* L.) were chosen (*Table 1*).

Field Trials: The seeds were sown in a randomized, complete block design on the organic certified research area in České Budějovice during 2009 and 2011. The seeding rate was adjusted to the density of 350 germinable grains per m^2. The crop stands were treated in compliance with the European legislation (the European Council Regulation (EC) No. 834/2007, the European Commission Regulation (EC) No. 889/2008.

Characteristics of the trial stations: the University of South Bohemia in České Budějovice (USB): Mild warm climate, soil type – pseudogley cambisols, kind of soil – loamy sand soil, altitude of 388 m. Results of agrochemical soil analysis are in *Table 2*.

Evaluation during the growing period: length of plant (at the end of the flowering stadium – DC 69); index of lodging (combination of intensity and degree of lodging of the crop stand on each parcel, mean of two measurements, after the heading – DC 59, before the harvest – DC 87); the degree of mildew infestation (DC 37; 51–61; 77) and brown rust infestation (DC 77) were expressed by a score in accordance with symptoms of a disease on plants (9 = no symptoms). After the harvest we measured the grain yield and calculated the protein yield per hectare.

C) Baking quality analysis

The following parameters were tested after the harvest and dehulling of the grains by the methods of the International Association for Cereal Chemistry (ICC): crude protein content (ICC 105/2); index of sedimentation - SDS test (ICC 151); wet gluten content (ICC 106/2) and gluten index (ICC 155).

D) Statistical Data Processing

Data were processed by the Statistica 9.0 (StatSoft. Inc., USA) program.

Table 1

List of tested varieties

Name of Variety/Accession	Identifier[1]	Origin[2]	Botanical Variety[3]
Triticum diccocum (SCHRANK) SCHUEBL			
Rudico	01C0200948	CZE	rufum SCHUEBL.
Weisser Sommer	01C0203993	DEU	dicoccum
May-Emmer	01C0203990	CHE	dicoccum
Triticum dicoccon (Brno)	01C0204022	CZE	rufum SCHUEBL.
Triticum dicoccon (Dagestan)	01C0204016	RUS	serbicum A. SCHULZ
Triticum dicoccon (Palestine)	01C0201261	ISR	serbicum A. SCHULZ
Triticum dicoccon (Tapioszele)	01C0201280	-	semicanum KOERN.
Triticum dicoccum (Tabor)	01C0204318	-	rufum SCHUEBL.
Triticum aestivum L. - control			
SW Kadrilj	01C0104877	SWE	lutescens (ALEF.) MANSF.
Jara	01C0200100	CZE	lutescens (ALEF.) MANSF.

[1] EVIGEZ (http://genbank.vurv.cz/genetic/resources/asp2/default_c.h); [2]Abbreviations of countries comply with ISO 3166-1 alpha-3; [3]Clasification according to: Dorofeev VF, Filatenko AA, Migušova EF (1980). Opredelitel pšenicy, Leningrad, 105 p.

Table 2

Agrochemical soil analysis

Year	pH ($CaCl_2$)	N-NH4	$N\text{-}NO_3$	P	K	Ca	Mg
		[$mg.kg^{-1}$]					
2009	5.91	15.5	8.1	120	65	114	1452
2010	6.67	2.42	7.3	111	86	1808	129
2011	6.75	5.06	17.4	140	136	2034	98

RESULTS AND DISCUSSIONS

There are more than 1 600 accessions of the genetic resources available in the European Wheat Database. Almost one half of the accessions do not have any indicated botanical variety. As for the other of the varieties, *dicoccon*, *haussknechtianum* A. SCHULZ, *rufum* SCHUEBL. and *aeruginosum* FLAKSB, prevail

(*table 3*). The emmer wheat genetic resources registered within Europe usually come from Armenia (234 varieties, which represent 13.4 per cent of all the emmer wheat varieties). Many varieties originate from Italy and Germany (*figure 1*). The varieties having an unknown origin (23 per cent of the accessions) represent an indispensable part of this category. The most of the emmer wheat varieties being registered within Europe are considered as „landraces“ (1075 varieties), which represents 61.5 per cent of all the emmer wheat varieties ever. 471 varieties have an unknown status (almost 27 per cent) (*figure 2*). The most of the emmer wheat varieties being registered within Europe are also considered as “spring forms“ (833 varieties). Only 298 varieties belong to winter forms. Six varieties belong to “intermediate forms”, which make a negligible part of the total amount of the emmer wheat varieties. 610 varieties do not have any indicated form (*figure 3*). Nowadays, the most of the emmer wheat varieties are located in Russia (482 varieties; 27.6 per cent), Germany (304 varieties) and in Ukraine (173 varieties). As for the Czech Republic, 133 varieties are located in this country, which represent 7.6 per cent (*figure 4*).

The paper work also presents and summarizes the findings resulting from the field trials which were executed under the organic farming conditions at the trial station located in České Budějovice. All the tested emmer wheat varieties make part of the collection of the wheat genetic resources. Particular morphological, biological and economic characteristics, just as the qualitative indicators, were tested and evaluated by the researchers. The morphological structure of wheat highly determines whether the certain variety is suitable/unsuitable for the organic farming conditions. The length of plant is the most important morphological characteristic, as it determines an ability of a completing to weeds (Moudrý J. *et al*., *2011*). The mean length of the emmer wheat plants (stalks) which were grown on the trial parcels located in České Budějovice achieved the value of 114 cm (as for the bread wheat plants, the mean value was lower – 98 cm) (*table 4*). According to Stehno Z. *et al*. (*2008*), the length of stalk may vary from 75 to 120 cm. The longer the stalks are, the more competitive to weeds the plants are (Cudney D.W. *et al*., *1991*). Resistance to lodging is an important and essential factor. The shorter plants are not automatically more resistant to lodging (Pagnotta M.A. *et al*., *2005*). The tested emmer wheat crops were less resistant to lodging than the control bread wheat crops. Rudico was the most resistant emmer wheat variety (the plants were 122 cm long at average). Whereas *T. dicoccon* (Dagestan ASSR) was the least resistant emmer wheat variety (the plants were 107 cm long at average).

Table 3

Amount of emmer wheat varieties registered in the European Wheat Database

Botanical variety	Number of Accessions
Triticum dicoccon SCHRANK	711
Triticum dicoccon SCHRANK var. *dicoccon*	228
Triticum dicoccon SCHRANK var. *haussknechtianum* A. SCHULZ	129
Triticum dicoccon SCHRANK var. *rufum* SCHUEBL.	120
Triticum dicoccon SCHRANK var. *aeruginosum* FLAKSB.	119
Triticum dicoccon SCHRANK var. *volgense* (FLAKSB.) FLAKSB.	91
Triticum dicoccon SCHRANK var. *serbicum* A. SCHULZ	59
Triticum dicoccon SCHRANK var. *arras* (HOCHST.) KOERN.	52
Triticum dicoccon SCHRANK var. *atratum* (HOST.) KOERN.	37
Triticum dicoccon SCHRANK var. *vasconicum* (STOLET.) FLAKSB.	35
Others	166

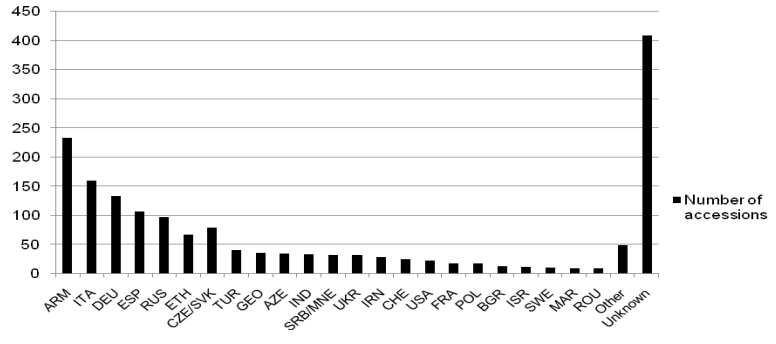

Figure 1 **Amount of accessions and countries of origin (Abbreviations according ISO 3166-1 alpha-3)**

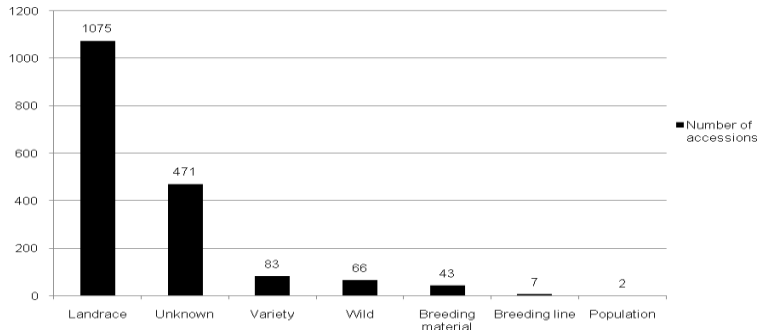

Figure 2 **Amount of varieties and breeding levels**

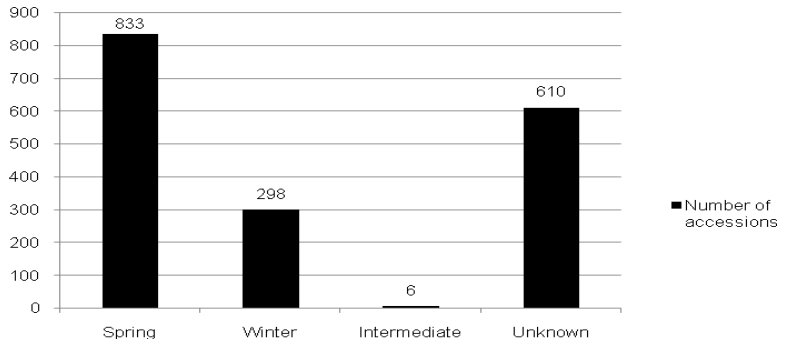

Figure 3 **Amount of varieties and types of growth**

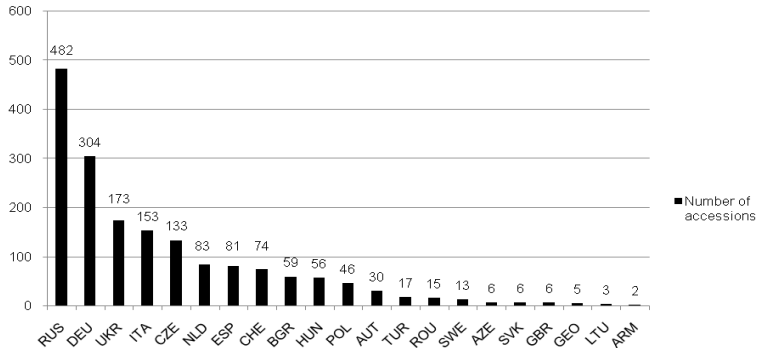

Figure 4 **Amount of varieties and countries of location (Abbreviations according ISO 3166-1 alpha-3)**

It means the variety (Rudico) producing longer stalks and plants was more resistant to lodging than the variety producing shorter stalks and plants [*T. dicoccon* (Dagestan ASSR)]. Concerning the bread wheat varieties, SW Kadrilj proved to be resistant to lodging (the plants were 84 cm long at average) - more resistant than an older Jara variety producing longer stalks than SW Kadrilj. The emmer wheat yield was formed via a high amount of productive tillers (1.6 tillers). The emmer wheat plants were forming more tillers than the control wheat plants (1.3 tillers). It also provoked a higher amount of emmer wheat spikes emerging just before the harvest itself. The emmer wheat grains were smaller than the control wheat grains (thousand grain weight = 30 g). The yield research carried out between 2009 and 2011 has come to the following findings: the emmer wheat varieties achieved 67 per cent of the yield rate of the control bread wheat varieties (Jara and SW Kadrilj), it means 2.03 $t.ha^{-1}$ at average (the control wheat varieties achieved the mean value of 3.02 $t.ha^{-1}$) (*table 4*). The grains were rid of hulls, and the hulls represented 32 per cent of the yield volume. The volume weight of the emmer wheat varieties was lower than the volume weight of the control wheat varieties but the difference was insignificant. The emmer wheat varieties were resistant to the common wheat diseases (i. e. mildew, brown rust, fusarioses, etc.). However, a slight spot infection of leaves and spikes was

noticed. A lot of the emmer wheat genetic resources are resistant to the fungal diseases (i. e. rust, mildew) and drought (Zaharieva M. *et al*., *2010*).

Table 4

Average of the evaluated characteristic values for three research years

Variety	Length of plant (cm)	Number of spikes (m^2)	Number of tillers	Weight of thousand grains (g)	Yield rate ($t.ha^{-1}$)	Amount of hulls (%)
Emmer wheat [Triticum diccocum (Schrank) Schuebl]						
Rudico	122±20	351±70	1.8±1.0	29±0	2.05±0.53	70±0
May-Emmer	114±25	395±71	1.4±0.6	30±0	1.86±0.33	72±0
Weisser Sommer	110±33	427±46	1.5±0.4	29±0	1.53±0.20	71±0
T. dicoccon..(Dagestan. ASSR)	107±23	395±97	1.4±0.5	32±0	2.05±1.06	66±0
T. dicoccon..(Palestine)	115±11	298±68	1.5±0.6	30±0	1.46±1.24	62±0
T. dicoccon..(Tapioszele)	113±16	473±169	1.5±0.4	34±0	2.50±2.38	75±0
T. dicoccon..(Brno)	108±11	409±105	1.9±1.0	29±0	2.65±2.67	62±0
T. dicoccum..(Tabor)	124±26	431±87	1.4±0.5	29±0	2.11±0.75	68±0
Mean	114±19	397±95	1.6±0.6	30±0	2.03±1.13	68±0
Bread wheat (Triticum aestivum L.)						
Jara	113±28	336±139	1.3±0.6	34±0	3.02±0.41	100
SW Kadrilj	84±20	298±56	1.3±0.6	40±0	3.01±1.18	100
Mean	98±27	317±97	1.3±0.5	37±0	3.02±0.72	100

The mean protein content achieved the value of 16.8 per cent (±2.2) in the emmer wheat grains and 13.3 per cent (±2.4) in the bread wheat grains. The emmer wheat grains also contained more wet gluten (39.89 per cent), whereas the control bread wheat grains contained 32.02 per cent of the wet gluten (*table 5*). The proportion and composition of proteins highly determine the quality of the emmer wheat grains. As for the emmer wheat grains, they may contain from 15 to 20 per cent of the proteins (Perrino P. *et al*., *1996 in* Stehno Z. *et al.*, *2008*). Some literal sources even mention the proportion of proteins exceeding 20 per cent (Stehno Z., *2007*). Rudico, the legally protected emmer wheat variety proved the crude protein content of 17 per cent and wet gluten content of 41 per cent. The value of SDS sedimentation test amounted to 37.7 ml. However, Rudico gluten proteins swell less than the proteins contained in the other varieties; therefore, flour made of the emmer wheat grains is not suitable for the baking process. The emmer wheat is, however, suitable for a production of unyeasty products (Marconi M. and Cubadda R., *2005*).

Rudico, the legally protected emmer wheat variety, is the best option for all the farmers interested in the emmer wheat growing. This variety was formed by a collective positive selection of the varieties from the genetic resources (Stehno Z., *2007*). It is resistant to the common wheat diseases, e.g. mildew, brown rust. The high proportion of crude proteins (19 – 20 per cent), the high proportion of gluten (approximately 45 per cent), are the most important qualitative parameters of the variety. The value of SDS sedimentation test may vary from 35 to 40 ml. The grain yield rate may be very high (when taking the wheat species into account) and may achieve 3 $t.ha^{-1}$ (when the prevailing conditions are favourable for the wheat species). It achieved 4.38 $t.ha^{-1}$ in 1998, when the small-plot trials were carried out. Our research trials have found out a lower grain yield rate (2.05 $t.ha^{-1}$) than (Stehno Z., *2007*) mention.

CONCLUSIONS

The basic information on the availability of the emmer wheat genetic resources may be easily found in the European Wheat Database. A user may find an information about each accession concerning the country of origin, the organisation/institution the variety is stored in, the taxon, the status, the year when the variety has been included in the collection, the form of growth and the availability in the database. There are almost two thousand samples of the genetic resources available throughout Europe nowadays. The varieties originating from Armenia, Italy and Germany are the prevailing ones. In most cases, these are land races of the spring form of wheat. The highest number of the genetic resources have been localised in Germany and Russia.

The emmer wheat is considered as a perspective crop from the yield formation point of view. It may be grown in the regions where the environmental conditions are less favourable or unfavourable for the bread wheat. Contrary to the bread wheat modern varieties, the emmer wheat, being grown in such regions, provides a sufficient yield rate. It is resistant to some fungal diseases as mildew, or brown rust. As for the quality, the emmer wheat plants contain a high proportion of proteins (almost 17 per cent) and wet gluten (almost 40 per cent) too, which are significant advantages of this crop. The emmer wheat proportions of proteins and wet gluten are higher than the proportions of proteins and wet gluten being found in the control bread wheat plants.

Table 5

Average of the grain qualitative indicator values for three research years

Variety	Proportion of proteins (%)	Wet gluten content (%)	Gluten Index	SDS-test (ml)	Zeleny test (ml)	Falling number (s)
Emmer wheat [Triticum diccocum (Schrank) Schuebl]						
Rudico	16.6±2.0	40.7±4.8	15±10	38±5	18±1	304±28
May-Emmer	17.0±1.6	41.7±2.3	17±1	42±11	17±7	331±64
Weisser Sommer	16.5±1.8	43.5±9.7	16±11	43±4	17±5	332±34
T. dicoccon..(Dagestan. ASSR)	16.7±2.2	36.0±0.0	12±0	19±6	10±3	200±104
T. dicoccon..(Palestine)	19.2±2.8	46.6±0.0	17±1	28±4	15±1	279±135
T. dicoccon..(Tapioszele)	17.2±2.6	39.6±3.7	12±8	23±6	10±1	327±9
T. dicoccon..(Brno)	14.8±2.7	30.9±6.8	10±9	23±6	12±4	279±122
T. dicoccum..(Tabor)	16.3±1.8	40.3±4.0	13±7	26±4	13±4	313±42
Mean	16.8±2.2	39.9±5.9	14±7	30±10	14±4	296±79
Bread wheat (Triticum aestivum L.)						
Jara	14.2±2.7	36.4±10.5	63±10	65±6	38±6	278±65
SW Kadrilj	12.4±2.3	27.7±6.8	68±6	76±8	45±7	269±78
Mean	13.3±2.5	32.0±9.2	65±8	70±9	42±7	274±65

On the other hand, the emmer wheat plants contain less swelling gluten protein types. Therefore, they are not suitable for the baking process. However, they are suitable for the production of unyeasty products. The mean emmer wheat yield rate has achieved 2.03 $t.ha^{-1}$. There were, nevertheless, significant differences between the individual emmer wheat varieties (the yield rate varied from 0.58 to 4.5 $t.ha^{-1}$). Rudico, a legally-protected variety, is considered as a perspective and suitable variety for the organic farming conditions.

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REFERENCES

Becker, H.C., Leon, J., 1988 - *Stability analysis in plant breeding*, Plant Breed., vol. 101, p. 1-23.

Belderok, B., Mesdag, H., Donner, D. A., 2000 - Bread-Making Quality of Wheat: a century of breeding in Europe, Springer, New York, USA, 428 p.

Börner, A., Neumann, K., Kobiljski, B., 2011 - *Wheat genetic resources - how to exploit*? Czech J. Genet. Plant Breed., vol. 47, p. S43-S48.

Braun, T., 1995 - *Barley cakes and emmer bread*. In: Wilkins, J. *et al*. (Eds.), *Food in Antiquity*, University of Exeter Press, Exeter, p. 25-37.

Ceccarelli, S., Grando, S., Bailey, E., Amri, A., El-Felah, M., Nassif, F., Rezgui, S., Yahyaoui, A., 2001 - *Farmer participation in barley breeding in Syria, Morocco and Tunisia*, Euphytica, vol. 122, p. 521-536.

Cudney, D.W., Jordan, L.S., Hall, A.E., 1991 - *Effect of wild oat (Avena fatua) infestations on light interception and growth rate of wheat* (*Triticum aestivum*), Weed Sci., vol. 39, p. 175-179.

Feldman, M., 2001 - *Origin of cultivated wheat*. In. Bojean, H. P., Angus, W. J. (Eds.), *The world wheat book: A history of wheat breeding*, Lavoiser Publishing, Paris, p. 3-56.

Finckh, M.R., 2008 - *Integration of breeding and technology into diversification strategies for disease control in modern agriculture*, Europ. J. Plant Pathol., vol. 121, p. 399-409.

Giuliani, A., Karagöz, A., Zencirci, N., 2009 - *Emmer Production and Market Potential in Marginal Mountainous Areas of Turkey*, Mount. Res. Develop., vol. 29, p. 220-229.

Hammer, K., 2000 - *Biodiversity of the Genus Triticum*. In: Wiethaler, C. *et al*. (Eds.), *Organic plant breeding and biodiversity of cultural plants*, NABU-FiBL, Bonn-Frick, p. 72-81.

Marconi, M., Cubadda, R., 2005 - *Emmer wheat*. In: Abdel-Aal, E-S. M., Wood, P. (Eds.), *Speciality grains for food and feed*, American Association of Cereal Chemists, St. Paul, USA, p. 63-108.

Marino, S., Tognetti, R., Alvino, A., 2009 - *Crop yield and grain quality of emmer populations grown in central Italy, as affected by nitrogen fertilization*, Europ. J. Agron., vol. 31, p.233-240.

Merezhko, A.F., 1998 - *Impact of plant genetic resources on wheat breeding*, Euphytica, vol. 100, p. 295-303.

Moudrý, J., Konvalina, P., Stehno, Z., Capouchová, I., Moudrý, J. jr., 2011 - *Ancient Wheat Species Can Extend Biodiversity of Cultivated Crops*, Sci. Res. Essays, vol. 6, p. 4273-4280

Pagnotta, M.A., Mondini, L., Atallah, M.F., 2005 - *Morphological and molecular characterization of Italian emmer wheat accessions*, Euphytica, vol. 146, p. 29-37.

Stehno, Z., Konvalina, P., Dotlačil, L., 2008 - *Metodika pěstování pšenice dvouzrnky (uplatněná metodika),* VURV, Praha, 20 p.

Stehno, Z., 2007 - *Emmer Wheat Rudico Can Extend the Spectra of Cultivated Plants*, Czech J. Genet. Plant Breed, vol. 43, p. 113-115.

Šramková, Z., Gregová, E., Šturdík, E., 2009 - *Genetic improvement of wheat - a review*, Nova Biotechnologica, vol. 9, p. 27-51.

Zaharieva, M., Ayana, N.G., Al Hakimi, A., Misra, S.C., Monneveux, P., 2010 - *Cultivated Emmer Wheat (Triticum diccocum Schrank), an Old Crop with a Promising Future: a Review*, Genet. Res. Crop Evol., vol. 57, p. 937-962.