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QUALITY CHARACTERISTICS OF EUROPEAN AVENA GENETIC RESOURCES COLLECTIONS

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ABSTRACT

The research project "Avena genetic resources for quality in human consumption" (AVEQ, 2007-2011) aimed at the agronomic and qualitative evaluation of European oat germplasm; for this purpose a working collection with more than 600 accessions, including modern commercial cultivars and wild species, was used.

The working collection was split in two groups and field grown in 2008 and 2009 in seven different locations: Estonia, Sweden, Poland, France, Italy, Romania and Bulgaria.

For each accession morphological and technological traits were registered. The results of this study indicated that modern varieties are significantly superior to old varieties and wild accessions in terms of yield and grain technological quality (seed weight and test weight).

A wide variability was observed for quantitative and qualitative traits, and some genotypes potentially interesting for breeding programs were identified.

Key words: filed experiments, test weight, seed weight and quality.

INTRODUCTION

Oat is a crop with an important European history and tradition. It has still high breeding potential, based on a wealth of genetic resources represented in the European gene banks. It is a crop highly adapted to sustainable management. Compared to the crops most widely used in current European agriculture it can be considered from an agronomical point of view as a low input crop. It is very suitable for organic agriculture, where comparable yields and technical quality can be produced (Saastamoinen et al., 2004; Meyer and Zwingelberg, 1996). This is due to its low demand for nitrogen fertilization, its low susceptibility for cereal diseases and its high competitiveness to weeds. This might even more apply to less developed forms, which have stronger vegetative development and greater crop height.

It results in generally low agrochemical input to oat cropping. Oat is considered valuable for disease reduction in cereal crop rotations, having in mind many diseases which are dominating throughout European agriculture. This can lead to reduced chemical plant protection even in the succeeding crops. So far, cultivars have not been developed specifically for human consumption (Lapveteläinen et al., 2001). The high value of oat in human nutrition, which is unique among cereals, is widely recognized (Hampshire, 1998; American Food and Drug Association, 1997). It is based on the following traits:

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• Protein content of oat grain is relatively high. Unique among cereal grain proteins is the fact, that high values for protein are reflected by high lysine contents (Hampshire, 1998). The biological value of the protein is high.

• Fat content in oat grain is high. Oat fat has a high proportion of polyunsaturated fatty acids. These have positive influence on the blood plasma (Berg et al., 1992). Fat has a positive impact on the aroma of oat products. On the other side it reduces storage stability of extruded products (Hampshire, 1998).

• Oat products can be added to carbohydrate containing food for reducing insulin requirements (Wood et al., 1989). It is suggested, that the reduction in serum cholesterol levels is effected mainly by increasing the viscosity in the gut. Thus molecular weight distribution of ß-glucans (Beer et al., 1997) is important.

The focus of this paper is on characterization and evaluation of accessions from European *ex situ* collections for traits, which are important for the quality of oats in human nutrition.

MATERIAL AND METHODS

In a cooperative project with 15 partners in nine European countries, genebank material and current commercial varieties were evaluated for traits considered important for future oat breeding in a European premium market. The evaluated working collection contains 567 accessions of hexaploid cultivated oats (*A. sativa* and *A. byzantina*), including 117 commercial cultivars, 46 accessions of diploid cultivated sand oats (*A. strigosa*), 5 accessions of tetraploid Abyssinian oats (*A. abyssinica*) and 34 wild relatives of various ploidy levels (*A. fatua*, *A. hybrida*, *A. sterilis*, *A. barabata*, *A. canariensis*, *A. damascena*, *A. hirtula*, *A. wiestii*). In 2008 and 2009 field experiments, laid out in augmented designs with eleven standard cultivars (mainly modern varieties bred in different European countries), were performed widely distributed all over Europe to sample harvest material for quality analysis.

As standard the following cultivars were used: Argentina, Auteuil, Belinda, Evora, Genziana, Ivory, Jaak, Mina, Mures and Saul. Plot sizes ranged from 2.0 to 3.0 m^2.

The paths were weeded out mechanically and the evaluation plots, manually. During vegetation period, herbicides and pesticides treatments were used depending by location.

All partners' countries observed the following descriptors: yield, seed weight and test weight.

All project results are available to the genetic resources community by the European Avena Database (EADB). Web applications are being developed for an oat crop portal supporting management of large cooperative projects on characterisation and evaluation of genetic resources.

RESULTS AND DISCUSSIONS

Harvest data were directly input online and have been already statistically evaluated. Based on the analysis of standard cultivars, the main examined factors (site and cultivar) and interactions were highly significant for yield, seed and test weight (Table 1). Also deviations from normal distribution (Shapiro Wilk test) and homogenous variances were highly significant (Shapiro and Wilk, 1965).

Table 1. Analysis of variance and tests of preconditions for parametric analysis with site as fixed factor (Estonia, Poland, France, Romania) for standard cultivars

	Yield		Seed weight		Test weight	
	F	P	F	P	F	P
Site	209	***	103	***	192	***
Cultivar	38	***	107	***	38	***
Site x Cultivar	7.71	***	5.64	***	3.20	***
Shapiro Wilk	0.9762	***	0.9529	***	0.9430	***
Bartlett ChiSq	71	**	120	***	128	***

Analysis with SAS procedure mixed, untransformed, site fix.

Highest average yields were obtained in Poland, next in Estonia (Table 2). Lower yields were obtained in France and lowest in Romania.

Each difference between two countries was statistically significant. Variances were high in Poland and Romania compared to Estonia and France. In Romania differences between cultivars could not be confirmed statistically. Belinda was consistently high yielding at all sites. Mina and Saul are naked cultivars and strictly not comparable. Evora, Argentina and Genziana gave comparably lower yields.

Table 2. Yield [100 g m^{-2}]: Multiple comparisons of means for standard cultivars in different experiments from North to South Europe

Cultivar	ESTONIA				POLAND				FRANCE				ROMANIA			
	N	Mean	SE		N	Mean	SE		N	Mean	SE		N	Mean	SE	
Argentina	5	3.4	0.20	de	5	4.3	0.41	de	5	3.0	0.17	ab	5	1.0	0.22	a
Auteuil	5	5.2	0.12	abc	5	6.6	0.69	bc	5	3.2	0.17	ab	5	1.5	0.33	a
Belinda	5	5.8	0.16	a	5	7.3	0.46	ab	5	4.3	0.32	a	5	2.2	0.60	a
Evora	5	2.8	0.29	e	5	3.2	0.58	e	5	2.4	0.12	b	5	1.4	0.25	a
Genziana	5	3.6	0.16	cde	5	5.5	0.18	cd	5	2.1	0.22	b	4	0.7	0.14	a
Ivory	5	5.6	0.20	a	5	8.4	0.37	a	5	3.1	0.23	ab	5	1.0	0.25	a
Jaak	5	4.9	0.15	abcd	5	8.8	0.41	a	4	2.5	0.29	b	5	1.6	0.26	a
Krezus	5	5.5	0.30	ab	5	7.8	0.35	ab	5	3.6	0.17	ab	5	2.2	0.33	a
Mina	5	3.0	0.16	e	5	4.2	0.37	de	5	2.1	0.08	b	5	1.3	0.33	A
Mures	5	4.4	0.28	abcde	5	6.7	0.41	bc	5	2.5	0.21	b	5	0.9	0.41	a
Saul	5	3.8	0.17	bcde	5	5.0	0.59	cd	5	2.3	0.24	b	5	0.9	0.17	a
All	55	4.4	0.15	(B)	55	6.2	0.27	(A)	54	2.8	0.11	(C)	54	1.4	0.11	(D)

Different letters indicate statistical significant differences (Tukey 0.05) within one site (column).

Ranges of yields in modern and obsolete cultivars were higher than in standards (Table 3). Despite lower average yielding of obsolete cultivars, some of them outyielded standards or modern cultivars on each site. Yields of *A. strigosa*, *A. abyssinica* and wild species accessions were consistently lower.

*Table 3.*Yield [100 g m^{-2}]: ranges in different experiments from North to South Europe

	ESTONIA Jogeva PBI		FRANCE INRA Clermond Ferrand		POLAND Blonie Institute		ROMANIA Suceava Genebank	
	N	Range	N	Range	N	Range	N	Range
Standard	55	1.7 - 4.4 - 6.4	54	1.3 - 2.8 - 4.8	55	2.3 - 6.2 - 9.5	54	0.1 - 1.4 - 3.9
Modern	12	3.8 - 5.3 - 7.5	10	1.5 - 2.8 - 3.5	12	1.2 - 6.6 - 9.4	9	0.7 - 1.9 - 3.9
Obsolete cultivars	259	0.4 - 3.8 - 7.7	252	0.2 - 2.8 - 5.0	256	0.0 - 4.9 - 9.7	235	0.1 - 1.4 - 4.9
A. strigosa	31	0.1 - 1.9 - 3.5	31	0.3 - 1.8 - 3.3	31	0.2 - 2.3 - 4.4	27	0.1 - 0.9 - 2.9
A. abyssinica	3	1.6 - 2.7 - 3.7	3	0.8 - 1.7 - 2.9	3	0.4 - 2.5 - 5.0	3	0.3 - 0.4 - 0.5
A. barbata	1	1.0			1	1.9	.	
A. canariensis	1	1.0			1	0.7	1	0.1
A. fatua					9	0.3 - 1.1 - 3.2	8	0.2 - 0.7 - 1.4
A. hirtula	3	1.6 - 1.6 - 1.7			3	1.0 - 1.3 - 1.7	3	0.3 - 0.3 - 0.4
A. sterilis	3	1.6 - 2.4 - 2.8			3	0.1 - 1.0 - 1.6	3	0.2 - 0.7 - 1.4

Seed weight was highest in Estonia, significantly lower in Poland and lowest in France and Romania (Table 4). Ivory had consistently highest seed weight at all sites. Evora was consistently low among the hulled cultivars.

Table 4. Seed weight [g]: Multiple comparisons of means for standard cultivars in different experiments from North to South Europe

Cultivar	ESTONIA Jogeva PBI				FRANCE INRA Clermond Ferrand				POLAND Blonie Institute				ROMANIA Suceava Genebank			
	N	Mean	SE		N	Mean	SE		N	Mean	SE		N	Mean	SE	
Argentina	5	39	0.7	bc	5	34	0.9	ab	5	37	0.5	ab	5	35	2.1	A
Auteuil	5	38	0.5	bc	5	31	1.6	bc	5	31	0.4	bc	5	30	1.7	Abcd
Belinda	5	42	0.4	b	5	30	1.1	bc	5	35	0.2	abc	5	30	0.6	Abc
Evora	5	35	0.6	c	5	26	1.0	cd	5	30	0.6	c	5	29	0.6	Bcd
Genziana	5	40	0.5	bc	5	36	0.9	ab	5	34	0.6	bc	5	29	2.6	Bcd
Ivory	5	49	0.6	a	5	38	1.0	a	5	41	0.4	a	5	35	0.8	A
Jaak	5	40	0.5	bc	5	35	1.0	ab	4	32	0.2	bc	5	25	2.7	Cd
Krezus	5	38	0.5	bc	5	30	0.7	bc	5	33	0.4	bc	5	32	0.6	Ab
Mina	5	25	0.6	d	5	20	0.5	e	5	22	0.3	d	5	24	0.7	D
Mures	5	40	0.6	bc	5	31	1.7	bc	5	33	0.4	bc	5	33	1.1	Ab
Saul	5	28	0.9	d	5	24	0.9	de	5	22	0.4	d	5	24	0.8	D
All	55	38	0.9	(A)	55	30	0.8	(C)	54	32	0.8	(B)	55	29	0.7	(C)

Different letters indicate statistical significant differences (Tukey 0.05) within one site (column).

Higher seed weight of obsolete cultivars compared to standards and modern cultivars was observed only in France and Poland (Table 5). *A. sterilis* accessions can reach high seed weights, but this is not comparable because of high hull percentage, hairs and awns.

Table 5. Seed weight [g]: ranges in different experiments from North to South Europe

	ESTONIA Jogeva PBI		FRANCE INRA Clermond Ferrand		POLAND Blonie Institute		ROMANIA Suceava Genebank	
	N	Range	N	Range	N	Range	N	Range
Standard	55	24 - 38 - 51	54	21 - 32 - 42	55	18 - 30 - 40	55	16 - 29 - 41
Modern	12	30 - 39 - 46	10	21 - 32 - 41	12	22 - 32 - 46	10	27 - 31 - 36
Obsolete cultivars	259	8 - 33 - 47	253	0 - 28 - 45	256	5 - 26 - 56	260	9 - 26 - 39
A. strigosa	31	7 -18 - 33	31	8 - 15 - 25	31	6 - 15 - 28	29	7 - 16 - 22
A.abyssinica	3	14 - 21 - 35	3	15 - 20 - 30	3	12 - 17 - 25	3	13 - 19 - 27
A. barbata	1	6			1	7		
A.canariensis	1	14			1	20	1	20
A fatua	.				9	13 - 20 - 29	9	16 - 20 - 25
A. hirtula	3	8 - 8 - 9			3	7 - 8 - 9	3	7 - 8 - 8
A sterilis	3	22 - 27 - 33			3	13 - 35 - 66	3	19 - 21 - 24

Test weight was highest in Estonia, second in France, third in Romania and lowest in Poland (Table 6). Each difference between countries was statistically significant. Seeds without hull of hull-less cultivars (Saul, Mina) resulted in higher test weight than hulled seeds.

Table 6. Test weight [kg/hl]: Multiple comparisons of means for standard cultivars in different experiments from North to South Europe in 2009

Cultivar	ESTONIA				POLAND				FRANCE				ROMAN IA			
	N	Mean	SE		N	Mean	SE		N	Mean	SE		N	Mean	SE	
Argentina	5	46	0.9	c	5	30	2.8	bc	5	44	0.6	b	3	35	1.2	bc
Auteuil	5	56	0.2	b	5	31	2.4	bc	5	46	0.9	b	4	35	1.3	bc
Belinda	5	53	0.3	bc	5	29	2.8	bc	5	46	0.3	b	5	35	0.8	bc
Evora	5	50	0.7	bc	5	26	2.0	c	5	44	0.5	b	4	35	1.3	bc
Genziana	5	49	1.2	bc	5	34	3.2	ab	5	49	0.6	b	4	38	1.1	bc
Ivory	5	55	1.0	b	5	27	1.4	bc	5	48	0.7	b	5	35	0.8	bc
Jaak	5	53	0.5	bc	5	31	1.2	abc	4	48	0.6	b	4	34	1.4	c
Krezus	5	51	0.8	bc	5	29	1.6	bc	5	44	1.1	b	5	32	0.2	c
Mina	5	53	0.8	bc	5	35	3.0	ab	5	60	0.8	a	4	43	2.4	ab
Mures	5	49	2.0	bc	5	30	1.3	bc	5	45	0.9	b	3	36	3.5	bc
Saul	5	66	0.6	a	5	39	2.6	a	5	62	1.2	a	5	48	3.8	a
All	55	53	0.7	(A)	55	31	0.8	(D)	54	49	0.9	(B)	46	37	0.9	(C)

Different letters indicate statistical significant differences (Tukey 0.05) within one site (column).

Concerning the ranges in different experiments for the hulled cultivars differences were not very consistent across the sites. In France, Poland and Romania some obsolete cultivars were observed with higher test weight than the standard and modern cultivars (Table 7).

*Table 7.*Test weight [kg/hl]: ranges in different experiments from North to South Europe in 2009

	ESTONIA Jogeva PBI		FRANCE INRA Clermond Ferrand		POLAND Blonie Institute		ROMANIA Suceava Genebank	
	N	Range	N	Range	N	Range	N	Range
Standard	55	41 - 53 - 68	54	42 - 49 - 65	55	20 - 31 - 47	46	31 - 37 - 55
Modern	12	52 - 53 - 55	10	42 - 49 - 65	12	20 - 29 - 40	8	30 - 37 - 46
Obsolete cultivars	259	35 - 52 - 68	251	19 - 47 - 71	245	17 - 30 - 49	185	29 - 36 - 59
A .abyssinica	3	39 - 44 - 51	3	35 - 42 - 47	2	28 - 32 - 36	1	34
A. strigosa	29	36 - 46 - 68	31	19 - 40 - 55	23	17 - 28 - 39	13	29 - 36 - 48

CONCLUSIONS

The results of this research show that the statistical evaluation emphasize a large influence of the different sites in yield, seed weight and test weight. Highest technical quality (seed weight, test weight) was achieved in Estonia. This confirms that Nordic conditions are optimal for the production of quality oats.

The standard cultivars Ivory performed consistently best in test weight. Obsolete cultivars normally had higher ranges in the harvest parameters, with higher deviations to undesirable expressions, but in some sites were superior to standard and modern cultivars.

Large differences in yield and technological quality (e.g. seed weight) were observed as a result of genotype and environmental influences. Modern hexaploid cultivars were superior for these traits to obsolete cultivars, wild or diploid types. Overall less diversity with a trend to higher yield and higher seed weight was found in the field experiments for modern cultivars compared to the other types.

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VARIATION OF GRAIN WEIGHT PER SPIKE OF WHEAT DEPENDING ON VARIETY AND SEED SIZE

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ABSTRACT

The aim of research was to establish the influence of seed size on grain weight per spike of three wheat varieties. A trial was set up using split-plot method in four replications in Pančevo in the period 2004-2006. The seed was divided according to the size in four fractions: 1.8, 2.0, 2.2, 2.5 and 2.8 mm. A significant interaction was determined between the tested varieties and the years of testing, whilst a highly significant interaction was determined between the years of testing and the seed size, the varieties and the seed size, between the tested varieties, the years of testing and the tested seed size. The highest grain weight per spike was determined in PKB-Christina variety (2.29 g), and Pobeda variety (2.25 g), whilst Vizija variety had the lowest grain weight per spike (2.11 g). The difference was highly significant. The analysis of variance determined a highly significant difference between the years when the experiment was conducted, which is often seen in this region. Highly significant differences in the grain weight per spike were determined at different seed sizes. Larger seeds produced higher grain weight per spikes, highest weight being obtained with largest seeds (≥ 2.8 mm).

Key words: wheat, variety, grain weight per spike, seed size.

INTRODUCTION

Grain weight per spike, as the last yield component, is the final in the development of many components that occur in the early ontogenic stages. Grain weight per spike plays a significant role in yield formation, because it directly affects harvest index. Grain weight per plant directly reflects the efficient use of nutrients and their translocation into generative parts of a plant (Borojević, 1983).

Grain weight can be influenced by cultural practices, if there is a genetic base. It could be expected that grain weight per spike is in correlation with parameters whose activity decreases in the period after heading, so the selection of these traits (main leaf area, internodes, spikes and duration of their photosynthetic rates) (Protić, 1980, 1982, 1983), as well as for the translocation of assimilates from leaves and stem to grain, is of special importance for producing high grain weight. Because there are genetic differences between varieties, it is necessary to find genotypes in which that translocation is efficient and to incorporate their genes into a new variety model.

Kobiljski et al. (1996) pointed out that there was a highly significant positive correlation between grain yield and grain weight per spike (r = 0.90). This shows that it is possible to make new wheat genotypes that would achieve high grain yield by increasing grain weight.

Seed size is important in determining stand establishment and early growth, and can have effects on further wheat plant development. Large seeds of wheat have higher germination energy and total

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germination. The plants from large seeds grow faster; they have a thicker stem, higher vigour and stronger tillering than plants from small seeds. As a result, large seeds (≥2.8 mm) yielded about 20% higher than medium large seeds (2.5 to 2.8 mm), and about 15% higher than small seeds (Borojević, 1964; Todorović et al., 2011). The aim of this paper is to determine the influence of seed size on one of the main components of yield (grain weight per spike) in three winter wheat varieties. These researches should help increasing grain weight per spike, in other words, to achieve higher yields per unit area.

MATERIAL AND METHODS

Three winter wheat varieties, different according to the tillering, stem height, leaf position, vegetation duration, genetic potential for grain yield and quality, were included in the trial, as follows: PKB-Christina variety – a mid-season variety of lower height, good disease resistance and cold hardiness, with a high genetic potential for grain yield and quality; Pobeda variety - a mid-season variety of good cold hardiness, lodging and powdery mildew resistance, it is currently our leading variety, known for its wide adaptability and a high yielding potential and Vizija variety –a mid-season variety with a good kernel quality, suitable for growing in intensive and less intensive production conditions. This variety is very adaptable and has a high genetic potential for grain yield.

The trial was set up at “Tamiš” Institute in Pančevo from 2003/2004 to 2005/2006, with split-plot system in four repetition and five different seed sizes (1.8, 2.0, 2.2, 2.5 and 2.8 mm). Elementary plot size was 5 m^2 (1 x 5 m). Mechanical sowing was done in the mid-October. Sowing density was 600 germinating kernels/m^2 and row spacing was 10 cm. Soil type was calcareous chernozem. The preceding crop was sunflower during all three years, with the usual crop management practices used for wheat in the Republic of Serbia. Hand harvesting was done in the phase of full ripeness, and threshing was done with thresher. The sample size for counting grain weight per spikes was 30 spikes in the stage of full maturity.

Data were processed statistically using the analysis of variance by MSTAT - C program, Michigan State University, Version 1. Year, variety and seed size were taken as factors in the analysis. The results were shown as a triennial average.

RESULTS AND DISCUSSION

Grain weight per spike is an important component of yield. A change in grain weight per spike drastically influences the final yield. In this research, the highest grain weight per spike was determined in PKB-Christina variety (2.29 g), and Pobeda variety (2.25 g), whilst Vizija variety had the lowest grain weight per spike (2.11 g).

The differences are statistically highly significant (Table 1 and 2). The analysis of variance determined a highly significant difference between the years when the experiment was conducted, which is often seen in this region.

That was particularly obvious in 2004, when the grain weight per spike was lower than in 2005 and 2006. There were some more severe fungal infections of vegetative organs, especially the spikes, in 2004 (Tables 1 and 2).

Highly significant differences in grain weight per spike were determined by different seed sizes. Thus, 1.8 mm-seed size gave 1.74 g grain weight per spike, and 2.0 mm-seed size gave 1.91 g grain weight per spike, whilst 2.2 mm-seed size gave 2.15 g grain weight per spike. 2.5 mm-seed size gave 2.49 g grain weight per spike and 2.8 mm seed size gave 2.79 g grain weight per spike (Tables 1 and 2). The continuous increase in grain weight per spike with increasing seed size was different from the behaviour of grain yield, which increased up to 2.5 mm seed size, but significantly decreased in the case of 2.8 mm seed size (Todorović et al., 2011). Obviously the largest seed size caused a decrease in the number of spikes per unit area, which counterbalanced the positive effect on grain weight per spike.

A highly significant interaction was determined between the tested varieties and the years of testing, the years of testing and the seed size, between the varieties and the seed size, between the varieties, the years of testing and the tested seed size (Table 1).

The production of organic matter per spike and spike weight are directly related with grain number and grain weight per spike. Grain number per spike depends on spikelet number, flower number per spike, the success of pollination and the success of the early organogenetic stages of flowers (Kraljević-Balalić, 1978).

Table 1. Analysis of variance: grain weight per spike of wheat varieties and different seed size

Source of variance	Degrees of freedom	Sum of squares	Mean square	F value	Significance
Repetition	3	0.047	0.016	0.3698	
Variety (V)	2	1.069	0.535	12.6843	**
Year (Y)	2	9.070	4.535	107.5771	**
V x Y	4	2.964	0.741	17.5789	**
Seed size (T)	4	14.732	3.683	87.3671	**
V x T	8	5.709	0.714	16.9294	**
Y x T	8	6.514	0.814	19.3153	**
V x Y x T	16	5.665	0.354	8.3989	**
Error	132	5.565	0.042		
Total	179	51.335			

** P ≤ 1

Table 2. Grain weight per spike of wheat varieties and different seed size

Year (Y)	Seed size, mm (T)	Variety (V) PKB- Christina	Pobeda	Vizija	YT $\bar{x}$	Y $\bar{x}$
2004	1.8	1.24	1.19	1.81	1.41	
	2.0	1.33	1.32	1.91	1.52	
	2.2	1.77	1.61	1.96	1.78	
	2.5	2.56	2.59	2.01	2.39	1.97
	2.8	2.81	2.72	2.74	2.76	
	VY $\bar{x}$	1.94	1.89	2.09		
2005	1.8	1.68	1.85	1.68	1.74	
	2.0	1.77	2.02	1.81	1.87	
	2.2	2.06	2.28	1.86	2.07	
	2.5	2.56	2.59	2.02	2.39	2.16
	2.8	2.81	2.72	2.74	2.76	
	VY $\bar{x}$	2.18	2.29	2.02		
2006	1.8	2.38	2.02	1.81	2.07	
	2.0	2.56	2.59	1.88	2.34	
	2.2	2.81	2.72	2.30	2.61	
	2.5	2.95	2.77	2.36	2.69	2.52
	2.8	3.02	2.82	2.74	2.86	
	VY $\bar{x}$	2.74	2.58	2.22	T $\bar{x}$	
VT $\bar{x}$	1.8	1.77	1.69	1.77	1.74	
	2.0	1.89	1.98	1.87	1.91	
	2.2	2.21	2.20	2.04	2.15	2.22
	2.5	2.69	2.65	2.13	2.49	
	2.8	2.88	2.75	2.74	2.79	
	V $\bar{x}$	2.29	2.25	2.11		

	Level of significance	V	ZY	T T	VVY	VVT	YYT	VVYT
LSD	5 %	00.07	00.07	00.10	00.13	00.17	00.17	00.29
	1 %	00.10	00.10	00.13	00.17	00.22	00.22	00.38

Using larger seeds increases seed rates per unit area and production costs. However, increased production costs were significantly less than the increase in yield per unit area, obtained by sowing larger seeds.

Higher estimates of heritability coupled with better genetic advance facilitate selection in developing new genotypes with desirable characteristics. Ajmal et al. (1995), Singh et al. (1999), Ghimirary and Sarkar (2000) and Shazly et al. (2000) found high heritability estimates, along with greater values of genetic advance, for the number of grains per spike.

Determination of correlation coefficients between various characters helps to obtain best combinations of attributes in wheat crop for obtaining higher return per unit area.

Nabi et al. (1998), Silva et al. (1998), Amar (1999), Dokuyueu and Akkaya (1999), and Shah et al. (1999) reported positive correlation of grain yield with grains per spike and 1000 grains weight both at genotypic and phenotypic levels. Although number of tillers, spikelets per spike, grains per spike and 1000 grain weight had positive correlations with grains yield, grain number per spike and 1000 grains weight were most important as contributing traits towards yield.

Dwivedi et al. (2002) found that total biomass showed the highest direct effect on grain yield, which was followed by tillers per plant and grain weight per ear. Correlation studies indicated that grain yield per plant had a positive correlation with grain yield per spike and grain number per spike; grain yield per spike with harvest index and grain number per spike on all the three dates of sowings. Thousand-grain weight was an important yield-contributing trait in rainfed situation and it showed a positive correlation with harvest index and the sowing dates (Mishra et al., 2001).

CONCLUSIONS

In triennial average, the highest grain weight had PKB-Christina variety (2.29 g), and Pobeda variety (2.25 g), whilst Vizija variety had the lowest grain yield (2.11 g). The difference was highly significant. The analysis of variance determined a highly significant difference between the years when the experiment was conducted, which is often seen in this region.

A highly significant difference was also determined between the seed size groups tested. Larger seeds produced higher grain weight per spikes, highest weight being obtained with largest seeds (≥2.8 mm). At the same time a highly significant interaction was determined between the years of testing and the seed size, the varieties and the seed size, as well as between the tested varieties, the years of testing and the tested seed size. This indicated that the effect of seed size was influenced by variety and weather conditions.

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