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UTILIZATION OF RESULTS OF INVESTIGATIONS FROM THE RANGE OF THE PHYSICAL PROPERTIES OF PLANTS FOR EVALUATION OF SOME INDEXES IMPORTANT FOR BREEDING

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INTRODUCTION

Common understanding of the necessity of close cooperation of specialists from different fields of agriculture creates a favourable atmesphere for the undertaking of inter-disciplinary investigations both within particular countries and in international cooperation. There is in this cooperation an important place also for agricultural genetics. This branch of science is at present paid much attention to, since the investigation methods it uses allow for solving many breeding problems of high practical significance. In a great simplification it is possible to state that agricultural genetics deals mainly with evaluating the biological variability of quantitative properties, dividing this variability into the heritable and non-heritable parts, and on this basis evaluating the heritability of properties of economic significance. Knowing the variability and heritability of the properties of interest to us it is possible to plan rationally the breeding program and to predict the rate of the genetic advance.

In the works published so far in the field of heritability the most attention is paid to cereal plants, and among them to such properties as the length of stalk, vegetation period, crop yield from one plant and its structure. This is fully understandable, considering the economic importance of this group of plants and this group of properties, and considering the simple technical means enabling the obtaining of results. The undertaking of investigations from the range of quantitative heritability of chemical or physical properties requires appropriate equipment — sometimes difficult to obtain or downright unique — and a close cooperation of a team of specialists with the participation of a geneticist-breeder.

I hope that at the present Conference the priciples of such cooperation will be worked out and that at the next meeting we will be able to discuss the heritability of such properties as for instance the grain-to--ear binding force in different types of cereals, the resistance of different agricultural crops to mechanical damage, the cutting resistance of stalk, etc. This information will be very much needed for the programming of the breeding of new varieties meeting the demands of modern technologies of cultivation, harvesting and processing.

BASIC PRINCIPLES OF THE GENETICS OF QUANTITATIVE PROPERTIES

The majority of properties of plants of economic importance are quantitative properties. These properties are formed under the influence of a numerous group of genes called polimeric. The genes of this group show different kinds of interactions among temselves, sometimes very complex. The broadly understood external environment causes also a specific reaction on the part of the genotypes. And for this reason it is difficult to determine the participation of a single gene in the formation of a quantitative property. Despity all the complexity of the various interactions it is, however, possible, with the help of the appropriate methods of biometric genetics, to separate the heritable and the non-heritable compents of variability.

The total variability of a given property in the investigated population is expressed statistically through phenotypic variance $\sigma^2{}_P$. The phenotypic variance includes the genetic variance $\sigma^2{}_G$, the source of which different kinds of gene action and the non-genetic, that is environmental variance $\sigma^2{}_E$. Through the term environmental variance we should understand the remaining part of the phenotypis variance, not resulting from genetic differences among indyviduals.
From this definition it follows that

$$\sigma^2{}_P = \sigma^2{}_G + \sigma^2{}_E. \tag{1}$$

At proper planning of the experiment it is possible to divide the genetic variance into further compents: additive $\sigma^2{}_A$, of domination $\sigma^2{}_D$ and of non-allelic interaction $\sigma^2{}_N$. The reaction of a population to selection depends mainly from the additive component of the genetic variance.

The evaluation of the phenotypic variance enables the calculation of the very important for breeding coefficient which is heritability. It is not an unequivocal term: it means both the heritability in the broad sense and herbitability in the narrow sense. Heritability in the broad sense informs to what extent the variability of a given property depends on the differentiation of genetic information passing from parents to offspring, and to what extent it results from the various environmental (non-genetic) conditions. This relation can be expressed by the formula:

$$H_{b.s.} = \frac{\sigma^2{}_G}{\sigma^2{}_P}. \tag{2}$$

Heritability in the narrow sense denotes the relation of the additive genetic variability to the phenotypic variability, which can be expressed by the formula:

$$H_{n.s.} = \frac{\sigma^2{}_A}{\sigma^2{}_P}. \tag{3}$$

The additive part of the genetic variability is determined by the accumulating operation of genes. The value of the additive genetic variance is equivalent to the part of variability that is passed from parents of offspring; as a rule it is greater than the domination and non-allelic variances.

Each of the indexes mentioned here has its faults and advantages. The evaluation of heritability in the broad sense ($H_{b.s.}$) is much easier, since it does not require complicated experimental models. For example it is possible to calculate this coeficient for any measurable property in a simple experiment set up with the method of blocks completely randomized, which comprises several genotypes (varieties, lines, or clones). Similarly in the evaluation of $H_{b.s.}$ for early cross-breeding generations it is enough to have measurements for the parent forms (P_1, P_2) and for the cross-breed of the second generation (F_2). The weak point of this coefficient is the fact that the calculated value is often overstated.

For the calculation of heritability in the narrow sense ($H_{n.s.}$) complcated experimental set-ups are necessary. For example the precision of analysis of variance can be increased by the application of routine called the diallelic analysis, which consists in cross-breeding in all the possible directions of many forms differing in a measurable property, and then making the analysis of the offspring. Experiment of this kind is very labour consuming, costly, and not everywhere possible to carry out. In publications concerning the problem range of heritability usually the index in the broad sense is given.

Apart from the heritability evaluation methods based on the analysis of variance of the genetic sources of variability of properties, also other methods are used, those based on either the establishing of the existence of linear correlation between the parent forms and their offspring, or regression b_{yx}, where the independent variable x is the earlier level of a property in every of the investigated individuals, and the dependent variable y is the later level, in two subsequent years. This last method can have application for many years plants, or for species reproducing themselves vegetatively. An extensive review of the methods of evaluation of heritability is given by Płochiński [5].

At the evaluation of heritability the fact should be considered that even at the application of the same statistical methods the index can differ both in different populations or in the same population investigated in different time and place. Despite the differences occuring among populations some properties as a rule show a high, others a low heritability. For instance to the properties showing high heritability for many species belongs the weight of 1000 grains and the length of the vegetation period; in turn the crop yield from one plant of from area unit is one of the generally low heritability properties. It is obvious that the higher degree of heritability a given property shows the better it is as a basis for selection and the better the chances that the directed selection will give the expected results, that is a cleas breeding (genetic) advance.

Considerable breeding advance of a given property can be obtained if the initial population will show: 1) high heritability H, 2) high phenotypic variability σ_P, and 3) sharp selection k is applied. The k values expressing selection difference in the units of standard deviation are given in appropriate statistical tables. So the formula for theoretical breeding advance resulting from selection carried out every time can be expressed as:

$$G_s = H \cdot \sigma_P \cdot k. \tag{4}$$

The possibility of producting the genetic advance in plant breeding is an unodoubted theoretical achievement of agricultural genetics. But in spite of all the scientific approach plant breeding is also an art. It was very well put by Brewbaker [2], when he wrote: "Few geneticists would disagree that something akin to intuition has made Burbanks out of people who could have not fathomed selection differentials or heritability coefficients".

THE HERITABILITY OF SOME PHYSICAL PROPERTIES OF PLANTS ON THE EXAMPLE OF WHEAT AND HOP

In publications concerning the heritability in cereals the most attention is paid to common wheat, which is fully justified by the economic importance of this species. Of the physical properties of interest to us the weight of 1000 grains is relatively well known, an important component of the structure of crop yielding. The majority of authors point to a high degree of genetic determination of this property; H quite often exceeds 50%, and sometimes even reaches 90% [1, 3, 6, 8]. This is also confirmed by my investigations (Table 1). Because of the relatively low

Table 1

Mean M, standard deviation δ, coefficient of variation W, heritability H and genetic advance G_s for F_2 winter wheat (line Z-70 c cv. Kaukaz)

Characters	M	δ	W	H	G_s
Grain resistance to static load (N)	83.2	11.755	18.6	0.784	30.1
1000 kernel weight (g)	37.7	5.229	13.9	0.567	16.2
Hardness (%)	16.7	5.8[illegible]8	35.1	0.389	28.2
Protein content (%)	13.7	1.572	11.5	0.402	9.5

Coefficients of correlation:
1) grain resistance to static load × hardness $r_{xy} = 0.537^{**}$,
2) 1000 kernel weight × hardness $r_{xy} = 0.358^{**}$,
3) 1000 kernel weight × grain resistance to static load $r_{xy} = 0.316^{**}$.

dependence of the weight of 1000 grains from the external conditions the thick grain varieties ensure a considerable stability of crop yielding. In contemporary breeding of intensive wheat varieties this property is paid much attention to, just next to the number of grains from area unit.

Among the very important, but still relatively little known, properties we should include the resistance of grain to permanent deformations. As follows from the investigations of the Institute of Agrophysics of Polish Academy ow Sciences in Lublin [9, 10] in relation to this property there occur considerable differences between the varieties of winter and spring wheat, even at same geometrical parameters of grain. This indicates the genotypis separateness of the analysed varieties.

In literature available to me I have not met any mentions about the heritability of this property. Therefore I will base only on the results of investigations carried out in the Institute of Plant Breeding and Seed Science of the Agricultural Academy in Lublin in close cooperation with the mentioned Institute of Agrophysics of Polish Academy of Sciences. The experimental material was constituted by grain collected in 1973 from two parent forms (P_1 — Z-70 line, P_2 — cv. Kaukaz) and from the second generation of this cross-breeding F_2. The number of the investigated plants was: P_1 — 25, P_2 — 25, F_2 — 100. Within each plant 10 measurements of the force causing permanent deformation of grains of the thickness of 2.6—2.8 mm were made at a constant moisture of about 11%. The measurements were made on prototype apparatus [10]. The heritability in the broad sense was calculated on the basis of the method of Mahmud and Kramer [4], using raw data. For the calculation of the genetic advance the selection coefficient of 5% ($k = 2.06$) was adopted.

Results of the calculations presented in Table i indicate that this prcperty is quite applicable for selection. The high heritability ($H = 78.4\%$) at a considerable phenotypic variability ($W = 18.6\%$) combined into giving a very high hypothetical genetic advance — over 30% of the mean population of F_2. This means that choosing for further breeding 5% of the best plants we should expect in F_3 an average increase of the value of this property by another 30%. A somewhat similar value of the genetic advance (28.2%) was found for the glassiness of grain, a property quite clearly correlated to the resistance to mechanical damage. For booth these properties the calculated coefficient of phenotypic correlation was $r_{xy} = 0.537$. Kolowca and Ślipek report the significant correlation of the two properties (abstracts of papers for the Conference).

Apart from the typically physical properties of grain, the heritability of the protein content determined with the DBC method was also analyzed in the discussed cross-breed material. This property showed the mean level of heritability ($H = 40.2\%$) and a relatively little changeability ($W = 11.5\%$); the calculated genetic advance was of the order of 9.5%, which for this impo tant qualitative property should be considered significant. A significant correlation between the protein content and the remaining three physical properties of grain was not proved.

A FEW REMARKS ON THE SUBJECT OF HERITABILITY OF PHYSICAL PROPERTIES IN HOP

An ideal for mechanized harvesting hip variety should be characterized first of all by weak binding of cone to sprout, and by a high elasticity of the bracteoles and the by medium size spherical cones.

The differentiation of varieties from the point of their applicability to mechanized harvestng is known in practice [7]. Some of them give minimum of losses in the optimum term, other ones quite considerable. Undoubtedly lower losses occur in varieties characterized by a weaker bond of cones with sprout. This property (beside many others) was the subject of two year investigations (1974—1975) carried out by the author on rather numerous material (90 plants) of cross-breeding origin (cv. Nothern Brewer x Polish variety). The considerable heritability ($H = 55.3\%$), understood as a coefficient of repetetiveness between the years, seems to indicate a possibility of successfull selection in the direction of easy plucking of the cones. The property in question did not show correlations with other properties of economic importance (crop yield, technological value), which can considerably simplify the obtaining of productive varieties of high technological value and at that applicable to mechanized harvesting.

In the present paper I pointed out only some problems from the border area between the agrophysics of agricultural crops and the agricultural genetics. Many things of methodological character require determinations in problem teams for the division of tasks to emerge and for the results to be comparable. And one more thing — it should be wished that the beautiful prototypes of measuring apparati be finally produced in long series and find their way also to posts dealing with the creation of new varieties of cultivable plants. Indisputable is the opinion of the editors of the American edition of the series „Foundations of contemporary genetics" that "Genetic research is alive with excitment and revolutionary advances" [2].

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