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SPIKE MORPHOLOGY AND VARIATION IN SPIKE PARAMETERS IN SPECIES *TRITICUM* × *SAVOVII* H.P.ST.

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Abstract

Modern agricultural production and the growing demand for qualitative grain inputs, suggest dynamic and constantly development of new technologies and varieties of cereals in order to meet the market requirements. Therefore breeders faced a number of difficulties, since combining quantitative with qualitative parameters of yield being a difficult and lengthy process. Wide hybridization allows valuable plant materials that incorporate such features such as high protein content, resistance to diseases and pests, tolerance to abiotic stress and etc, to be obtained. The species Triticum ×savovii (2n=6x=42, $A^uA^uBBA^bA^b$) is amphidiploid obtained as a result of interspecific hybridization, which combines the genomes of the species Triticum polonicum (2n=4x=28, A^uA^uBB) and Triticum boeoticum (2n=2x=14, A^bA^b). Since both are characterized by very valuable qualities, they represent significant interest for the breeding of the wheat species. In order to determine its eligibility to participate in the hybridization programs as starting breeding material, the morphological parameters of the spikes and grains of species Triticum ×savovii were studied within 2 years. Moderate to significant variation in the indicators related to the weight of spike and the weight and the number of grains in a spike was settled. Less is the reported variation in the length of the spike but not for the indicators associated therewith. There were no significant variations in the weight of 1000 grains, which highlights the comparative uniformity of the resulting production of studied amphidiploid. There are, however, some differences between productivity associated with growing conditions (factor "economic year"), which suggests differences in some of the climatic factors. However, the species indicates stability and flexibility in relation to the morphological characteristics of the formed spikes, which together with its other characteristics (resistance to diseases), makes it valuable for inclusion in the breeding programs of the wheat species.

Key words: *amphidiploid, spike morphology, Triticum ×savovii, variation.*

INTRODUCTION

Agricultural production of the modern stage of its development and the ever increasing global demand for more quality grain raw materials sets numerous problems about the crops yield (von Braun, 2007). It is therefore necessary to be rapidly set up agricultural technologies and new varieties which should meet the global needs for food and feed (Crosson and Anderson, 1992). Notwithstanding this dinamics, in the developed countries is necessary to maintain a certain level of agrodiversity being able to satisfy the various industrial requirements. Therefore, it is not sufficient to grow limited number of crop plants, but it is necessary plant species from other geographical areas to be introduced, as well as new species with varying characteristics to be created using classical breeding methods (Atanasov, 2013). Thus, plant production could be enriched, but also the sources of the initial breeding material of the existing crops will increase.

Wide hybridization is a method of classical breeding, whereby phylogenetically distant species are crossed to create intergeneric and interspecific hybrid and amphidiploid forms (Stoyanov et al., 2010). Its significance is quite diversified because by this method could both create new species and resynthesize existing ones based on their phylogenetic origin, but also to transfer valuable genes carrying different types of resistance and tolerance to biotic and abiotic stress factors into the crops (Stoyanov, 2013a). The wide hybridization has great importance in cereals and especially in wheat species. There are numerous amphidiploid forms in tribus *Triticae*, and transfer of many resistance genes in common winter wheat (Stoyanov, 2013a; Spetsov et al., 2008; Spetsov et al., 2009). Although wide hybridization is associated with many difficulties related to species incompatibility at preembryonic, embryonic and postembryonic level, modern biotechnological methods could be effectively used to overcome them (Stoyanov, 2013).

Triticum ×*savovii* (2n = 6x = 42, $A^uA^uBBA^bA^b$) is an amphidiploid, first described by Spetsov and Savov (1992) and as a separate species of the genus *Triticum* by Stoyanov (2014). The species originated from a cross between the species *Triticum polonicum* (2n = 4x = 28, A^uA^uBB) and *Triticum boeoticum* (2n = 2x = 14, A^bA^b) uniting their genomes. It strongly likened the spike morphology of *Triticum polonicum*, but grains are smaller and slightly shriveled. The species is highly resistant to powdery mildew, brown rust and septoria leaf blight (Stoyanov, 2014a). Its treshability is considerably more difficult than *Triticum polonicum*, due to its hard glumes and lemmas and paleas.

The importance of this species for the breeding programs of wheat species is significant, because it combines hexaploid level with valuable genome of *Triticum boeoticum*. Therefore it is necessary to be examined in details in relation to its features. It is important to be evaluated by morphological, physiological, ecological, phytopathological, entomological point of view, and to be outpointed to what extent is able to meet the requirements as initial material in modern dynamic breeding (Stoyanov, 2014b). The determination of many valuable features would allow its possible introduction as a cultivated plant species.

The main purpose of this study is a morphological analysis of spikes of the species *Triticum* × *savovii*, originating from different economic years to be made, and the impact of the environment on various studied parameters to be assessed in order to determine the suitability of the species to be involved as a initial material in breeding programs of different wheat species.

MATERIALS AND METHODS

An accession of the wheat species *Triticum* × *savovii* is used, originating from the collection of Dobrudzha Agricultural Institute - General Toshevo. 15 numbers of seeds of the accession were sown in a scheme with row spacing 30 cm and 5 cm inside the rows. Sowing is carried out in 2012/2013 and 2013/2014 economic year respectively on 11.11.2012 and 06.11.2013, under field conditions in the area of Stozher, Dobrich region.

Harvesting is carried out in full maturity phase in the economic years 2012/2013 and 2013/2014 respectively on 20.07.2013 and 16.07.2014. Of each sample were randomly selected 20 fully mature spikes free of diseases and pests. An assessment of the morphology of spikes of each sample is made by 6 quantitative: length of spike (LS), length of spike with awns (LSA), weight of spike (WS), number of spikelets in a spike (NSS), weight of the grains in a spike (WGS), number of grains in a spike (NGS) and 6 index parameters: awness index (AI) - ratio between LSA and LS, weight distribution along the length of spike (WDLS) - ratio between WS and LS, number of spikelets to the length of spike (NSLS) - ratio between NSS and LS, average weight of a spikelet (AWS) – ratio between WS and NSS, mass of 1000 grains (M1000) – set by a standart methodology, grain index (GI) - ratio between WGS and WS, productivity distribution along the length of spike (PDLS) - ratio between WGS and LS, number of grains along the length of spike (NGLS) - ratio between NGS and LS, average productivity of a spikelet (APS) - ratio between WGS and NSS, average number of grains in a spikelet (ANGS) - ratio between NGS and NSS, weight of straw in the spike (WSS) - difference between WS and WGS.

To neutralize the influence of the factor "year" in order to establish biometrical relations in the amphidiploid, are calculated six specific weight indeces as a corrected value of the weight of 1000 grains (according to Stoyanov, 2015a) - a specific index eliminating the factor influence (SEFI) - ratio between M1000 and WSS; SEFI2 - ration between M1000 and the product between WSS and NSS; SEFI3 - ratio between M1000 and NSS; SEFI4 - ratio between M1000 and the product of AI and NSS; SEFI5 - ratio between M1000 and AI; SEFI6 - ratio between M1000 and NSLS. An additional indicator - specific index eliminating the year influence (SEYI) - a product between the ratio of WGS and NGS with LS is established. The corrective parameters are determined based on the hypothesis that the year did not affect the number of formed spikelets, largely on the weight of the vegetative part of the spike and to the awness index. SEYI additional indicator is based on the hypothesis that the indicators WGS, NGS and LS are in the biological equilibrium regardless of environmental conditions.

Data of the average daily temperatures during the period 01.10.2012 - 06.30.2013 and 10.01.2013 - 30.06.2014, and the amount of precipitation in the same periods are summarized. The temperature and rainfall data were obtained from measurements with automatic meteorological station LaCrosse. Measurements were taken twice daily in 07:00 and 19:00. The data were averaged in two periods (vegetative - 01.10 - 31.03; and reproductive - 01.04 - 30.06) and total. (Abbreviations: AVT - average vegetation temperature; AVFT - average vegetative-formation temperature; ARFT - average reproductive-formation temperature; TVT - total vegetation precipitation; TVFP - total vegetative-formation precipitation; TRFP - total reproductive-formation precipitation).

The data obtained is averaged and also the standard deviation (SD) is calculated, by years and total. The total variation coefficient (VC) is calculated. A correlation analysis between all recorded parameters and climatic characteristics is made. One-way ANOVA for considering the effects of the year on amphidiploid is conducted. It has been used a method of adding a third medium component representing the data of morphological parameters, averaged for the two study periods – average year (AY). It is reported the significance of the results. In order to summarize the data and for variational analysis was used software Microsoft Excel 2003 and for ANOVA and correlation analysis - IBM SPSS Statistics 19.

RESULTS AND DISCUSSIONS

Data about the studied morphological parameters are presented in Table 1. From the table could be monitored the slight variations in indicators NSS, LS, LSA, AI, NSLS and M1000 and the high variations in WS, WGS and NGS, and the index parameters associated with WGS and M1000. The slight variation in the first six listed indicators is due to the similar external morphology of the spikes and grains (Figure 1, 2, 3, 4), which is emphasized by the uniform genetic background of the studied plants. In the second group of indicators, high variation is caused by the uneven seedset and filling the grain of spikes in different periods, which is indicative of the influence of environmental factors on them. Lack of stability of yield components is a typical sign of the most wide hybrids and amphidiploids, especially in different growing conditions. Similar data have been reported in other amphidiploid wheat species, synthetic hexaploid wheats and intergeneric hybrids and amphidiploids (Spetsov and Savov, 1992; Spetsov et al., 2008; Spetsov et al., 2009; Niskidashvili, 1984; Stoyanov et al., 2012; Lalkova et al., 2004). There is high variability within the plant of the studied accession in the second year of cultivation, indicating differences in the size and seedset of the spikes caused by deteriorating environmental conditions. Firstly this could be due to the difference in nutrition of the additional tillers and secondly - in inhomogeneity of the plant population.

The difference in the environmental conditions could be monitored from the data presented in Table 2. There are, too large differences in the average temperatures and precipitation in the two studied periods. 2013/2014 economic year is characterized by very low temperatures during the period 01.04 - 30.06, compared with the previous year, which allows the presence of variation in plant development. Lower temperature during this period, in combination with higher rainfall are firstly a prerequisite for low fertility and secondly to the delay in the physiological processes of the grain filling. This would lead to an increase in the variation in some of the weight parameters as the amphidiploid plants are characterized by a high degree of instability in the yield of the spikes (Stoyanov, 2014d) obtained by the additional tillers. In combination with higher temperatures during the period 01.10-31.03 in 2013/2014, the present conditions are reason for higher tillering. This together with the slower physiological processes into the reproductive period, leading to instability in the seedset of the the main spike due to the distribution of the nutrients to more tillers (Stoyanov, 2013c). This thesis is underlined by higher variability of the indicators NSS, LS, WS, WGS and NGS in the economic 2013/2014 (Table 1).

Figure 1. Spikes of *Triticum ×savovii* of 2012/2013 economic year

Figure 2. Seeds of *Triticum ×savovii* of 2012/2013 economic year

The data from the conducted one-way ANOVA are presented in Table 3. The factor "year", which generally refers to the environmental conditions, enables to follow the reaction of a particular genotype, depending on the specific characteristics in the growing period. Usually these factors in wheat species are associated with a very strong influence on weight parameters. Various studies in other cereals (Tsenov et al., 2006; Rachovska and Uhr, 2010; Reeves et al., 1999; Georgieva et al., 2004) emphasize its widespread impact on parameters such as M1000, WS, WGS, NGS, LS. However, the degree of impact of growing conditions is directly related to the specific genotype (Stoyanov, 2013b).

Figure 3. Spikes of *Triticum ×savovii* of 2013/2014 economic year

Figure 4. Seeds of *Triticum ×savovii* of 2013/2014 economic year

The factor "year" has no impact on the index NSS in the studied accession. Despite of the wide variation in the economic 2013/2014, there are no significant differences between the studied periods. This allows to assert that the environmental conditions do not affect the spike formation in the phase stem extension (Stoyanov, 2014b). This is emphasized by the uniform values of AVFT and TVFP in both years of cultivation. Complete lack of correlation between the meteorological parameters and the NSS confirms moreover the absence of influence of growing conditions.
The indicators LS and LSA are too variative parameters that could be strongly influenced by environmental conditions. Similar dependences have been reported about amphidiploid

accessions, and for different wheat species (Tsenov et al., 2004; Tsenov et al., 2006; Rachovska and Uhr, 2010; Reeves et al., 1999; Georgieva et al., 2004; Stoyanov, 2013b; Stoyanov, 2014b; Stoyanov, 2014c; Stoyanov, 2014d; Stoyanov, 2015). The significant influence of environmental conditions is indicative of the differences in values between the two study periods, since their formation is related to the period 01.04-30.06, which for the two economic years differ as in precipitation but also in the average temperatures.

The weight of the spike and the weight of grains in a spike like LS and LSA are highly varying parameters, but they form their values rather dynamic (Rachovska and Uhr, 2010; Asif et al., 1999; Fischer and HilleRisLambers, 1978; Fonseca and Patterson, 1968; Grieve et al., 1992; Kashif and Khaliq, 2004; Leilah and Al-Khateeb, 2005). The presence of highly significant differences between the two periods is indicative of highly deteriorated environmental conditions due to intense rainfall in June 2014, coinciding with the phase of grain filling. Lack of enough intensive photosynthesis, because of less light in daylight hours and reduced temperatures suggest impaired nutrients flow and hence lower and highly variable values of WS and WGS.

Similar is the impact on the indicator NGS (Siddique et al., 1989). Rainfall in May 2014 is a prerequisite for reducing the degree of cross-pollination between plants of the accession and to increase self-pollination. As the studied amphidiploid like triticale has a hybrid character, it could be presumed that a certain low level of sterility is a result of abnormalities in the meiosis. Therefore NGS performed much higher values in the 2012/2013 economic year.

Particularly strong and significant is the influence on the indicator M1000. Although during every year, this indicator could be characterized by moderate to high variability, there are observed significant differences for different periods. Since the M1000 is a specific ratio of the number of formed grains in weight units of a particular spike (Stoyanov, 2013b), it could be seek the simultaneous influence of the year on the parameters WGS and NGS. The presence of high significance implies an accumulation of a number of factors, and different mechanism of formation of the two parameters. Similar significance levels of M1000 are reported from many authors and researches in wheat (Rachovska and Uhr, 2010; Asif et al., 1999; Fischer and HilleRisLambers, 1978; Fonseca and Patterson, 1968; Grieve et al., 1992; Kashif and Khaliq, 2004; Leilah and Al-Khateeb, 2005).

The meanings of the index parameters NSLS, WDLS, AWS, NGLS, PDLS, APS, ANGS, GI and WSS followed a similar trend with the M1000. This is because these parameters are specific ratios of features that are largely influenced by the environmental conditions (Stoyanov, 2014b; Stoyanov, 2013b). Due to the fact that on their components affect environmental conditions, but with different intensities and at different times, its influence is accumulated in this kind of parameters. Less is only the impact on the indicator NSLS as one of its compmnens is not affected by environmental conditions, and the other to a lesser extent. Similar should be the trend in the indicators AWS, APS and ANGS, but they are influenced by the strong meanings of WS, WGS and NGS.

The values of the index indicators should have a sustainable character, as they represent specific biological ratios into the plant biology (Stoyanov, 2014c). In spite of the fact that in amphidiploids amongst the cereals there are typical unstable values of the correlations between the components of the yield in progressive generations (Stoyanov et al., 2010), they are retained to a certain levels. However, deteriorating environmental conditions during the 2013/2014 economic year have an impact on such dependencies. This indicates the presence of particular genetic mechanisms that violate biological ratios in order to preserve the reproduction of the species (Ayala and Kiger, 1987). For this reason, regardless of the environmental conditions it should be a relation between certain parameters which is not affected by the growing period because the genotype for both periods remained unchanged. This is important in breeding work, since it allows to distinguish the effect of genotype from the environmental influence and thus is associated with resistance of a genotype in relation to the reproduction to a variety of factor effects.

Such kind of ratios represents the indicator AI. Regardless of the period of the study, its variation remains relatively moderately low, even in economic 2012/2013. Lack of significant values to growing conditions, assumes that the length of the awns is strictly in relation to the length of the spike. This is because LS and LSA are formed by the action of the same conditions and environmental factors (Stoyanov, 2013b).

The parameters, SEFI, SEFI2, SEFI3, SEFI4, SEFI5 and SEFI6 in the studied plants give an idea of the strong intensity of the influence of the factor "year" on the formation of the components of yield. Although they are specific corrective indicators of M1000 and its corrective components NSS is not affected by environmental conditions for the studied genotype, the presence of high significance for SEFI SEFI2, SEFI3, SEFI4 and SEFI5 is indicative of the presence of various factors of the environmental conditions, which form the values of the components of a particular coefficient. In SEFI and SEFI2 is observed effect like to the index parameters, because WSS participates as a component, which is significant affected by the environmental conditions, since its values are related to the intensity of the vegetative growth of the spikes.

SEFI6 unlike other corrective parameters is characterized by a lack of significance regarding the influence of environmental conditions. This is likely due to the involvement of LS as an element of NSLS and also NSS. However, since NSS operates through the genotypic factors, it could not eliminate the importance of a formation factor of the environmental conditions. Therefore, it is calculated specific additional parameter SEYI. It includes the effect of three highly variative parameters – WGS, NGS and LS. Lack of significance in relation to the factor "year" proves the existence of biological ratio in the studied amphidiploid, which excludes specific variability due to the hybrid nature of the plant species. The operation of LS exhibit that the environment has a effect on it throughout whole reproductive-forming period - 01.04-30.06 while on NGS is (relatively) from 01-31.05 and for WGS - 01-30.06.

The dependencies and the impact of the environmental conditions on the index and corrective parameters are confirmed by the values of correlation coefficients (Table 4).

Regardless of the low values of the parameters of the studied accession of the species *Triticum ×savovii*, due to deteriorating environmental conditions in the economic 2013/2014, the studied plants are distinguished by biometrically and biologically stable genotype and could be effectively used as an initial material in breeding programs of different wheat species.

CONCLUSIONS

Based on the results mentioned above the following conclusions could be made:

1. The parameters NSS, LS, LSA, NSLS, AI and M1000 are distinguished by low to moderate variability due to the similar morphology because of the identical genotype of the studied accession.
2. The parameters WS, WGS, NGS are characterized by high levels of variation due to uneven seedset and due to the impact of growing conditions in different periods.
3. All studied morphological quantitative parameters with the exception of NSS and index parameters excluding AI are influenced reliable and significant in relation to the factor "year", based on the conducted ANOVA.
4. All index parameters correlate high and significantly with the climate indicators, which highlights the importance of growing conditions in the formation of the spike morphology.
5. The corrective parameters SEFI, SEFI2, SEFI3, SEFI4 and SEFI5 do not eliminate the influence of environmental conditions, while SEFI5 and SEYI are not affected significantly, emphasizing the presence of biological ratios in the species *Triticum ×savovii*, determining its stable genotype, which makes it suitable for use as initial material in breeding programs for the wheat species.

Table 1. Data of the morphological analysis of spikes of the species *Triticum ×savovii*

Parameter	Year	AV	SD	VC	Parameter	Year	AV	SD	VC
NSS	2012/2013	14.35	1.93	13.43	NGLS	2012/2013	0.451	0.101	22.40
	2013/2014	14.45	3.28	22.73		2013/2014	0.221	0.082	37.12
	AY	14.40	1.89	13.12		AY	0.329	0.071	21.53
	AV	14.40	2.41	16.75		AV	0.333	0.127	38.00
LS	2012/2013	90.75	12.01	13.23	PDLS	2012/2013	0.026	0.008	32.38
	2013/2014	106.05	16.40	15.46		2013/2014	0.009	0.004	49.69
	AY	98.40	11.34	11.52		AY	0.015	0.005	34.20
	AV	98.40	14.63	14.87		AV	0.017	0.009	55.60
LSA	2012/2013	174.15	16.94	9.73	APS	2012/2013	0.158	0.030	19.20
	2013/2014	190.15	16.21	8.52		2013/2014	0.068	0.027	39.52
	AY	182.15	11.87	6.52		AY	0.112	0.023	20.40
	AV	182.15	16.30	8.95		AV	0.113	0.045	40.28
WS	2012/2013	3.02	0.71	23.57	ANGS	2012/2013	2.83	0.46	16.12
	2013/2014	2.03	0.67	32.82		2013/2014	1.63	0.58	35.66
	AY	2.53	0.54	21.25		AY	2.23	0.41	18.20
	AV	2.53	0.75	29.72		AV	2.23	0.69	30.86
WGS	2012/2013	2.28	0.57	25.08	WSS	2012/2013	0.74	0.17	23.64
	2013/2014	0.98	0.44	44.81		2013/2014	1.05	0.38	36.65
	AY	1.64	0.38	23.49		AY	0.90	0.23	26.15
	AV	1.63	0.71	43.35		AV	0.89	0.30	33.89
NGS	2012/2013	40.70	9.18	22.56	SEFI	2012/2013	79.84	18.67	23.38
	2013/2014	23.65	9.94	42.02		2013/2014	44.42	16.96	38.17
	AY	32.18	7.56	23.48		AY	60.35	15.12	25.05
	AV	32.18	11.25	34.97		AV	61.54	22.18	36.04
AI	2012/2013	1.94	0.28	14.16	SEFI2	2012/2013	5.83	2.28	39.04
	2013/2014	1.82	0.24	13.23		2013/2014	3.49	2.14	61.40
	AY	1.87	0.17	9.37		AY	4.37	1.64	37.58
	AV	1.88	0.24	12.56		AV	4.57	2.23	48.81
NSLS	2012/2013	0.161	0.031	19.44	SEFI3	2012/2013	4.00	0.84	21.03
	2013/2014	0.137	0.019	14.12		2013/2014	3.02	0.91	30.23
	AY	0.148	0.015	10.05		AY	3.59	0.59	16.53
	AV	0.148	0.025	16.55		AV	3.54	0.88	24.88
WDLS	2012/2013	0.034	0.009	27.86	SEFI4	2012/2013	2.10	0.54	25.83
	2013/2014	0.019	0.004	23.54		2013/2014	1.66	0.44	26.65
	AY	0.025	0.005	20.52		AY	1.93	0.32	16.58
	AV	0.026	0.009	34.40		AV	1.90	0.47	24.96
AWS	2012/2013	0.210	0.036	17.27	SEFI5	2012/2013	29.36	4.84	16.48
	2013/2014	0.139	0.029	21.12		2013/2014	23.21	5.93	25.56
	AY	0.175	0.025	14.54		AY	27.44	3.21	11.70
	AV	0.175	0.042	24.05		AV	26.67	5.38	20.16
M1000	2012/2013	56.12	6.19	11.03	SEFI6	2012/2013	363.98	93.13	25.59
	2013/2014	41.38	8.32	20.12		2013/2014	313.89	82.80	26.38
	AY	50.83	4.24	8.35		AY	351.03	57.62	16.41
	AV	49.44	8.84	17.89		AV	342.97	80.80	23.56
GI	2012/2013	0.75	0.04	5.38	SEYI	2012/2013	5.11	0.95	18.51
	2013/2014	0.47	0.12	26.36		2013/2014	4.43	1.21	27.27
	AY	0.65	0.06	9.54		AY	5.01	0.74	14.75
	AV	0.62	0.14	22.96		AV	4.85	1.01	20.88

AV – average value; SD – standard deviation; VC – variation coefficient; AY – average year

Table 2. Temperature and precipitation data for the studied period

Months	AMT, ºC			TMP, mm		
	2012/2013	2013/2014	AY	2012/2013	2013/2014	AY
October	16.1	12.1	14.1	73.5	79	76.25
November	9.2	9.5	9.4	41	29	35
December	0.9	1.8	1.4	142	10	76
January	1.2	2.6	1.9	47	153	100
February	3.6	4.7	4.2	34.5	19	26.75
March	6.2	8.7	7.5	31	56	43.5
April	13.4	11.5	12.5	39.5	39	39.25
May	19.7	15.6	17.7	20.5	120	70.25
June	20.9	19.2	20.1	60	234	147
AVT	10.1	9.5	9.8	-	-	-
AVFT	6.2	6.6	6.4	-	-	-
ARFT	18.0	15.4	16.7	-	-	-
TVP	-	-	-	489	739	614
TVFP	-	-	-	369	346	358
TRFP	-	-	-	120	393	257

AMT – average monthly temperature; TMP – total monthly precipitation; AY – average year; AVT – average vegetation temperature; AVFT – average vegetative-formation temperature; ARFT – average reproductive-formation temperature; TVT – total vegetation precipitation; TVFP – total vegetative-formation precipitation; TRFP – total reproductive-formation precipitation

Table 3. ANOVA of the morphological parameters

Paramater	Sum of Squares	degrees of freedom	Mean Square	F	Significance
NSS	0.100	2	0.050	0.008	0.992
LS	2340.900	2	1170.450	6.482	0.003
LSA	2560.000	2	1280.000	5.560	0.006
WS	9.712	2	4.856	11.749	0.000
WGS	16.874	2	8.437	37.802	0.000
NGS	2907.025	2	1453.513	18.155	0.000
AI	0.154	2	0.077	1.407	0.253
NSLS	0.006	2	0.003	5.535	0.006
WDLS	0.002	2	0.001	23.872	0.000
AWS	0.050	2	0.025	26.766	0.000
M1000	2229.744	2	1114.872	26.638	0.000
GI	0.813	2	0.406	58.478	0.000
NGLS	0.530	2	0.265	36.300	0.000
PDLS	0.003	2	0.001	36.559	0.000
APS	0.080	2	0.040	55.666	0.000
ANGS	14.412	2	7.206	30.531	0.000
WSS	0.983	2	0.491	6.326	0.003
SEFI	12586.393	2	6293.196	21.834	0.000
SEFI2	55.782	2	27.891	6.704	0.002
SEFI3	9.735	2	4.868	7.705	0.001
SEFI4	1.979	2	0.990	5.020	0.010
SEFI5	396.306	2	198.153	8.629	0.001
SEFI6	27039.159	2	13519.579	2.152	0.126
SEYI	5.386	2	2.693	2.790	0.070

Table 4. Correlation analysis between morphological parameters and climatic data

Parameter	AVT	AVFT	ARFT	TVP	TVFP	TRFP
NSS[1]	-.017	.017	-.017	.017	-.017	.017
LS[2]	-.430**	.430**	-.430**	.430**	-.430**	.430**
LSA	-.404**	.404**	-.404**	.404**	-.404**	.404**
WS[3]	.540**	-.540**	.540**	-.540**	.540**	-.540**
WGS	.755**	-.755**	.755**	-.755**	.755**	-.755**
NGS	.624**	-.624**	.624**	-.624**	.624**	-.624**
AI	.214	-.214	.214	-.214	.213	-.214
NSLS	.403**	-.403**	.403**	-.403**	.402**	-.403**
WDLS	.672**	-.672**	.672**	-.672**	.670**	-.672**
AWS	.696**	-.696**	.696**	-.696**	.696**	-.696**
GI	.812**	-.812**	.812**	-.812**	.815**	-.812**
NGLS	.748**	-.748**	.748**	-.748**	.747**	-.748**
M1000	.686**	-.686**	.686**	-.686**	.689**	-.686**
PDLS	.740**	-.740**	.740**	-.740**	.737**	-.741**
APS	.813**	-.813**	.813**	-.813**	.813**	-.813**
ANGS	.719**	-.719**	.719**	-.719**	.719**	-.719**
WSS	-.426**	.426**	-.426**	.426**	-.426**	.426**
SEFI	.658**	-.658**	.658**	-.658**	.656**	-.658**
SEFI2	.432**	-.432**	.432**	-.432**	.430**	-.432**
SEFI3	.459**	-.459**	.459**	-.459**	.460**	-.459**
SEFI4	.383**	-.383**	.383**	-.383**	.384**	-.383**
SEFI5	.471**	-.471**	.471**	-.471**	.474**	-.471**
SEFI6	.255*	-.255*	.255*	-.255*	.257*	-.255*
SEYI	.276*	-.276*	.276*	-.276*	.279*	-.276*

*- the data is significant at level of $p<0.05$; **- the data is significant at level of $p<0.01$; 1 (in *italic*) – parameters not influenced by environmental conditions; 2 (normal) – parameter influenced by environmental condition in moderate or very low level; 3 (**bolded**) – parameters influenced by environmental conditions in a high level.

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