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Criteria for Assessing the Reproductive Potential of Traditional Varieties of Winter Soft Wheat and the Possibility of Their Use in the Selection Process

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Abstract

The article considers the achieved productive potential of the winter soft wheat ear based on traditional varieties of this crop - Belokoloska, Nemerchanskaya, Sedouska, Saksonka No. 354, Traditional winter No. 346, Hybrid No. 22417 - cultivated on the Krasnodar Territory till 1928. The paper studies the processes of the reproductive potential achievement on the basis of counting the number of flowers embedded in the ear at the 6th stage of organogenesis to the number of grains at the 12th stage of organogenesis. Preselective evaluation was carried out for the features characterizing the reproductive potential of varieties. The influence of environmental factors was studied, and the variability of the reproductive potential caused by the artificial decrease in plant height due to the use of retardant was estimated. It was established that the completeness of the development of the upper spikes testified to the balance of the behavior of morphogenetic processes of the ear development as a whole, and this indicator might also be used to assess the genotype potential productivity in the given ecological conditions of cultivation.

Key words: Achieved productivity, traditional winter wheat varieties, environmental factors, retardant.

INTRODUCTION

One of the problems of the modern selection is the reduction of genetic diversity, the so-called "bottleneck" effect, which leads to deficit of donors of agronomic characters. In this regard, the urgency of studying both the potential donors of these characters and the methods that allow them to be identified is increasing. According to P.P. Lukyanenko, in the first quarter of the last century, "until 1928, local varieties of winter soft wheat had been cultivated in the Kuban" [1; 2; 3]. Such cultivars, which have not been subjected to modern selection methods, are undoubtedly a promising starting material, and their study is relevant for plants selection and genetics.

Thus, six traditional varieties of soft winter wheat - Belokoloska, Nemerchanskaya, Sedouska, Saksonka No. 354, Traditional winter No. 346, Hybrid No. 22417 cultivated in the territory of the Krasnodar Territory till 1928 - were selected for research. These varieties are characterized by tall and long ear with a large number of segments (23-25 pieces). All the varieties were received from the collection of the N.I. Vavilov Research Institute of Plant Industry in 2012. We chose the widely known Bezostaya 1 variety of the selection of the Krasnodar Scientific Research Institute n.a. P.P. Lukyanenko as a check one because of its high adaptability and phylogenetic proximity to the traditional varieties that were cultivated in the Kuban in the early XXth century [4; 5]. In one of the chapters of this work, the check variety is also the object of research.

The purpose of the research was to study the criteria for assessing the reproductive potential of traditional varieties of soft winter wheat in the early stages of its development and to determine the possibility of using them to evaluate the selection material for productivity.

The following tasks were identified to achieve this goal:

– To conduct preselective evaluation of the traditional varieties of winter wheat by the features characterizing the reproductive potential of the varieties;
– To study the influence of environmental factors in the growing year on the achievement of the potential productivity of the varieties under study;
– To assess the changes in the potential productivity of traditional varieties of winter wheat caused by artificial lowering of plant height due to the use of retardant; and
– To develop criteria for assessing the potential productivity of winter wheat varieties, and to study their relationship to individual actual plant productivity.

METHODS

The experiment had been planned in two versions and three replications with randomized arrangement of plots, and was conducted from 2012 to 2015 on the experimental field of the Kuban State Agrarian University. Plot size was 1x1.5 m with drill seeding, inter-row spacing of 0.15 m, seeding rate of 20 grains per running meter. The first version of the experiment was treated with the TseTseTse 750 retardant in the phase of winter wheat tillering, the second version was without treatment.

To assess the achievement of the reproductive potential of soft wheat, the method of morphophysiological control was used. According to it (BBCH code), a representative sample was selected from the population at the 43rd stage. After that, the number of planted flowers (the potential ear productivity) was counted in the main ear. Then at the time of full ripeness, the number of grains in the ear (the actual productivity of the spike) was counted in a similar sample. Substituting the average data in the

formula below, we would yield a fraction of the flowers that had formed a full-value grain. (6)

$$EP_{Ad}(\%) = \frac{EP_{At}}{EP_P} \times 100, \text{ where:}$$

EP_{Ad} was achieved ear productivity;

EP_{At} was actual ear productivity; and

EP_P was potential ear productivity;

The calculation of the elements of the plant productivity structure was carried out according to generally accepted methods. [7]

Mathematical data processing was carried out by means of two-way dispersion and correlation analysis [8; 9] using Statistica 6.0 and Microsoft Excel 2010 with a 95 percent confidence interval.

During all the years of research in autumn and winter, there was sufficient or excessive amount of precipitation. In 2014-2015 these precipitations limited the lack of moisture in the first half of spring, but in 2013 the amount of precipitation in the spring period was almost 2 times higher than the average annual rate that caused growth of the vegetative mass and subsequent lodging of tall-growing varieties.

The temperature regime has kept the trend of the recent years; mild winter was followed by a warm spring, only in autumn 2013-14 the air temperature was slightly below the average one.

DISCUSSION AND RESULTS

To study the effect of the growing year on the achieved productivity of the spike, variance analysis was used in the varieties under study, where the genotype of the variety and the agricultural year served as the main factors of variability (Table 1).

The results of the action and interaction of the above-described factors were reliable, since in all three cases the actual Fisher coefficient exceeded its tabulated value [9]. The analysis of variance indicated that, on average, per variation of the achieved productivity, the conditions of the year of cultivation affected by 7.9% of the total variance, and by 36.5% the implementation of this indicator depended on the variety genotype. Therefore, it was expected that in different years different genotypes showed greater variance (38.5%).

Thus, in different years the achieved productivity was different.

2015 was the most favorable for most varieties, when the Belokoloska, Traditional winter and Bezostaya 1 check variety exceeded the average achieved productivity by 10.1, 4.2 and 6.7%. For the Sedouska variety the best was 2014, when its achieved productivity was above the average by 5.3%. In general, this indicator is very sensitive to weather conditions, and its variability is highly dependent on the variety genotype.

One of the tasks of the research was to study the change in the achieved productivity of varieties with artificial lowering of plant height. We used the TseTseTse 750 retardant for this purpose. The retardant action is based on the regulation of phytohormonal activity [10]. Therefore there are no side effects of its influence on soft wheat plants. The results of the variance analysis, where variability factors are the variety genotype and the retardant effect, indicate a significant effect of both studied factors (Table 2).

Table 1 - Results of variance analysis of data from two-factor vegetative experiment; factorial feature is achieved productivity of the spike, Krasnodar, 2013-2015

Dispersion	Sum of squares SS	Coefficient of determination R^2, %	Degree of freedom df	Average square MS	F_f	F_{05}
Total	3523.8	100	62			
Repetitions	12.4		2			
Year A	279.3	7.9	2	139.7	9.5	3.3
B Variety	1284.7	36.5	6	214.1	14.5	2.3
AB interaction	1358.2	38.5	12	113.2	7.7	2
Balance (errors)	589.2	17.1	40	14.7		

Table 2 - Results of variance analysis of data from two-factor vegetative experiment; factorial feature is achieved productivity, Krasnodar, 2013-2015

Dispersion	Sum of squares SS	Coefficient of determination R^2,	Degree of freedom df	Average square MS	F_f	F05
Total	2202.4	100	41			
Repetitions	20.1		2			
A Retardant	315.6	14.1	1	315.6	43.9	3.3
B Variety	1386.2	63.2	6	231.0	32.1	2.3
AB interaction	336.6	15.3	12	28.1	3.9	2.0
Balance (errors)	143.9	7.1	20	7.2		

The coefficient of determination indicated a high proportion of the influence of soft wheat genotype on the factorial feature, 63.2% of the total variance, and a much smaller share of the retardant effect, 14.1%.

Under the influence of the retardant, all varieties on average decreased by 15.9 cm. In versions, also all varieties except for Traditional winter, No. 22417 had reliably reduced in height (Table 3).

On average, all the varieties were inferior to the check variety in terms of factor "A", but the tallest was hybrid No. 22417, and the Traditional winter variety No. 346, in contrast, was the least tall among the traditional ones. The greatest decrease in height was observed in the Belokoloska variety, the second place on this indicator was taken by the check variety, and the third – by the Nemerchanskaya variety. Compared to the check ones, all varieties were significantly higher.

According to some authors, the decrease in the height of soft wheat in phylogenesis through directional selection was directly related to the increase in yield [11]. Thus, we suggested that decrease in plant height through the retardant could also significantly affect the achievement of potential productivity. (Figure 1)

Table 3 - Reduction of winter wheat plants in the height as a result of the retardant effect, see Krasnodar (2013-2015).

Variety	Height of plants in the version		Height reduction	Average LSD_{05}= 5.3	Deviation from check variety, cm
	with retardant	without retardant			
Belokoloska	98.2	119.4	21.2	108.8	+24.2
Nemerchanskaya	100.4	118.8	18.4	109.6	+25
Sedouska	99.7	116.8	17.1	108.3	+23.7
Saksonka No. 354	99.4	114.4	15	106.9	+22.3
No. 22417	108	120.6	12.6	114.3	+29.7
Traditional winter No. 346	99	106.9	7.9	103	+18.4
Bezostaya 1 (check)	75.1	94.2	19.1	84.6	–
Average LSD_{05} = 10.1	97.1	113	15.9	–	–
LSD_{05} for special average = 14.2 (LSD – least significance difference) I - LSD05 = 3.1					

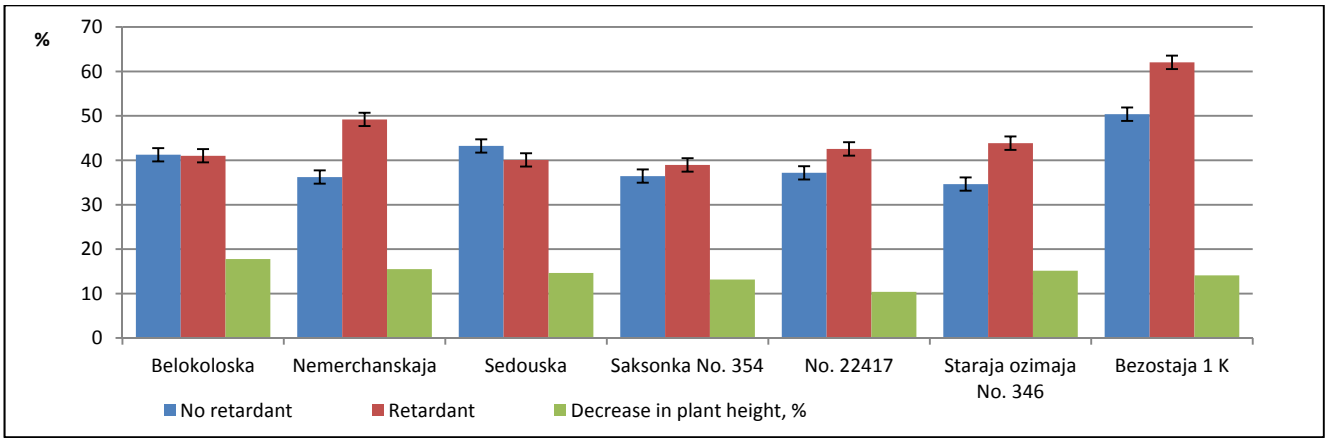

Figure 1 - Change in the achieved productivity of the ear of winter soft wheat varieties against the background of decrease in plant height under the influence of the retardant, Krasnodar, 2013-2015

Table 4 - Deviations of the values of the main quantitative characteristics from the check Bezostaya 1 variety, Krasnodar, 2013-2015

Variety / Feature	Belokoloska	Nemerchanskaya	Sedouska	Saksonka No. 354	No. 22417	Traditional winter No. 346	Best traditional variety by this feature
Grains weight in spike, g	-0.7	-1.2	-0.9	-1.1	-1.1	-1.2	Belokoloska
Mass of husk from spike, g	-0.2	-0.3	-0.2	-0.4	-0.4	-0.2	Traditional winter No. 346, Sedouska, Belokoloska
Weight of the 1st internode, g	-0.1	-0.2	-0.1	-0.2	-0.1	-0.2	Belokoloska, Sedouska, No. 22417
Plant height, cm	+31.9	+31.4	+29.4	+19.5	+33.1	+27.0	Saksonka No. 354
Ear length, cm	+0.8	-0.8	-0.5	-1.3	-0.9	-1.7	Belokoloska
Number of grains in spike, pcs.	-14.7	-21.1	-16.6	-20.6	-12.2	-21.0	No. 22417
Number of spikelets in spike, pcs.	+3.1	-0.1	+0.8	+0.9	+0.8	-1.8	Belokoloska
Ear weight, g	-1.1	-1.5	-1.1	-1.5	-1.5	-1.4	Belokoloska, Sedouska
Length of the 1st internode, g	+3.3	+2.1	+2.4	+0.9	+3.4	+1.4	Saksonka No. 354

We can see from the graph that the maximum decrease in height was recorded in the Belokoloska variety - 17.8% (21.2 cm), but the change in the achieved productivity did not go beyond the error of the experiment. A similar situation was observed in the Sedouska and Saksonka No. 354 varieties. The increase in the achieved productivity was 13 points for the Nemerchanskaya variety with decrease in plant height by 15.5% (18.4 cm) compared to the version without retardants. Traditional Winter No. 346 (9.3 points) and Bezostaya 1 (11.7 points) ranked second and third on this indicator, respectively.

Varietal appurtenance of soft wheat plants caused greater variability of the studied features than the retardant effect, but the artificial decrease in plant height caused by the growth inhibiting preparation also had a significant impact. In view of the fact that the genetic potential of tall-grown varieties may not manifest itself even in conditions favorable for cultivation, the artificial reduction in plant height by the growth inhibiting preparation is an effective way to identify the potential and actual productivity of such genotypes.

Quantitative characteristics are an informative indicator of the variety value. Given that the old varieties exhibit high polymorphism and variation in a number of key quantitative features and selection indices, we believe that their use for the variety evaluation will be more informative when compared with the parameters of a knowingly better variety for a given zone.

In our experiment the check variety is the most perfect one from the point of view of the selection value, therefore, by comparing its quantitative characteristics with the parameters of the traditional varieties, we can identify the most valuable genotypes (Table 4).

We can see from the table that by feature of the grain weight in the spike Belokoloska variety was the leading one, yielding to the check variety only by 0.7 g. By the mass of husk from the ear, the least inferior to the standard were the Traditional Winter variety No. 346, Sedouska, Belokoloska (-0.2 g). By the weight of the first internode, the Belokoloska, Sedouska, No. 22417 (0.1 g) varieties were closest to the check one, by the plant height - Saksonka No. 354 variety. Belokoloska exceeded the check variety by the length of the ear by 0.8 cm. Variety No. 22417, by the number of grains in the spike, was less than the rest (-12.2 grains). The number of spikelets in the ear was higher by 3.1 pcs in the Belokoloska variety. On the basis of the ear weight, the Belokoloska and Sedouska were closer to the check variety, and by the length of the first internode - Saksonka No. 354. Thus, it was shown that for some parameters the traditional Belokoloska and Sedouska varieties were the closest to the check one.

To determine the effect of potential productivity on the main characteristics of the productivity of the ripe spike, we performed a correlation analysis (Table 5).

The analysis indicated the importance of the correlation between the characteristics of all varieties under study. All connections were positive, the strength of the links varied from medium (Nemerchanskaya, Sedouska) to strong (other varieties). In the Bezostaya 1 variety the relationship between the features studied was the closest to the functional one, which indicated a significant influence of the number of flowers in the ear on the number of grains by the time of the ear ripeness.

The nature of the correlations of potential productivity with a mass of 1,000 grains pointed to the inverse relationship of these features (Table 6).

The criterion of significance showed the unreliability of the correlation relationship among the characteristics studied in the Traditional Winter No. 346 variety. In all other cases, the dependence of the parameters was reliable.

Table 5 - Correlation between the number of grains from the main ear at the 93rd stage (BBCH) and the number of flowers formed at the 43rd stage of the winter soft wheat development, Krasnodar, 2013-2015

Variety	Number of flowers at the 43rd stage, pcs.		Number of grains from the ear at the 93rd stage, pcs.		Correlation, r	Significance criterion, t_{act}
Belokoloska	81.9	±6.52	34.0	±9.11	0.7	2.84
Nemerchanskaya	73.9	±9.33	26.7	±3.92	0.6	3.50
Sedouska	79.4	±3.51	34.3	±4.81	0.5	3.54
Saksonka No. 354	80.5	±6.04	29.3	±2.84	0.8	3.21
No. 22417	83.2	±9.02	30.9	±3.92	0.7	2.87
Traditional winter No. 346	81.5	±3.83	28.3	±3.51	0.7	2.73
Bezostaya 1 (check)	76.7	±8.01	39.0	±9.13	0.9	3.87
t_{theor}	-	-	-	-	-	2.31

Table 6 - Correlation of the mass of 1,000 grains with the number of flowers formed at the 43rd stage (BBCH) of winter soft wheat development, Krasnodar, 2013-2015

Variety	Number of flowers at the 43rd stage, pcs.		Mass of husk from spike, g		Correlation, r	Significance criterion, t_{act}
Belokoloska	81.9	±6.51	1.54	±0.31	-0.23	2.25
Nemerchanskaya	73.9	±9.32	1.21	±0.21	-0.03	1.25
Sedouska	79.4	±3.53	1.50	±0.32	-0.06	1.32
Saksonka No. 354	80.5	±6.06	1.21	±0.39	-0.05	0.94
No. 22417	83.2	±9.24	1.31	±0.34	-0.27	2.54
Traditional winter No. 346	81.5	±3.11	1.26	±0.27	0.09	0.24
Bezostaya 1 (check)	76.7	±8.01	2.40	±0.36	-0.56	2.55
t_{theor}	-	-				2.31

The bond strength varied from the average (Belokoloska and Saksonka No. 354) to the strong one (Nemerchanskaya, Sedouska, No. 22417 and Bezostaya 1). Scientists have long noted a negative correlation between the mass of 1,000 grains and the number of grains in the ear [12]. Thus, with a fairly high probability, it could be concluded that an excessively high number of flowers in the ear also adversely affected the mass of 1,000 grains.

As regards the correlation between the potential productivity and the mass of grains from the spike, the null hypothesis was not confirmed for the majority of varieties under study. Negative correlation for this pair of characters had Bezostaya 1 and No. 22417 varieties. The null hypothesis was not confirmed with respect to most varieties. Negative correlation for this pair of characters had Bezostaya 1 and No. 22417 varieties. The lack of correlation of these characters in most studied varieties indicated the buffering of the "number of flowers in the ear at the 43rd stage" (BBCH) character.

Studying the causes of elimination of up to 50 percent or more of the flowers planted in the ear during the course of the 40-42 stages (BBCH) [13], we came to the conclusion that one of the reasons for this might be the lack of plastic substances during the critical periods of the ear development, and under optimal development conditions the reason for this might be the low conductive ability of phloem in the narrowest part of the stem - the lower part of the ear. Therefore, plants with a wider stem in combination with a large number of flowers in the ear could have better potential for ear efficiency (Figure 2).

The formula below combines both of the above-described indicators.

$$I_{PP} = \frac{\sum FE}{W_{LP}} \times 10 \text{, where}$$

I_{PP} is the index of potential productivity, $\sum FE$, is the amount of flowers in the ear, W_{LP} is the width of the lower part of the ear.

To determine the effect of this index on the ear productivity, we performed a correlation analysis (Table 7)

The negative correlation indicated the inverse relationship of the values studied. The bond strength varied from moderate (Traditional Winter variety) to medium (Bezostaya 1). The significance criterion indicated the unreliability of the correlation for the only one variety - Sedouska. Due to the high influence of this index on the seed productivity of the spike, it was proposed to use it as an evaluation criterion for the identification of the most valuable genotypes.

In the selection evaluation of wheat lines and hybrids, it is important to know the extent of achievement of genetically engineered productivity in given environmental conditions. The completeness of the achievement of genetic potential is indirectly indicated by many, mainly quantitative, signs [13]. However, the task becomes more complicated if it is necessary to conduct an express assessment of the variety potential in the field environment.

The formation of the upper spikelets by the apical meristem is the final process of its life activity [14]. In this regard, we believe that the degree of development of the last two spikelets can be considered as an indicator of the achievement of the variety potential in the given environmental conditions. The correlation analysis data (Table 8) indicated the reliability of the connection of this indicator with the productivity of soft wheat.

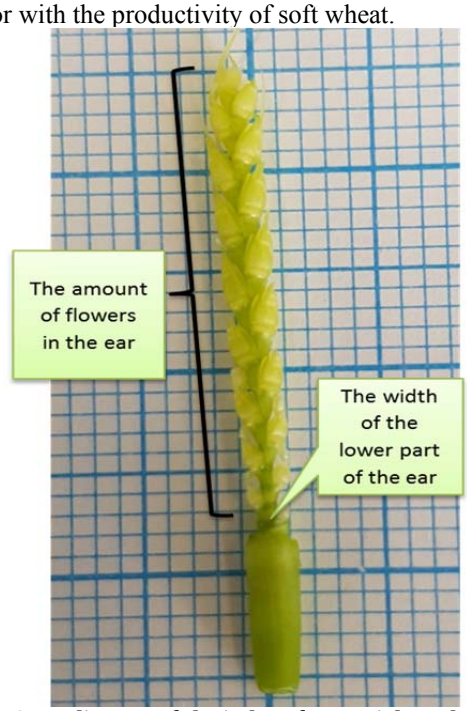

Figure 2 - Indicators of the index of potential productivity based on the ear of soft winter wheat of Bezostaya 1 variety, Krasnodar, 2015

Table 7 - Indicators constituting the index of potential productivity and its correlation with the number of grains in the ear in the studied varieties of soft winter wheat, Krasnodar, 2013-2015

Variety	Average W_{LP}, mm	Average $\sum FE$, pcs	I_{PP}	Correlation, r	t_{act}	
Belokoloska	1.7	85.3	5.4	-0.45	2.31	t(0.05)=2.31
Nemerchanskaya	2.3	77.1	4.7	-0.32	2.54	
Sedouska	2.0	75.9	4.4	-0.27	1.89	
Saksonka No. 354	1.7	80.7	4.2	-0.46	2.36	
Hybrid No. 22417	1.7	83.6	4.3	-0.29	2.98	
Traditional winter No. 346	2.5	83.1	5.4	-0.24	2.25	
Bezostaya 1 (check)	2.8	71.3	4.8	-0.51	2.98	

Table 8 - Correlation of the number of grains in the ear with the development of 2 upper spikelets, Krasnodar, 2013-2015

Variety	Correlation, r	Average, pcs.	Average number of grains in the last 2 spikelets, pcs	t_{act}	
Belokoloska	0.40	29.4	1.5	2.48	
Nemerchanskaya	0.48	30.7	1.7	2.57	
Sedouska	0.72	33.1	2.1	1.81	$t_{(0.05)} = 2.31$
Saksonka No. 354	0.85	26.3	1.6	0.98	
Hybrid No. 22417	0.83	30.4	1.8	2.33	
Traditional winter No. 346	0.94	26.0	1.9	2.46	
Bezostaya 1 (check)	0.87	27.5	2.4	2.98	

The correlation relation turned out to be positive, which indicated direct dependence of the state of two upper spikelets on the grains/ear. The bond strength varied from a moderate one (0.4 for the Belokoloska variety) to a very strong one (0.94 for the Traditional Winter variety No. 346). Sedouska with t_{act} = 1.81 and Saksonka No. 354 with t_{act} = 0.98 did not pass the experiment by the criterion of significance equal to 2.31.

CONCLUSION

The completeness of development of the upper spikelets testifies to the balance of the behavior of morphogenetic ear development processes as a whole [15]. Thus, based on the analysis results, we have concluded that this indicator may be used to assess the potential productivity of the genotype in the given ecological conditions of cultivation.

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