ZESZYTY PROBLEMOWE POSTĘPÓW NAUK ROLNICZYCH 1978 z. 203

THE ROLE OF SOIL CONDITIONS IN THE FORMATION OF SOME MECHANICAL PROPERTIES OF CEREALS

Bogusław Szot

Changeability of the physical properties of cereals comprises a very wide range and undoubtedly depends on many internal and external factors which not always can be determined in absolute values. Surely one of them is the soil, influencing to a degree the differentiation of some parameters. This problem has not been dealt with widely so far. Very scarce information to be found in Pieper's works [1] suggests that with the evaluation of grain, apart from the variety features, the soil conditions should also be considered. The author, however, did not present in detail the participation of soil in the formation of the physical properties of seeds. The development of investigations of the physical properties of plants that took place in recent years created a greater interest also in this direction of research.

On the basis of the results of investigations carried aut in the Institute of Agrophysics of Polish Academy of Sciences in Lublin a considerable changeability of the physical properties of cereal grain determined by differentiated soil factors [5, 6] was established. These facts confirmed the assumption that soil conditions significantly change the range of changeability of many physical parameters of grain. Hence it seems purposeful to extend this type of investigation for the determination of the limit values of particular properties, the grasping the dynamics of the changes and for the determination of the actual role of soil conditions in the formation of the physical properties of plant materials.

METHODOLOGY OF INVESTIGATIONS

The investigation material was constituted by stalks and grains of winter wheat (the 500/69 variety), rye (the AR 3 variety) and *Triticale* (the TCL 5/69 variety), that came from experiments carried out on micro-fields in the period 1973/74 on the lands of the Institute of Fertilization, Cultivation and Soil Science in Puławy. The micro-fields (each of them about 15-16 m^2 in area) constitute a unique (in Poland) system of nine different soils (of natural genetic levels) situated side by side. They represent the following systematic units:

I — acid brown soil (derived from weakly clayey sand),
II — acid brown soil (derived from medium clayey sand),
III — brown limestone soil (with the granulometric composition of strong clayey sand),
IV — brown fen soil (with the granulometric composition of medium clay),
V — leached brown soil (derived from loess),
VI — black earth proper (with the granulometric composition of light silty loam),
VII — acid brown soil (derived from silty sand),
VIII — brown soil proper (derived from silt formations of water origin),
IX — brown soil proper (derived from light loamy sand).

The enumerated soils differed among themselves not only in their granulometric composition but also in their basic chemical properties. The humus content in the arable layer varied from 0.64 to 3.86%, and the hydrolitic acidity from 0.45 to 2.33 me/100 mg of soil. Also the reaction formed a very wide range (from 3.9 to 7.5 pH_{KCL}). The content of nutrients assimilable for plants formed also a very wide range: P_2O_5 — from 9.2 to 41.0 mg/100 g of soil; K_2O — from 3.6 to 13.0; and Mg from 0.4 to 13.4 mg/100 g of soil.

Such a considerable changeability of soil conditions at the same climatic conditions created an opportunity of evaluating the influence of soil on the formation of the physical properties of cereals, the more so that all the micro-fields were subjected to the same agrotechnical measures (including fertilization) and the same date of sowing. Harvesting was carried out after full maturity of the cereals was established.

The harvested material served for the determination of
— the elasticity coefficients for the stalk,
— the grain-to-ear binding forces,
— the grain resistance to static loading together with the determination of the level of temporary deformations and the energy that caused them.

For the determination of the basic mechanical properties of the stalk the following measurements were made: force causing the bending of a 6 cm long section of the stalk (bending arrow), outer and inner diameter and the thickness of the stalk wall. The investigations were carried out on a prototype apparatus of the Institute of Agrophysics. Then, by the application of adapted mathematical formulae [4], the elasticity coefficients for the subsequent sections and for the whole stalk were calculated.

The measurements of the grain-to-ear binding force were carried out on the resistance measuring apparatus "Instron" with the direct method [2, 3, 5, 8] in three parts of the ear (lower, medium and upper).

The immediate resistance of grain to static loading was determined on a prototype apparatus of the Institute of Agrophysics [7]. From the obtained diagrams presenting the courses of the linear increasing of loading in function of deformation the values of the force and the degree of deformation were read. Also the value of the energy causing the immediate deformations was calculated. The measurements were carried out on grains of precisely determined thickness (2.0, 2.5, 3.0 mm) and moisture of 10.7—12.1% (air dry).

RESULTS OF INVESTIGATIONS

The values of the elasticity coefficient change markedly along the length of the stalk, and the influence of soil on this changeability is particularly visible during the analysis of results concerning winter wheat (Fig. 1). For rye the values clearly decrease to the stalk height of about 70 cm, where there occurs a relative equalization of the curves characterizing this property (Fig. 2), though there can be seen the differentiating influence of the particular soils, similarly as in the case of *Triticale* (Fig. 3).

The absolute values of the elasticity coefficients characterizing the whole stalk (Table 1) vary — for winter wheat — from 1084.50 N/mm² (brown soil proper — VIII) to 3576.53 N/mm² (brown limestone soil — III). For rye the range of mean values is slightly narrower, and is closed by 1234.51 N/mm² (leached brown soil — V) and 1891.63 N/mm² (acid brown soil — VII). Lower values were established for *Triticale* — from 879.96 N/mm² (acid brown soil — VII) to 1330.75 N/mm² (brown fen soil — IV). The particular soils considerably influenced the changeability of the elasticity of plants, which is particularly important for the evaluation of the susceptibility to lodging and for preventing this phenomenon in particular local conditions.

The values of the grain-to-ear binding force show a considerable changeability among the particular parts of the ear (Table 2). The lowest values were found for the upper part of the ear medium values for the medium part and the highest values for the lower part of the ear. Only for rye a relatively small differentiation among the parts was found. However for a clear majority of the compared mean values there are

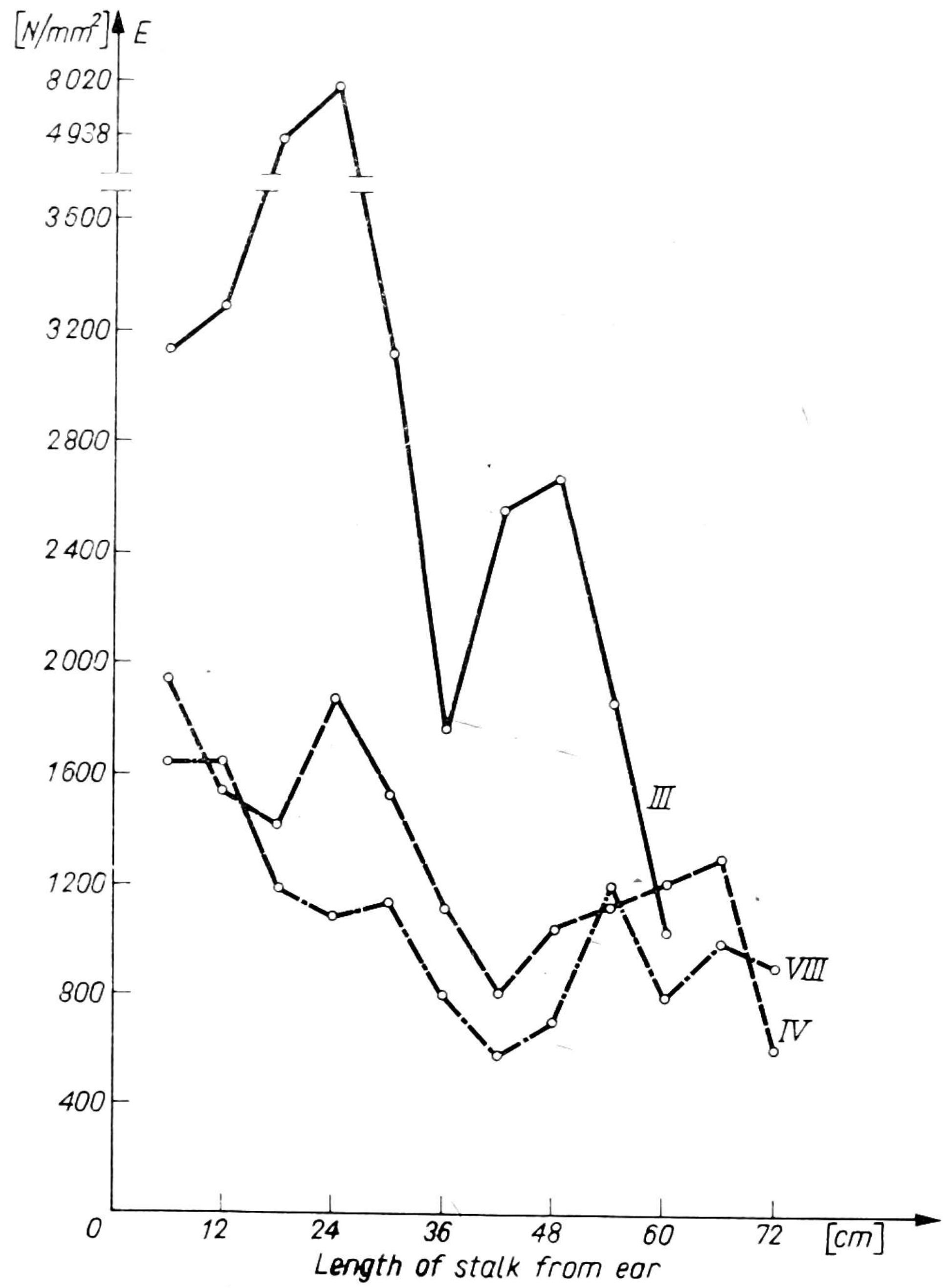

Fig. 1. Distribution of the elasticity coefficient values on the length of a stalk of winter wheat (Jana variety) cultivated on various soils (III, IV, VIII)

considerable differences. The extreme mean values form a very wide range (1.32—2.10 N for wheat, 0.78—1.22 N for rye and 1.03—1.80 N for *Triticale*). Statistical analysis showed also a considerable influence of soil on the changeability of this property of cereals. The mean values for the whole ear formed the range from 1.46 to 1.68 N for wheat, from 0.91 to 1.05 N for rye and from 1.15 to 1.45 N for *Triticale*. Hence it also follows that the influence of the particular soils on the cohesion of grain with the ear torus is different for different kinds of cereals. The brown soil proper (IX) caused the strongest bond between grain and ear for wheat, while for rye it was the acid brown soil (VII) and for *Triticale* the acid brown soil derived from weakly clayey sand (I). The lo-

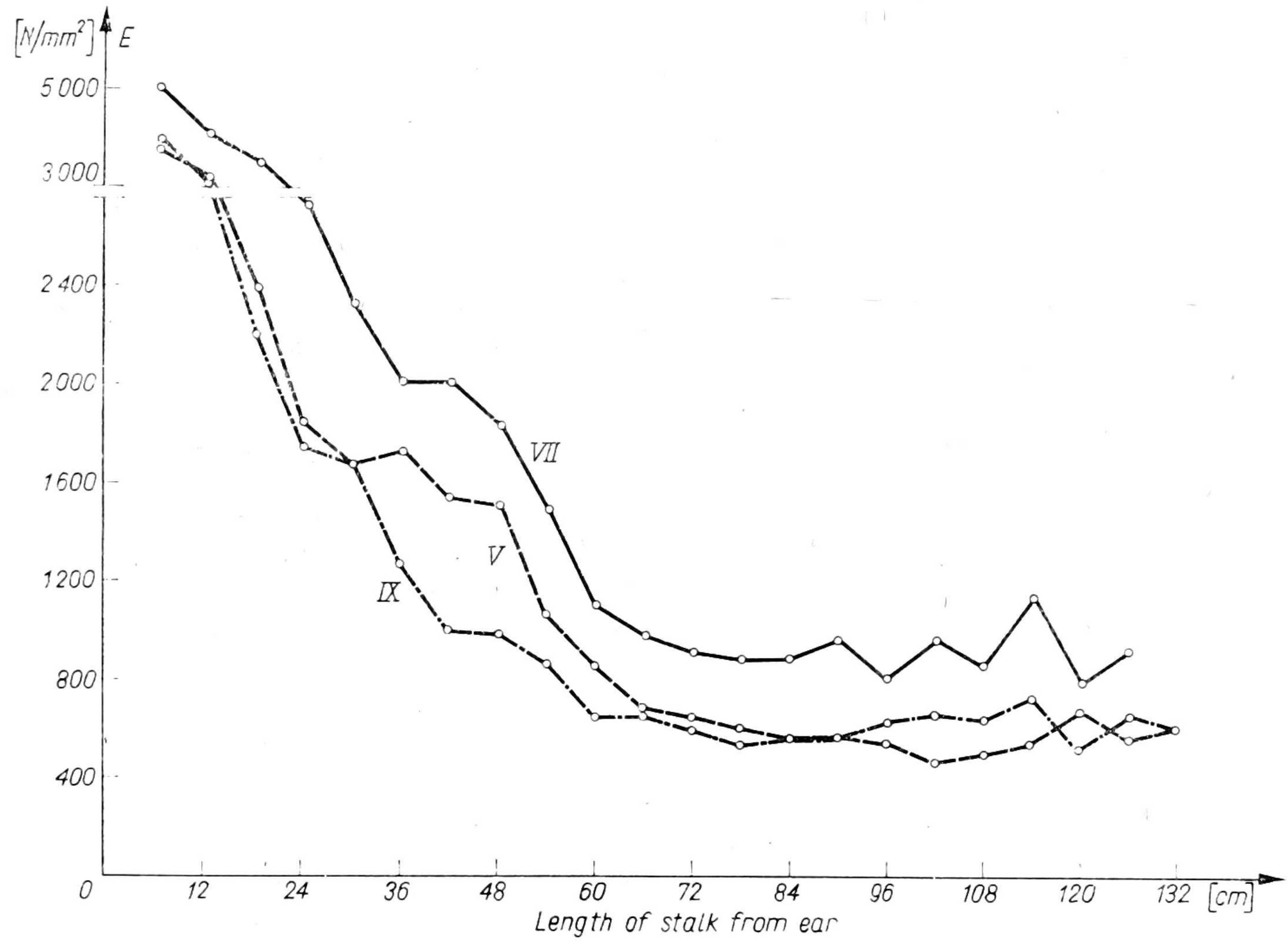

Fig. 2. Distribution of the elasticity coefficient values on the length of a stalk of rye (the AR 3 variety) cultivated on various soils (V, VII, IX)

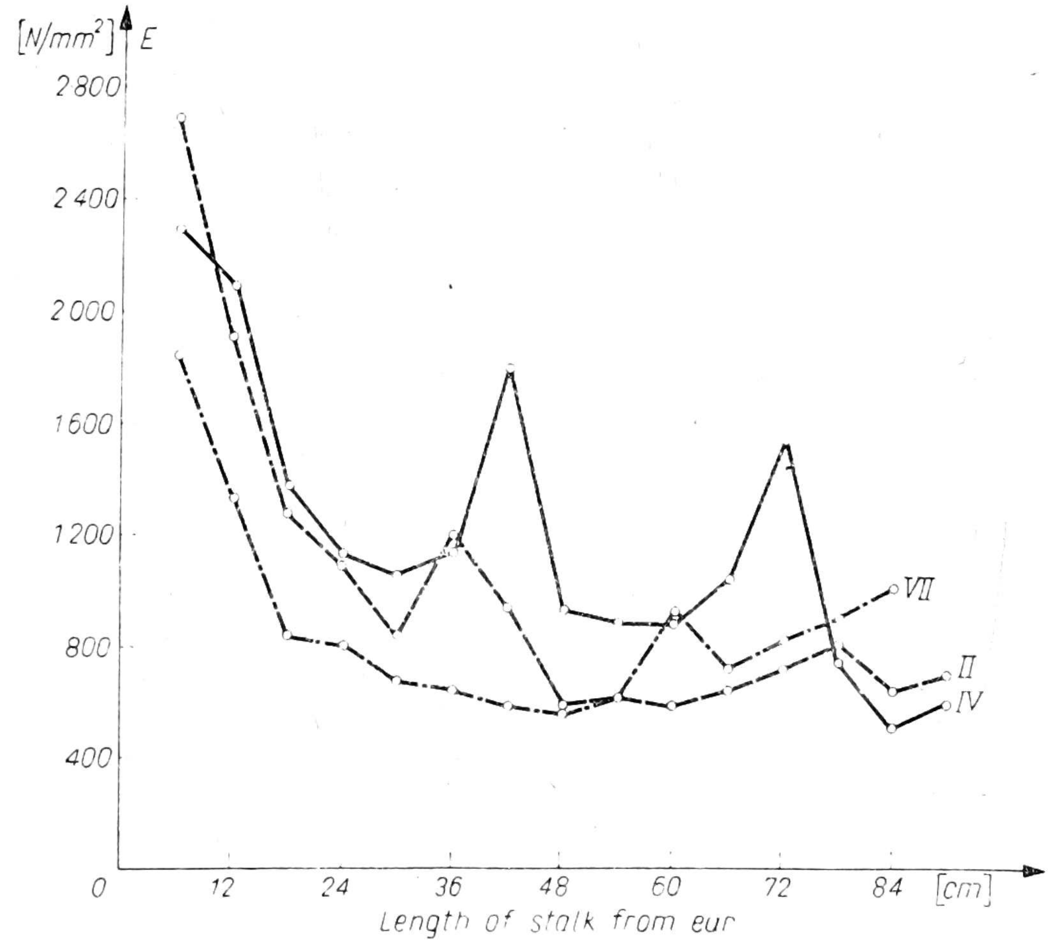

Fig. 3. Distribution of the elasticity coeficient values on the length of a stalk of Triticale (the TCL 5/69 variety) cultivated on various soils (II, IV, VII)

Table 1

Mean values of the elasticity coefficients of cereal stalks (N/mm^2) grown on various soils

Soil (micro-field number)	Winter wheat Jana variety	Rye the AR 3 variety	*Triticale* the TCL 5/69 variety
I	2404.84	1764.07	974.21
II	2640.39	1390.54	1076.99
III	3576.53	1720.57	1023.92
IV	1377.19	1614.49	1330.79
V	1315.29	1234.51	919.56
VI	1238.49	1777.17	957.92
VII	1256.04	1891.63	879.96
VIII	1084.50	1590.15	989.26
IX	1419.78	1247.62	900.38
Average value	1764.18	1578.98	1005.48

west values of the grain-to-ear binding force were shown by the cereals cultivated on the acid brown soil derived from medium loamy sand — II (wheat), the brown fen soil — IV (rye) and the leached brown soil — V (*Triticale*).

Characterizing the resistance to static loading, it was established that the resistance of grains is closely correlated with their thickness (Table 3). The thicker the grains the greater their resistance to loading. The statistically proved significance of the differences concerns all the compared mean values. In the range of the three investigated kinds of cereals the values of forces causing the damaging of the grain structure form a very wide range. The most resistant proved to be the grains of rye, the least — those of wheat. The influence of soils on the changeability of this property is great, particularly in the range of the particular thickness fractions. In turn, the mean values corresponding to the particular micro-fields indicate that wheat grain harvested on the acid brown soil (I) are the most resistant to static loading (61.01 N), while the most susceptible are those grown on the brown fen soil (IV — 47.08 N). The extreme values for rye were obtained by growing it on the brown limestone soil — III (98.01 N) and on the brown soil proper — IX (87.99 N). The most resistant grains of *Triticale* were obtained from the brown soil proper — VIII (82.30 N) and the least resistant from the acid brown soil — II (68.57 N).

The immediate deformations of grains resulting from the static loading are characterized by changeability determined both by the sizes of

Table 2

Mean values of the grain-to-ear binding force (N) for winter wheat, rye and Triticale cultivated on various soils

Soil (micro-field number)	Winter wheat—Jana variety				Rye—the AR 3 variety				*Triticale*—the TCL 5/69 variety			
	the parts of ear			mean value for whole ear	the parts of ear			mean value for whole ear	the parts of ear			mean value for whole ear
	lower	middle	upper		lower	middle	upper		lower	middle	upper	
I	1.38	1.69	1.39	1.49	0.89	1.07	0.94	0.97	1.19	1.80	1.35	1.45
II	1.33	1.74	1.32	1.46	0.91	1.07	0.95	0.98	1.17	1.57	1.19	1.31
III	1.51	1.84	1.48	1.61	0.86	1.13	0.92	0.97	1.17	1.65	1.23	1.35
IV	1.49	1.79	1.44	1.53	0.81	0.98	0.92	0.91	1.15	1.60	1.12	1.29
V	1.56	1.95	1.50	1.67	0.99	1.11	1.00	1.03	1.03	1.39	1.04	1.15
VI	1.66	1.79	1.34	1.60	0.78	1.07	0.94	0.93	1.17	1.60	1.16	1.31
VII	1.53	1.95	1.44	1.64	0.95	1.20	0.99	1.05	1.29	1.63	1.25	1.39
VIII	1.49	1.83	1.33	1.55	0.96	1.19	0.94	1.03	1.37	1.59	1.19	1.38
IX	1.47	2.10	1.45	1.68	0.97	1.22	0.93	1.04	1.34	1.69	1.21	1.41
Avarage value	1.49	1.85	1.41	1.58	0.90	1.11	0.95	0.99	1.21	1.61	1.19	1.34

The smallest significant difference (P = 0.05)

between the parts of ear — wheat 0.04, rye 0.03, *Triticale* 0.04,
between soils — " 0.08, " 0.05, " 0.07,
in the interaction between
soil and part of ear — " 0.14, " 0.10, " 0.13.

Table 3

Mean values of the immediate resistance of grain to static loading (N)

Soil (micro—field number)	Winter wheat—Jana variety grain sizes (mm)				Rye—the AR 3 variety grain sizes (mm)				*Triticale*—the TCL 5/69 variety grain sizes (mm)			
	2.0	2.5	3.0	mean value	2.0	2.5	3.0	mean value	2.0	2.5	3.0	mean value
I	38.45	64.05	80.63	61.01	78.97	102.41	102.80	94.76	52.97	73.57	87.11	71.22
II	32.66	68.47	73.28	58.17	85.34	97.80	94.47	92.50	56.89	60.92	87.89	68.57
III	32.37	49.14	72.88	51.50	84.07	92.60	117.42	98.01	63.56	72.00	101.72	79.06
IV	34.13	44.63	62.29	47.08	81.12	100.74	110.46	97.51	59.35	73.67	99.66	77.59
V	41.98	51.01	69.94	54.34	86.42	93.39	114.28	98.00	58.86	84.36	95.25	79.46
VI	37.57	60.03	63.27	53.66	74.85	101.23	99.57	91.91	61.80	68.57	101.92	77.49
VII	38.74	59.84	78.67	59.05	77.59	94.96	103.69	92.11	61.11	78.18	86.62	75.34
VIII	43.06	53.95	68.96	55.32	82.60	88.19	95.05	88.58	56.30	77.30	113.10	82.30
IX	41.98	61.99	78.38	60.82	72.49	91.13	100.45	87.99	61.41	76.41	107.02	81.61
Average value	37.86	56.99	72.10	55.67	80.44	95.84	104.28	93.50	59.15	73.83	97.80	76.97

The smallest significant difference ($P = 0.05$)

between grain sizes —	wheat 2.64,	rye 3.23,	*Triticale* 2.64,	
between soils —	" 4.90	" 5.88	" 5.29,	
in the interaction between size and soil —	" 8.63	" 10.69	" 9.22.	

Table 4

Mean values of the immediate deformationg of grain (%) resulting from static loading

Soil (micro-field number)	Winter wheat—Jana variety				Rye—the AR 3 varietty				*Triticale*—the TCL 5/69 variety			
	grain sizes (mm)			mean value	grain sizes (mm)			mean value	grain sizes (mm)			mean value
	2.0	2.5	3.0		2.0	2.5	3.0		2.0	2.5	3.0	
I	9.0	9.2	7.3	8.4	13.0	11.2	10.3	11.2	11.5	12.4	10.0	11.2
II	7.5	8.0	10.0	8.6	14.0	12.8	10.0	12.0	12.0	11.2	9.0	10.8
III	8.5	10.0	9.7	9.6	18.5	11.2	13.7	14.0	14.0	10.4	11.7	11.6
IV	8.5	9.6	9.7	9.6	14.5	11.6	10.3	12.0	13.0	11.6	11.3	12.0
V	9.5	7.6	9.7	8.8	14.9	11.2	10.7	12.0	14.0	12.0	11.0	12.4
VI	7.5	9.2	9.0	8.6	12.5	11.6	9.3	11.1	13.0	11.2	11.3	11.6
VII	8.5	9.6	9.3	9.2	13.5	11.6	11.0	12.0	15.5	13.6	9.7	12.4
VIII	9.0	9.2	7.7	8.7	15.0	11.6	9.3	11.6	13.5	11.2	15.3	13.6
IX	10.5	10.4	10.0	10.4	12.0	11.6	10.0	11.2	13.5	13.2	13.3	13.2
Average value	9.0	9.2	9.3	9.2	14.5	11.6	10.7	12.0	13.5	12.0	11.3	12.0

The smallest significant difference (P = 0.05),
between grain sizes — wheat 0.6, rye 0.5, *Triticale* 0.6,
between soils — „ 1.1 „ 1.0 „ 1.1,
in the interaction between size and soil — " 2.0 " 1.7 " 2.0.

Table 5

Mean values of energy (mJ) causing the immediate deformations of grain

Soil (micro-field number	Winter wheat—Jana variety				Rye—the AR 3 variety				*Triticale*—the TCL 5/69 variety			
	grain sizes (mm)			mean value	grain sizes (mm)			mean value	grain sizes (mm)			mean value
	2.0	2.5	3.0		2.0	2.5	3.0		2.0	2.5	3.0	
I	3.15	7.99	9.39	6.84	7.89	11.23	16.12	11.75	4.98	10.50	11.66	9.05
II	3.00	6.49	9.83	6.44	10.12	13.89	13.94	12.65	5.81	7.36	9.92	7.70
III	3.63	7.31	11.57	7.50	15.10	12.25	24.59	17.32	8.67	6.63	15.73	10.34
IV	3.34	6.29	9.24	6.29	8.86	12.93	16.07	12.62	6.87	9.68	15.83	10.79
V	4.94	5.18	8.62	6.24	12.25	9.78	15.44	12.49	7.21	13.12	14.47	11.60
VI	2.91	6.54	8.86	6.10	7.12	13.26	15.74	12.04	7.21	9.88	17.57	11.55
VII	2.95	6.78	10.46	6.73	9.88	12.49	17.67	13.35	8.62	11.91	11.52	10.68
VIII	3.19	6.15	7.65	5.66	10.50	12.59	13.55	12.21	6.73	9.92	21.40	12.68
IX	4.07	7.07	11.42	7.52	8.08	11.96	14.09	11.38	5.13	10.94	20.23	12.10
Average value	3.46	6.64	9.67	6.59	9.98	12.26	16.36	12.87	6.80	9.99	15.37	10.72

The smallest significant difference ($P = 0.05$),

between grain sizes — wheat 0.80, rye 1.22, *Triticale* 1.09,
between soils — „ 1.75 „ 2.11 „ 1.90,
in the interaction between size and soil — „ 2.98 „ 3.66 „ 3.63.

grains and by their origin from different soils. (Table 4). Relative values of the deformations (in %) for wheat grain show a tendency to grow together with the sizes of the grains, while in the case of rye and *Triticale* the deformations are greater than in the case of wheat, and their values decrease with their sizes, for most of the compared mean values. The influence of soil is apparent for all kinds of cereals, though the differences are not so great as was the case during the evaluation of the resistance to deformations. For wheat the values vary from 8.4% (acid brown soil — I) to 10.4% (brown soil proper — IX), for rye from 11.1% (black earth proper — VI) to 14.0% (brown limestone soil — III), and for *Triticale* from 10.8% (acid brown soil — II) to 13.6% (brown soil proper — VIII). Hence it follows that the grains of the particular cereals react differently to differentiated soil conditions.

The value of energy causing the immediate deformations is closely connected with the sizes of the grains. It increases with the thickness of the grains with all the kinds of cereals, and the lowest values are connected with wheat and the highest with rye (Table 5). The influence of soil on this property is considerable similarly as with the evaluation of the other mechanical properties. The extreme values for rye (from 11.38 to 17.32 mJ) and *Triticale* (from 7.70 to 12.68 mJ) correspond to the same soil units as in the case of evaluating the resistance of grain to static loading. In the case of wheat, however, there is no such agreement. The lowest values of energy were noted for grain grown on the brown soil proper derived from silt formations of water origin — VIII (5.66 mJ) and the highest for grain grown on the brown soil proper derived from light loamy sand — IX (7.52 mJ). Though it should be mentioned that it is in the case of wheat that the smallest differences between the mean values occur.

RECAPITULATION

Analyzing the results of the investigations it was found that soil conditions play a very important role in the formation of the mechanical properties of cereals. The changeability of these properties was connected so far mainly with the kinds of cereals, and in the case of more precise evaluations — with varieties. It turns out however that the range of the changeability becomes much wider when the origin of the material is included in the considerations. Hence it is difficult to determine the limit values of the mechanical properties even for varieties if we exclude the whole system of external factors decisively influencing plants, and in consequence their physical properties, the knowledge of which can have a decisive importance fo the optimiza-

tion of all the processes connected with the cultivation and har-
optimization of all the processes connected with the cultivation and harvesting, the transportation, storage and processing of agricultural crops. These problems are also closely connected with the limitation of qualitative and quantitative losses of the reproduction and consumption materials.

On the basis of the obtained results it is possible to assume that soil conditions constitute one of the factors influencing the changeabillity of mechanical properties of cereals. Hénce follow suggestions of extending the complex investigations, comprising a greater number of properties and environmental elements in which the growth and development of plants takes place.

REFERENCES

1. Pieper H.: Das Saatgut, 1930.
2. Řezniček R.: Experimental examination of bond strength of Grain on the Ear. Journal of Agric. Engng. Res. vol 15, 1970.
3. Řezniček R. Patočka K., Kadrmas J.: Pevnost vazby zrna v klasu u pšenice a žita. Zemědělská Technika 17, č. 7, 1971.
4. Skubisz G.: Wyznaczenie modułu Younga źdźbła pszenicy ozimej na podstawie pomiarów polowych i laboratoryjnych (materiały konferencyjne — maszynopis).
5. Szot B.: Metodyczne aspekty oceny wpływu warunków glebowych na zmienność niektórych cech fizycznych ziarna pszenicy. Rocz. Nauk rol. s. D, t. 160, 1976.
6. Szot B.: Wstępna ocena wpływu gleby na dorodność ziarna zbóż. Post. Nauk rol. nr 5, 1973.
7. Szot B., Grundas S., Grochowicz M.: Metodyka określania odporności ziarna zbóż na odkształcenia mechaniczne. Rocz. Nauk rol. t. 70, s. C, z. 3, 1973.
8. Szot B., Grundas S., Grochowicz M.: Metoda określania siły wiążącej ziarno z kłosem. Rocz. Nauk rol. t. 70 s. C z. 4, 1974.

B. Szot

ROLA WARUNKÓW GLEBOWYCH W KSZTAŁTOWANIU SIĘ NIEKTÓRYCH CECH MECHANICZNYCH ZBÓŻ

Streszczenie

Przeprowadzono badania mające na celu ocenę wpływu zróżnicowanych warunków glebowych na zmienność niektórych cech fizycznych ziarna i źdźbła roślin zbożowych. Materiał badawczy pochodził z poletek, które reprezentują 9 różnych jednostek systematycznych gleb, zlokalizowanych obok siebie.

Na podstawie uzyskanych wyników stwierdzono bardzo duży wpływ gleb na kształtowanie się badanych cech.

Współczynniki sprężystości źdźbła wahały się w szerokich granicach, obejmując zakres od 1084 do 3576 N/mm² dla pszenicy ozimej (ród 500/69), od 1234 do 1892 N/mm² dla żyta (ród AR 3) i od 879 do 1331 N/mm² dla *Triticale* (ród TCL 5/69).

Najwyższe średnie wartości siły związania ziarna z kłosem stwierdzono u pszenicy (1,32—2,10 N), najniższe zaś u żyta (0,78—1,22 N), a pośrednie u *Triticale* (1,03—1,80).

Wpływ gleb powodował też zróżnicowanie odporności pojedynczych ziarniaków na obciążenia statyczne i dla pszenicy średnie wartości zamykały się w przedziale od 47,08 do 61,01 N, dla żyta od 87,99 do 98,01 N, a dla *Triticale* od 68,57 do 82,30 N.

Wielkość doraźnych odkształceń ziarna (8,4—14,0%) oraz energii je powodującej (5,66—17,32 mJ) była w znacznej mierze skorelowana z granicznymi wartościami odpowiadającymi obciążeniom.

Б. Шот

РОЛЬ ПОЧВЕННЫХ УСЛОВИЙ В ФОРМИРОВАНИИ НЕКОТОРЫХ МЕХАНИЧЕСКИХ СВОЙСТВ ЗЕРНОВЫХ КУЛЬТУР

Резюме

Были проведены исследования, имеющие целью оценку влияния дифференцированных почвенных условий на изменчивость некоторых физических свойств зерна и стебля зерновых растений. Исследуемый материал происходил с участков, представлявших собой 9 различных систематических единиц почв, размещенных друг рядом с другом.

На основании полученных результатов обнаружилось очень крупное влияние почв на формирование исследуемых свойств.

Коэффициенты упругости стебля колебались в пределах: 1084-3576 N/мм² для озимой пшеницы (род 500/69), 1234-1892 N/мм² для ржи (род AR 3) и 879-1331 N/мм² для тритикале (род TCL 5/69).

Наивысшие средние величины силы связывания зерна с колосом были обнаружены у пшеницы (1,32-2,10 N), самые же низкие — у ржи (0,78-1,22 N), а посредственные — у тритикале (1,03-1,80).

Влияние почв вызывало также дифференциацию устойчивости отдельных зерновок к статическим нагрузкам, и для пшеницы средние величины заключались в пределах 47,08-61,01 N, для ржи 87,99-98,01 N, а для тритикале 68,57-82,30 N.

Величины временных деформаций зерна (8,4-14,0%) и вызывающей их энергии (5,66-17,32 мдж) были в значительной мере скоррелированы с предельными величинами, соответствующими нагрузкам.

Address of the author

Doc. Dr Bogusław Szot,
Institute of Agrophysics, Polish Academy of Sciences,
ul. Krakowskie Przedmieście 39, 20-076 Lublin, Poland