COMPARISON OF METHODS OF DIRECT MEASUREMENT OF THE GRAIN-TO-EAR BINDING FORCE

Radoš Řezniček, Bogusław Szot, Karel Patočka, Stanisław Grundas, Josef Kadrmas

Modern technology of harvesting and threshing requires the knowledge of the mechanical properties of cereals, if the objective is to optimize these processes and to limit the quantitative and qualitative losses of grain. One of the factors causing these losses is the spontaneous sheding of grain in field or by the hitting of elements of the hervesting system, another one is the unthreshed grain left in ears. In the first case the grains are bound to the ear torus with too low forces, while the leaving of unthreshed grain occurs with varieties strongly binding grain with ear, at improper regulation of threshing machines.

The getting to know these phenomena was the object of investigations in the ranges of plant breeding and harvest mechanization. The so far known methods for the determination of the susceptibility of cereals to grain shedding were based generally on indirect measurements, utilizing the action of inertia forces on grain in various types of centrifuge [1, 2, 3, 12] or in vibration apparati [9] and shock apparati [2, 4]. It was found, however, that applying these methods it is difficult to grasp the relationship between the weight of grain and the value of force necessary to remove grain from ear, the more so that grains in its middle part mature faster, are of better quality, the heaviest, and get separated from it the first [11, 12]. Using these methods they concluded that the best grains from the middle part of ear get broken off from the ear torus at the application of low forces.

The recently worked out direct methods are based on measurements of force binding particular grains with ear [5 — 8, 10]. The absolute values of the force obtained on this way enable a fuller and most probably a more exact characterization of the investigated material.

With the help of direct methods investigations were carried out in the Institute of Physics of the Higher School of Agriculture in Prague (Cze-

choslovakia) and in the Institute of Agrophysics of Polish Academy of Sciences in Lublin (Poland). The two posts, within the frames of international scientific cooperation, undertook an attempt at confronting the applied methods in order to compare them and to unify the ways of making measurements, and the ranges of investigations.

METHODOLOGY OF INVESTIGATIONS

The investigations were carried out in the period 1973—1975. The material was constituted by cereal varieties cultivated in both countries on a wider scale and staying in the range of experiments for at least the period of the mentioned three years. In effect the investigations comprised the winter wheats Kaukaz and Mironowskaja, and the spring wheat Zlatka, of the varieties cultivated in Czechoslovakia, and the winter wheats Kaukaz, Grana and Helenka, and the rye Dańkowskie Złote, of the varieties cultivated in Poland. From each variety 60 ears were randomly chosen in the period of full maturity, in order to carry out investigations on 30 ears in each of the two posts. The joint methodological assumptions included the measurement of the grain-to-ear binding force in its three parts — lower, middle and upper (Fig. 1). In each part 3 grains were removed from different ears, paying attention that the force acted along the longest axis of the grain. Because of the small object of interest precision pliers were constructed, enabling the getting hold of grain without impairing its connection with the ear torus and the surrounding glumes (Fig. 2). The measurements of the force necessary to re-

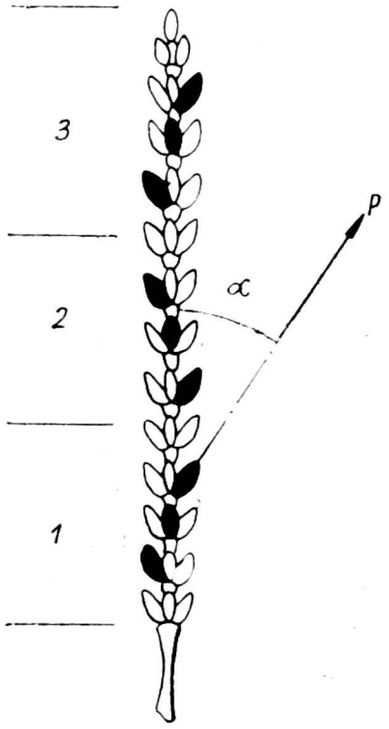

Fig. 1. Diagram of the division of ear into parts: *1* — lower part, *2* — middle, *3* — upper, *P* — direction of the action of the breaking force, α — angle of the action of force *P* (in accordance with the symmetry axis of grain)

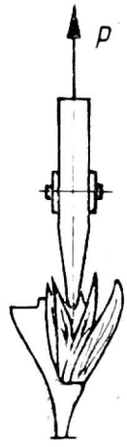

Fig. 2. Method for getting hold of the grain in ear torus

move grain from ear were made on three different apparati. In the Institute of Physics of the Higher School of Agriculture in Prague on a prototype micropicker based on a tensometric system (Fig. 3), and in the

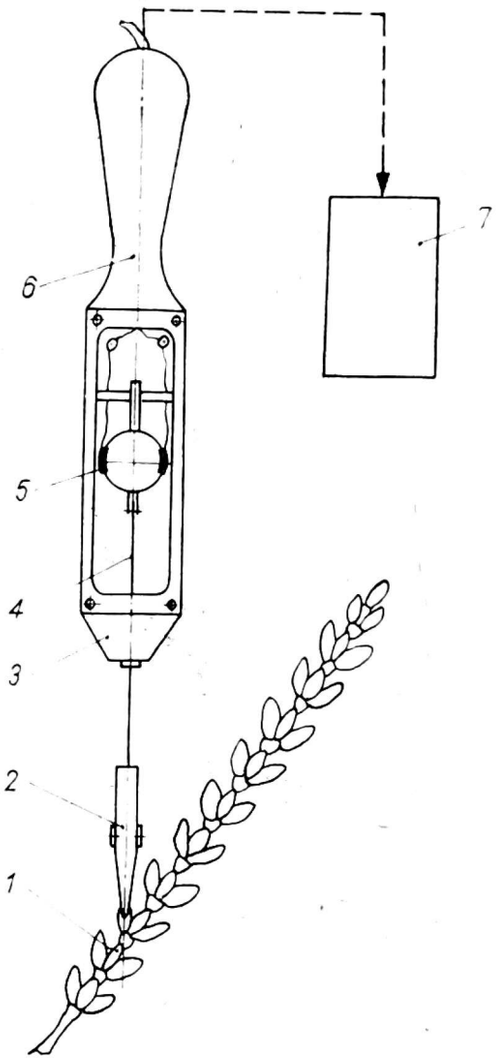

Fig. 3. Diagram of the tensometric micro-picker (WSR — Praga): *1* — ear, *2* — pliers, *3* — body of the micro-pincker, *4* — flexible connector, *5* — tensometric ring, *6* — holder of the micro-picker, *7* — recorder

Institute of Agrophysics of Polish Academy of Sciences in Lublin on a prototype electromagnetic micropicker (Fig. 4) and in the period (1974—1975 also on the resistance measuring apparatus "Instron" with the application of a head in the loading range 0—5 N (Fig. 5).

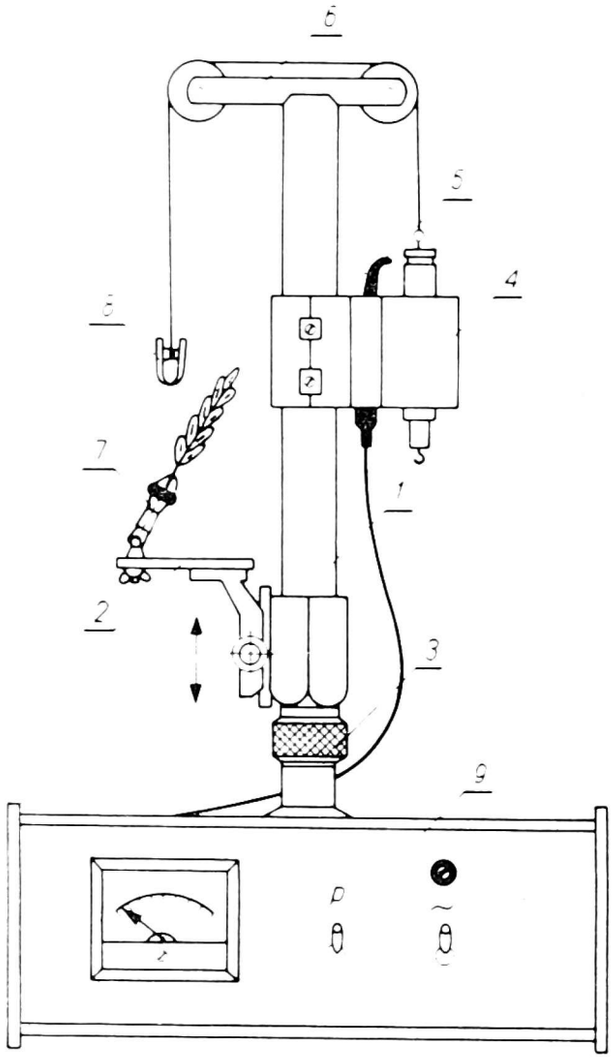

Fig. 4. Diagram of the eletcromagnetic micro-picker (ZA PAN — Lublin): *1* — vertical column, *2* — measuring table, *3* — clamp nut, *4* — electromagnet, *5* — indicator of the initial position of the core, *6* — perpendicular outrigger with tackles, *7* — articulated selflocking holder, *8* — pliers, *9* — operating system

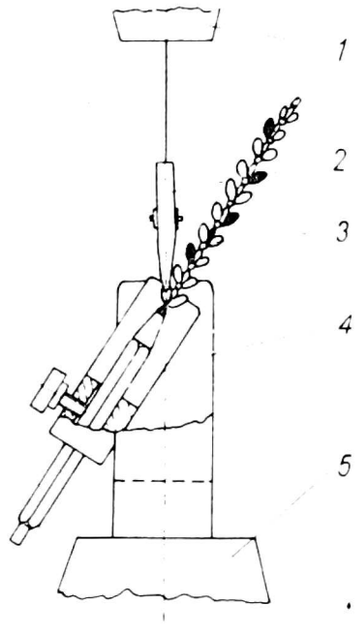

Fig. 5. Diagram of the measuring system of the Instron 1253 machine: *1* — loading head, *2* — pliers, *3* — ear, *4* — universal holder, *5* — base of the holder

RESULTS OF THE INVESTIGATIONS

Results obtained from the investigations were subjected to statistical calculations using four-fold classification, and in order to grasp the quantitative differences the Tukey's halfranges of credibility were calcula-

ted. Concluding was carried out at the significance level $\alpha = 0.05$ (Tables 1 and 2).

The mean values of the grain-to-ear binding force are presented in Tables 3—6.

Table 1

Values of test functions from analyses of variance

Source of variability		F^o	F 0.05
A — parts of ear		2081.81	2.99
B — methods		19.18	3.84
C — varieties		1358.16	2.09
D — years		73.77	2.99
Interactions	AB	20.23	2.99
	AC	85.70	1.75
	AD	24.62	2.37
	BC	21.70	2.09
	BD	843.87	2.99
	CD	83.18	1.75
	ABC	2.07	1.75
	ABD	52.76	2.37
	ACD	8.44	1.52
	BCD	53.07	1 75
	ABCD	7.23	1.52

Table 2

Tukey's half-ranges of credibility for particular sources of variability

Source of variability		The smallest significant difference (P = 0.05)	Source of variability	The smallest significant difference (P = 0.05)
A — parts of ear		0.01	BD	0.02
B — methods		0.03	CD	0.04
C — varieties		0.02	ABC	0.06
D — years		0.05	ABD	0.04
Inter-actions	AB	0.02	ACD	0.08
	AC	0.04	BCD	0.06
	AD	0.03	ABCD	0.11
	BC	0.03		

Table 3

Mean values of the grain-to-ear binding force (N) obtained on the basis of measurements in 1973

Varieties		Measurements carried out in Poland				Measurements carried out in Czechoslovakia				Mean values from measurements in both countries			
		part of ear			mean value for whole ear	part of ear			mean value for whole ear	part of ear			mean value for whole ear
		lower	middle	upper		lower	middle	upper		lower	middle	upper	
Cultivated in Czechoslowakia	Kaukaz	1.42	1.63	1.12	1.39	1.82	2.35	1.34	1.84	1.62	1.99	1.23	1.61
	Mironowskaja	1.43	1.71	1.25	1.43	2.15	2.62	1.68	2.15	1.79	2.17	1.41	1.79
	Zlatka	1.28	1.63	1.19	1.37	1.86	2.43	1.41	1.90	1.57	2.03	1.30	1.63
Cultivated in Poland	Helenka	0.97	1.03	0.89	0.93	1.54	1.66	1.17	1.46	1.26	1.30	1.03	1.19
	Kaukaz	1.23	1.31	1.14	1.27	1.76	2.13	1.38	1.76	1.50	1.72	1.23	1.48
	Grana	1.11	1.15	1.15	1.14	1.64	1.90	1.27	1.60	1.37	1.52	1.16	1.35
	Dańkowskie Złote	0.93	0.98	0.92	0.94	1.24	1.34	1.10	1.23	1.08	1.16	1.01	1.08
Mean value		1.21	1.44	1.14	1.29	1.72	2.06	1.34	1.70	1.45	1.70	1.20	1.46

Table 4

Mean values of the grain-to-ear binding force (N) obtained on the basis of measurements in 1974

Varieties		Measurements carried out in Poland				Measurements carried out in Czechoslovakia				Mean values from measurements in both countries			
		part of ear			mean value for whole ear	part of ear			mean value for whole ear	part of ear			meen value for whole ear
		lower	middle	upper		lower	middle	upper		lower	middle	upper	
Cultivated in Czecho-slovakia	Kaukaz	2.17	2.49	1.66	2.11	2.00	2.22	1.43	1.88	2.08	2.35	1.55	2.00
	Mironowskaja	1.98	2.30	1.57	1.95	2.15	2.54	1.44	2.04	2.07	2.42	1.51	2.01
	Zlatka	1.72	1.80	1.43	1.65	1.74	1.98	1.19	1.63	1.73	1.89	1.31	1.64
Cultivated in Poland	Helenka	1.04	1.21	0.91	1.06	1.11	1.02	0.92	1.02	1.07	1.12	0.91	1.04
	Kaukaz	1.82	2.13	1.38	1.78	1.61	1.68	1.28	1.53	1.71	1.91	1.33	1.65
	Grana	1.20	1.24	1.05	1.25	1.12	1.02	0.87	1.01	1.16	1.26	0.96	1.13
	Dańkowskie Złote	1.16	1.29	1.08	1.18	1.26	1.38	1.29	1.31	1.21	1.33	1.18	1.24
Mean value		1.59	1.82	1.30	1.57	1.57	1.69	1.20	1.49	1.58	1.75	1.25	1.53

Table 5

Mean values of the grain-to-ear binding force (N) obtained on the basis of measurements in 1975

Varieties		Measurements carried out in Poland				Measurements carried out in Czechoslovakia				Mean values from measurements in both countries			
		part of ear			mean value for whole ear	part of ear			mean value for whole ear	part of ear			mean value for whole ear
		lower	middle	upper		lower	middle	upper		lower	middle	upper	
Cultivated in Czechoslowakia	Kaukaz	2.12	2.41	1.26	1.93	1.70	1.90	1.16	1.58	1.91	2.15	1.21	1.76
	Mironowskaja	2.39	2.68	1.56	2.21	1.90	2.11	1.17	1.73	2.15	2.40	1.36	1.97
	Zlatka	2.08	2.55	1.40	2.01	1.71	1.87	1.18	1.59	1.89	2.21	1.29	1.80
Cultivated in Poland	Helenka	0.73	0.90	0.59	0.74	0.86	1.05	0.77	0.89	0.80	0.97	0.68	0.82
	Kaukaz	1.06	1.57	0.96	1.20	1.24	1.95	1.07	1.42	1.15	1.76	1.02	1.31
	Grana Dańkowskie	0.87	1.40	0.79	1.02	1.05	1.53	0.94	1.17	0.96	1.46	0.87	1.10
	Złote	1.35	1.41	1.29	1.35	1.08	1.26	1.04	1.13	1.21	1.34	1.17	1.24
Mean value		1.51	1.85	1.12	1.49	1.36	1.67	1.05	1.36	1.44	1.76	1.08	1.43

Table 6

Mean values of the grain-to-ear binding force (N) obtained from measurements in the period 1973—1975

Varieties		Measurements carried out in Poland				Measurements carried out in Czechoslovakia				Mean values from measurements in both countries			
		part of ear			mean value for whole ear	part of ear			mean value for whole ear	part of ear			mean value for whole ear
		lower	middle	upper		lower	middle	upper		lower	middle	upper	
Cultivated in Czechoslovakia	Kaukaz	1.90	2.18	1.35	1.81	1.84	2.15	1.31	1.77	1.87	2.17	1.33	1.79
	Mironowskaja	1.94	2.23	1.43	1.86	2.07	2.42	1.43	1.97	2.00	2.33	1.43	1.92
	Zlatka	1.69	1.99	1.34	1.68	1.77	2.09	2.26	1.71	1.73	2.04	1.30	1.69
Cultivated in Poland	Helenka	0.97	1.02	0.80	0.99	1.17	1.24	0.95	1.12	1.04	1.13	0.87	1.02
	Kaukaz	1.37	1.67	1.14	1.39	1.54	1.92	1.24	1.57	1.45	1.79	1.19	1.48
	Grana Dańkowskie	1.12	1.36	0.96	1.12	1.27	1.48	1.03	1.26	1.17	1.42	1.04	1.21
	Złote	1.15	1.23	1.10	1.16	1.19	1.33	1.14	1.22	1.17	1.28	1.12	1.19
Mean value		1.48	1.69	1.16	1.44	1.55	1.81	1.20	1.52	1.49	1.74	1.18	1.47

The results obtained indicate unequivocally that grains are bound the strongest in the middle part of ear, the weakest in the upper part, and the medium values occur for the lower part of ear. Also significant differences between the particular years were noted, which undoubtedly results from the variable atmospheric conditions. Grains were bound the strongest in 1974 and the weakest in 1975.

The varieties cultivated in Czechoslovakia are characterized by decidedly higher value of the grain-to-ear binding force in comparison to the Polish varieties. It should be assumed that the decisive influence on this property is first of all that of the soil-climatic conditions, since the Kaukaz variety cultivated in both countries for three years showed in Czechoslovakia significantly higher values of the grain-to-ear binding force than in Poland. Out of the six investigated varieties of wheat and one variety of rye, the Mironowskaja wheat was characterized by the highest

Table 7

Values of indexes of the variability of grain-to-ear binding force of cereals for the period 1973—1975

Varieties		Variability index (%)
Cultivated in Czechoslovakia	Kaukaz	32.32
	Mironowskaja	34.25
	Zlatka	35.80
Cultivated in Poland	Helenka	37.49
	Kaukaz	34.30
	Grana	35.72
	Dańkowskie Złote	28.54
Parts of ear	lover	38.86
	middle	37.64
	upper	35.35
For measurements carried out in Czechoslovakia		38.1
For measurements carried out in Poland		39.3

values of the force during the period of investigations. The Helenka wheat and the Dańkowskie Złote rye kept grain in ear the weakest.

During the measurements a considerable distribution of single values of the force was noted, which confirms the variability of the investigated

property. It formed a range characteristic of plant material. The variability coefficients are presented in Table 7.

All the values of the variability coefficient for wheats exceed 30%, and in the case of the Helenka variety, the most susceptible to grain shedding — it is 37.49%. The lowest coefficient characterized the Dańkowskie Złote rye (28.54%) which probably results from the fact that in this kind of cereal there occur smaller differences of the value of the force on the length of ear. The variability coefficients of the force for the particular parts of ear are very high and form the range from 35.35% (the upper part) to 38.86% (the lower part). So high variability results from the considerable distribution of the value, which is a not too advantageous phenomenon and requires a precise analysis at the optimization of the harvesting technology.

RECAPITULATION

On the basis of the investigations carried out in the period of three years it was established that the methods of direct measurement of the grain-to-ear binding force applied in Czechoslovakia and in Poland are sufficiently accurate and allow for exact determination of this important property of cereals. The joint assumptions enabled the unification of the course of action during the measurements, creating a chance of confrontation and comparison of results. The slight differences between the results obtained can undoubtedly have their source in the impossibility of making measurements at the same time in both countries, and the necessity of transporting the plant material (ears). Hence the results of measurements carried out in Czechoslovakia in the period of three years are slightly higher than those obtained in Poland.

The so far used indirect methods of measurement of the grain-to-ear binding force are loaded with a certain error and do not allow to determine the variability ranges of the investigated properties. They can serve first of all for testing the particular varieties from the point of determining the most advantageous term of harvesting. While with the help of the direct methods it is possible to obtain a full and comprehensive characterization of cereals and to determine — on the basis of results obtained — the parameters of the harvesting and threshing machines, thus limiting to minimum the quantitative losses of grain.

The investigations carried out jointly within the frames of international cooperation with the application of direct methods constitute — in the opinion of the authors — an important step forward in the works on unifying the methods of investigating the mechanical properties of cultivable plants.

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PORÓWNANIE METOD BEZPOŚREDNIEGO POMIARU SIŁY ZWIĄZANIA ZIARNA Z KŁOSEM

Streszczenie

Siłę związania ziarna z kłosem, jako ważną cechę z punktu widzenia hodowli roślin i optymalizacji zbioru, określano metodami bezpośrednimi. W tym celu skonstruowano niezależnie dwa aparaty prototypowe. Umożliwiają one takie uchwycenie kłosa, aby siła oddzielająca ziarno działała wzdłuż jego osi symetrii. Przeprowadzono również pomiary na aparaturze wytrzymałościowej „Instron", stosując odpowiednie oprzyrządowanie.

Uzyskane wyniki badań pszenicy jarej i żyta — uprawianych w Polsce i Czechosłowacji — obejmują analogiczne poziomy wartości skrajnych, co świadczy o dużej dokładności pomiarowej zastosowanych aparatów. Stwierdzono — charakterystyczne dla tych zbóż — zróżnicowanie siły związania ziarna w różnych strefach kłosa. Najwyższe wartości występują w strefie środkowej, najmniejsze w górnej, pośrednie zaś w dolnej.

Udowodniono całkowitą przydatność wspomnianych trzech aparatów do tego typu badań.

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СРАВНЕНИЕ МЕТОДОВ ПРЯМОГО ИЗМЕРЕНИЯ СИЛЫ СВЯЗЫВАНИЯ ЗЕРНА С КОЛОСОМ

Резюме

Силу связывания зерна с колосом как свойство, важное с точки зрения растениеводства и оптимализации уборки, определяли прямыми методами. С той целью сконструировали независимо друг от друга два прототипных прибора. Они дают возможность захватить колос так, чтобы сила, отделяющая зерно, действовала вдоль его оси симетрии. Были проведены также измерения на аппаратуре для прочностных испытаний „Инстрон" с применением соответствующего оборудования.

Полученные результаты исследований яровой и озимой пшеницы, а также ржи, возделываемых в Польше и Чехословакии, включают в себя аналогичные уровни крайних величин, что свидетельствует о большой измерительной точности примененных приборов. Констатировали характерную для этих знаков дифференциацию силы связывания зерна в различных зонах колоса. Наивысшие величины отмечаются в центральной части, наименьшие — в верхней, а посредственные — в нижней.

Доказали полную пригодность упомянутых трех приборов для этого рода исследований.

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