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Productivity structure of new genotypes and perspective lines of winter malting barley (*Hordeum vulgare* L.)

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Abstract

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The long phenological development of the cereals determines the great variety of factors, which influence the vegetative growth and the formation of their productivity. A priority of the contemporary agricultural practices is the better balance between the agro ecological, biological and technological elements and the higher profitability of production, while limiting the unfavorable effects on the environment. In this relation, breeding is faced with the problem of developing cultivars which can efficiently utilize the nutrients from soil and at a later stage convert them into grain yield.

The aim of this investigation was to determine the productivity structure of new genotypes and perspective lines of winter malting barley (*Hordeum vulgare* L.), developed at Agricultural Institute – Karnobat and Dobrudzha Agricultural Institute – General Toshevo, as well as the correlation between grain yield and its components. The investigation was carried out during cropping seasons 2014–2016, which were very different with regard to the combination of meteorological factors. All investigated components of the formed shoot mass, which contributed to the realization of the biological yield potential of the malting barley cultivars, were influenced by the meteorological conditions of the respective year, by the specificity of the cultivar and by their interaction. It was found that the year conditions had determining role for the formation of the biological potential of the leaves, stems, spike and grain. The cultivar had a dominant role for the formation of the number of spikes per ha, the total shoot mass, 1000 kernel weight, the weight of the non-grain part of the spike and its percent from the weight of spike, respectively the weight of grain. By the grain yield formed, all tested materials exceeded the standard Kaskadyor 3. The exceeding varied from 9.02 % in cultivar Yaspis to 52.58 % in line 1015-127. Cultivars Asparuh, Deviniya and Ahat also had high mean productivity, exceeding the standard with 47.56 %, 45. 56% and 41.41%, respectively. High positive correlations were found between grain yield and spike yield, GHI, weight of grain per spike, weight of 1000 grain, NGPS and total mass. The investigated winter malting barley cultivars, regardless of their breeding location, possess high productivity potential and are suitable for growing in the region of Dobrudzha.

Keywords: winter malting barley; yield structure; productivity potential

Introduction

Yield is a generalizing criterion for evaluation of the tolerance of a specific genotype to the unfavorable environmental conditions. The long phenological development of the cereals is the reason for the great variety of factors, which influence their vegetative growth and the formation of productivity. Depending on the growth stage of the plants, the mechanism of reaction is specific.

The tolerance to the types of abiotic stress is related to a great number of morphological (Ceccarelli et al., 1991) and phenological peculiarities (Francia et al., 2007; Gonzales et al., 2007), and to basic physiological and bio chemical processes (Koornneef et al., 1997; Sorrells et al, 2000; Amudha and Balasubramani, 2011). This determines its complex nature of inheritance and imposes the necessity to combine

different approaches in the breeding and improvement work (Nguyen, 2000; Sreenivasulu et al., 2007).

The goals of the contemporary agricultural practices are the better balance between the agro ecological, biological and technological elements for higher yields, qualitative indices and their stability, while limiting the negative effect on the environment (Gleick, 2003; Swaminathan, 2007; Rockstrom, 2009). The development of intensive cereal cultivars, including barley, is a way for increasing productivity. In this relation, breeding is facing the problem of developing cultivars efficiently utilizing the nutrients from soil and converting them into grain yield at a later stage of their development.

The aim of this investigation was to determine the productivity structure of new genotypes and perspective lines of winter malting barley (*Hordeum vulgare* L.) developed at Agricultural Institute – Karnobat and Dobrudzha Agricultural Institute – General Toshevo, as well as the correlation between grain yield and its components.

Material and Methods

The investigation was carried out during 2014 – 2016 in the barley breeding field of Dobrudzha Agricultural Institute – General Toshevo. The object of the study were winter malting barley accessions with specific phenological and biological peculiarities. With the exception of line 1015-127, which is being tested within the system of the national Executive Agency of Variety Testing, Field Inspection and Seed Control, all other cultivars are included in the varietal list of Bulgaria (Table 1). The productivity structure of the accessions was determined at the final stage by taking samples of plants with rectangular sampling frames in three replications. The plant material was processed by organs, with subsequent determination of the yield from each of them. Their percent in the total formed shoot mass was also determined (Table 2).

The experiment was designed in three replications, the size of the harvest plot being 10 m^2. The sowing norm was 430 germinating seeds per 1 m^2. The previous crop was grain pea during all investigated years. At the end of February, nutrition was done with 0.05 t.ha^{-1} active matter nitrogen. The soil type in the experimental field was leached chernozem (*Haplic Chernozems*). This area was with slightly acid soil reaction and concentration of exchangeable potassium, characterizing the 0–20 and 20–40 cm layers as having good reserves of potassium available to plants (Figures 1 and 2). Concerning the conditions for phosphorus nutrition, the area

Table 1. Core collection of winter malting barley accessions

Accessions	Systematic affiliation	Breeding center
Asparuh	var. *nutans*	Institute of Agriculture – Karnobat
Ahat	var. *nutans*	Dobrudzha Agricultural Institute – Gen. Toshevo
Deviniya	var. *nutans*	Institute of Agriculture – Karnobat
Kaskadyor 3 – St	var. *erectum*	Dobrudzha Agricultural Institute – Gen. Toshevo
Kuber	var. *nutans*	Institute of Agriculture – Karnobat
Lardeia	var. *nutans*	Institute of Agriculture – Karnobat
Odisey	var. *nutans*	Institute of Agriculture – Karnobat
Orfej	var. *nutans*	Institute of Agriculture – Karnobat
Sayra	var. *nutans*	Institute of Agriculture – Karnobat
Zagoretz	var. *nutans*	Institute of Agriculture – Karnobat
Yaspis	var. *nutans*	Dobrudzha Agricultural Institute – Gen. Toshevo
1015-127	var. *erectum*	Dobrudzha Agricultural Institute – Gen. Toshevo

Source: Authors' own elaboration

Table 2. Investigated indices determining the productivity structure

Investigated indices	Abbreviation
Leaves, kg/ha	
Percent of leaves from total shoot biomass, %	Leaves HI
Stems, kg/ha	
Percent of stems from total shoot biomass, %	Stems HI
Spikes, kg/ha	
Percent of spikes to total shoot biomass, %	Spikes HI
Number of productive tillers, no/ha	NoSpikes
Weight of Spikes, kg/ha	
Grain, kg/ha	
Harvest index, %	GHI
Percent of grain from spike weight, %	GHI in Spike
Weight of Grain per Spike, g	
Weight of 1000 grain, g	
Non Grain part of Spike, kg/ha	NGPS
Percent of non-grain part of spike from the total shoot biomass, %	NGPS HI
Percent of non-grain part of spike from spike weight, %	NGPS HI in Spike
Vegetative mass, kg/ha	
Percent of vegetative mass from the total shoot biomass, %	V. mass HI
Total mass, kg/ha	

Source: Authors' own elaboration

can be considered having moderate reserves. The available forms of nitrogen, especially the nitrate form, were in insufficient amounts at the beginning of September. The content of total nitrogen and phosphorus was 174.2 mg N/100 g and 0.170% P_2O_5, respectively. The organic matter in soil by layers was 1.36% (0–20 cm) and 1.38% C (20–40 cm), averaged for the investigated period.

The agronomy practices not subject of this investigation were in accordance with the accepted growing technology of this crop (Gramatikov et al., 2004).

The data on the dynamics of the main meteorological elements characterized the vegetative growth periods as very

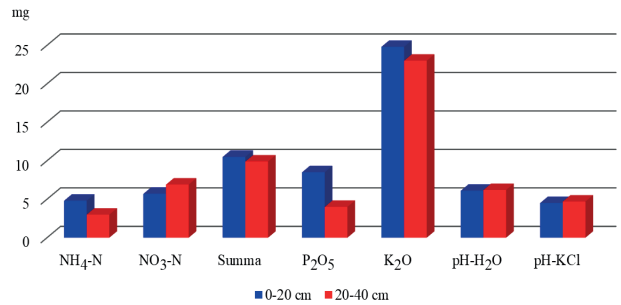


Fig. 1. Agrochemical characteristics of the trial field (NH_4 and NO_3 mg/1000 g; P_2O_5 and K_2O mg/100 g soil)
Source: Authors' own elaboration

different. The total sums of rainfalls during the autumn-and winter months of all three years were approximately the same – 323.5 mm (2014), 358.5 mm (2015) and 313.5 mm (2016). They exceeded the mean long term values (1952–2013), with approximately 100.8 mm. Their distribution, however, was marked by considerable dynamics. This tendency was even stronger during the period from the beginning of spring vegetative growth till harvesting. Year 2014 was with highest precipitation sum: 623.8 mm. There were significant rainfalls during planting (156.3 mm in October of 2013) and during heading and harvesting – 78.2 mm and 192.5 mm, respectively. The year is considered "humid", exceeding the mean long term norms 1.6 times. Cropping seasons 2015 and 2016 were also characterized with higher precipitation sums during the vegetative growth of barley, the exceeding according to the mean long term rainfalls being 1.2 and 1.3 times, respectively. Their distribution during April – June was extremely uneven. In 2015, their sum was lowest – only 90.5 mm.

With regard to temperatures, all three years were characterized with warmer conditions for development of the crop during the entire period of vegetative growth – an average of 10.5°C and exceeding of the mean long term temperatures with 1.6°C. Apart from the warmer conditions for autumn-and-winter vegetative growth, the values during April-June

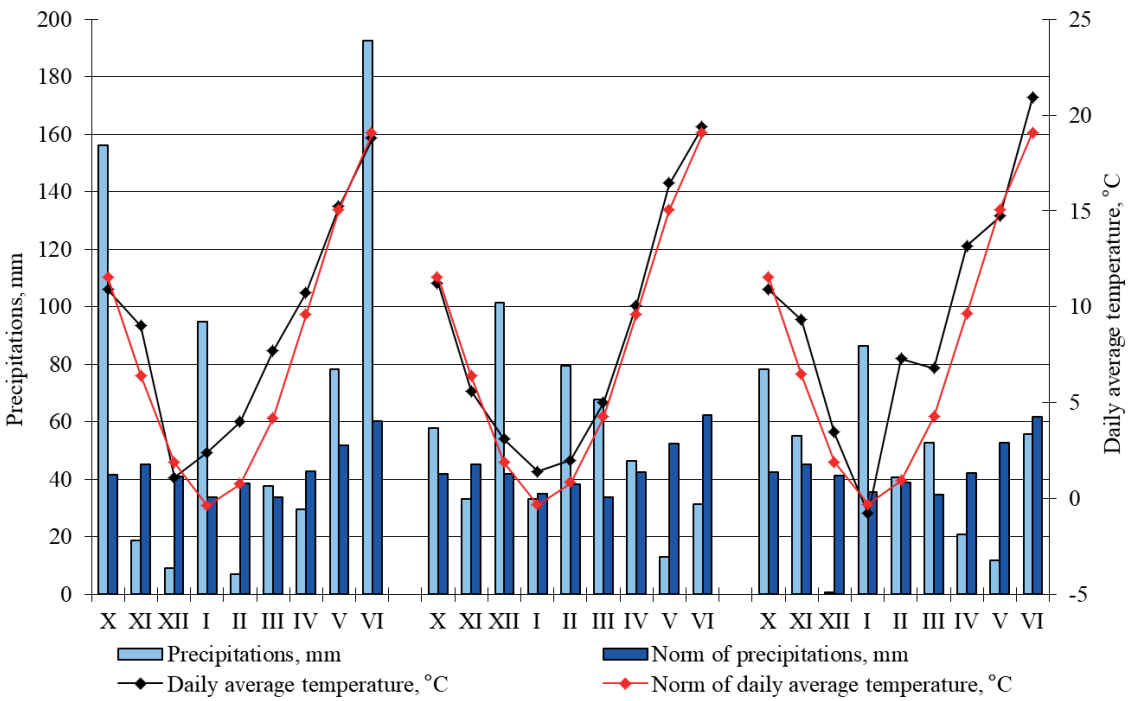


Fig. 2. Meteorological characteristics of the investigated years
Source: Authors' own elaboration

exceeded the mean long-term values of the investigated period with 1.1°C (2014), 1.5°C (2015) and 2.4°C (2016), respectively. The dynamics of the main meteorological elements was a prerequisite for serious effect of this factor on the yield structure of the tested barley accessions.

The results from the crop analyses were subjected to analyses of variance (ANOVA), using the general linear model procedure of the statistical analysis system (SAS, 2004). The statistical analysis was performed for each parameter, and the values compared as per Duncan's least significant difference test at $p < 0.05$. Pearson's correlation coefficients between structural elements in crops were calculated to evaluate the relation between grain yields and other barley organs. Correlation analyses were computed using the software package SPSS (version 19.0).

Results and Discussions

The results obtained from the analysis of the variances of the investigated characteristics of the genotype as a factor showed statistical significance of its effect on the productivity of the separate organs, both over investigated years and averaged for the period (Table 3). During cropping seasons 2015 and 2016, the percent of grain and the non-grain part of the spike (NGPS) from the weight of the spike itself was not significant. Averaged for the period, the factor year influenced all investigated elements of the productivity structure at a maximum level of significance (Table 4). The interaction genotype x year also had significant effect on the values of the investigated characteristics, with the exception of NGPS of spikes.

These results were confirmed by the strength of the independent and combined effect of the factors on the size of the obtained yields by organs (Figure 3). It was observed that under the same nutrition regime, the dynamics of the meteorological components in the course of the vegetative growth, although having different strength, was the decisive factor. Among the organs forming the vegetative biomass, the factor year had the highest effect on the weight of stems (87.2%), followed by that of leaves (76.0%) and of NGPS (31.68%). Thus, the factor explained 82.34% of the variation in total vegetative mass yield and 88.99% of the variation in the harvest index.

A predominant strength of effect of the factor *year* on the reproductive organ (spike) and the grain in it was determined, but it was significantly less expressed in comparison to its effect on the weight of leaves, stems and vegetative mass as a whole. The strength of their independent and combined effect on grain yield and its harvest indices varied within a wide range (Figure 4). The role of the *genotype* for the formation of grain yield significantly increased in com-

Table 3. Analysis of the variances of the investigated indices – factor *genotype* (values of parameter *p*).

Dependent Variable	df	2014			2015			2016			2014-2016		
		Mean Square	F	Sig.	Mean Square	F	Sig.	Mean Square	F	Sig.	Mean Square	F	Sig.
Leaves	11	697.4	71.9	.000	1147.8	67.3	.000	296.0	11.4	.000	741.4	42.2	.000
Leaves HI	11	5.4	302.9	.000	2.1	17.5	.000	.883	5.0	.000	3.1	29.2	.000
Stems	11	12155.4	159.0	.000	11259.5	7.5	.000	5048.1	14.9	.000	136418	21.4	.000
Stems HI	11	30.2	450.8	.000	9.8	3.0	.012	4.7	6.5	.000	24.8	18.4	.000
Spikes	11	46921.8	433.6	.000	53547.7	243.2	.000	10143.2	35.7	.000	59531.3	291.7	.000
Spikes HI	11	50.9	928.5	.000	14.0	5.5	.000	6.5	7.8	.000	36.3	31.8	.000
NoSpikes	11	42914.9	45.7	.000	130381.6	98.1	.000	39530.0	47.1	.000	135945.5	131.2	.000
Weight of Spikes	11	.049	186.6	.000	.131	48.2	.000	.032	29.3	.000	.153	114.8	.000
Grain	11	42977.2	130.6	.000	46803.9	175.7	.000	8552.8	16.4	.000	55144.4	148.1	.000
GHI	11	59.6	89.8	.000	17.3	6.2	.000	9.0	7.1	.000	47.8	30.2	.000
GHI in Spikes	11	33.3	9.0	.000	7.1	2.1	.062^{NS}	5.2	2.3	.045^{NS}	27.6	8.9	.000
Weight of Grain	11	.049	186.6	.000	.106	48.9	.000	.024	20.7	.000	.118	99.1	.000
Mass of 1000	11	47.4	144.7	.000	20.375	187.349	.000	19.1	759.2	.000	49.733	323.1	.000
Non Grain Part of Spike	11	861.6	4.8	.001	739.2	2.4	.036^{NS}	368.9	3.5	.005	1141.7	5.7	.000
NGPS HI	11	3.6	5.0	.000	2.7	1.8	.113^{NS}	1.5	2.0	.082^{NS}	5.4	5.5	.000
NGPS HI in Spikes	11	33.3	9.0	.000	7.1	2.1	.062^{NS}	5.2	2.3	.045^{NS}	27.6	8.9	.000
V.mass	11	18676.9	106.9	.000	22655.4	13.2	.000	9253.8	27.5	.000	22803.9	30.7	.000
V.mass HI	11	59.6	89.8	.000	17.3	6.2	.000	9.0	7.1	.000	47.8	30.2	.000
T.mass	11	95378.7	230.5	.000	120069.0	55.8	.000	29637.3	34.9	.000	117961.6	103.6	.000

Source: Authors' own elaboration

Table 4. Analysis of the variances of the investigated indices – factors *year* and *genotype x year* (2014 – 2016)

Dependent Variable	df	Factor *year*			*Genotype x year*		
		Mean Square	F	Sig.	Mean Square	F	Sig.
Leaves	11	37296.8	2122.1	0.000	700.2	39.8	0.000
Leaves HI	11	103.1	981.8	0.000	2.7	25.3	0.000
Stems	11	1066157.7	1668.6	0.000	7410.4	11.6	0.000
Stems HI	11	3565.0	2637.9	0.000	9.9	7.4	0.000
Spikes	11	702558.0	3442.2	0.000	25540.1	125.1	0.000
Spikes HI	11	4677.5	4092.5	0.000	17.5	15.3	0.000
NoSpikes	11	229613.0	221.7	0.000	38440.5	37.1	0.000
Weight of Spikes	11	1.5	1127.2	0.000	.033	25.1	0.000
Grain	11	602172.9	1617.3	0.000	21593.5	58.0	0.000
GHI	11	3818.9	2416.5	0.000	19.1	12.1	0.000
GHI in Spikes	11	40.5	13.0	0.000	9.0	2.9	0.000
Weight of Grain	11	1.2	1035.3	0.000	.030	25.4	0.000
Mass of 1000	11	831.238	5400.5	0.000	18.589	120.770	0.000
Non Grain Part of Spike	11	5025.0	25.2	0.000	414.2	2.1	0.011
NGPS HI	11	55.6	56.6	0.000	1.2	1.2	0.300^{NS}
NGPS HI in Spikes	11	40.5	13.0	0.000	9.0	2.9	0.000
V. mass	11	1296791.4	1746.2	0.000	13890.4	18.7	0.000
V. mass HI	11	3818.9	2416.5	0.000	19.1	12.1	0.000
T. mass	11	523632.5	460.1	0.000	63564.3	55.9	0.000

Source: Authors' own elaboration

parison to its role for the formation of the yield from leaves, stems and total vegetative biomass. The genotype is the main factor which controls the huskiness of the spike and the percent of grain in it (GHI in spikes).

Under the conditions of this experiment, the *genotype x year* interaction and the *genotype* played a determining role for the formation of the total shoot biomass (T. mass) (Figure 5). The strength of their effect was 37.36 % and 34.66 %, respectively. The effects on the values of 1000 kernel weight were also clearly expressed, the genotype playing a leading role (55.56 %).

The variations in the effect of the year conditions on the structural components of yield were determined by the specific combination of the meteorological factors during the spring vegetative growth of the crop. The severe drought during April-June of 2015, and especially in May (12.9 mm), coincided with the most critical phase from the development of barley. This reflected seriously on the yield from vegetative biomass (Table 5).

This yield was with lowest values in 2015, while the yield from the total formed shoot biomass was comparatively high. As a result, the percent of the vegetative biomass, averaged for all tested genotypes, was low (42.61%). Cropping season 2014 was characterized with abundant rainfalls. Their sum during May – June was significant. It contributed to the accumulation of a large amount of biomass and caused lodging at early stages from the development of barley. In cropping season 2016, there was comparatively proportional distribution between grain yield and yield of vegetative mass in the total biomass. This percent was averagely 50.74%.

Within this context, contrary to the logical expectations, the highest mean grain yield was obtained in 2015 – 8169 kg/ha (Figure 6). Drought, in its various expressions, is the main limiting factor for the production of cereals. The formation of the yield components may be influenced by water deficiency at any stage from their phenological development. The reproductive stage remains the most critical one, when the processes of pollination, fertilization and grain filling occur. Soil drought is often accompanied with high air temperatures and low air humidity. Under such conditions, the number of formed grains was strongly reduced. Saini and Aspinall (1982) summarized the main reasons: sterility of the pollen and the female gametophyte, various modifications of the somatic tissues impeding the normal transfer of pollen to the stigma of the ovary or its sprouting, inhibition of the cell division and perishing of the young embryo. Fabian et al. (2011) observed reduced size of the mature embryo, as well as various changes in the accumulation of b starch granules and prolamins. The observations showed that the recovering ability of the genotype is especially important for the end

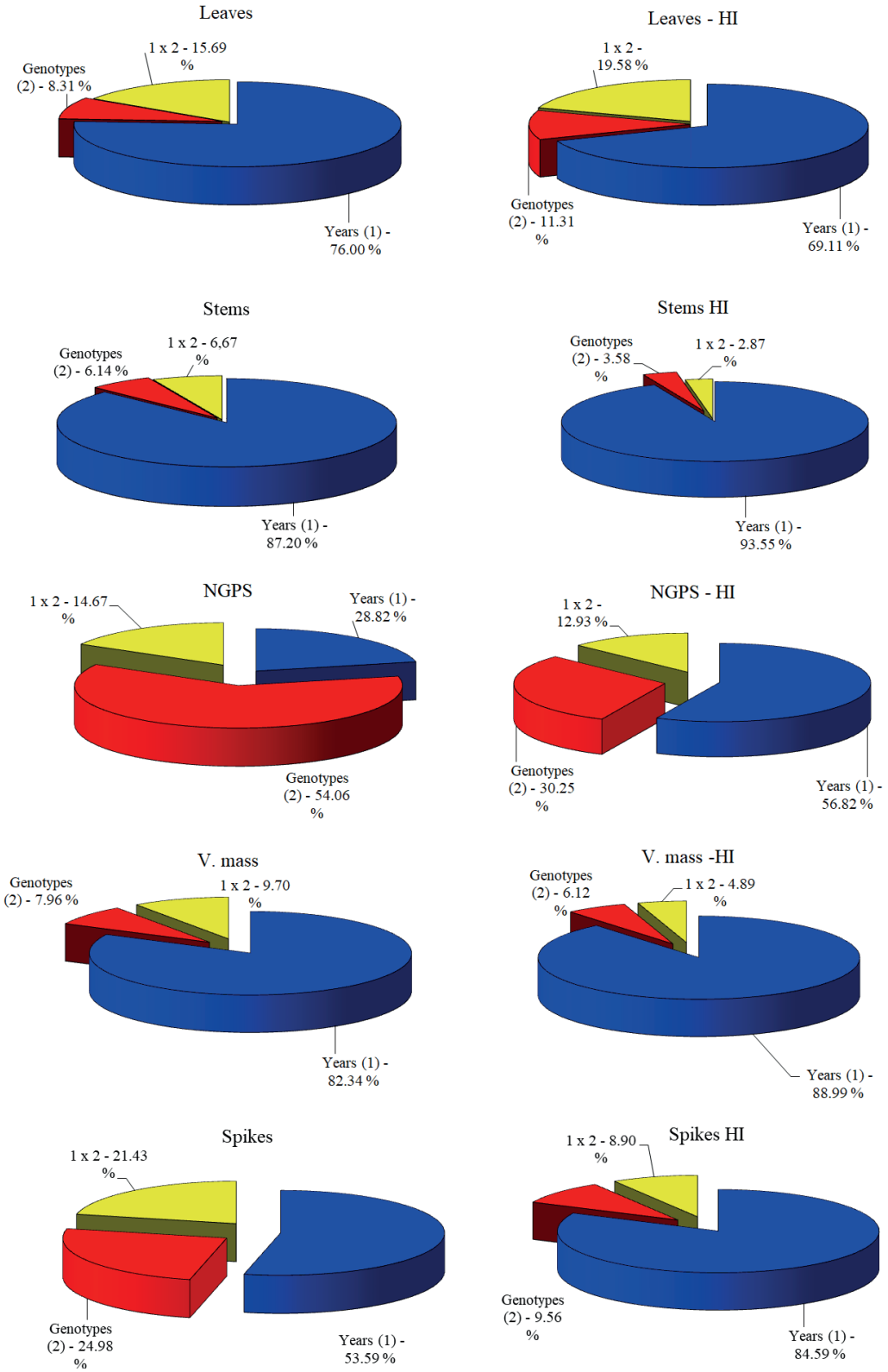


Fig. 3. Strength of effect of the factors on barley vegetative mass productivity structure, %
Source: Authors' own elaboration

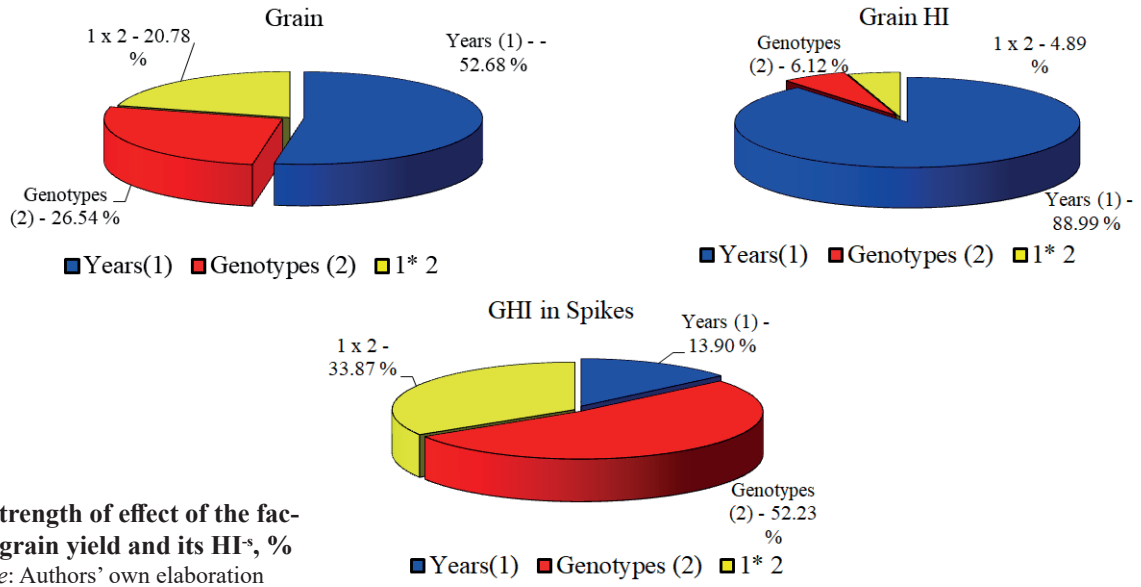


Fig. 4. Strength of effect of the factors on grain yield and its HI-s, %
Source: Authors' own elaboration

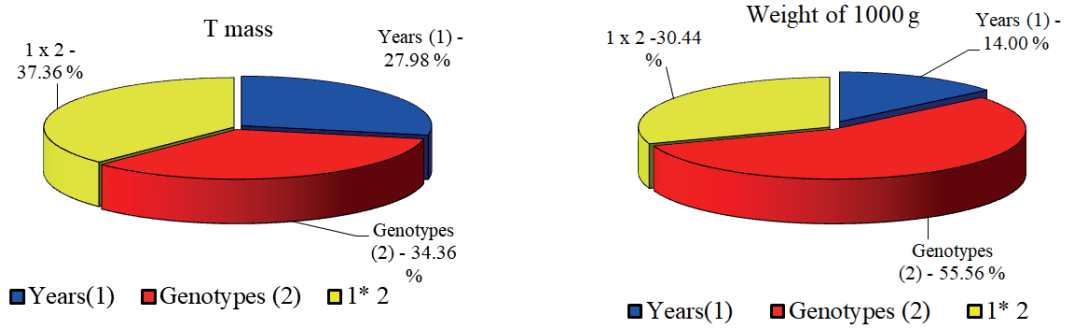


Fig. 5. Strength of effect of the factors on total mass productivity and weight of 1000 grain, %
Source: Authors' own elaboration

productivity under stress conditions. At the earlier stages, the negative effect is related to decrease of the total number of productive tillers (McMaster et al, 1994; Gonzalez et al., 2007). In our case, the very good available moisture reserves in soil during the autumn-and-winter period of 2015, as well as the April rainfalls, contributed for the overcoming of the stress, which occurred due to insufficient precipitation by the end of the vegetative growth. The grain yield was lowest in the very humid year, when the tested malting barley accessions suffered from lodging. Against this background, the harvest index of grain demonstrated the same dynamics of its values during the investigated periods – from 36.93% (2014) to 57.39% (2015), when determining its percent from the formed shoot mass (Figure 7). The very good results achieved in 2015 are a direct indication that there was not any significant discomfort in the work of the plants roots, while noting a very high level of carbohydrates reutilization from the vegetative mass to the grain.

Table 5. Mean V. mass, V. mass HI and T. mass over years

Year	V. mass (kg/ha)	V. mass HI, %	T. mass (kg/ha)
2014	9549 a	63.07 a	15228 a
2015	6061 c	42.61 c	14230 b
2016	6510 b	50.74 b	12828 c

Source: Authors' own elaboration

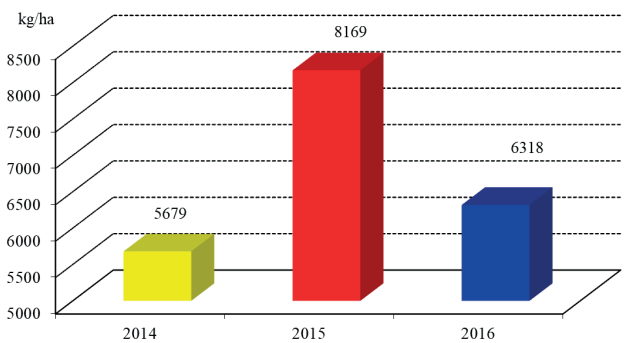


Fig. 6. Mean grain yield over years, kg/ha
Source: Authors' own elaboration

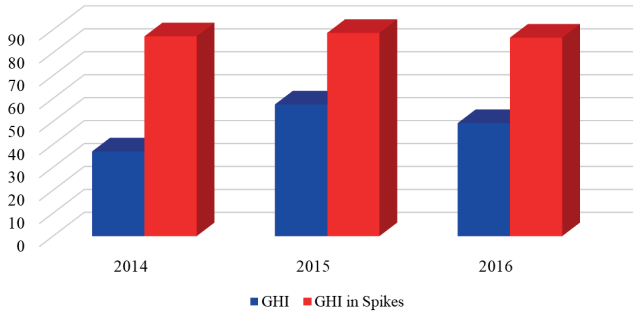


Fig. 7. Grain harvest index to total biomass and weight of spike, %

Source: Authors' own elaboration

Averaged for the investigated period, the yield from the respective organs of the vegetative biomass and their respective percent varied considerably depending on the genotype (Table 6). By yield of leaves and stem mass, all tested materials exceeded the standard cultivar Kaskadyor 3. Cultivar Ahat was with highest biomass of leaves and stems, and highest huskiness of spike was determined in cultivars Odisey, Yaspis and Kaskadyor 3.

In each cropping season, the productivity of the investigated malting barley genotypes varied within a wide range (Table 7). Under the very humid conditions of 2014, highest grain yield was obtained from line 1015-127 – 7763 kg/ha. The exceeding according to the standard Kaskadyor 3 was with 54.7 %. Under these conditions, cultivars Deniniya, Sayra and Ahat demonstrated productivity over 600 kg/da. In 2015, the productivity of the genotypes varied from 607 kg/da (Kaskadyor 3) to 9642 kg/ha (line 1015-127). Yield over 9000 kg/ha was obtained from cultivars Deviniya, Asparuh and Zagoretz. The mean productivity of the malting accessions was with 44.2 % higher than the mean productivity in 2014 regardless of the drought which occurred in May. In cropping season 2016, the variation of yield according to the genotype, was also a permanent tendency. The mean yields exceeded with 11.4 % the yields obtained in 2014. Under these conditions, the productivity potential of cultivars Asparuh (7162 kg/ha) and Kuber (7065 kg/ha) were fully expressed. The abundant rainfalls in May (117.7 mm) had negative effect on the productivity of Deviniya, Orfej, Sayra and Yaspis, as well as line 1015-127, the yield from which was below the standard. The differentiation according to the mean productivity was very well expressed. Line 1015-127 was with highest grain yield, exceeding the standard with 52.6 %. Cultivars Asparuh, Deviniya and Ahat were also with high mean yields, over 7000 kg/ha. The tested accessions of winter malting barley are representatives of the contemporary Bulgarian breeding. During 2014–2016, they exceeded by grain yield the standard Kaskadyor 3 with a mean of 35.3 % and can be successfully grown in north Bulgaria.

Table 7. Productivity of malting barley genotypes over years, kg/da

Genotypes	2014	2015	2016
Asparuh	582.5 b	948.9 a	716.2 a
Ahat	605.5 b	857.3 c	691.6 ab
Deviniya	682.1 ab	956.3 a	575.7 d
Zagoretz	533.0 b	902.3 b	612.7 c
Kaskadyor 3 – st	304.8 c	607.0 g	607.0 cd
Kuber	595.9 b	786.8 e	706.5 a
Lardeia	542.5 b	863.1 c	662.3 b
Odisey	538.9 b	820.2 cd	667.4 b
Orphej	564.1 b	799.7 d	591.0 cd
Sayra	650.6 b	653.4 f	575.0 d
Yaspis	423.6 bc	643.8 f	593.7 cd
1015-127	776.3 a	964.2 a	582.7 cd

Source: Authors' own elaboration

Table 6. Productivity (kg/da) and HI (%) of vegetative mass organs according to genotypes, averaged for 2014–2016

Genotypes	Leaves	Leaves HI	Stems	Stems HI	NGPS	NGPS HI	NGPS HI in Spike
Asparuh	99.5 f	6.84 e	519.7 f	35.94 f	81.7 e	5.64 ef	9.94 e
Ahat	128.0 a	8.21 bc	596.6 a	38.31 abc	100.0 c	6.53 def	12.39 cd
Deviniya	113.3 bc	7.45 d	547.8 de	36.60 efg	88.1 de	6.06 e	10.86 de
Zagoretz	100.0 f	7.32 de	484.0 g	35.71 fg	98.3 c	7.22 b	12.74 c
Kaskadyor 3 st	99.0 f	8.65 a	456.9 h	39.66 a	80.3 e	6.99 bcd	14.44 ab
Kuber	104.1 e	7.01 e	562.3 cd	37.81 b	101.8 b	7.03 bcd	12.81 c
Lardeia	106.1 d	7.33 de	572.6 c	39.71 a	79.3 e	5.48 f	10.07 e
Odisey	108.2 d	7.48 d	544.6 de	37.72 ab	115.4 a	8.00 a	14.86 a
Orfej	118.3 bc	8.45 a	510.1 fg	36.79 cde	96.7 c	7.11 b	12.97 bc
Sayra	106.1 d	7.72 c	512.1 fg	37.12 bcd	88.9 d	6.92 cde	12.45 c
Yaspis	109.5 c	8.34 bc	535.7 ef	40.53 a	100.3 c	7.81 ab	15.50 a
1015-127	120.2 b	7.63 c	555.4 b	35.52 h	106.9 ab	7.01 bcd	12.28 cd

Source: Authors' own elaboration

Thousand kernel weight is used not only as a breeding criterion for improvement of productivity (Wiersma et al., 2001), but also as an indirect approach to breeding for drought resistance (Sharma et al., 2008). Depending on the year conditions, this trait varied within a wide range (Table 8). Highest values were formed in 2015 – a mean of 50.76 g. The exceeding of the mean value for 2014 was with 22.41%. In cropping season 2016, the mean 1000 kernel weight was 44.00 g, exceeding the value in 2014 with 6.09 %. In that year, the grain formed was small (41.47 g). The reason was the high amount of rainfalls, which caused lodging and poor grain filling during the most critical stage of barley development. A number of investigations have shown that the efficiency of the biomass translocation and the participation of the pre-anthesis assimilates in grain vary within a wide range, both in malting (Przulj and Momcilovic, 2003; Kostadinova and Ganusheva, 2013) and in feed barley (Dordas, 2012; Mirosavljevic et al., 2015). Apart from productivity, these processes also affect a number of qualitative and quantitative parameters of grain. The genotypic differentiation according to the trait 1000 grain weight was very well expressed not only by years but also averaged for the period.

Table 8. 1000 kernel weight over years, g

Genotypes	2014	2015	2016
Asparuh	43.92 b	52.53 b	46.04 b
Ahat	44.35 b	51.73 e	45.75 c
Deviniya	42.58 bc	48.81 fg	44.98 e
Zagoretz	40.21 cd	51.41 ef	40.98 h
Kaskadyor 3 – st	31.39 g	52.07 c	43.92 f
Kuber	44.43 b	52.02 d	46.99 a
Lardeia	40.79 c	47.85 g	40.04 i
Odisey	43.68 b	54.50 a	45.28 d
Orphej	38.86 f	46.25 h	43.03 g
Sayra	39.47 e	47.91 g	39.98 i
Yaspis	40.98 c	49.91 f	47.06 a
1015-127	46.96 a	54.15 a	43.89 f

Source: Authors' own elaboration

Line 1015-127, besides being the most productive, was also a leader by grain weight with a mean value of 48.33 g. The results obtained on the mean value of the indices weight of grain per spike and 1000 kernel weight by year of investigation revealed synchronicity in the response of the tested malting barley genotypes (Figure 8). High correlations were found between grain yield and the investigated traits, both over years and averaged for the investigated period (Table 9).

Among the organs of the vegetative biomass and averaged for the period, the grain yield was in highest correlation with the weight of stems, the non-grain part of spike and the vegetative biomass. High and positive coefficients were determined for weight of spikes, the harvest index, 1000 kernel weight and the total shoot biomass formed. Similar results have also been reported in other investigations carried out under different conditions. It has been discussed that under extreme factors, the ability of the plant to remobilize assimilates is especially important for realization of the productive potential (Ebadi et al., 2007; Fang et al., 2010).

The grain yield from the obtained malting barley genotypes followed the course of their total and vegetative biomass formed, which is yet another confirmation of the results obtained from the correlation analysis (Figure 9).

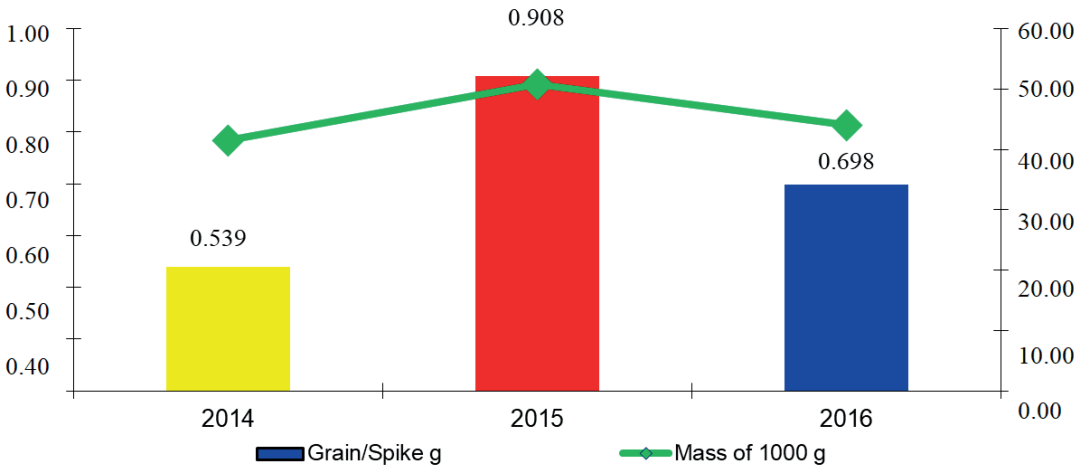


Fig. 8. Weight of grain per spike and 1000 kernel weight averaged for 2014–2016
Source: Authors' own elaboration

Table 9. Correlations of grain productivity with the indices of over ground biomass organs (Pearson Correlations)

Indices	2014	2015	2016	2014–2016
Leaves	0.133	0.655**	0.407*	-0.160
Leaves HI	-0.770**	-0.056	-0.181	-0.516**
Stems	0.643**	0.684**	0.656**	-0.378**
Stems HI	-0.851**	-0.194	-0.226	-0.748**
Spikes	0.987**	0.988**	0.972**	0.993**
Spikes HI	0.907**	0.200	0.268	0.739**
NoSpikes	0.268	0.355*	0.300	0.014
Weight of Spikes	0.805**	0.278	0.254	0.725**
Grain	1	1	1	1
GHI	0.925**	0.364*	0.434**	0.783**
GHI in Spikes	0.646**	0.406*	0.455**	0.542**
Weight of Grain per Spike	0.852**	0.316	0.322	0.753**
1000 kernel weight	0.755**	0.223	0.374*	0.782**
NGPS	0.349*	0.319	0.097	0.425**
NGPS HI	-0.036	-0.361*	-0.410*	0.103
NGPS HI in Spikes	-0.329	-0.406*	-0.455**	-0.542**
V. mass	0.581**	0.720**	0.600**	-0.311**
V. mass HI	-0.925**	-0.364*	-0.434**	-0.783**
Total weight	0.932**	0.948**	0.893**	0.493**

Source: Authors' own elaboration

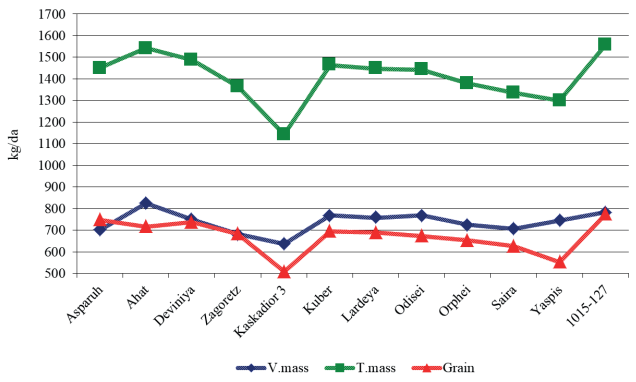


Fig. 9. Yield from the main structural elements of productivity, averaged for the period of investigation
Source: Authors' own elaboration

Conclusion

All investigated components of the formed shoot mass, which contributed to the realization of the biological yield potential of the malting barley cultivars, were influenced by the meteorological conditions of the respective year, by the specificity of the cultivar and by their interaction. It was found that the year conditions had determining role for the formation of the biological potential of the leaves, stems, spike and grain. The cultivar had a dominant role for the formation of the number of spikes per ha, the total shoot mass, 1000 kernel weight, the weight of the non-grain part of the spike and its percent from the weight of spike, respectively the weight of grain.

During the investigated period, the biological potential of the cultivars was realized fully in 2015 – 8169 kg/ha grain. The productivity of the investigated materials in 2014 and 2016 was, respectively, 69.5% and 77.3% from that of 2015. By the grain yield formed, all tested materials exceeded the standard Kaskadyor 3. The exceeding varied from 9.02 % in cultivar Yaspis to 52.58 % in line 1015-127. Cultivars Asparuh, Deviniya and Ahat also had high mean productivity, exceeding the standard with 47.56 %, 45. 56% and 41.41%, respectively.

Line 1015-127 was definitely with the largest grain – 48.33 g mean 1000 kernel weight. During the investigated period the grain of cultivars Odisey, Kuber, Asparuh and Ahat was characterized with values of this index above 47 g.

High positive correlations were found between grain yield and spike yield, GHI, weight of grain per spike, 1000 kernel weight, NGPS and total mass. The investigated winter malting barley cultivars, regardless of their breeding location, possess high productivity potential, and are suitable for growing in the region of Dobrudzha.

References

Amudha, J. & Balasubramani, G. (2011). Recent molecular advances to combat abiotic stress tolerance in crop plants. *Biotechnology and Molecular Biology Review, 6*(2), 31–58.

Ceccarelli, S., Acevedo, E. & Grando, S. (1991). Breeding for yield stability in unpredictable environments: single traits, interactions between traits, and architecture of genotypes. *Euphytica, 56*, 169–185.

Dordas, Ch. (2012). Variation in dry matter and nitrogen accumulation and remobilization in barley as affected by fertilization, cultivar, and source–sink relations. *Europ. J. Agronomy, 37*, 31–42.

Ebadi, A., Sajed, K. & Asgari, R. (2007). Effects of water deficit on dry matter remobilization and grain filling trend in three spring barley genotypes. *J. Food. Agric. Environ., 5*, 359–362.

Fabian, A., Jager, K., Rakszegi, M. & Barnabas, B. (2011). Embryo and endosperm development in wheat (*Triticum aestivum* L.) kernels subjected to drought stress. *Plant Cell Rep., 30*(4), 551–563.

Fang, Y., Xu, B., Turner, N. & Li, F. (2010). Grain yield, dry matter accumulation and remobilization, and root respiration in winter wheat as affected by seeding rate and root pruning. *Eur. J. Agron., 33*, 257–266.

Francia, E., Barabaschi, D., Tondelli, A., Laido, G., Rizza, F., Stanca, A., Busconi, M., Fogher, C., Stockinger, E. & Pecchioni, N. (2007). Fine mapping of a HvCBF gene cluster at the frost resistance locus Fr-H2 in barley. *Theor. Appl. Genet., 115*, 1083–1091.

Francia, E., Tondelli, A., Rizza, F., Badeck, F., Nicosia, O., Akar, T., Grando, S., Al-Yassin, A., Benbelkacem, A., Thomas, W., Eeuwijk, F., Romagosa, I., Stanca, A. & Pecchioni, N. (2011). Determinants of barley grain yield in a range of Mediterranean environment. *Field Crops Research, 120*, 169–178.

Gleick, P. (2003). Water use. *Annual Review of Environment and Resources, 28*, 275–314.

Gonzalez, A., Marthin, Is. & Ayerbe, L. (2007). Response of barley genotypes to terminal soil moisture stress: phenology, growth, and yield. *Australian Journal of Agricultural Research, 58*, 29–37.

Gramatikov, B., Penchev, P., Koteva, V., Krasteva, Hr., Stankov, St., Navushchanov, St., Zarkov, B. & Atanasova D. (2004). *Technology for growing barley*. Agropress, Sofia, 64 (Bg).

Koornneef, M., Alonso-Blanco, C. & Peeters, A. (1997). Genetic approaches in plant physiology. *New Phytologist, 137*, 1–8.

Kostadinova, Sv. & Ganusheva, N. (2013). Accumulation and reutilization of the dry biomass in barley cultivars and lines. *Agrarian sciences, IV* (12), 41–45 (Bg).

McMaster, G., Wilhelm, W. & Bartling, P. (1994). Irrigation and culm contribution to yield and yield components of winter wheat. *Agronomy Journal, 86*, 1123–1127.

Mirosavljevic, M., Przulj, N., Momcilovic, V., Hristov, N. & Maksimovic, I. (2015). Dry matter accumulation and remobilization in winter barley as affected genotype and sowing date. *Genetika, 47*(2), 751–763.

Nguyen, H. (2000). Molecular dissection of drought resistance in crop plants: from traits to genes. In: J-M Ribaut, D. Poland (eds.) Molecular approaches for the genetic improvement of cereals for stable production in water-limited environments. *A Strategic Planning Workshop held at CIMMYT*, El Batan, Mexico, 21–25 June 1999, p. 180.

Przulj, N. & Momcilvic, V. (2003). Dry matter and nitrogen accumulation and use in spring barley. *Plant Soil Environ., 49*(1), 36–47.

Rockstrom, J., Falkenmark, M., Karlberg, L., Hoff, H., Rost, S. & Gerten, D. (2009). Future water availability for global food production: The potential of green water for increasing resilience to global change. *Water Resources Research № 45*.

Saini, H. & Aspinall, D. (1982). Abnormal sporogenesis in wheat (*Triticum aestivum* L.) induced by short periods of high temperature. *Annals of Botany, 49*, 853–846.

SAS (2004). Statistical Analysis System, SAS Institute, Inc. Cary., N. C. USA.

Sharma, R., Tiwary, A. & Ortiz Ferrara, G. (2008). Reduction in kernel weight as a potential indirect selection criterion for wheat grain yield under terminal heat stress. *Plant Breeding, 127*, 241–248.

Sorrells, M., Diab, A. & Nachit, M. (2000). Comparative genetics of drought tolerance. In: *Durum wheat improvement in the Mediterranean region: new challenges*. Proceedings of a seminar, Zaragoza, Spain, 12–14 April, 191–201.

Sreenivasulu, N., Sopory, S. & Kishor, P. (2007). Deciphering the regulatory mechanisms of abiotic stress tolerance in plants by genomic approaches. *Gene, 388*, 1–13.

Swaminathan, M. (2007). Can science and technology feed the world in 2025? *Field Crops Research, 104*(1–3), 3–9.

Wiersma, J., Busch, R., Fulcher, G. & Hareland, G. (2001). Recurrent selection for kernel weight in spring wheat. *Crop Science, 41*, 999–1005.

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