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METHOD FOR DETERMINING LINEAR DENSITY OF CROP PLANT ELEMENTS

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Summary. Method for determining linear density of crop plant elements enabling to define their inertia parameters has been offered. This method permits to improve accuracy of process modeling related to spatial movement of plant elements with diverse forms and inhomogeneous structure when they are planted or excavated. The analytical and experimental procedures of the method have been given. The inertia parameters of different types of fruit crop stocks taking into account their linear density have been determined.

Keywords: linear density, mass, static moment, inertia moment.

Problem statement. One of the basic parameters you need to consider when developing mathematical models of the processes connected with planting or excavating plants of crops (sugar beet, potatoes, tomato seedlings, stocks, saplings, etc.) is their mass, static moment and inertia moment. For modelling such the objects, the initial dependences are being derived from physical, biological and other regularities describing their functioning. In our case this is agricultural plants elements moving from a starting position into defined one. It is possible to increase accuracy of moving processes modelling in the space of plant elements having various forms and non-uniform structure by means of calculating of the parameters of their inertia taking into account linear density. Therefore, obtaining the dependences characterizing linear density change of plant elements is the actual task.

Recent researches and publications analysis. Present researches, in which analytical methods of parameters defining of inertia for simple and complex bodies have been described, can be applied mainly for calculating and designing machines and mechanisms parts [1,2]. When defining the inertia parameters of crop plant elements it is possible to apply physical pendulum technique [3]. Therefore, in paper [4] the inertia moment of tomato seedlings was being defined by “swing” method. For this purpose, the mass of seedling and the distance from the gravity center to plant root system was being defined. Then the plant was suspended by root system by means of thread of a certain length, deviated from vertical on the given angle and was let off. The oscillation period thus was defined and the required moment of inertia was calculated. In paper [5] when substantiating the parameters of working tools of the beet-harvesting machine the theoretical method of defining the moment of inertia for root crop of sugar beet relatively to its axes has been offered. It is also necessary to take into account the mass and length of root crop cone part in the sample. If the body is homogeneous it is possible to calculate precisely its moment of inertia, having presented a body as a limit of the sum of infinitely large number of products of infinitesimal elements of *dm* mass per square of their distance from the axis [1]. In this case definition for the moment of inertia of a body is being calculated as a volume integral.

$$J = \int_m r^2 dm = \int_V \rho r^2 dV , \qquad (1)$$

where $dm = \rho dV$ - mass of a small element of dV body volume;

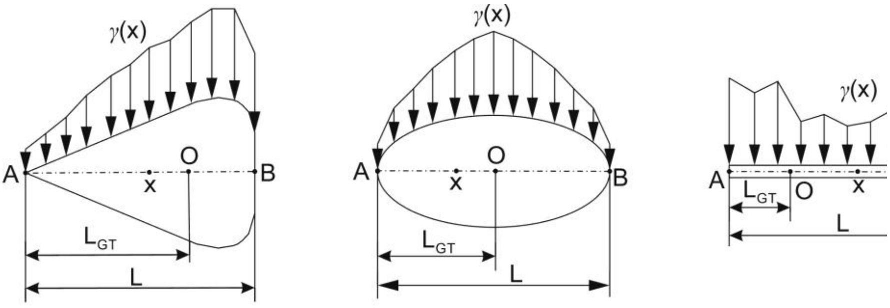
ρ - body density;

r - distance from dV body element to the axis.

It is difficult to calculate precisely the moment of inertia of plant elements by the formula (1), since real bodies don’t have proper geometrical form and homogeneous structure. To consider heterogeneity of plant elements structure, when defining its parameters of inertia, it is expedient to use its linear density change which shows the distribution of body mass along its length.

The purpose of research. To develop the method to determine a linear density of crop plant elements for its further application for defining their inertia parameters.

Main part. Plant elements linear density distribution schemes of various forms are presented on fig. 1.



a) b) c)

A - a conventional point of plant starting; *B* - a conventional point of plant ending; *O* - the plant gravity center; *L*- total length of a plant; L_{GC} – the distance to gravity center; *x* - the current point on a longitudinal axis of plant sectionγ *(x)* - linear density of a plant.

Figure 1 - Plant elements linear density distribution schemes of various forms: a) conical (sugar beet root crop); b) elliptical (potato root crop); c) cylindrical (tomato seedlings, stock or sapling of fruit crop).

Then mass, the static moment and the inertia moment of plant element relatively to p. *A* can be determined by the formulae [1]

$$I_0 = \int_0^L \gamma(x)dx; \quad I_1 = \int_0^L \gamma(x)x dx; \quad I_2 = \int_0^L \gamma(x)x^2 dx, \qquad (2)$$

where *x* - the current point on a longitudinal axis of plant section (fig. 1);

I_0 - mass of a plant, kg;

I_1 - the static moment of a plant relatively to p. *A*, m^3;

I_2- the moment of inertia of a plant relatively to p. *A*, kg $\cdot m^2$;

To define how the plant density is being distributed along its length, in vitro it is necessary [6]:

1) to create the sample of studied plant elements;
2) to define L total length of each plant:
3) to divide physically each plant into n_i parts, with length l_i equal to 20-25 mm;
4) to define m_i mass of each separated element of a plant.

The parameters value of the separated plant parts can be presented in the form of table 1.

Table 1 - The parameters value of the separated parts of plant elements

Number parts, n	Length l, m	Mass m, kg	Linear density γ_i, kg/m
1	l_1	m_1	γ_1
2	l_2	m_2	γ_2
…	…	…	…
n	l_n	m_n	γ_n

Values of linear density for each of parts can be calculated by the formula

$$\gamma_i = \frac{m_i}{l_i}, \tag{3}$$

where γ_i – linear density of the separated part of a plant, kg/m;
m_i – mass of the separated part of a plant, kg;
l_i – length of the separated part of a plant, m.

However, the linear density of the separated part of the plant being calculated on a formula (2) does not display the dependence of its change along a plant length. To determine change of linear density along a plant length its value should be set in the form of function $\gamma^{(i)}(x)$, where x – the current point on a longitudinal axis of plant section (fig.1). This function displays linear density j-plant along the length of a piece from p. A, the argument of which is the dependence Ax to L. Using the data of table 1 it is possible to set this function in the points: $(l_{1/2})/L;(l_1+l_{2/2})L;(l_1+l_2+l_{3/2})/L$ etc. in such a manner that function

$\gamma^{(i)}(x)$ can be considered equal to values (3) on the first, second and the further pieces (of separated parts).

To define the value of $\gamma^{(i)}(x)$ function in intermediate points is possible by means of linear interpolation [7]. According to this method if f_0, f_1 is value of $f(x)$ function in points x_0, x_1, then function value in other points is being defined by Lagrange formula

$$f(x) = \frac{1}{x_1 - x_0} \begin{vmatrix} x - x_0 & f_0 \\ x - x_1 & f_1 \end{vmatrix}. \tag{4}$$

Using the formula (4), let's set $\gamma^{(i)}(x)$ function in such a form:

$$\gamma^{(i)}(x) = \begin{cases} \frac{2L}{l_1 + l_2}\left(\gamma_2\left(x - \frac{l_1}{2L}\right) - \gamma_1\left(x - \frac{l_2}{2L} - \frac{l_1}{L}\right)\right), \\ if \quad x < \frac{l_2}{2L} + \frac{l_1}{L} \\ \frac{2L}{l_j + l_{j+1}}\left(\gamma_{j+1}\left(x - \frac{l_j}{2L} - \frac{1}{L}\sum_{k=1}^{j-1} l_k\right) - \gamma_j\left(x - \frac{l_{j+1}}{2L} - \frac{1}{L}\sum_{k=1}^{j} l_k\right)\right), \\ if \quad \frac{l_j}{2L} + \frac{1}{L}\sum_{k=1}^{j-1} l_k < x < \frac{l_{j+1}}{2L} + \frac{1}{L}\sum_{k=1}^{j} l_k \\ \frac{2L}{l_n + l_{n-1}}\left(\gamma_n\left(x - \frac{l_{n-1}}{2L} - \frac{1}{L}\sum_{k=1}^{n-2} l_k\right) - \gamma_{n-1}\left(x - \frac{l_n}{2L} - \frac{1}{L}\sum_{k=1}^{n-1} l_k\right)\right), \\ if \quad x > \frac{l_{n-1}}{2L} + \frac{1}{L}\sum_{k=1}^{n-2} l_k \end{cases} \tag{5}$$

To determine an average arithmetic value of linear density being in this case the determined component of $\gamma^{(i)}(x)$ function along relative length of a plant, the formula is used

$$\gamma_{cp}(x) = \frac{1}{N}\sum_{i=1}^{N} \gamma^{(i)}(x). \tag{6}$$

A deviation from average value for each function will be considered as a stochastic component. It will be the standard deviation determined by the formula

$$\sigma(x) = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(\gamma^{(i)}(x) - \gamma_{cp}(x))^2} \qquad (7)$$

The results of research. The offered method has been applied for defining of parameters of inertia of fruit crop stocks. Two types of stocks have been selected for research: pome (M9 apple) and stone – (sweet cherries) stocks..

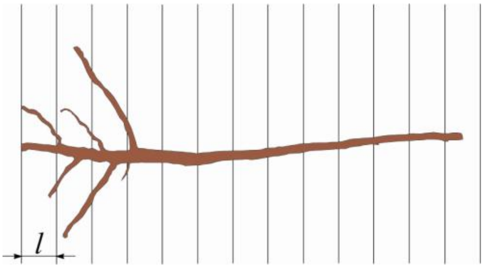
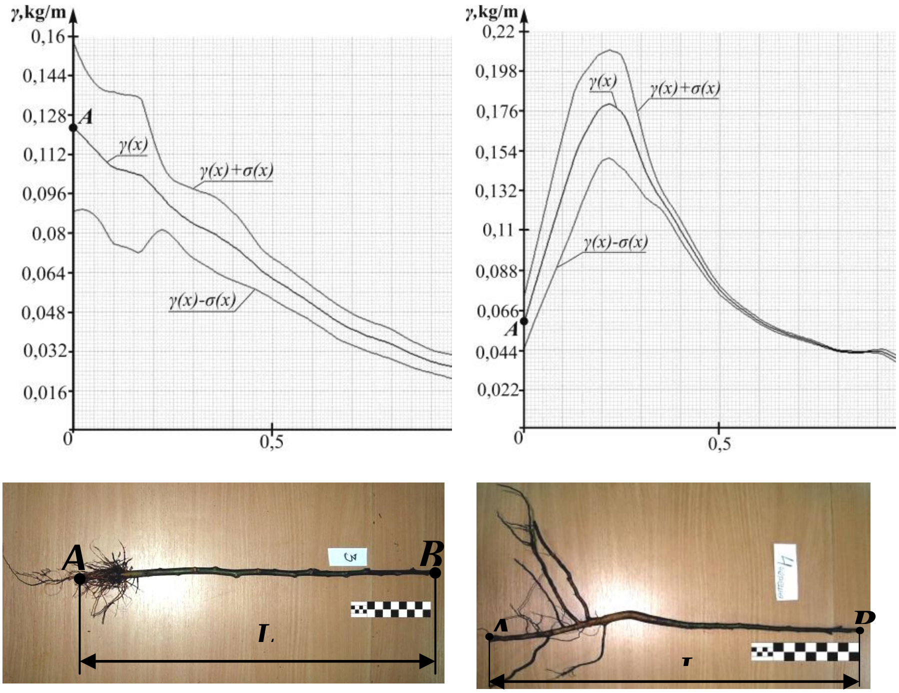


Figure 2 – The scheme of stock separation into parts.

The samples of 50 stock pieces of each type have been formed in such ranges of lengths: for M9 apple stocks - from 400 to 540 mm, sweet cherry stocks - from 450 to 550 mm. *L* lengths of each stock in the sample have been defined as well as l_i lengths (fig. 2) of the separated parts and their m_i massesUsing the formula (4) with the help of software shell Delphi 7 the distribution of the linear density of the stock types under research has been calculated, the graphs of which are presented in Fig 3.

Table 2 - Parameters of inertia of fruit crop stocks.

Stock types	Mass, kg		Static moment, m^3		Inertia moment, $kg \cdot m^2$	
	min	max	min	max	min	max
Pome stocks (M9applestocks)	$23 \cdot 10^{-3}$	$43 \cdot 10^{-3}$	$4 \cdot 10^{-3}$	$8 \cdot 10^{-3}$	$6 \cdot 10^{-4}$	$16 \cdot 10^{-4}$
Stone stocks (sweet cherries-stocks)	$36 \cdot 10^{-3}$	$59 \cdot 10^{-3}$	$12 \cdot 10^{-3}$	$21 \cdot 10^{-3}$	$3 \cdot 10^{-3}$	$71 \cdot 10^{-4}$



a) b)

Figure 3 - Graphs of change for stocks linear density: a) M9 apple - stocks; b) sweet cherries - stocks

Analyzing these dependences, enables to come to conclusion that distribution of linear density depends on a stock type. For pome stocks (fig. 3, a) the density gradually decreases from the root basis (p. A - 0,122 kg/m) to stock top (t. B - 0,022 kg/m). For stone stocks the distribution is different (fig. 3,b). Value of density increases from a root part (p. A - 0,06 kg/m) to gravity center where value of linear density accepts the greatest value - 0,18 kg/m, and decreases further to stock top (p. B - 0,03 kg/m).

Then by the formulae (1) the mass, the static moment and the inertia moment of stocks relatively to root system have been calculated as given in table 2.

The obtained data have been used for mathematical model developing of stock fruit crops planting process by the disk type device [8] possessing probabilistic nature and presupposing the variable mass, the static moment and the inertia moment of stocks calculation.

Conclusions. The offered method for defining linear density of plant elements can be used while determining their inertia parameters and can be applied when developing mathematical models of processes planting or excavating connected with moving plant elements of various crops in space.

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СПОСОБ ОПРЕДЕЛЕНИЯ ЛИНЕЙНОЙ ПЛОТНОСТИ ОРГАНОВ РАСТЕНИЙ СЕЛЬСКОХОЗЯЙСТВЕННЫХ КУЛЬТУР

И.А.Чижиков

Аннотация

Предложен способ определения линейной плотности органов растений сельскохозяйственных культур, с помощью которого можно определить их параметры инерции. Данный способ позволяет повысить точность моделирования процессов, связанных с перемещением в пространстве органов растений, имеющих разнообразные формы и неоднородную структуру при их посадке или выкопке. Приведена аналитическая и экспериментальная части способа. Определены параметры инерции разных видов подвоев плодовых культур с учетом их линейной плотности.

Ключевые слова: линейная плотность, масса, статический момент, момент инерции.