Application of Shape Analysis to the Assessment of Geometrical Properties of Grains in the Selected Species of Spring Cereals

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Abstract. The competition in many branches of industry including agriculture has grown as a result of Polish access to the European Union. It resulted in the intense research development in order to intensify production processes and improve the quality of the final product. One of the methods which might be helpful in this process is the shape analysis. This method makes it possible to measure selected properties of materials in a very precise way. The paper presents the possibilities of computer analysis in the research of grain geometrical features of 128 species of cereals. The program ImageJ was used. It enabled us to define surface, perimeter, width, height and circular projection of every caryopsis. Shape analysis also helps to define basic values of the tested features of caryopsis species. Significant differences between the shape of tested cereals species were indicated. However, significant differences between varieties of the same species were not found. Barley grain had the largest average surface while rye grain had the smallest one. Winter barley grain had the largest perimeter and spring wheat had the smallest one. Oat was characterized by the longest average length while spring wheat had the smallest one. Winter barley had the largest grain width and rye had the smallest one. Spring wheat grain is the most circular while oat grain is the less circular one.

Taking into consideration the data mentioned above, one can use them in the production of equipment and machines used for seed planting, selection, segregation of cereal seeds both in agriculture as well as in agricultural and food processing industry.

Key words: caryopsis, spring cereals, grain, shape analysis, geometrical features.

1. Introduction and purpose of study

Cereals represents about 50% of world's crop production. What is more, they are the main ingredient of food due to high protein and carbohydrates content. They are also a valuable resource used in industry and for renewable energy ([18], p. 5-10). Due to large number of agricultural areas and moderate climate, Poland has a great potential in crop production, especially wheat production. It is willingly cultivated because its grain is rich in starches. Moreover, it contains the most protein and gluten in comparison with other crops [17].

After Polish access to the European Union the guarantee of specific crops parameters is an essential aspect in order to meet quality requirements concerning fresh and processed products and consequently consumer needs. The inspection of the processing and production and classification of a final product is necessary [11]. The access to the

European Union resulted in an increase in competition and demands for products with specific parameters. It forces manufacturers to obtain raw material of the most balanced technological parameters which guarantees efficient processing and obtaining the final product of the highest quality [3]. Thus, milling industry forces manufacturers to standardize raw material in terms of grain size as well as cereal growing of higher usability. Determination of optimal geometrical properties of grain cereals for processing makes it possible to search the relationships between grain size and its quality defining the features which influence the technological processes [6].

Geometrical features of the grain have a significant meaning during sorting, fragmentation and hulling of grain [2]. Caryopses can have different shape and a large variation of dimensions. Varieties of such features as size, shape, weight, moisture, colour and physical characteristics of grain occur between varieties even between one species. It is the result of biological differences, the place of maturation on a plant stem, cultivation techniques and soil and climate conditions [6]. Shape difference is a feature which is used in sorting and separation process. The shape of a single caryopsis has a relevant influence on total mixture of grain material, for example, it determines the angle of internal friction, the angle of dump response or decides about stress distribution in the mixture [8, 9]. This is the reason why the grain of standardized parameters have the highest technological value, and the most important feature is the even spread in length, width and thickness. Assessment of grain distribution having desirable features has the highest cognitive value and has a significant impact on cultivation [3].

The development of agriculture led to its intense automation. Processing and storage industry are the branches which dictate the requirements for engines, machines and equipment used for processing plant materials. Knowledge of physical features concerning processing of raw materials and their compounds which influence the interactions between the material and the technical system is necessary for proper machinery and equipment design. Such information is essential for high quality of a product and safe running of the processes [14].

Conventional and laboratory methods of plant materials assessment require much work and need expensive measuring equipment. This is the reason why modern measuring techniques which use image processing are becoming more and more popular in agri-food product quality testing [10, 5]. Nowadays computer vision techniques are used in many spheres of life, for example, in medicine and natural or engineering science. They are also used for supervising technological processes and assessment of object features. In agriculture they are used for inspection of the control in sorting and agricultural equipment and for the assessment of agricultural products quality. Identification of the features such as geometry, colours and surface structure with visual systems make it possible to detect the relationship between technological value of food materials and their external features. In the case of cereals the analysis concerns mainly the relationships between caryopsis dimensions, colour of seed cover, surface shape and gluten amount or rheological features [7, 16]. The method of image analysis used in technology of grain materials makes it possible to make a quantitative assessment of component distribution of grainy system mixture precisely. This method gives an opportunity to overcome difficulties in assessment of grainy system mixing. A number of studies confirmed that that mixed colours arrangement of components on the surface of mixer cross section reflects empirical distributions of all the components of the whole volume which shows the applicability of this method in assessment of grainy mixtures state [1, 12, 13].

2. Research methodology

The research was carried out in 2013. Geometrical features of 128 varieties of 5 crops species were analysed. Cereal grains came from field experiments in COBORU (Experimental Centre of Variety Assessment in Poland). The average level of farming technique, basic mineral fertilization which take into account the type of soil, location and lodging protection were used. In addition, two fungicide manipulations were used – in the phase of full disseminating at the beginning of heading. The following varieties and species were tested: 14 varieties of spring wheat, 31 varieties of winter wheat, 14 varieties of rye, 6 varieties of spring rye, 25 varieties of winter rye, 9 varieties of oat, 19 varieties of spring oat and 10 varieties of winter oat. All the tested varieties were listed in the national register.

The features of 50 randomly selected caryopses of every variety were defined. The computer program ImageJ [20] was used. Every sample of the variety were arranged in 10 rows: 10 pieces which are reversed with furrow to scanner screen. The seeds were put on a white background. They had the same dimension for every test. Having taken a picture, they were analysed with a computer program consisting of determination of such geometrical parameters as surface, perimeter, length, width and circularity of every caryopsis. The obtained data were analysed using statistical methods. Statistical measures such as average, minimum, maximum, standard deviation, coefficient of variation, correlation and regression were calculated. The obtained results of grain were compared with their yielding in order to choose the most favourable variety.

3. Results and discussion

Winter Barley

The variety Nickela had the largest surface of grain among tested varieties of winter barely while the variety Skarpia had the smallest one (Tab. 1). It must be said that the caryopses of tested varieties demonstrated quite aligned parameters of tested geometrical features. However, essential differences in distribution of tested features have not been found. The variety Holmes had the highest average grain yield 77.5 dt/ha. The variety Nickela had the largest average level of 60 dt/ha while the variety Skarpia with the smallest caryopsis had 55 dt/ha. The variety Fridericus 49.9 dt/ha had the smallest yield.

Spring Barley

Among the tested varieties of spring barley no essential differences were found (Tab. 2). The variety Gawrosz had the smallest caryopsis among tested varieties while the variety Despina had the most aligned one with regard to the tested geometrical features. During a field experiment the variety Ella 64.8 dt/ha demonstrated the highest average yield while the variety KWS Orphelia had the lowest one 51 dt/ha. The variety Despina achieved yield of 59.2 dt/ha and the variety Gawrosz 52.7 dt/ha.

Oat

As for the tested varieties of oat, the variety Bingo had the largest surface of grain while the variety Nogus had the smallest one (Tab. 3). At the same time the variety Nogus had the most circular grain among all the tested varieties of oat. During a field experiment the variety Bingo had the highest grain yield 57.4 dt/ha and the varieties Siwek (44.6 dt/ha) and Nagus 44.5 dt/ha had the lowest ones.

Spring wheat

Among the tested varieties of spring wheat the largest area of grain surface Parabola variety had the largest surface and Trappe had the smallest one (Tab. 4). During a field experiment the Tybalt variety 75 dt/ha had the largest average yield growth whereas the variety Ostka Smolic 58.4 dt/ha had the smallest one. The varieties of Parabola and Trappe achieved yield at the similar level 66.4 dt/ha and 67 dt/ha.

Tab. 1. Average values of geometrical features concerning winter barley varieties with grain yield.

	Surface [cm^2]	**Perimeter [cm]**	**Length [cm]**	**Width [cm]**	**Circularity**	**Grain yield dt/ha**
Antonella	0.1145	1.5545	0.6453	0.2491	0.6009	58.4
Holmes	0.1242	1.6484	0.6767	0.2653	0.5835	77.5
Nickela	0.1353	1.5934	0.639	0.2923	0.673	60
Skarpia	0.1037	1.4285	0.5857	0.239	0.6408	55
Karakan	0.1196	1.6441	0.6977	0.2414	0.562	37.4
KWS Meridian	0.1103	1.5558	0.6504	0.2395	0.5807	65
Souleyka	0.1192	1.5785	0.65	0.2561	0.613	65.6
Titus	0.1109	1.5553	0.6548	0.2356	0.5806	65.5
Henriete	0.1148	1.5202	0.6289	0.2487	0.6258	51.1
Fridericus	0.118	1.5597	0.6438	0.2551	0.6148	49.9

Tab. 2. Geometrical values of winter barley caryopsis.

	Surface [cm^2]	**Perimeter** [cm]	**Length** [cm]	**Width** [cm]	**Circularity**	**Grain yield** dt/ha
Natasia	0.1037	1.4285	0.5857	0.239	0.6408	52.7
Despina	0.1081	1.4099	0.5669	0.26	0.685	59.2
Gawrosz	0.09	1.2618	0.5066	0.2355	0.7125	52.7
Skald	0.1056	1.3778	0.55	0.2561	0.6992	60
Gooluck	0.1041	1.3651	0.5445	0.2558	0.7012	60
Mercada	0.1079	1.4048	0.5623	0.2562	0.6874	52
KWS Atrika	0.107	1.3871	0.5538	0.2576	0.6995	53.8
Iron	0.0992	1.3474	0.5419	0.2481	0.6867	51.9
KWS Aliciana	0.1018	1.3602	0.5437	0.2532	0.6933	54.6
Ella	0.1035	1.37	0.5484	0.2574	0.6926	64.8
Basic	0.1033	1.3696	0.5494	0.254	0.6937	53.1
Fariba	0.0964	1.3332	0.5385	0.2443	0.6822	52.4
KWS Orphelia	0.0936	1.2747	0.5038	0.2493	0.7239	51
Suweren	0.1034	1.3936	0.5654	0.2483	0.6712	58.9
Raskud	0.1009	1.3537	0.5438	0.2507	0.6932	60.6
Soldo	0.0981	1.3493	0.546	0.2438	0.6771	59.1
Conchita	0.1068	1.4072	0.5658	0.258	0.681	57.2
Skald	0.1016	1.3623	0.5457	0.2526	0.6884	60
Kucyk	0.0996	1.3203	0.5221	0.2552	0.7179	65.5

Tab. 3. Average individual features of oat varieties grain.

	Surface [cm^2]	**Perimeter** [cm]	**Length** [cm]	**Width** [cm]	**Circularity**	**Grain yield** dt/ha
Gniady	0.1114	1.516	0.6367	0.2276	0.6055	55.6
Haker	0.1133	1.6367	0.709	0.2076	0.5298	54.8
Zuch	0.1176	1.734	0.76	0.2068	0.4912	45.1
Siwek	0.0835	1.3487	0.5681	0.1979	0.5893	44.6
Nogus	0.067	1.1426	0.4694	0.1809	0.6457	44.5
Krezus	0.1161	1.6097	0.689	0.2252	0.5646	53
Arden	0.1201	1.6937	0.7343	0.2182	0.5283	55.8
Maczo	0.0868	1.363	0.5729	0.1964	0.5914	46.1
Bingo	0.1218	1.7336	0.7489	0.2293	0.5083	57.4

Tab. 4. The average values of geometrical parameters of spring wheat.

	Surface [cm^2]	**Perimeter [cm]**	**Length [cm]**	**Width [cm]**	**Circularity**	**Grain yield dt/ha**
Kandela	0.0775	1.0845	0.3962	0.243	0.826	67.4
Radocha	0.0855	1.1351	0.41	0.2544	0.8314	72.9
Hewilla	0.0761	1.0678	0.3871	0.2423	0.8363	65
Izera	0.0812	1.1149	0.4103	0.2473	0.8195	72.5
Tybalt	0.0846	1.139	0.4211	0.2506	0.8167	75
KWS Torridon	0.0757	1.0697	0.3907	0.2398	0.8296	65.2
Monsun	0.0812	1.1149	0.4103	0.2473	0.8195	64.7
Trappe	0.0657	0.9946	0.3635	0.2249	0.8316	66.4
Łagwa	0.078	1.0768	0.3866	0.2472	0.8437	70.5
Parabola	0.095	1.2101	0.4445	0.263	0.8147	67
Arabeska	0.0742	1.0436	0.3681	0.2481	0.8533	68
Katoda	0.0735	1.0509	0.3772	0.2399	0.8347	63.6
Ostka Smolnic	0.075	1.0734	0.3947	0.2347	0.8165	58.4
SMH 87	0.0856	1.2236	0.4672	0.2258	0.727	68.3

Winter wheat

Among the tested varieties of winter wheat the Komnata variety had the largest area of surface and perimeter of grains while the Garantus variety had the smallest one (Tab. 5). The variety of Garantus has the best circularity of grains. The Jantarka variety had the most similar values of measured geometrical features of grains. During a field experiment the Fidelius variety 88.7 dt/ha had the largest average yield growth whereas Komnata had the smallest one, the hard wheat variety, 48.1 dt/ha and the Belenus variety 58.4 dt/ha. The Garantus variety achieved yield at the level of 75.1 dt/ha and the Jantarka variety 72.5 dt/ha.

Spring triticale

Among the tested varieties of spring triticale the largest area of surface was found in the varieties of Milkaro and Anrus, the smallest one – in the Bojko variety (Tab. 6). The grain of the Andrus variety had the largest perimeter while the Bojko variety was characterized by the smallest grain circularity. Milkaro is a spring triticale variety which emphasizes the most general features of the appropriate grain image. In the experimental field the highest yield was obtained by the varieties of Andrus 58 dt/ha and Nagano 57.7 dt/ha, whereas the lowest yield was obtained by the Milkaro variety 52.5 dt/ha.

Tab. 5. The average values of geometrical parameters of winter wheat.

	Surface [cm^2]	Perimeter [cm]	Length [cm]	Width [cm]	Circularity	Grain yield dt/ha
Kranich	0.0727	1.0528	0.3856	0.2349	0.822	75
Fidelius	0.0807	1.1019	0.4024	0.2488	0.8329	88.7
Skagen	0.0782	1.082	0.3916	0.2437	0.8373	69.8
Mulan	0.0777	1.0829	0.397	0.2417	0.8313	72.6
Figura	0.0755	1.069	0.3916	0.2401	0.8296	70.9
Torrild	0.0773	1.0745	0.3873	0.2444	0.8391	73.4
Kohelia	0.0858	1.1432	0.4229	0.2502	0.8225	75.8
Markiza	0.076	1.0728	0.3958	0.236	0.8265	72.7
Natula	0.0797	1.0963	0.403	0.245	0.8318	71.9
Meteor	0.076	1.066	0.3827	0.245	0.8381	65.1
Sailor	0.0766	1.0642	0.3824	0.2464	0.8488	73.3
Bockris	0.0789	1.0872	0.3973	0.2451	0.8364	71.5
Linus	0.0834	1.123	0.4104	0.2494	0.8291	75.1
Elipsa	0.0791	1.0912	0.3941	0.2459	0.8329	78.1
Komnata	0.1021	1.3152	0.5122	0.2464	0.7414	48.1
Satyna	0.0759	1.0845	0.4062	0.2305	0.8092	66.8
Forkida	0.0817	1.1084	0.4011	0.2516	0.8337	75
KWS Ozon	0.078	1.0858	0.3963	0.2414	0.8288	75.3
Garantus	0.0667	0.9887	0.3489	0.2359	0.8563	75.1
Bogatka	0.0839	1.1261	0.4108	0.2551	0.8306	75.8
Bystra	0.079	1.0868	0.3905	0.2478	0.8399	70.9
Jantarka	0.0917	1.1773	0.4304	0.2629	0.8303	72.5
Bamberka	0.0881	1.1416	0.4078	0.2643	0.848	59.7
Ostroga	0.0917	1.1703	0.4187	0.2681	0.84	66
Meister	0.0906	1.1756	0.4335	0.2553	0.8212	67
Oxal	0.0854	1.1339	0.4129	0.2539	0.8317	70.2
Smaragd	0.0811	1.095	0.3898	0.2535	0.8472	76.1
KWS Dacanto	0.0853	1.1316	0.4089	0.2543	0.8352	76.8
Arkadia	0.0849	1.137	0.4189	0.2496	0.8231	73.7
Muszelka	0.0844	1.1238	0.409	0.2522	0.8374	67
Belenus	0.0694	1.0264	0.3743	0.2299	0.8244	58.4

Tab. 6. The average values of geometrical parameters of some varieties of spring triticale grains.

	Surface [cm^2]	**Perimeter [cm]**	**Length [cm]**	**Width [cm]**	**Circularity**	**Grain yield dt/ha**
Nagano	0.0875	1.2059	0.4666	0.2372	0.7529	57.7
Andrus	0.0994	1.3414	0.5368	0.2369	0.6925	58
Mieszko	0.0869	1.2303	0.485	0.2279	0.7189	53.8
Milkaro	0.0999	1.3159	0.518	0.2448	0.7227	52.5
Milewo	0.0938	1.2872	0.5131	0.2314	0.709	53.4
Dublet	0.0909	1.2354	0.4834	0.2364	0.7463	55.4

Winter triticale

Among the tested winter triticale varieties the largest area of grain surface was found in the Algoso and Borowik varieties, the smallest one – in the Bereniko variety. Furthermore, the varieties of Algoso and Borowik had the largest grain perimeter. The largest average grain yield was registered for the KWS Trisol 86.7 dt/ha, the Pigmej short–stem variety, 83.5 dt/ha and the Agostino short-stem variety, 82 dt/ha. The lowest yield was obtained by the Pizarro variety, on the average by 63.4 dt/ha and the Leontino variety, 61.5 dt/ha.

Rye

Among the tested rye varieties the varieties of Armand and Brasetto had the largest area of grain surface, while the smallest one – the Domir variety (Tab. 7). The varieties of Armand and Brasetto had the largest grain perimeter. The length of examined grains as well as their width show a little difference between them. In the experimental field the largest average yield characterised the hybrid varieties: Brasetto 78.3 dt/ha, Visello 72.9 dt/ha and Gonello 72.6 dt/ha, whereas the smallest one – the Bosmo variety 54.6 dt/ha and the Herakles variety 54.8 dt/ha. The Armand variety achieved yield at the level of 60.7 dt/ha and the Domir variety 60.2 dt/ha.

The development of digital techniques extends the abilities to process the picture. Using fast processes makes it possible to carry out multilateral activities in order to interpret and make the most of the acquired picture [8]. The computer analysis allows us to bring the numerical information to the light in a very efficient and precise way, which gives the fast, repetitive and objective assessment of the grain quality. It is becoming more and more common in the plant production as claimed by Guzek in [19]. Diversity of geometrical features: area of surface, perimeter, width, length and circularity describing the shape of grains, makes it possible to use computer image analysis techniques to identify the cereal grains, as claimed by Zapotoczny in [16]. The role of digital image analysis in the grain materials technology is very significant. The colour characteristics

Tab. 7. The average values of geometrical parameters of some varieties of winter triticale grains.

	Surface [cm^2]	**Perimeter [cm]**	**Length [cm]**	**Width [cm]**	**Circularity**	**Grain yield dt/ha**
Borwo	0.0852	1.1699	0.449	0.2397	0.7798	79.5
Gniewko	0.0853	1.1779	0.4559	0.2379	0.7707	74.2
Tulus	0.0961	1.303	0.5218	0.2384	0.7103	76.8
Algoso	0.1077	1.3493	0.532	0.2551	0.7416	76.7
Pizarro	0.1019	1.3088	0.5144	0.2527	0.7461	63.4
Mikado	0.0898	1.2429	0.494	0.2316	0.7283	73.7
Borowik	0.1076	1.3671	0.5407	0.2503	0.7218	79.4
Moderato	0.0788	1.1386	0.441	0.227	0.7628	69.9
Sorento	0.0909	1.2787	0.5133	0.2257	0.697	76.6
Elpaso	0.0773	1.1482	0.4521	0.2211	0.7352	81.4
Leontino	0.0855	1.1865	0.4612	0.2348	0.7598	61.5
Pawo	0.0861	1.1944	0.4673	0.2389	0.7582	71.2
Fredro	0.079	1.1413	0.4428	0.2273	0.7612	72.9
Cerber	0.093	1.2724	0.5039	0.2404	0.721	77.6
Maestozo	0.0905	1.263	0.5071	0.2262	0.7119	70.4
Bereniko	0.0765	1.0969	0.4161	0.2307	0.7976	68.8
Baltiko	0.0886	1.233	0.4892	0.2303	0.7316	75.4
Atletico	0.094	1.249	0.4911	0.2408	0.7554	75.7
Grenado	0.089	1.2245	0.485	0.239	0.7449	81.1
Alekto	0.0877	1.197	0.4645	0.2389	0.7678	68.3
Cyrkon	0.0962	1.2983	0.5152	0.2419	0.7161	75.4
Agostino	0.0901	1.2243	0.4804	0.2393	0.7543	82
Witon	0.0784	1.1357	0.441	0.2288	0.7618	76.7
Pigmej	0.0847	1.1988	0.4731	0.2265	0.7374	83.5
KWS Trisol	0.1004	1.3123	0.5191	0.2516	0.7308	86.7

Tab. 8. The average values of geometrical parameters of rye grains.

	Surface [**cm**^{2}]	**Perimeter** [**cm**]	**Length** [**cm**]	**Width** [**cm**]	**Circularity**	**Grain yield dt/ha**
Brasetto	0.0733	1.1508	0.4635	0.2015	0.6938	78.3
Armand	0.0748	1.1606	0.4604	0.2091	0.6968	60.7
Dańk. Diament	0.0687	1.0854	0.428	0.2027	0.7311	62.7
SU Skaltio	0.0686	1.1146	0.4498	0.1909	0.6944	67.7
Dańk. Amber	0.0687	1.1091	0.4466	0.1956	0.7017	58.8
Visello	0.0707	1.1267	0.4551	0.1993	0.6977	72.9
Palazzo	0.067	1.0938	0.4368	0.1962	0.7027	64.4
SU Drive	0.067	1.0938	0.4368	0.1962	0.7027	66.2
Bosmo	0.0697	1.1229	0.4537	0.1943	0.694	54.6
Stanko	0.0673	1.0955	0.4403	0.1948	0.7037	67.2
Domir	0.0659	1.0757	0.4237	0.2038	0.7149	60.2
Minello	0.0667	1.0917	0.4411	0.1923	0.7025	68.9
Horyzo	0.0707	1.1217	0.4507	0.1964	0.7046	65.2
Gonello	0.0707	1.1382	0.4642	0.1915	0.6837	72.6

Tab. 9. The finished average results of the geometrical crop species.

	Surface [**cm**^{2}]	**Perimeter** [**cm**]	**Length** [**cm**]	**Width** [**cm**]	**Circularity**
Winter triticale	0.0896	1.2285	0.4829	0.2366	0.7441
Spring triticale	0.0916	1.2675	0.502	0.2315	0.7144
Rye	0.0693	1.1156	0.4479	0.1977	0.6994
Spring wheat	0.0776	1.0876	0.3971	0.2417	0.8236
Winter wheat	0.0812	1.1069	0.4037	0.2474	0.8302
Oats	0.1042	1.5309	0.6542	0.21	0.5616
Winter barley	0.1171	1.5638	0.6472	0.2522	0.6075
Spring barley	0.1011	1.3555	0.5432	0.2509	0.6925

of homogeneous grain system was found to be a great way to estimate the quantity of decay of mixed components. The above described method solves the problem of rating the mixing of grain systems [15]. The knowledge about the physical features of cereal products allows to assess their technological quality for consumption or feeding. Besides, the seed dimensions and shape refer to the endosperm or other parts of the grain (e.g. covering), and make it possible to describe the milling value of seeds. A system based on the digital image analysis can fulfill a function of estimating the quality of seeds in the storage, for the business trading and in the material preparing processes for milling. The scheme of geometrical features can help to build the basis of models, describing the agricultural properties of examined varieties.

4. Conclusions

- Using the digital shape analysis made it possible to obtain the accurate survey of examined geometrical values: area of surface, perimeter, length, width and circularity of grains.
- The crop with the largest area of grain surface and perimeter is winter barley. Not only for this reason it takes the first place, but it also has the widest seeds among the rest of crops. The longest grains are found in oats – 0,6542 cm. The best grain circularity is found in winter triticale – 0,8302 cm. The smallest values of the grain perimeter – 1,0876 cm, and the grain width – 0,3971 cm are found in spring wheat. It is the same with the grain heights of that crop – 1977 cm. Oats have very weak grain circularity – 0,5616 cm, mainly due to the typical kind of surface.
- It is observed that there is a relationship between the received data from the shape analysis of grains and the grain yield of crops.
- The computer image analysis makes it possible to determine the parameters of agricultural equipment and machines with great precision: seed drills, combines, crushers for feed stuff production and mills of the 21st century.

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