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THE DETERMINATION OF PHYSICO-MECHANICAL PROPERTIES OF THE SEEDLINGS

BY

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Abstract. In the process of transplanting the seedlings are subject to various mechanical tests, especially when in contact with the working bodies of the planting machines and thus can suffer severe injury that can slow down their development or even wilting.

To avoid these drawbacks it is necessary to determine the maximum efforts that the plant can withstand. The solution to this problem is given by the theory of elasticity used in the strengths of materials, if the seedlings are treated, like other plants, as natural composite materials.

Therefore it was determined that the seedlings may have the value of the longitudinal modulus of elasticity between 41.93 and 63.43 MPa (except for cabbage with 200.19 MPa) and a specific resistance to crushing of over 0.2 N/mm, which means that the maximum compression force that the seedling can withstand in the working process without being injured can be around 4-5 daN.

Key words: vegetable production, seedlings, composite materials, elasticity module, crushing resistance.

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1. Introduction

Establishment of crops by planting seedlings produced in greenhouses and solariums is a necessary objective, providing the following advantages:

getting extra early and early productions safe and constant; scheduling the production and consumption of fresh vegetable products; possibility of sorting material quality, planted with selected and uniform plants; lowering the seeds quantity for a surface; shorten the length of occupancy of the land by plants, offering the possibility of making successive crops and, especially, to extend the area of cultivation for heat demanding plant, giving the opportunity of growing vegetables and in colder areas etc.

Manpower requirements for this sector of agriculture is very high up to 130-140 days-man/ha crop, and where the establishment is done by seedling culture is more added 30-50 days-man/ha for seedling preparation.

Production and planting of seedlings is very beneficial, but it is necessary to reduce the consumption of manpower and supplementary expenses by mechanical planting.

By automating the planting operations the usage of manual work is reduced by 3-4 times, increases productivity, allowing planting in the optimum, uniform distribution of plants per row, the rows being straight and equally distant is making it possible to be mechanically worked.

For optimizing the planting machineries is necessary to study the existing systemic correlations between the agro-biological characteristics of the seedlings, constructive and work parameters of the machines and physical-mechanical properties of the soil that influences the working quality indicators and energy related indicators.

The trials regarding the mechanical characteristics of the seedlings took place in laboratory conditions, were verified in the field and were composed of the determination of: dimension characteristics of tomatoes, peppers, eggplant and cabbage seedlings; coefficients of static friction and dynamic for slipping and rolling over of seedlings on surfaces covered with steel board, rubber and plastic; elasticity module and resistance against crushing of seedlings; soil characteristics from the stationery channel; constructive parameters of the machine; quality indicators; energy and economical indicators of the planting process (Balan, 1998).

In this paper are presented the results obtained for determination of the elasticity and resistance against crushing of seedlings.

2. Experimental Procedure

2.1. Work Procedure and the Equipment Used for Determining the Longitudinal Elasticity

In the planting process the seedling are exposed to mechanical factors and for avoiding damages is necessary to determine the maximum efforts that the plant can withstand.

For an efficient calculation of the material resistance, in general, and seedlings in particular, it must be known the elasticity module to determine the tension, relative displacements and deformations based on the general theory of elasticity from material resistance. In order for the material not to suffer irreversible deformation is necessary to know the applied forces, shape conditions and the elastic constants of the material: longitudinal elasticity module *E*, transversal elasticity module *G* or transversal contraction coefficient υ.

For the researches completed in material resistance it was established that steel, wood,cereal stems and cashcrop plants are following Hooke's law being considered natural composites.

Agricultural materials in general, are defined through a more vaste area of variation of the mechanical charactheristics and have a much hugher number of factors that could influence the charactheristics of a specie and even of a variety.

This being said seedlings, like young plants, with a high content of water and smaller size that adult plants, may be applied the same methods like for mature plants like determination of logitudinal elasticity module:

− Through the bending method, considering the sample lenght 1 and inertia moment $I_{z,}$ simply leaning at both ends and charged at the middle with a concetrated force.

− Through the vibration method, considering the same lenght sample 1 and the inertia moment I_z embedded at one end and loaded with a concentrated charge *F* on the loose end and subject of a state of oscilation, (Balan *et al*., 1997).

The working method is establishing in an analytical way a relationship that allows calculating the longitudinal modulus of elasticity *E*.

When using the first method is considered (Fig. 1) a sample 1 of lengths *l* simply leaned on both sides on the bearings 2 and 3, to which is applied in the middle a load 4 placed on the pan 5.

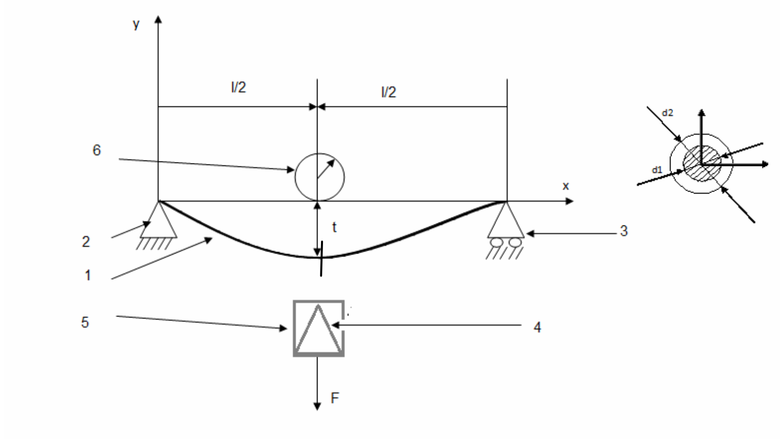

Fig. 1 − Diagram for determining modulus of elasticity by the method of the simple bar leaning in the middle loaded with concentrated changers.

Under the action of the load $F = mg$, the sample is deformed by an arrow f that is measured by a clock 6.

It is known that the deformation f, at the middle of the sample under the action of force F is given by:

$$f = \frac{Fl^3}{48EI_z}, \quad [\text{mm}] \tag{1}$$

where: I_z is the axial moment of inertia.

Assuming that the test sample is a cylindrical bar, with homogenous structure, of diameter $d = (d_1+d_2)/2$ we can calculate the moment of axial inertia:

$$I_z = \frac{\pi d^4}{64}, \quad [\text{mm}^4] \tag{2}$$

Replacing the axial moment of inertia from 2 in relation 1, is determined the modulus of longitudinal elasticity E by the relation:

$$E = \frac{64Fl^3}{48\pi fd^4}, \quad [\text{MPa}] \tag{3}$$

If the sample is loaded with small loads ΔF_i below the limit if proportionality and the deformations Δf_i are measured, the modulus of elasticity is measured:

$$E = \frac{l^3}{48 I_4} \frac{\Delta F_i}{\Delta f_i} = k \frac{\Delta F_i}{\Delta f_i}, \quad \text{[MPa]} \tag{4}$$

where: ΔF_i is the load variation between an attempt and another, [N]; Δf_i − the increasing the arrow at a variation of the load F, [mm], read on the clock (for the samples with the same average diameter)

When the sample is downloaded, the clock is read again to check if the load was made in an elastic domain, meaning at the total discharge the sample came back to its initial shape. The samples were obtained from seedling sections with the section approximately constant along the length 1 between the two supports.

2.2. Working Methods and Devices Used for Determining the Force of Resistance to Crushing of the Seedlings

In the process of planting, the seedling is tested in general, at the compression force with which the mobile blade of the catcher presses the seedling on the fix blade, in order to keep it fixed in relation to the catcher, in the process of transportation from the supply point until the release in the gutter open by the clutch.

To determine the maximum force that the seedling can support in the working process without being injured, this is tested with known forces before planting or during vegetation.

Determination of the resistance to crushing of the seedlings before planting is performed by the following method:

− Choose lots of seedlings from the same species and variety and of the same size;

− Measure the stem diameter at 2cm from the root and at a distance equal with the width of the catcher;

− Samples are required on the compression with known forces on a length equal to the width f the catcher. A lot for a sample is made out of three seedlings and the application force F grows from a sample to sample with 1N. Each seedling is marked with a plastic ring where is written the applied force;

− The seedlings are planted in order, in the same environmental conditions;

− The seedling development in time is monitored.

For the seedling that the resistance to crushing was higher than the limit, will wilt.

The parameters that influence the resistance to crushing are: variety, species, package diameter, nature of the surfaces in contact, duration of the application, seedling moisture etc. The attempts have to be repeated in order to check the influence of each parameter.

The specific resistance to crushing or the contact tension R_s is determined with the Hertz relationship, considering the form of the shapes in contact a cylinder of radius r on a flat surface:

$$R_s = \sqrt{\frac{1}{2\pi}\frac{FE}{lr}}, \qquad [\mathrm{N/mm^2}] \tag{5}$$

The form of the contact area is a rectangle of lengths equal with the width l of the catcher and the width b determined with the following relationship:

$$b = \sqrt{\frac{8Fr}{\pi lE}}, \quad [\mathrm{mm}] \tag{6}$$

To perform the tests it was used a device that is consisting of a modified balance (Fig. 2) where under the tray where the loadings can be added (adjustable height) is placed the sample on a table having the same dimension as the catcher.

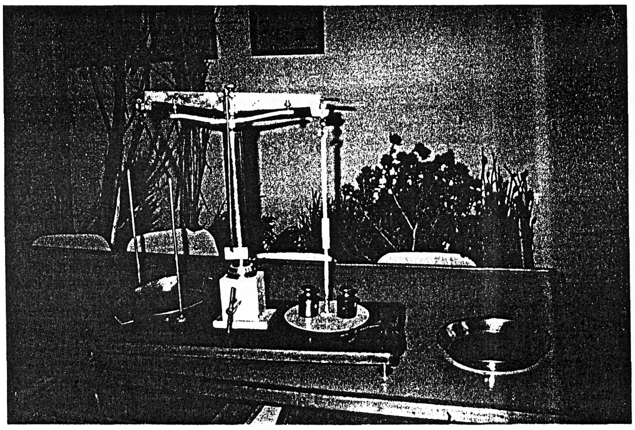

Fig. 2 – Modified balance.

The advantage of the method is that the sequence of operations of the planting process is followed.

To check the accuracy of the calculation of the elasticity module and the validity of the laboratory trials the force of resistance for seedling crushing was determined.

Through this method determinations are made on planted seedlings rooted already, 2 days after planting.

The force increases until it reaches the value of crushing the seedlings when the seedlings are dying. Another option would be that on the trial plot to be loaded differently the seedlings with forces varying with 1N.

The first option has the disadvantage that the trial period increases very much but is precise. Both options of this method don't follow the right sequence of the operations.

For the practical testing of the trials is necessary to build a mobile device to load the samples with known variable forces (Fig. 3).

The mobile device to determine the force of resistance for seedling crushing is compose out of a motherboard (1) on which a support pillar (2) is mounted which can be rotated on horizontal plane, mounting it on the desired position with the help of the screw (3).

On the pillar (2) you can mount, in a certain position, a measuring device with the screws 4 and 5.

The measuring device is built out of a fixed board (6), a mobile board (7) on which an arc is supported at an end. On the other end of the arc an indicator (9) is mounted that can slide on a scale line (10), mounted on the motherboard. The measuring device is supported by a central shaft (11) that is sliding through the mobile board and the arc and is reinforced on the board where the indicator is mounted. On the shaft (11) you can mount a calibration device built out of a cable (12), pulley (13) and a weight platter (14) or a loading device built of a screw (15), a lever (16) and a bolt reinforced on the shaft (11).

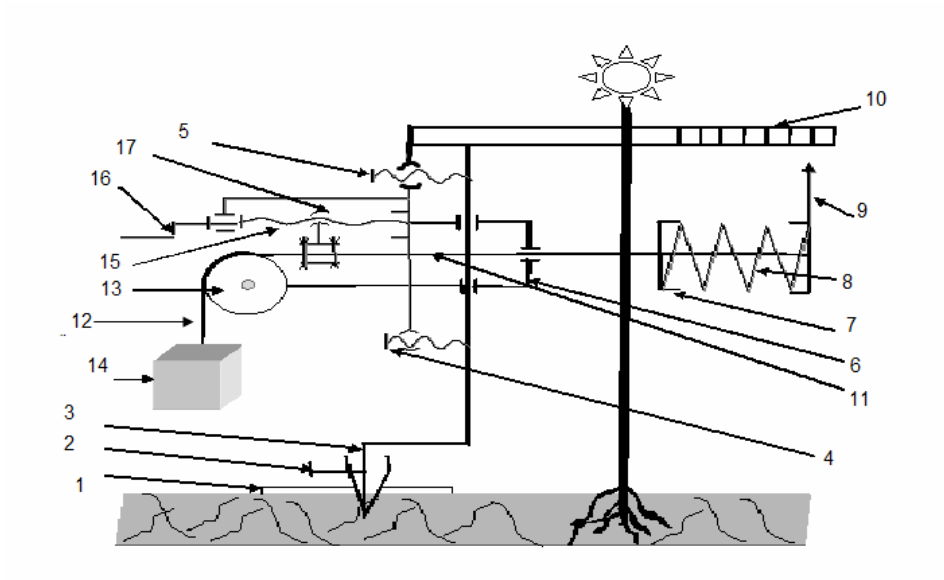

Fig. 3 − Mobile device to determine seedling crushing resistance.

The calibration of the measuring device is done in the laboratory on in the field and has the role of establishing the movement of the indicator towards the scaled line for different known tasks.

For conducting the trials, the device is positioned next to the seedling, usually on the irrigation row. The measuring device is positioned in the seedling loading area.

The bolt of the loading mechanism is engaged on the dynamometer axis, the mobile board is approached to the seedling and once it is well caught between the two boards, the indicator is positioned against the 0 mark on the scaled line by moving the scaled line.

The diameter of the seedling is measured on the both ends of the board and the lever is rotated, exercising the desired pressure on the seedling.

The trial is made on a 10 seedling with similar characteristics. Once the observation period has passed the trial is repeated with forces higher and higher until the seedlings die.

3. Experimental Results

From the data analysis obtained in Table 1, mean values for 10 samples of each variety, the conclusion is that the elasticity module of seedlings has very low values compared with other plants mainly due to higher seedling moisture.

Tomato, pepper and eggplant seedlings have similar longitudinal elasticity values compared with cabbage seedlings which is 3-4 times higher.

The following elasticity mean values and respective variations were determined: tomato seedlings 56.54 MPa with −27% to +38%; pepper seedlings 41.93 MPa with −21.3% to +29.8%; long pepper 46.62 MPa with −31% to +31.5%; eggplant seedlings 63.7 MPa with −26.5% to +25.5% and cabbage seedlings 200.19 MPa with −28.12% to +35.8%.

Table 1

Physic-Mechanical Properties of Seedlings

Sample (species)	U [%]	d [mm]	I_z [mm^4]	F [N]	f [mm]	E [MPa]
Tomato	85.2	3.24	5.9091	0.0196	1.005	56.54
Green pepper	87.95	2.46	2.02	$19.6\text{x}10^{-3}$	3.06	41.93
Long pepper	86.6	2.87	4.35	0.042	3.98	46.02
Cabbage	85.2	3.38	6.93	0.049	1.45	63.47
Eggplant	82.9	4.4	24.77	0.22	1.99	200.19

Tomatoes, peppers and eggplants have medium values for stem diameter and similar longitudinal elasticity module values. For the 4 varieties the mean elasticity module value was 51.99 MPa with tomatoes 8.7% higher, peppers with 19% lower, long pepper with 11.5% lower and eggplants with 22% higher.

Samples from cabbage seedlings have a mean elasticity module value higher than the other varieties (4 times higher), due to the different vegetation phase (cabbage is sown earlier) and also due to it's lower moisture level.

It can be stated that the determinations are accurately performed and the variations are acceptable. Physical-mechanical properties of seedlings are different for the same variety and species due to vegetation phase, moisture/humidity and all the other factors influencing the development stages.

The humidity of the sample influences the module's elasticity. This way, once the moisture of the seedling decreases, the value of the longitudinal elasticity of the module increases, so with the maturation of the seedling, it's resistance to crushing is higher.

Determining the specific force of resistance to crushing of the seedlings was done in two situations: with unplanted seedlings (V1) and during vegetation (V2).The data obtained (Table 2) shows that the tomato and eggplant seedlings withstand a compression force of 4 to 5 daN, without the plant to suffer in the development process.

Tomato seedlings can withstand a compression force of 45.148 N with a range from −9.18% to +15.17% if required before plating and an average force of 48.082 N with a range from −11.96% to +10% if they are subject to compression after planting.

Table 2

The Limit Force of Crushing the Seedlings, F_s

Specia	d_m, [mm]		S, [mm^2]		F_s, [N]	
	V 1	V2	V 1	V2	V 1	V2
Tomato	3.2	2.99	186	173.4	45.148	48.08
Cabbage	3.37	3.59	202.2	215.4	46.832	49.06

Depending on the section required, it was determined the specific resistance to crushing, reporting the force to each section and obtaining in the first case the average value for tomato of 0.2496 N/mm^2, with variation limits of +3.5% and −13.71% and in the second case values of 0.2886 N/mm^2 with variations from +12.43% to −11.8%.

For the eggplant seedlings tried before planting the value obtained are: average value of the maximum crushing force of 46.832 N with variations from −11.7% to +13.17% and an average value of 49.065 N with a range from −11% to + 8% for the test seedlings during vegetation.

One can determine the limit force of crushing the seedlings, F, and the specific resistance to crushing [N/mm^2] also for other species for which we have determined the value of the modulus of elasticity.

The specific resistance to crushing when trying the seedling before planting is 0.2318 N/mm^2, with a variation 13.71% to +3.5% and an average value of 0.2268 N/mm^2 with a range from −11.8 to +12.43% in the second case.

The eggplant seedlings withstand a compressive force slightly higher than tomato seedlings and the specific resistance value to crushing is smaller because the average diameter in this case is greater.

To eliminate the risk of injury of the seedling during planting process is recommended that the value of the pressure force on the mobile blade of the catcher to be lower than the average value of the limit force (F_m) determined in Table 2 with 20-25%.

4. Conclusions

Including also seedlings together with cereals stems and technical plants, in the category of the natural composite materials that respect Hooke's law, one can determine the mechanical characteristics using knowledge of the strengths of materials.

This paper presents the working method for determining the module of elasticity and resistance to crushing of the seedlings and the final results.

The longitudinal modulus of elasticity for the seedlings was determined using the bending method, considering the sample of length l and the moment of inertia I_z, simply leaning on both ends and loaded in the middle with a known concentrated force where the formed arrow is measured.

The maximum force that the seedling can withstand without being injured was determined. This is tested with known forces before planting or during vegetation and with the help of Hertz's rule, the specific resistance to crushing or the contact pressure is calculated.

Further research is needed to determine to which extent the resistance to crushing is influenced by the variety, species, diameter of the package, nature of the contact surface, testing duration, the moisture of the seedling etc. The attempts must be repeated in order to check the influence of every parameter.

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DETERMINAREA CARACTERISTICILOR FIZICO-MECANICE ALE RĂSADURILOR

(Rezumat)

În procesul de transplantare răsadurile sunt supuse la diferite solicitări mecanice, mai ales în contactul cu organele de lucru ale maşinilor de plantat, şi în acest fel pot suferi vătămări severe care pot încetini dezvoltarea lor sau chiar ofilirea. Pentru a evita aceste neajunsuri este necesar să se determine eforturile maxime pe care planta le poate suporta. Soluția pentru rezolvarea acestei probleme este dată de teoria elasticității utilizată în rezistența materialelor, dacă răsadurile sunt asimilate, ca şi alte plante, materialelor compozite naturale.

Astfel s-a determinat că răsadurile pot avea valoarea modulului de elasticitate longitudinal între 41,93 şi 63,43 MPa (excepție fiind varza cu 200,19 MPa) şi o rezistență specifică la strivire de peste 0,2 N/mm^2, de unde rezultă că forța maximă de compresiune pe care răsadul o poate suporta în procesul de lucru fără ca să fie vătămat poate fi de 4-5 daN.