Lehr- und Forschungszentrum für Landwirtschaft
Raumberg-Gumpenstein

62. Tagung der Vereinigung der Pflanzenzüchter und Saatgutkaufleute Österreichs 2011, 49 – 53
ISBN: 978-3-902559-74-6

Influence of different water supply on yield parameters and quality of winter wheat

Clemens Flamm[1*], Caroline Engel[1], Elisabeth Zechner[2], Maren Livaja[3], Michael Schmolke[3] and János Pauk[4]

Abstract

In 2010 and 2011 25 winter wheat varieties were cultivated under water stress and irrigated conditions at two Austrian and one Hungarian location. Generally, yield and yield parameters were influenced negatively by drought stress. Protein content, sedimentation value, maximum resistance and dough energy in the extensogram as well as baking volume were mostly positively influenced under dry conditions. Test weight reacted only at one site in 2010. Decrease of test weight was negatively correlated with the date of ripening of the varieties. In the high quality group the varieties Bitop and GK Kalász diminished their yield in the smallest way. This was due to smaller reductions of the thousand kernel weight in comparison to other varieties. Komarom and GK Petur reached the highest yield in the rainfed and irrigated trials. Bitop and GK Kalász showed the least increase in their protein content and sedimentation value. Exklusiv, GK Békés and Bitop reached the highest protein content under both conditions. Bitop and Exklusiv had the best protein quality. In the medium quality group, the yield and protein content of Brilliant reacted the least. For the breeder the most interesting varieties concerning drought tolerance are Bitop in the high quality group and Brilliant in the medium quality group.

Keywords

Baking quality, drought stress, protein, *Triticum aestivum*, yield

Introduction

Higher temperatures and irregular or low precipitation influence the agriculture directly. That is why in October 2009 the CORNET research project *Winter wheat cultivars maintaining high yield under environmental stress* was started with a view to the effects of climate change. The whole project was divided in three different work packages: field trials, quality aspects and mapping of QTLs for drought tolerance. This paper reports some results of the quality part, nevertheless yield and yield parameters will also be presented. The following research questions were defined: are there influences of water supply on yield components and quality parameters? Do the tested varieties react differently to the two levels of water supply? What are the consequences for breeding regarding the results?

Materials and Methods

In 2010 and 2011 25 winter wheat varieties were cultivated at two Austrian locations, i.e. Breitstetten and Tattendorf, in the Pannonic region and at one Hungarian site, i.e. Szeged. At each location the varieties were cultivated in the natural precipitation surrounding and, additionally, in an irrigated form. The irrigation treatments were the following: 40-58 mm supplementary water divided into two parts in Austria and 10 mm in Hungary in 2010, and 80-90 mm in Austria and 44 mm in Hungary divided into three and four parts, respectively, in 2011. The selected varieties represented a wide range of baking quality. Each of the participating countries, i.e. Austria, Germany and Hungary, proposed eight genotypes. Capo was selected as supplementary check variety. The field experiments were arranged as lattice designs with three to four replications. Plot size varied from 6.5 m² (Hungary) to 12.5-13.5 m² (Austria). In Austria nitrogen fertilization ranged in total from 93 to 140 kg N ha^{-1} divided into three doses on each location, in Hungary 100 kg N ha^{-1} divided into two doses were applied.

The following quality parameters were analyzed: thousand kernel weight (g, 86% d.m.), hectolitre weight (kg, ISO 7971-2), protein content (% d.m., Dumas-method ICC Standard Method 167; N×5.7) and Zeleny sedimentation value (ml, ICC Standard Method 116). According to OBERFORSTER et al. (1994) the 25 varieties were divided into three quality groups (high baking quality, medium baking quality, feed wheat). Extensogram and baking tests were carried out for eight varieties.

Results

From *Figure 1* it is obvious that in the high quality group the varieties Komarom, Element and GK Petur had the highest differences in yield with changing water supply. Bitop and GK Kalász reacted the least. In the medium quality group the varieties Tiger, GK Szala and Eurojet reduced their yield in the rainfed conditions from about 10 to 7 dt ha^{-1}, while Pegassos, Tacitus and Brilliant showed smaller differences in grain yield between the irrigated and rainfed treatment.

[1] Österreichische Agentur für Gesundheit und Ernährungssicherheit GmbH, Spargelfeldstraße 191, A-1220 WIEN
[2] Saatzucht Edelhof, Edelhof 1, A-3910 ZWETTL
[3] Technische Universität München, Lehrstuhl für Pflanzenzüchtung, Emil Ramann Straße 4, D-85354 FREISING
[4] Cereal Research Non-Profit Company, Department of Biotechnology, PO Box 391, H-6701 SZEGED
[*] Ansprechpartner: Clemens FLAMM, clemens.flamm@ages.at

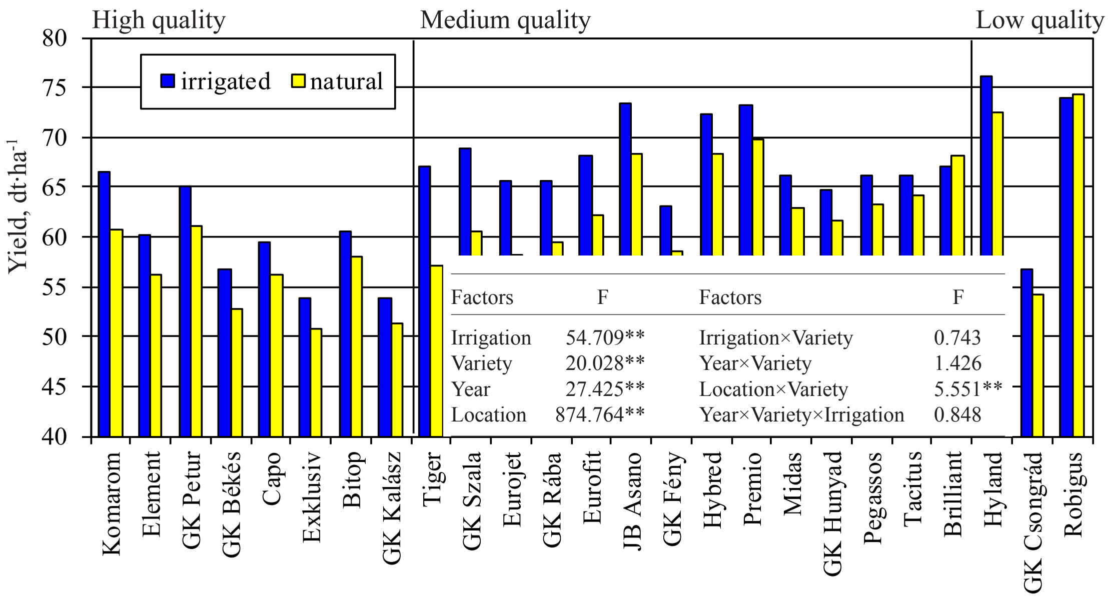

Figure 1: **Reaction in grain yield of 25 winter wheat varieties to different water supply** (means of 2 locations 2010 and 3 locations 2011; ordered by decreasing differences between rainfed and irrigated trials)

In the low quality group the differences were small for all varieties. In the analysis of variance the factors irrigation, variety, year and location were all significant. In regard to the interactions only the location by variety interaction was significant. This means that the reaction of varieties concerning water supply (irrigation×variety) was statistically not varying.

For the analysis of yield components the varieties were clustered into three groups regarding the predominance of one of the primary yield components (*Table 1*): varieties with more ears per square meter, varieties which achieve their yield by a high number of kernels per ear and varieties with a higher thousand kernel weight. No significant differences between the groups were found. In the analysis of variance the factors irrigation and variety were significant. The interaction between location and variety was significant for the parameter ears per square meter.

Most varieties reacted to water deficit by decreasing the primary and secondary yield components. Only a few genotypes reacted by increasing some components. GK Kalász, Komarom, Robigus, Element, GK Hunyad and Tacitus had more ears per m² in the trials with less available water. Capo

Table 1: **Reaction and analysis of variance of yield components of 25 winter wheat varieties in regard to reduced water supply** (2 locations 2010 and 3 locations 2011 of thousand kernel weight and kernels per square meter; 2 locations 2011 for the other parameters)

	Ears per m²	Kernels per ear	1000 kernel weight (g)	Kernels per m²	Ear weight (g)
Capo	-	+	-	-	+
GK Békés, GK Fény	-	-	-	-	-
GK Csongrád	-	+	-	-	+
GK Kalász, Komarom	+	-	-	-	-
Brilliant	-	+	+	-	+
Eurofit	-	+	-	-	-
GK Petur, Hybred	-	-	-	-	-
Hyland	-	+	-	-	-
Robigus	+	-	-	-	-
Bitop	-	-	-	-	-
Element	+	-	-	-	-
Eurojet	-	+	-	-	-
Exklusiv	-	+	-	+	-
GK Hunyad	+	-	-	-	-
GK Rába, GK Szala	-	-	-	-	-
JB Asano, Midas	-	-	-	-	-
Pegassos	-	+	-	-	-
Premio, Tiger	-	-	-	-	-
Tacitus	+	-	-	-	-
Mean	-25	-2.7	-1.9	-1207	-0.2
Irrigation	33.880**	8.279**	19.306**	6.547**	18.679**
Variety	4.248**	6.056**	11.355**	3.275**	2.723**
Irrigation×variety	2.668**	1.157	0.327	0.074	0.634

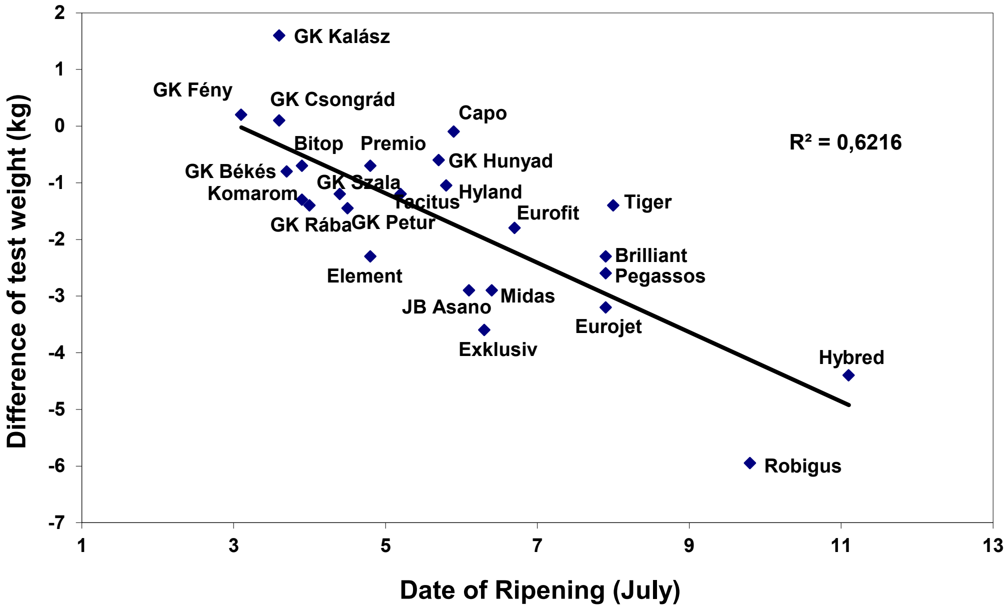

Figure 2: **Correlation of the reaction of test weight to reduced water supply (Tattendorf 2010) and the date of ripening (means of 10 trials 2010-2011) of 25 wheat varieties**

(-104 ears m^{-2}), GK Csongrád (-102 ears m^{-2}), Eurojet (-75 ears m^{-2}) and Eurofit (-58 ears m^{-2}) were the varieties with the greatest differences in ear density between rainfed and irrigated trials. On the other hand these varieties in addition to Brilliant, Hyland, Exklusiv and Pegassos produced more kernels per ear under drought stress. Robigus (-15 grains ear^{-1}), Tacitus (-11 grains ear^{-1}) and Komarom (-10 grains ear^{-1}) showed the greatest differences between irrigated and rainfed trials. An increased thousand kernel weight was only measured for Brilliant. The varieties with the greatest differences were Eurojet (-4.1 g), Pegassos (-3.7 g) and GK Rába as well as Eurofit (-3.6 g), whereas Premio, GK Kalász and Bitop reached approximately the same grain size in both trials. The number of kernels per square meter decreased with most of the varieties except Exklusiv (+126). Hybred with 2523, Tiger with 2193 and GK Skala with 2011 grains per square meter less showed the greatest differences in grains m^{-2} between irrigated and rainfed trials. Robigus, Tacitus and Komarom had from 0.5 g to 0.6 g lighter ears in the rainfed sites than in the irrigated ones. A few varieties achieved a slightly higher ear weight under drought stress (Capo, GK Csongrád, Brilliant).

For test weight no effects of different water supply were found when analysing the mean of all Austrian and Hungarian trials. However, test weight mostly reacts to drought stress just before the harvest. To better demonstrate these

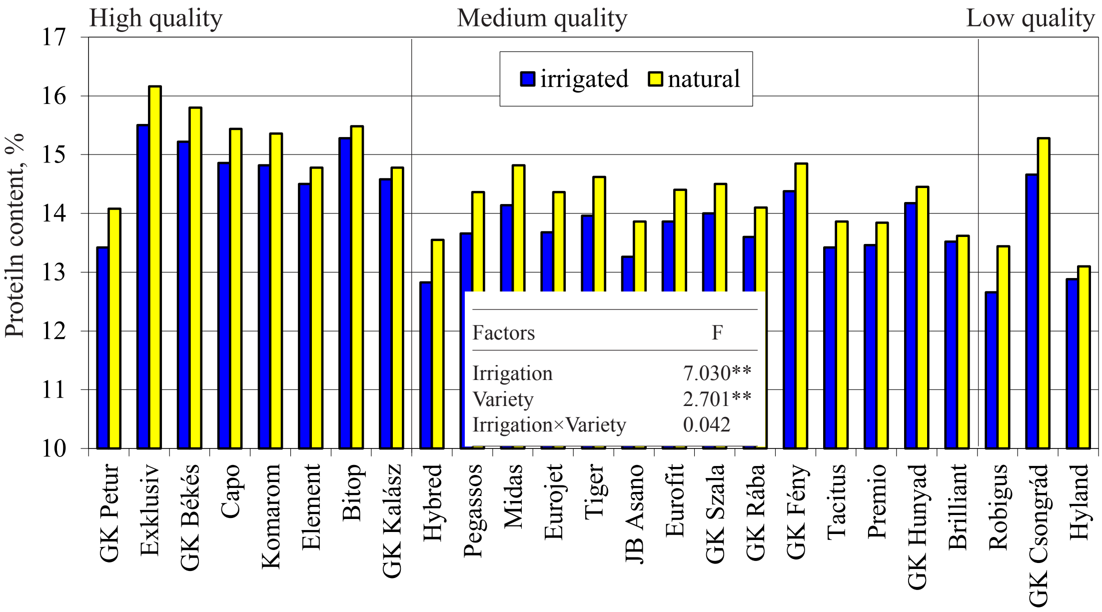

Figure 3: **Reaction in protein content of 25 winter wheat varieties to different water supply** (means of 2 locations 2010 and 3 locations 2011; ordered by decreasing differences between rainfed and irrigated trials)

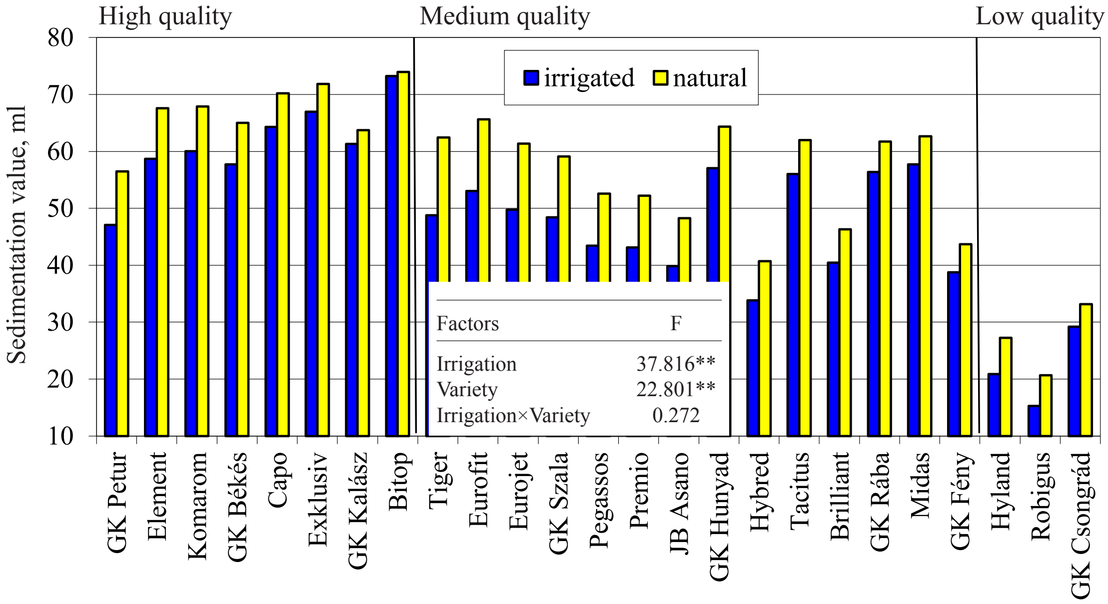

Figure 4: **Reaction in sedimentation value of 25 winter wheat varieties to different water supply** (means of 1 location 2010 and 2 locations 2011; ordered by decreasing differences between rainfed and irrigated trials)

effects, one trial location (Tattendorf 2010) was selected. There the rainfed trial was heavily stressed some weeks before the harvest. This became obvious by regarding flag leaf senescence data and leaf rolling estimations. In the irrigated trial the effects on these factors was less apparent. By correlating the decrease of test weight of the varieties of this trial with the date of ripening (*Figure 2*) a significant correlation (r=-0.79**) was found. Late maturing varieties like Hybred and Robigus lost -4 to -6 kg test weight, whereas early maturing varieties like GK Fény, GK Csongrád, GK Kalász, GK Békés and Bitop showed the least decreases.

Significant effects of drought stress were observed for protein content resulting in increased protein content (*Figure 3*). No significant irrigation×variety interaction was found. Robigus, Hybred, Pegassos, Midas, Eurojet, Tiger, GK Petur and Exklusiv increased their protein level by 0.78 to 0.66%. Hyland, Bitop, GK Kalász and Brilliant showed only a 0.22 to 0.10% increase. The highest protein content under both conditions were observed for Exklusiv (16.2 and 15.5 %).The sedimentation value of all varieties increased significantly as a result of water stress (*Figure 4*). The variety×irrigation interaction was found to be not significant. Varieties Tiger (+13.6 ml), Eurofit (+12.6 ml), Eurojet (+11.6 ml) and GK Szala (+10.7 ml) reacted more to a reduction in available water than Bitop (+0.7 ml) and GK Kalász (+2.4 ml). The other varieties were in between these extremes. Bitop reached the highest sedimentation values under both conditions (74.0 and 73.3 ml).

Concerning extensogram and baking volume significant effects and tendencies of water availability were observed (*Table 2*). Dough energy (after 135 min resting time) increased on average by 20 cm². Maximum dough resistance increased on average 58, 80 and 81 EU for 45, 90 and 135 min resting time, respectively. Robigus reacted the most with +253 EU after 90 min resting time. The increase of maximum resistance after 90 and 135 min resting time, however, was not significant. GK Kalász showed only minor effects in response to less available water. Bread volume

Table 2: **Reaction and analysis of variance of extensogram parameters and baking volume of 8 winter wheat varieties in regard to reduced water supply** (1 locations 2010 and 2 locations 2011)

	Extensogram				
	Energy (cm²)	Maximum resistance (EU)			Baking volume
Variety/Source	135 min	45 min	90 min	135 min	(ml 100 g^{-1} flour)
Capo	+27	+80	+128	+76	+62
Exklusiv	+39	+105	+155	+146	+57
GK Csongrád	+9	+54	+60	+66	+38
GK Fény	+25	-30	-37	+63	-55
GK Kalász	-1	+48	-36	-3	-8
GK Petur	+16	+14	+30	+15	+3
Hyland	+9	+50	+85	+68	+5
Robigus	+33	+145	+253	+217	+90
Mean	+20	+58	+80	+81	+24
Irrigation	7.868**	4.701*	3.696	3.492	3.186
Variety	16.374**	19.032**	16.442**	16.086**	11.769**
Irrigation×variety	0.469	0.500	0.700	0.332	1.467

tended to increase for the rainfed trials, only for GK Fény (-50 ml) and GK Kalász (-8 ml) a reduced baking volume was measured.

Intervarietal correlation analyses between yield decreases after drought stress and yield as well as quality parameters showed no significance.

Discussion

Grain yield is negatively influenced by drought (FOULKES et al. 2007, ARAUS et al. 2008, KHAN et al. 2010). Like in the present study Bitop and Exklusiv showed the lowest yield reduction under drought stress also in another nursery (OBERFORSTER and FLAMM 2007). In the present study the varieties Bitop and Exklusiv showed the lowest yield reduction under drought stress. Generally, besides grain yield all yield components decrease with decreasing water availability (DUGGAN et al. 2000, ESKANDARI and KAZEMI 2010). Analysis of variance in the present study clearly demonstrated that yield and its components were affected by irrigation. Irrigated plants reached higher values for the investigated yield traits. These results were valid for each cluster of varieties with a different emphasis on yield components which means that no yield component is more tolerant against drought stress. No significant irrigation by variety interaction was determined for all yield parameters, except ear density. In the present study ear density was generally low.

Protein content and sedimentation value were positively influenced by water stress. FOIS et al. (2011) described positive effects of drought stress on protein content in durum wheat. BALLA et al. (2011) reported reductions in the inextricable polymeric protein fraction and glutenin-to-gliadin ratio in wheat due to drought and heat stress, despite a higher protein content. EISVAND et al. (2006) and HRSTKOVA and VEJRAZKA (2010) reported increased protein content, Zeleny sedimentation value and gluten content under drought. Contrary BALLA and VEISZ (2007) reported an increased protein content but lower Zeleny values. This may be explained by a different interaction of heat and drought stress.

Acknowledgements

This project was framed by CORNET (COllective Research NETworking) and financed in Austria by the Austrian Research Promotion Agency (FFG), Saatgut Österreich and the breeding companies Saatzucht Donau GesmbH & CoKG and Saatzucht Edelhof. In Germany the project was supported by the German Federation of Private Plant Breeders (GFP) and financed by the German Federation of Industrial Research Associations (AiF) and the Ministry of Economics and Technology (BMWi). In Hungary the financing partners were the National Office for Reseach and Technology (NKTH) and the Hungarian Seed Association.

References

ARAUS JL, SLAFER G, ROYO C, SERRET MD, 2008: Breeding for yield potential and stress adaptation in cereals. Crit Rev Plant Sci 27: 377-412.

BALLA K, VEISZ O, 2007: Effect of heat stress and drought on the grain quality of wheat. Acta Agron Ovariensis 49: 451-455.

BALLA K, RAKSZEGI M, LI Z, BEKES F, BENCZE S, VEISZ O, 2011: Quality of winter wheat in relation to heat and drought shock after anthesis. Czech J Food Sci 29: 117-128.

DUGGAN BL, DOMITRUK DR, FOWLER DB, 2000: Yield component variation in winter wheat grown under drought stress. Can J Plant Sci 280: 739-745.

EISVAND HR, AHMADI A, BUSHEHRI AAS, POOSTINI K, JAHANSOOZ MR, 2006: Effect of drought stress and timing of nitrogen application on N remobilization, bread-making quality and the pattern of storage proteins in wheat grains. Iran J Agric Sci 36: 1489-1497.

ESKANDARI H, KAZEMI K, 2010: Response of different bread wheat (*Triticum aestivum* L.) genotypes to post-anthesis water deficit. Not Sci Biol 2: 49-52.

FOIS S, SCHLICHTING L, MARCHYLO B, DEXTER J, MOTZO R, GIUNTA F, 2011: Environmental conditions affect semolina quality in durum wheat (*Triticum turgidum* ssp. *durum* L.) cultivars with different gluten strength and gluten protein composition. J Sci Food Agric. 91: 2664-2673.

FOULKES MJ, SYLVESTER-BRADLEY R, WEIGHTMAN R, SNAPE JW, 2007: Identifying physiological traits associated with improved drought resistance in winter wheat. Field Crop Res 103: 11-24.

HRSTKOVA P, VEJRAZKA K, 2010: Effects of drought on grain quality parameters in winter wheat. Proc 9th Alps-Adria Sci Workshop, Soil Relations, 12-17 Apr, Špičak, Czech Republic. Novenytermeles 59, Suppl 1: 219-222.

KHAN AJ, AZAM F, ALI A, 2010: Relationship of morphological traits and grain yield in recombinant inbred wheat lines grown under drought conditions. Pakistan J Bot 42: 259-267.

OBERFORSTER M, FLAMM C, 2007: Reaktion eines Weizensortiments auf induzierten Trockenstress. Vortr Pflanzenzüchtg 72: 199-202.

OBERFORSTER M, SCHMIDT L, WERTEKER M, 1994: Bewertungsschema ´94 der technologischen Qualität von Weizensorten (Weichweizen). In: Bundesanstalt für Pflanzenbau (Hrsg.), Jahrbuch 1993, pp. 257-280. Bundesamt und Forschungszentrum für Landwirtschaft, Wien.

Note: *The online version of the proceedings includes all figures in colour. It can be downloaded either from the homepage of the meeting (http://www.raumberg-gumpenstein.at/ - Downloads - Fachveranstaltungen/Tagungen - Saatzüchtertagung - Saatzüchtertagung 2011) or requested from the corresponding author.*