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Some Tensile and Bending Characteristics of Wheat Stalks

INTRODUCTION

During almost all technological processes agricultural products are exposed to different mechanical loads which are accompanied by deformation. This must be either sufficiently great (for cutting, pressing etc.) or sufficiently slight in order to avoid damage (harvesting of vegetables and fruits). Consequently, the mechanical strength of products here plays an important role. A large variety of agricultural products, their complex biological structure, constant changes in mechanical and physical properties render it difficult or impossible to find general rules determining the behavior of these materials effected by loading [1]. For instance, mechanical properties of the same potato or wheat variety depend on the vegetation stage, weather and soil conditions, on their storage duration, temperature and moisture during measurement. Thus, designers of agricultural machines may have used, so far, results of experimental studies which have been often performed at random.

The paper presents the results of studies on the mechanical properties of wheat stalks during tension and bending including the effect of fertilization and stage of plant vegetation. This paper is part of a large-scale research project focusing on mechanical properties of cereal stalks [2,3].

METHODS OF INVESTIGATIONS

Studies were carried out on stalks of Polish Jara wheat (*Triticum aestivum L. var. Lutescens cv Jara*). The wheat was cultivated on experimental plots with differentiated nitrogen fertilization: 50, 100 and 150 kg of pure component per ha, respectively. Doses most frequently used are 80–100 kg/ha. Potassium and phosphatic fertilization was constant. Each fifty stalks were collected during milk,

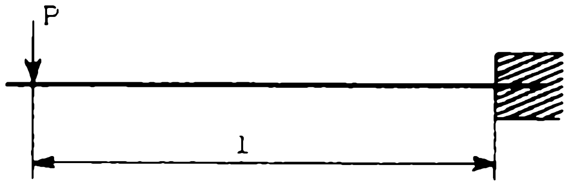

Fig. 1. Load diagram of sample

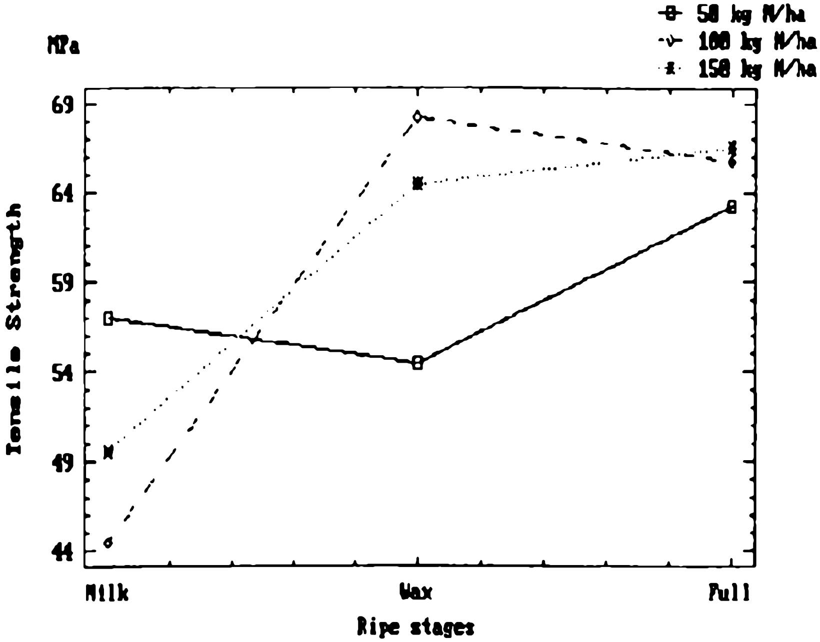

Fig. 2. Influence of fertilization on tensile strength

wax and full ripeness. Samples were cut from the middle of the second internode below the ear. As it is well known, it is this part of the stalk that most often gets damaged, e.g. due to lodging [4].

The tensile test was applied using the ZT-100 tensile testing machine. The samples were fixed in flat, rubber-protected clamps, so they could not be damaged by them and most often breaking took place in the part between the clamps and not in the clamps themselves. From the tensile test the tensile strength Rm was determined:

$$Rm = \frac{Pt}{A}, \tag{1}$$

where: Rm — tensile strength, Pt — maximum tensile force, A — sample cross-section area.

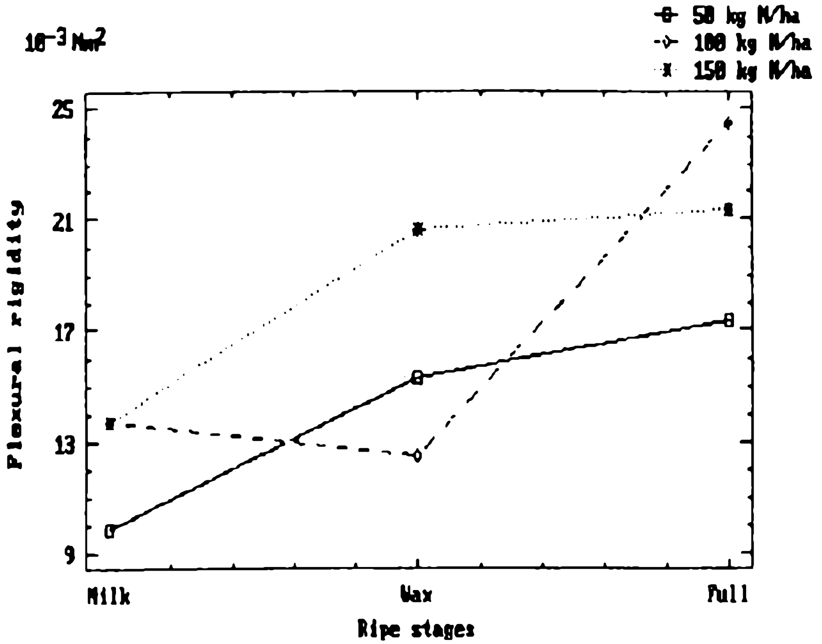

Fig. 3. Influence of fertilization on flexural rigidity

A device constructed by the author was used for the bending test. One end of a sample was fixed in a drill chuck used as a clamp. To avoid crushing the sample by the clamp a 10 mm long steel pin of adequate diameter was inserted into the part of sample to be fixed. To the free end of a sample a piece of thread was attached and connected with a strain gauge force transducer. The measuring range was 0–1 N, its accuracy 0.05 N. Deflection of the sample at the point of load, that is to say, displacement of the free end of the sample was measured by means of a microscope with a measuring eye piece with accuracy of $2 \cdot 10^{-6}$ m. It is a simpler method, less time-consuming than the previously used method of holographic interferometry [5] and laser speckle photography [6]. That is why it was possible to make measurements in 50 repetitions, however at the cost of measurement accuracy. Holographic interferometry and laser speckle-photography enable the measurement of sample deflection with higher accuracy.

Samples were preloaded with 0.1—0.2 N and then loaded with main load ranged 0.3–0.6 N. Fig. 1 presents the load diagram of the sample. For the sample loaded in such a way the relationship between deflection and load is the following:

$$f = \frac{Pl^3}{3EI}, \tag{2}$$

f — deflection at a point of load, P — load, l — gauge length of sample (from the

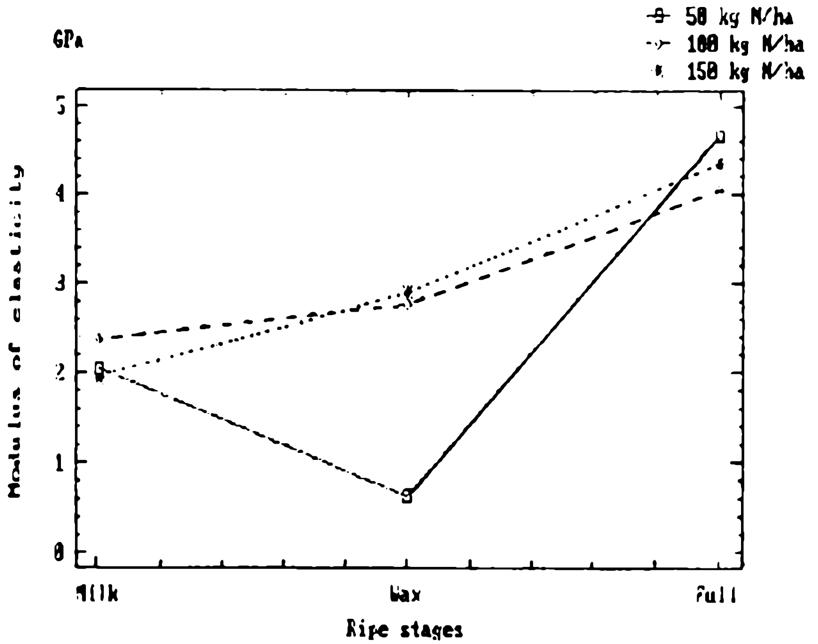

Fig. 4. Influence of fertilization on modulus of elasticity

fixed end to the point of load), E — modulus of elasticity, I — moment of inertia of the sample cross-section area.

Transforming formula (2) the stalk modulus of elasticity E was calculated:

$$E = \frac{Pl^3}{3fI}, \tag{3}$$

and flexured rigidity EI (product of modulus of elasticity and moment of inertia):

$$EI = \frac{Pl^3}{3f}. \tag{4}$$

Accuracy of the values calculated from the formulae (1–3) depends, to a large extent, on the accuracy of determining the cross-section area and the moment of inertia. Accurate calculations would be very difficult due to the geometrically complex shape of this cross-section. It has been assumed that the cross-section of a stalk is shaped like a solid circular ring. The moment of inertia of such a cross-section can be calculated from the formula:

$$I = \frac{\pi}{64}[d_o^4 - d_i^4], \tag{5}$$

where: d_o — outside diameter, d_i — inside diameter.

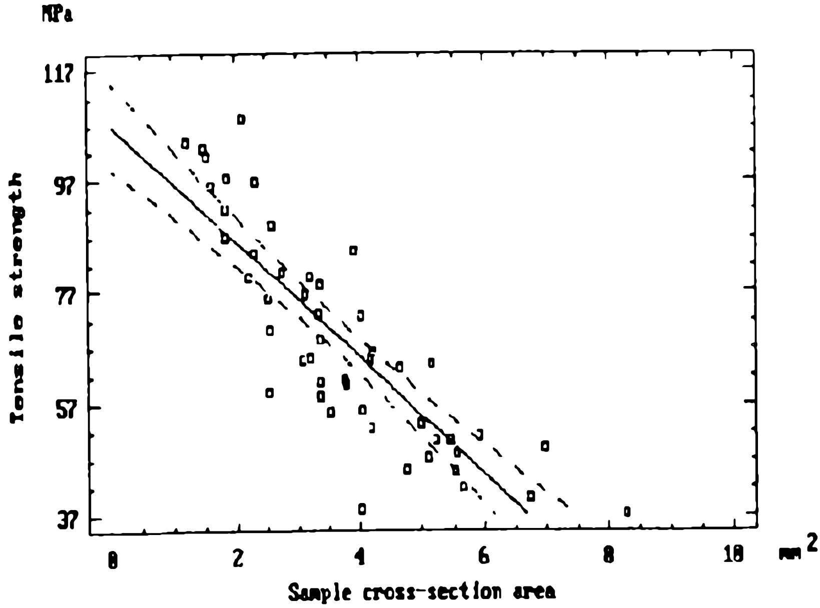

Fig. 5. Regression of tensile strength on sample cross-section area. Dashed line — 95 percent confidence interval

Certainly, accepting such an assumption is highly approximative. In fact the cross-section is filled with various materials of cell structure and if one can talk about the solid material it is only possible to talk about cell walls, which is again highly approximative.

Most often, results of studies on mechanical properties of agricultural products are used for comparative purposes (comparison of varieties, effect of fertilization etc.). Then, such simplification can be allowed.

RESULTS

Graphs in Fig. 2÷4 present the dependence of stalk mechanical properties on fertilization level and on vegetation stage. Tensile strength (Fig. 2) reaches its highest values at full ripeness (except fertilization 100 kg/ha). The effect of fertilization is different at each stage. It is statistically not significant at full ripeness. Likewise, flexural rigidity (Fig. 3) and modulus of elasticity (Fig. 4) reaches its highest values at full ripeness. The effect of fertilization on modulus of elasticity is small.

An interesting dependence has been observed, common to all the stages and fertilization levels, namely: tensile strength and modulus of elasticity are the higher the smaller is the sample cross-section area. For isotropic, homogeneous materials e.g. steel and other metals such a dependence does not occur. It can be said

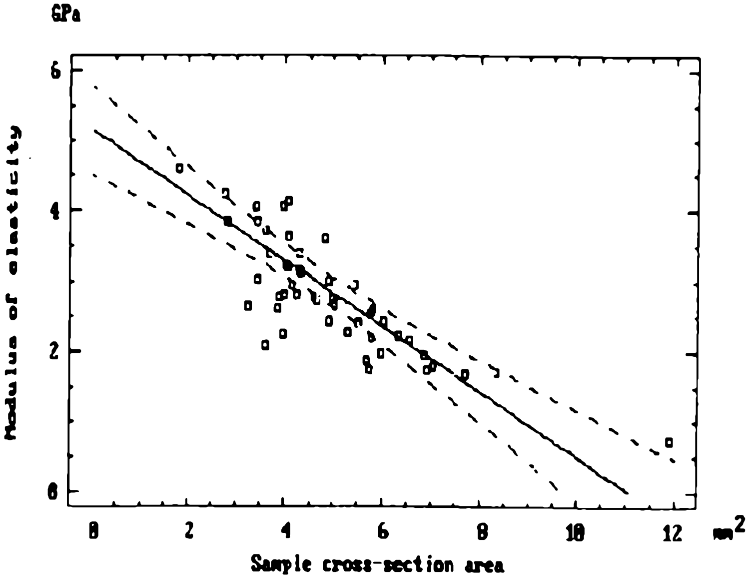

Fig. 6. Regression of modulus of elasticity on sample cross-section area. Dashed line — 95 percent confidence interval

that nature "makes up" material deficiency with its quality. The above-mentioned dependence is more conspicuous with regard to tensile strength (Fig. 5) — the coefficient of determination (R-squared) ranges from 0.45 to 0.75 — than with regard to modulus of elasticity (Fig. 6) — coefficient of determination ranges from 0.25 to 0.45. Both graphs, as an example, show the results for wax ripe stage and 100 kg N/ha fertilization level.

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