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AGROBIOLOGICAL CHARACTERISTICS AND PRODUCTIVE CAPABILITIES OF SPRING BARLEY ACCESSIONS

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Abstract

The study was conducted during the period of 2021-2023 at the Institute of Agriculture in Karnobat. It examined 34 breeding lines and varieties of spring barley from Bulgarian plant breeding and introduction. The aim of the present study was to provide an agrobiological characterization and to investigate the productive capabilities of 34 breeding accessions—varieties and lines of spring barley. It was found that the Astoria variety had the highest 1000-grain weight at 53.0 g, followed by the Bulgarian perspective line KT 1248 at 52.0 g. The highest crude protein content of 13.2% was found in the Venera variety and perspective line KT 1254. The year conditions had the greatest influence on the productivity of the studied breeding accessions of spring barley, accounting for 52.07% of the total variation. The genotype factor accounted for 28.76%, while the interaction of the two factors had the weakest influence, accounting for 19.17% of the total variation. The introduced varieties Annabell and Jacinta had high and stable yields over the three years of the study. Out of the Bulgarian selection, the most productive were the perspective lines KT 1733 with 6,780 kg/ha, KT 341 with 6,750 kg/ha, and KT 1248 with 6,720 kg/ha. The year 2023 was the most favourable in terms of climate conditions for realizing the productive potential of the studied varieties and lines.

Keywords: spring barley, agrobiological characteristics, productivity, quality

INTRODUCTION

Historically, barley (*Hordeum vulgare* L.) has been the predominant cereal crop grown in various agricultural regions. The genus *Hordeum* includes all the diverse forms of cultivated barley (Breshkov, 1976). There is a wide variety of biological types adapted to different soil and extreme climatic conditions. In various parts of the world, barley is mainly grown as a winter and spring crop. In Central and Western European countries with a temperate-cool and humid climate, spring barley is predominantly grown. In Bulgaria, the varietal composition of barley is represented by winter and winter-spring biotypes, which are less dependent on climatic factors. According to Breshkov et al. (1975), spring barley in Bulgaria, due to the drier continental climate, achieves better yields only in the high fields of South-western Bulgaria, where rainfall is more abundant and evenly distributed, and temperatures are more moderate. The spring barley biotype requires a shorter vernalization period and has unsatisfactory cold resistance. Until 1965, mainly malting barley was grown as a spring crop (Gocheva, 2019).

Under the soil-climatic conditions of Bulgaria, winter barley varieties form high and stable yields compared to spring varieties, which is why breeders focus their attention and efforts on creating winter varieties (Vulchev & Dyulgerova, 2011; Dyulgerova & Vulchev, 2012; Valcheva & Vulchev, 2013; Gocheva et al, 2016; Dimova & Vulchev, 2019). At the Institute of Agriculture in Karnobat, which is the main barley breeding center in Bulgaria, collections of accessions of different

geographical origins are tested annually. Many of these are the basis of the barley breeding program and contribute to the creation of new varieties.

Alongside the in-depth breeding-genetic and theoretical studies on winter barley, the breeding program of the Institute has resumed the breeding selection of spring barley ever after 1990. The first spring variety bred at the Institute was Venera, recognized in 2016. It is a high-yielding variety, approved by EAVTFISC (Executive Agency for Variety Testing, Field Inspection and Seed Control) as a national standard for the two-row barley. In 2021, the first multi-row spring variety, Yasmina, was recognized and included as a standard for testing the multi-row barley (Dimova, 2024). Two more spring barley varieties, Denis and Saveliya, were also created at the Institute and recognized by EAVTFISC and registered List A of the Official Variety List of the Republic of Bulgaria in 2020. The varieties are high-yielding, and their quality meets the high requirements of the European standards. Productivity is a major breeding trait, and its improvement is a primary goal in every barley breeding program (Dimitrova-Doneva et al., 2014a; Dimitrova-Doneva et al., 2014b; Dimova, 2015).

The main breeding challenges for barley, particularly spring barley, are related to yield improvement (Lekes & Roskosna, 1975; Kudla & Bilinski, 1998; Neykov, 2016).

The aim of the present study was to provide an agrobiological characterization and to investigate the productive capabilities of 34 breeding accessions —varieties and lines of spring barley from Bulgarian breeding and introduction.

MATERIALS AND METHODS

The study was conducted during the period 2021-2023 at the Institute of Agriculture in Karnobat. It examined 34 breeding accessions - varieties and lines of spring barley. Most of the studied accessions are varieties from introduction and varieties and lines from Bulgarian breeding created at the Institute of Agriculture in Karnobat. The experiment was set up according to the EAVTFISC Methodology for conducting competitive variety trials with barley for VCU (Value for Cultivation and Use) from 2010, using the standard method in four replications with a plot size of 10 m^2. A mean standard for the group was used as control.

During the vegetation period, phenological observations were conducted, and assessments were made for heading date, plant height (cm), and lodging resistance (scale 9-1). The assessments of the breeding materials were made according to the EAVTFISC Methodology (2010) and CPVO (2019). The grain quality was determined by the following indicators: 1000-grain (g) hectoliter (kg) and crude protein content (by the Kjeldahl method). Yields and the obtained data were mathematically processed (with dispersion and variance analyses) by Microsoft Excel^{xp} 2010.

RESULTS AND DISCUSSION

The study period covers three consecutive years, which differ in terms of climatic conditions.

Figures 1 and 2 present the mean monthly temperatures and rainfall during the vegetation period of spring barley.

The agricultural year of 2021 was warmer throughout almost the entire vegetation period of spring barley compared to the multi-year values, but with sufficient rainfall during vegetation. The months of March and April were colder and wetter, which partly delayed the initial development of the plants but provided good soil moisture for the subsequent growth and development phases. The rainfall in June ensured good grain filling and nourishment in the spikes.

The second year of the study period was characterized by a dry and cool spring, with

rainfall below the multi-year averages. The lack of significant rainfall in March had a particularly negative economic impact. The rainfall in April provided good soil moisture for the plants and supported their development during the tillering and stem-elongation phases. The rainfall in June positively affected grain filling and ripening of the spikes. In terms of temperature, the year was marked by unusually high temperatures, with the average temperature for the period being 2.1°C higher than the multi-year average.

The agricultural year of 2023 was characterized by a wet spring and a hot summer. Good soil moisture at the end of March and the beginning of April allowed for the establishment of a good potential yield and normal tillering. April and May were cooler, with temperatures one degree below the multi-year average, but with sufficient rainfall (+39.7 mm), which favoured good crop density and grain yield formation.

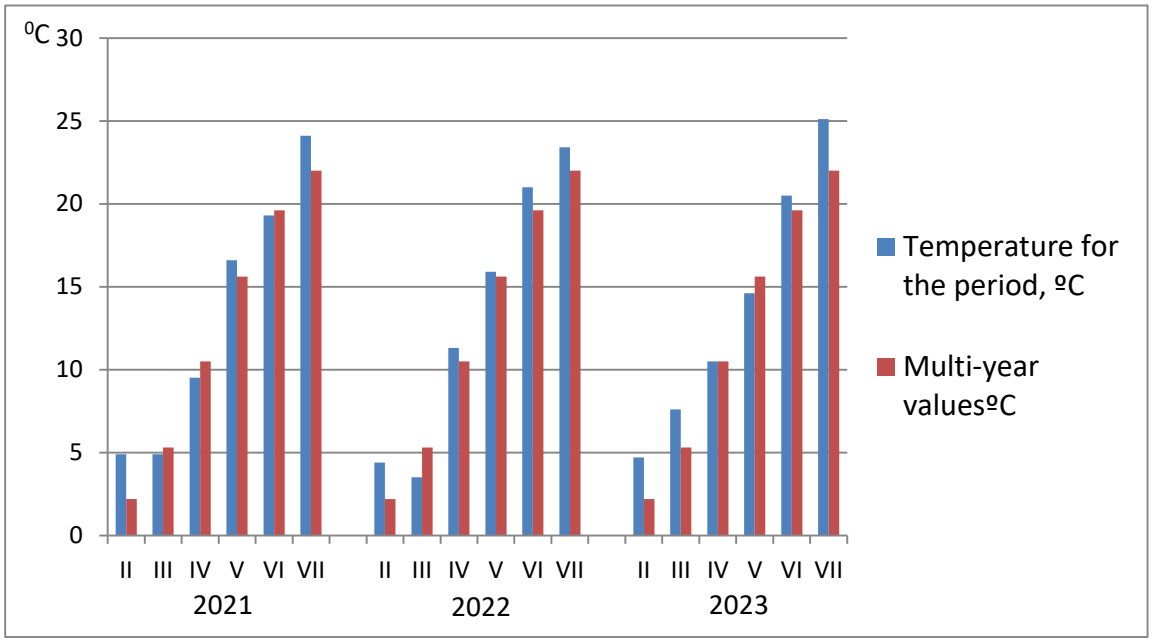

Figure 1. Meteorological characteristics of the mean monthly temperature during the study period, ^{0}C.

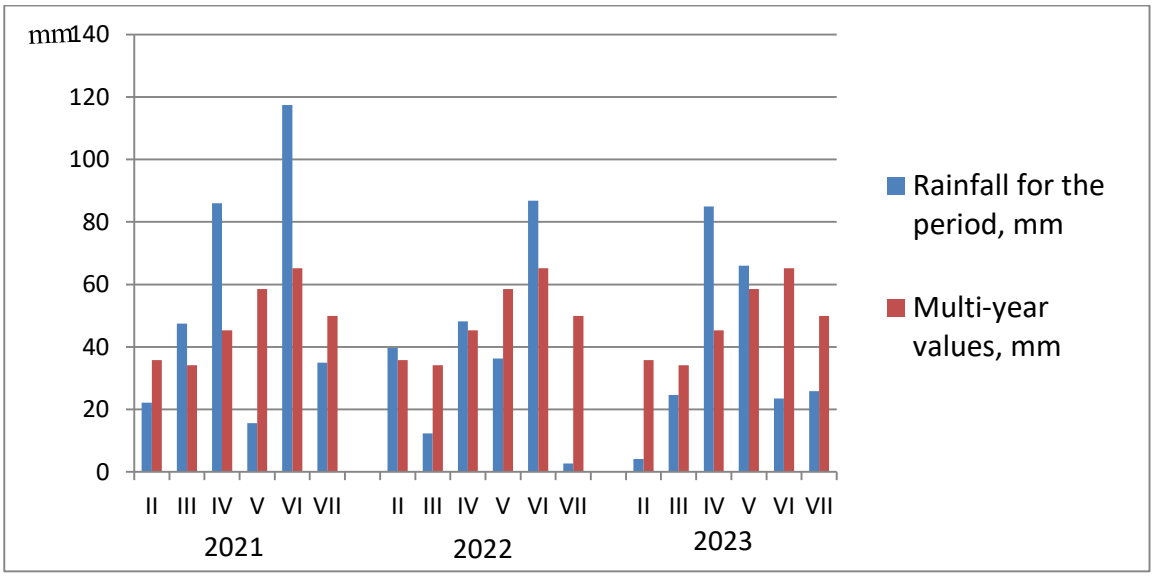

Figure 2. Meteorological characteristics – rainfall per month for the study period, mm/mm^2

Table 1 presents data on the origin of the breeding accessions. The tested varieties from introduction are from Denmark - 7 varieties (Gunhild, Jacinta, Alliot, Nery Sejet, Opal Abed, Proanthocyanidin-free 18.159, Lysimax), from Germany - 9 varieties (Grit, Alexis, Annabell, Barke, Krona, Gimpel, Scarlet, Fink, Bodega), from France - 3 varieties (Natasha, Josefin, Astoria), from Russia - 1 variety (Zernogradskij 73), from England - 1 variety (Maris Baldric), and from Italy - 1 variety (Modena). The studied Bulgarian accessions, selected at the Institute, were represented by the two-row varieties Venera, Saveliya, and Denis, and perspective lines KT 1247, KT 1248, KT 1254, KT 1255, KT 1732, KT 1733, KT 1734, KT 338, and KT 341.

Table 1. Breeding accessions – origin.

№	Breeding accessions	Origin	№	Breeding accessions	Origin
1.	Gunhild	Denmark	18.	Scarlet	Germany
2.	Grit	Germany	19.	Fink	Germany
3.	Alexis	Germany	20.	Zernogradskij 73	Russia
4.	Jacinta	Denmark	21.	Bodega	Germany
5.	Annabell	Germany	22.	Astoria	France
6.	Modena	Italy	23.	Venera	Bulgaria
7.	Alliot	Denmark	24.	Saveliya	Bulgaria
8.	Barke	Germany	25.	Denis	Bulgaria
9.	Krona	Germany	26.	KT 1247	Bulgaria
10.	Gimpel	Germany	27.	KT 1248	Bulgaria
11.	Natasha	France	28.	KT 1254	Bulgaria
12.	Nery Sejet	Denmark	29.	KT1255	Bulgaria
13.	Opal Abed	Denmark	30.	KT 1732	Bulgaria
14.	Maris Baldric	England	31.	KT 1733	Bulgaria
15.	Proanthocyanidin-free18.159	Denmark	32.	KT 1734	Bulgaria
16.	Lysimax	Denmark	33.	KT 338	Bulgaria
17.	Josefin	France	34.	KT 341	Bulgaria

During the vegetation period of the study, phenological observations were conducted (Table 2). The heading date was recorded, plant height (cm) was measured, and lodging resistance was assessed using a scale of 1 to 9 for the tested materials. The data show that the heading date of the mean standard ranged from 16 May to 31 May. The earliest heading on 16 May was observed for the Russian variety Zernogradskij 73 and the Bulgarian variety Denis, while the latest heading on 31 May was observed for the perspective Bulgarian line KT 1247 and the French variety Josefin. The data on plant height indicate that the height is completely acceptable from a breeding perspective. The height of the mean standard was 82 cm, and for the tested breeding materials, it varied from 63 cm to 104 cm. The shortest height was measured for the variety Jacinta at 63 cm, and the tallest was for the Bulgarian perspective line KT 1255 at 104 cm. Despite the measured height exceeding 100 cm for some of the tested materials, no lodging was recorded, indicating significant breeding progress in this trait, and the breeding accessions were rated 9 for non-lodging.

Table 3 presents data on the yield by the year and mean values for the study period. The mean data for the grain quality indicators of the studied breeding materials are also reflected. The data in the table show that the mean yield for the group of tested materials in 2021 was

4440.08 kg/ha. The lowest yield was from the variety Bodega - 2860 kg/ha, and the highest was from Jacinta - 6500 kg/ha, with a mean yield for the year standard of 4480 kg/ha. In the following year of 2022, the mean yield for all accessions was 4853.23 kg/ha, with the lowest productivity of 3300 kg/ha recorded for the variety OPAL ABED, and the highest of 6250 kg/ha for the variety Modena, with a mean yield for the year standard of 4850 kg/ha. The results show that the most favourable year in the study period was 2023, with a mean yield for all accessions of 6378.82 kg/ha. The variety with the lowest productive potential was Bodega - 4400 kg/ha, and the highest potential was for Annabell, which formed a yield of 8190 kg/ha, with a mean yield for the year standard of 6410 kg/ha.

Table 2. Phenological observations and assessments – the mean for the period 2021-2023.

Breeding accessions	Variety	Heading date	Plant height cm	Lodging resistance (scale 9-1)
Mean standard	nut	16-31.05	82	9
Gunhild	nut	26.05	81	9
Grit	nut	26.05	79	9
Alexis	nut	26.05	74	9
Jacinta	nut	28.05	63	9
Annabell	nut	28.05	72	9
Modena	nut	28.05	78	9
Alliot	nut	28.05	78	9
Barke	nut	28.05	65	9
Krona	nut	28.05	74	9
Gimpel	nut	27.05	74	9
Natasha	nut	27.05	68	9
Nery Sejet	nut	25.05	69	9
Opal Abed	nut	25.05	73	9
Maris Baldric	nut	25.05	71	9
Proanthocyanidin-free18.159	nut	28.05	72	9
Lysimax	nut	28.05	75	9
Josefin	nut	31.05	95	9
Scarlet	nut	24.05	97	9
Fink	er	21.05	85	9
Zernogradskij 73	nut	16.05	82	9
Bodega	nut	23.05	88	9
Astoria	nut	20.05	85	9
Venera	nut	26.05	71	9
Saveliya	nut	20.05	75	9
Denis	nut	16.05	91	9
KT 1247	nut	31.05	100	9
KT 1248	er	26.05	98	9
KT 1254	nut	30.05	103	9
KT1255	nut	26.05	104	9
KT 1732	nut	20.05	101	9
KT 1733	nut	21.05	83	9
KT 1734	nut	21.05	91	9
KT 338	nut	22.05	85	9
KT 341	nut	19.05	75	9

Table 3. Grain yield and quality mean for the period 2021 - 2023, kg/ha.

Breeding accessions	Grain yield (kg/ha)				Quality traits		
	2021	2022	2023	Mean (kg/ha)	1000-grain weight, g	Hectolitre weight, kg	Protein content, %
Mean standard	4480	4850	6410	5247	46.2	76.6	12.2
Gunhild	5390***	5010n	7270***	5890	45.5	70.6	11.7
Grit	5060**	4950n	6220n	5410	38.0	72.1	11.3
Alexis	5200***	5340**	6740n	5760	45.0	70.4	11.7
Jacinta	6500***	5500***	7500***	6500	37.0	69.4	11.2
Annabell	5960***	6200***	8190***	6783	39.0	72.3	11.7
Modena	5040**	6250***	6650n	5980	47.0	71.3	11.4
Alliot	6040***	5430**	7680***	6383	43.0	69.1	12.0
Barke	5210***	4970n	6870*	5683	44.5	70.4	12.1
Krona	5500***	5370**	7010**	5960	42.5	70.6	12.5
Gimpel	4960**	4610n	7120**	5563	41.0	73.6	12.2
Natasha	4240n	5080n	7610***	5643	39.5	68.5	12.2
Nery Sejet	5430***	4360--	6240n	5343	41.0	75.1	11.0
Opal Abed	5393***	3300---	5290---	4661	37.0	73.1	12.1
Maris Baldric	5350***	3740---	6680n	5257	40.0	75.6	10.8
Proanthocyanidin-free18.159	5300***	5050n	5300---	5217	34.5	73.6	11.3
LYSIMAX	5750***	4060---	6910*	5573	33.5	71.6	10.5
Josefin	3100---	4910n	5470---	4493	46.0	72.2	12.2
Scarlet	3050---	4850n	5430---	4443	44.0	74.5	12.1
Fink	3590---	4600n	5560---	4583	45.0	74.0	11.1
Zernogradskij 73	3690---	4380--	6180n	4750	48.0	72.9	11.8
Bodega	2860---	5210*	4400---	4157	51.5	73.0	10.6
Astoria	3410---	4100---	6000n	4503	53.0	74.0	10.5
Venera	4140n	4210---	6380n	4910	41.5	70.8	13.2
Saveliya	3980-	4910n	5880-	4630	45.0	76.4	10.9
Denis	3380---	4070---	5840-	4430	43.0	74.6	12.7
KT 1247	4330n	5330**	5840-	5167	47.5	73.0	11.4
KT 1248	3460---	4430-	6720n	4870	52.0	71.3	11.8
KT 1254	3640---	4730n	6680n	5017	44.0	69.3	13.2
KT1255	3430---	5650***	5700--	4927	45.0	72.8	12.0
KT 1732	4350n	5110n	6220n	5227	43.0	73.3	9.9
KT 1733	3580---	5430**	6780n	5263	45.5	72.5	9.9
KT 1734	3520---	4640n	5930-	4997	49.8	73.2	10.0
KT 338	3660---	4330--	5840-	4610	48.5	72.5	11.9
KT 341	3470---	4900n	6750n	5040	44.5	72.6	11.7
min	2860	3300	4400	4157	33.5	68.5	9.9
max	6500	6250	8190	6783	53.0	76.4	13.2
Mean	4440.08	4853.23	6378.82				
GD 5%	40.38	33.00	44.66				
1%	54.10	44.23	59.84				
0.01%	71.40	58.37	78.98				

Legend: Significance at p<0.01%; 1%;5%.

The mean yield of the breeding materials was 6378.82 kg/ha, which was 1938.74 kg/ha more than in 2021 and 1525.59 kg/ha more than in 2022. In 2023, which was the most favourable of the three years of testing, high yields with very good demonstration were achieved by the varieties Alliot - 7680 kg/ha and NATASHA - 7610 kg/ha, with a standard yield of 6410 kg/ha. The varieties GIMPEL - 7120 kg/ha and KRONA - 7010 kg/ha also showed good demonstrability. Apart from the Bulgarian breeding selection, the most productive were the perspective lines KT 1733-6780 kg/ha, KT 341-6750 kg/ha, and KT 1248-6720 kg/ha.

The dispersion analysis on yield (Table 3) showed that the German variety, Annabell, had a very good demonstrability over the three years of the study. Annabell achieved the highest mean yield for the period of 6783 kg/ha compared to the mean standard yield of 5247 kg/ha. Following Annabell, the variety Jacinta also had a very good demonstrability over the three years of testing, with a mean yield of 6500 kg/ha compared to the average standard yield of 5247 kg/ha.

The data presented in Table 3 on the qualitative characteristics of the studied materials show that the 1000-grain weight of the mean standard was 46.2 g, while for the lines, it varied from 33.5 g to 53.0 g. The highest 1000-grain weight was found for the variety Astoria (53.0 g), followed by the Bulgarian perspective line KT 1248 (52.0 g). The hectolitre weight also showed good values, ranging from 68.5 kg to 76.4 kg. The crude protein content for the mean standard was 12.2%, and for the accessions, it varied from 9.9% to 13.2%. The highest crude protein content of 13.2% was established in the variety Venera and perspective line KT 1254.

The conducted variance analysis (Table 4) showed that the year conditions had the greatest influence on the productivity of the studied spring barley accessions. The strength of this factor accounts for 52.07% of the total variation. The genotype factor represents 28.76%, and the interaction between the two factors had the least influence, accounting for 19.17% of the total variation.

Table 4. Variance analysis of yield as dependent on the genotype and year conditions.

Factor	***SS***	***df***	***MS***	***F experimental***	**η**	***F critical***		
						0.05	*0.01*	*0.001*
Total	7114017	407						
Factor (A)-year	2976149	2	1488074	325.60***	52.07	3.03	4.68	7.15
Factor (B)- genotype	1644017	33	49818.71	10.90***	28.76	1.49	1.69	2.75
A x B	1095375	66	16596.58	3.63***	19.17	1.35	1.53	1.81
Error	1398476	306	4570.184					

CONCLUSION

Agrobiological characteristics were examined and productivity study was conducted on 34 spring barley accessions, both Bulgarian and introduced. The introduction varieties, Annabell and Jacinta, showed high and stable yields over the three years of the present study. Apart from the Bulgarian breeding selection, the most productive are perspective lines KT 1733-6780 kg/ha, KT 341-6750 kg/ha, and KT 1248-6720 kg/ha. The year conditions have the greatest influence on the demonstrated productivity of the studied breeding accessions, accounting for 52.07% of the total variation.

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