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ASPECTS REGARDING THE AUTOMATION OF THE SEEDLING TRANSPLANTING

THE DEVELOPMENT OF THE PRODUCTION AND AUTOMATIC PLANTING TECHNOLOGY FOR PLUG SEEDLINGS

BY

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Abstract. Worldwide, seedlings automatic transplanting machines are designed, from the operational and economic point of view, for large holdings. In Romania, the share of farm land fruits and vegetables under 2 hectares is over 70%. The aim of this work is the development of a technologie for automatic seedlings transplanting, tailored to our country, in order to include a simple machine construction with extraction, transport and gravitational distribution of the prefabricated plug planting material,raised in plastic rigid air-pruning trays.

Key words: seedling; plug; transplanter; automatic.

1. Introduction

Automation technologies in agriculture is a process that takes place globally and in vegetable growing, where labor demand is highest, is central (Shaw, 1986). From technical and economic efficiency point of view, automatic transplanters must ensure, as compared to manual planting, high productivity through high-speed working process of and reducing auxiliary times, give the

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opportunity to make multiple operations simultaneously, the setting up of several types of crops, better quality of the work (Harstela, 2004). All of these requirements should be linked to the cost of the construction, because these machines are complicated, maintenance and adjustments demanding and are, therefore, expensive (Rantala *et al*., 2009). There is no automatic seedlings transplanter machine being imported in our country under the conditions of Romanian vegetables microfarms (most of them with area less than 5 hectares) facing a decline in the specialized labor force, insufficient financial resources for investment for an automatic transplanter and for the seedlings production system.

The automatic transplanting technology designed for our country's conditions must include a simple designed machine with mechanical gravitational extraction, transport and distribution of the seedling with prefabricated Jiffy plugs, raised in rigid plastics trays. In order to achieve this goal, it must be complied three main objectives:

− Making an experimental automatic transplanting machine ;

− Establish the methodology to obtaine results in a general experiment research, done on ground channel, under laboratory conditions;

− Statistical analysis and interpretation of experimental data, in order for the comparison with the agrotehnics rules imposed for transplanters.

2. Technical Design of the Research Base of the Automatic Planting Seedlings Process

The study of the planting process involves the achieve of the automatic transplanting prototype and the obtaining of the plug seedlings adapted to the machine's characteristics.

2.1. General Considerations Relating to the Design of the Seedlings Automatic Transplanting Machine

The seedlings machinery (Fig. 1) consists of the following components: frame with clamping device to motocultor (1), planting driving wheel (2), transmission (3), planting device (4), distribution device (5), supply system (6), seedlings tray (7) and soil seedlings fastening device (8).

Planting wheel, by contact with the ground, is ensuring the movement to the other systems via transmission levers. So, the planting device supplied with a plug seedlings by the distribution, carried out it's delivering at zero speed relative to the ground, in the hole opened by the wheel planting spurs. The material supply planting shall be made from the tray, at regular intervals, in the distribution device tubes. Planting material shall be fixed in the soil by the vertical winged pads, which provides ground mobilization in an combined action: the base plate of the pads presses soil and vertical wings move it toward the center of planted row.

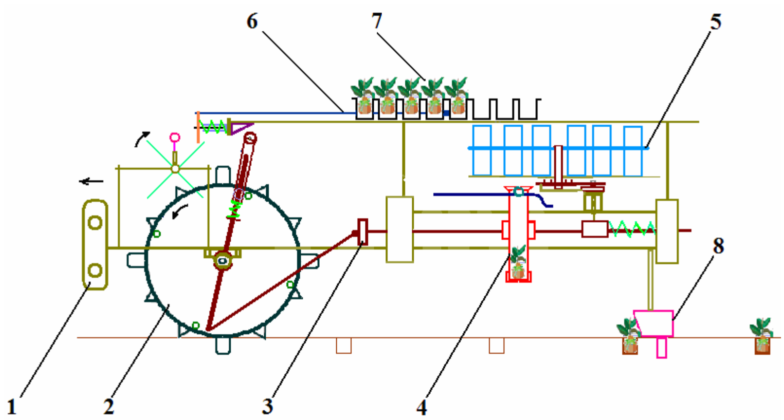


Fig. 1 – Seedlings transplanting machine:
1 – frame with coupling system; 2 – planting driving wheel; 3 – transmission; 4 – planting device; 5 – distribution device; 6 – supply system; 7 – seedlings tray; 8 – soil seedlings fastening device.

2.2. General Considerations Concerning Alveolar Tray and Plug Seedlings

2.2.1. *Alveolar Tray*

The alveolar tray includes growth cells arranged lengthwise in straight rows, and on width in arc rows shape (Fig. 2).

2.2.2. *Seedlings Nutrient Substrate*

Seedling is the one which dictates the configuration of the machine and the whole planting process. Its parameters are related to the two components: nutrient growing substrate and the organic component, the plant itself.

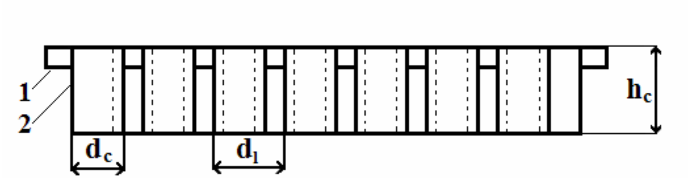
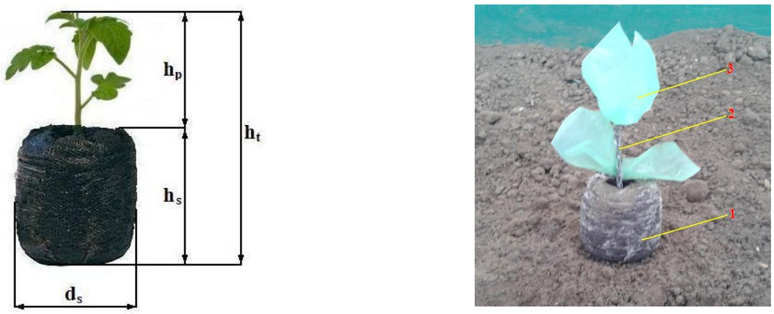


Fig. 2 – Alveolar tray:
d_c – cell growth diameter; h_c – cell growth height; d_l – the distance between two consecutive cells in rows 1 – tray body; 2 – growth cell.

After the peat's water absorption, the diameter and the height of the plug (Fig. 3 *a*) are linked to the characteristics of the tray:



a *b*

Fig. 3 − Seedlings plug:
a − real seedlings: d_s − the diameter of substrate nutrient; h_s − the height of substrate; h_p − plant height; h_t − total height of seedling; *b* − plug seedling simulacrum:
1 − Plug; 2 − stem; 3 − foliar system.

− Cell diameter must be greater than the diameter of substrate $d_c > d_s$, to allows the phenomenon of air-pruning, and when planting, to facilitate the extraction;

− Cell height must be greater than the height of substrate $h_c > h_s$, so that it does not distort over the cell's edges, making the bottom's extraction impossible;

It is appropriate to use a pseudo-planting seedling material, made up from a real Jiffy in which is inserted an imitation of plastic material leaves and a thin wire metallic stem (Fig. 3 *b*). The substrate represent 90% of the total weight of the seedling and it can be assumed that the center of gravity in vertical transport is not moved significantly in the simulacrum case.

3. Material and Method

The designed model of the planting machine automatic must meet the agrotechnics and economics indicators of the planting process.The attain of these objectives, and the comparison with the indicated parameters of the transplanters, shall be made by the results of the experiments on a soil testing channel, tests influenced by seedlings (organic and substrate components) and soil planting properties and constructive and functional parameters of the transplanting machine.

3.1. Channel Characteristics of the Ground

The testing of the transplanting machine and the measurements of the parameters are carried out on a soil channel stand (Fig. 4) (Țenu *et al.*, 2012). The rig is composed of: soil channel, carriage, traction system of the trolley, load charging system of the wheel and compacting roller and tractive force measurement systems.

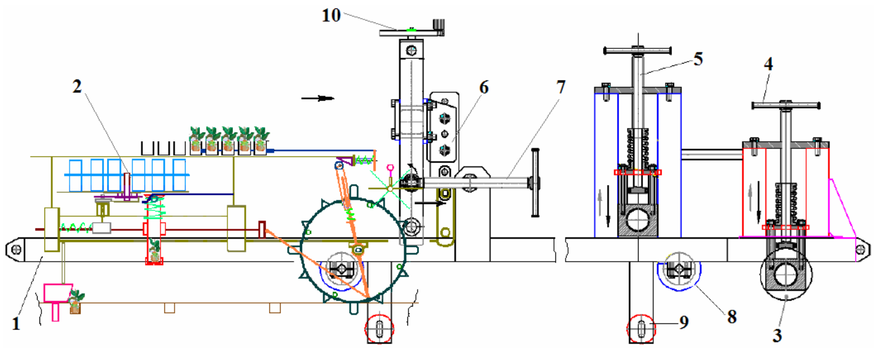


Fig. 4 − The trolley stand with planting machine automatic:
1 − trolley; 2 − furrower; 3 −breaker; 4 − mechanism for positioning the vertical crusher; 5 − loading mechanism with the load of the wheel; 6 − mounting bracket of the machine; 7 − adjusting device for the extent of tilt; 8 − roller upper; 9 − lower rollers; 10 − tool for adjusting the vertical mounting of the machine.

The operating working variant of the soil channel rig is the one in which the carriage with the transplanter is towed by cable with the 5.5 kw and 1000 rpm traction motor and the tow line has LAUMAS Mod. SL C3 1000 daN strain gauge load cells.

3.1.1. *Soil Characteristics of the Testing Soil Channel*

The necessary measurements for the establishment of the soil characteristics are made using a metric frame, a set of sieves and an analytical balance for the particle size analysis and an Eijkelkamp penetrometer with an electrodes device, for measuring the penetration resistance and the soil humidity to determine the soil type. The soil from the rig tests can be described as cambic chernozem loam-clay texture soil type, with size aggregates between 0.02…10 mm and moisture of 17 to 19%.

3.1.2. *The Characteristics of Planting Material*

The simulacra of seedlings shall be carried out in variations within 20%, limits, except for plug, where uniformity variations are limited at approximately 5% (Table 1).

Table 1

The Ranges of Variation Characteristics of Seedlings Simulacrelor

The seedling total height h_t [mm]	The airline height h_p [mm]	The plug height h_s [mm]	The plug diameter d_s [mm]	Foliage diameter d_c [mm]	Number of leaves [Qty.]	Plug weight m_r [g]
120-160	64-96	38-42	38-43	48-72	2-4	42-47

4. Transplanting Machine Experimentation

4.1. Experiment's Structure

A polifactorial experiment, of automatic seedling transplanting on the soil channel, generates the data processed in order to calculate the quality and operating indicators. The parameters that will receive significant value for highlighting machine performances are:

− Theoretical distance between plants on the row, given by the number of spurs on the planter wheel, namely: n = 4 spurs with d_{pt} = 0.321 m and n = 3 spurs with d_{pt} = 0.429 m;

− The machine speeds are: V_{1m} = 0.150 m/s, V_{2m} = 0.227 m/s and V_{3m} = 0.285 m/s;

− The distance between the pads' wings axis w: 0.130 m, 0.160 m and 0.200 m;

− The wings angle with the motion direction β: 10, 15 and 20º.

There will be carried out three rehearsals for each variant, so there are 54 variants with a total of 162 repetitions.

The measured values in order to calculate the indicators (Balan, 1998; Ciubarin, 1972; Trandafir *et al*., 1976) are:

1. The deviation from the planted row **a** (Fig. 5) is determined by measuring the distance from the stem to a laser beam, parallelly emitted to the row.

2. Distance between plants per row $\mathbf{d_p}$ **(**Fig. 6) is measured using a tape measure.

3. Planting depth **u** (Fig. 7) is determined by soil underlying up to the bottom of the plug and measuring using a caliper gauge depth.

4. Seedling mounting in the ground F_r can be established by comparing the measured **Φ** force necessary to extract fixed seedling from the soil (Fig. 8), with the tensile force thereof **.**

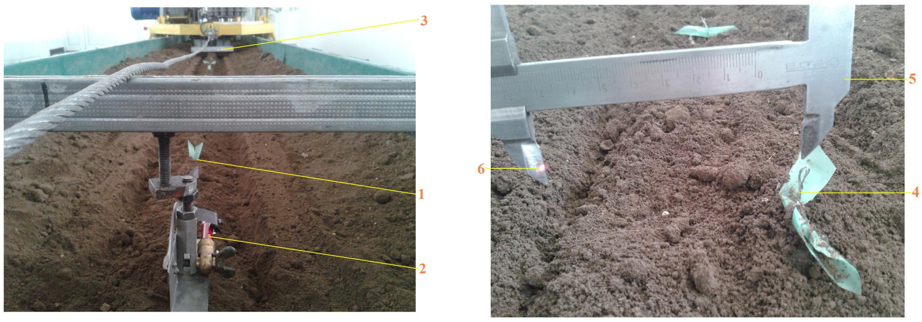
5. The tilt degree in the longitudinal direction $\mathbf{g_{rl}}$, respectively transverse direction $\mathbf{g_{rt}}$ is measured with a device which uses rapporteur and spirit level for leveling, mounted on the laser system support (Fig. 9).

6. Working speed $\mathbf{V_m}$ is selected by changing the current supply of the traction motor of the trolley channel, through an inverter frequency.

7. The traction force $\mathbf{F_m}$ is calculated by converting value given on the screen by a weighing controller from kilograms in Newtons.

4.2. Experimental Results

There have been chosen six variants covering all used parameter values, The data, presented in Table 2, are supplemented by specifying the planting faults, contained in the column entitled "Comments".



a *b*

Fig. 5 − Measuring deviation from the shaft of the planting row planted: *a*) 1 − row planted; 2 − laser; 3 − point laser on the part of sight; *b*) 4 − seedlings; 5 − sliding calliper; 6 − laserpoint on the calliper beak.

Fig. 6 − Measuring distance between plants per row.

Fig. 7 − Measuring planting depth.

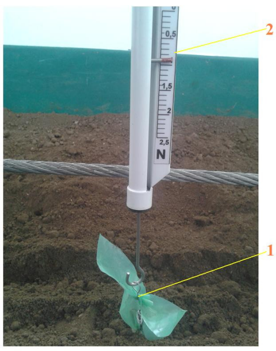


Fig. 8 − Force measurement extraction.

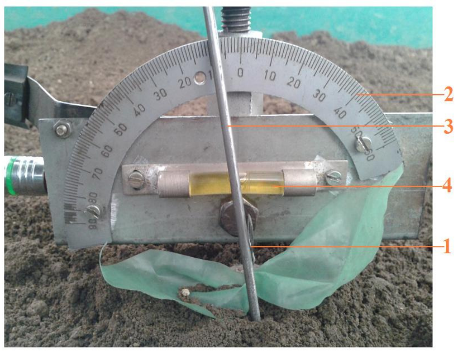


Fig. 9 − Measuring the inclination degree.

Table 2

Experimental Data Corresponding to Selected Variants

No.	Variants	Statistical indicator	Measured values							Observation
			a [m]	$\mathbf{d_p}$ [m]	**u** [m]	**Φ** [N]	$\mathbf{g_{rl}}$ [º]	$\mathbf{g_{rt}}$ [º]	$\mathbf{F_m}$ [N]	
1.	Var9	minimum	0.000	0.393	0.044	0.9	0	0	254.972	$1g_{rl}$+1u(î)
	n=4,w=3d_s	maximum	0.005	0.414	0.066	1.6	46	5	264.779	
	β=20º,V_{3m}	average	0.0015	0.404	0.058	1.20	11.67	2.79	259.875	
		St Dev	0.0015	0.0070	0.0057	1.1954	9.01	1.215	5.6620	
2.	Var14	minimum	0.000	0.389	0.000	0.0	0	0	254.972	1 d_{p-}
	n=4.w=4d_s	maximum	0.005	0.404	0.065	1.5	16	5	264.779	1Φ
	β=15º,V_{2m}	average	0.0012	0.397	0.054	1.16	8.91	2.25	259.912	1u(n)
		St Dev	0.0011	0.0037	0.0122	0.3573	4.19	1.452	5.6623	
3.	Var19	minimum	0.000	0.378	0.043	0.6	5	0	254.972	1u(n)
	n=4,w=5d_s	maximum	0.007	0.389	0.061	1.6	15	3	264.779	1Φ
	β=10º,V_{1m}	average	0.0015	0.382	0.052	1.10	10.37	1.25	259.875	
		St Dev	0.0015	0.0027	0.0052	0.2062	2.29	1.073	5.6620	
4.	Var31	minimum	0.000	0.488	0.046	0.6	0	0	245.166	1Φ
	n=3,w=3d_s	maximum	0.005	0.499	0.057	1.4	18	5	254.972	1 r_v
	β=15º,V_{1m}	average	0.0014	0.494	0.053	1.13	7.62	2.33	250.069	
		St Dev	0.0013	0.0029	0.0027	0.1465	4.78	1.37	5.6614	
5.	Var44	minimum	0.000	0.501	0.053	0.5	2	0	254.972	1Φ
	n=3,w=4d_s	maximum	0.005	0.513	0.063	1.4	48	5	264.779	$1g_{rl}$+ $1r_v$
	β=20º,V_{2m}	average	0.0017	0.507	0.057	1.22	9.79	2.50	259.875	
		St Dev	0.0014	0.0034	0.0023	0.2187	8.45	1.61	5.6620	
6.	Var48	minimum	0.000	0.501	0.044	0.5	7	0	254.972	1u(n)+$1r_v$
	n=3,w=5d_s	maximum	0.005	0.512	0.062	1.5	15	4	264.779	2Φ
	β=10º,V_{3m}	average	0.0014	0.505	0.054	1.16	11.38	2.20	259.875	
		St Dev	0.0011	0.0027	0.0027	0.2039	1.996	1.250	5.6620	

Table 3 lists the calculated quality, energy and economic indicators, as well as the peak reference values from literature.

1. Maximum calculated deviations from the row shaft ranging between 0.0033 and 0.0055 m, which is far below the value allowed by the agrotehnic index, of 0.02 m.

Table 3
Calculated Values of Quality, Energy and Economic Indicators

No.	Indicator		Symbol	Variants						Set point value
	Type	Name		Var9	Var14	Var19	Var31	Var44	Var48	
1.	Quality	Maximum deviation from the planted row	A_{rmax} [m]	0.0035	0.0038	0.0055	0.0036	0.0033	0.0036	0.02
2.		Distance deviation between plants on the row	A_d [%]	1.73	0.93	0.70	0.58	0.67	0.53	10
3.		Planting gaps number	G_p [%]	0.00	4.16	0.00	0.00	0.00	0.00	5
4.		Planting depth deviation	A_u [%]	9.82	22.22	10.00	5.09	4.03	5.00	10
5.		Soil seedling fixing degree	F_r [%]	100	91.66	95.83	95.83	95.83	91.66	95
6.		Planted seedling inclination	$Î_{rl}$ [%]	4.16	0.00	0.00	0.00	4.16	0.00	5
			$Î_{rt}$ [%]	0.00	0.00	0.00	0.00	0.00	0.00	5
7.		Right planted seedlings	Z_c [%]	95.83	95.83	100	95.83	95.83	95.83	95
8.		Planting frequency	F_d [s^{-1}]	0.70	0.57	0.40	0.30	0.44	0.56	0.41
9.	Energy	Working speed	V [m/s]	1.026	0. 817	0. 540	0. 540	0.817	1.026	0.3
10.		Traction force	F_m [N]	259.875	259.912	259.875	250.069	259.875	259.875	–
11.		Traction power	P_t [W]	74.064	59.00	38.98	37.51	58.99	74.06	–
12.		Slippage coefficient	α [%]	20.14	19.14	15.96	13.15	15.38	15.04	20
13.	Economic	Working capacity 50.000 plants/ha	Ω [ha/h]	0.050	0.041	0.028	0.021	0.032	0.040	0.014

2. Deviation of the seedlings distance on row is between 0.53% and 1.73%, much lower than the 10% value indicated in the literature.

3. Voids after planting, demonstrated by seedlings remained on the soil surface; as a percentage, shall be values from 0 to 4.16%, which are below the maximum limit of 5% imposed by rules.

4. Planting depth maximum deviations is ranging between 0.004 and 0.011 m. The relative deviation from the average of the planting depth, is contained in a range between 4.03% and 22.22%. The imposed value shall not exceed 10%, condition respected in five variants of six, the exception being variant 14, with the value of 22.22% , due fault indicated by seedling remained on the ground surface. As we are talking about an accidentally event (4 cases for more than 1,200 seedlings planted), it can be considered that this quality index is met.

5. Seedlings fixed in the ground (for values of the extraction force between 0.5-2 N) varies between 91.66 and 100%, and the quality standard for this index is at least 95%; it can be assumed that this index is reached to the limit.

6. Inclined seedlings in longitudinal direction above the maximum value allowed by 60° (or 30° from vertical) are between 0 and 4.16%; allowed value is the maximum 5%. In the transverse direction, the percentage tilt seedlings more than the allowed limit of 45° is 0.

7. Seedlings planted correctly represented a percentage between 95.83 and 100%. The specified value for this indicator it must not exceed 95%.

8. Frequency planting varies between 0.30 s^{-1} up to 0.70 s^{-1} (18 to 42 seedlings/min.), lower than the human operated semi-automatic planters quality indicators (20 to 25 seedlings/min). Only one variant with the lowest speed leads to a value of the planting frequency below the limit, the others being between or higher than the values indicated above, exceeding the imposed standards.

Considerations on energy indicators for the transpanting machine.

9. The two chosen speeds covers similar semi-automatic planters velocities (0.150 m/s, 0.227 m/s, *i.e.* 0.540 km/h, 0.817 km/h) or exceeds this (by 0.285 m/s, *i.e.* 1.026 km/h), the reference values for semi-automatic seedlings machines being 0.2 - 0.3 km/h.

10. The planter wheel slip varies between 13.15 percent and 20.14 percent, corresponding to agrotehnic value of 20% with the minor exceeded exception.

11. The tractive force varies between 250.069 and 259.875 N, being one magnitude order lower than the developed force of a 8 HP motocultor.

12. In a similar way, the power required for towing machine, between 34 and 74 W, represents only a fraction of the power available for a motocultor.

13. The values obtained by the tested transplanting machine, ranging between 0.021 and 0.050 ha/h must be compared with the production capacity indicator, of 0.014 ha/h, resulting an excess of productivity regarding the semiautomatic planters.

5. Conclusions

I. The results of referred calculated indicators allow to establish that the agrotehnics requirements imposed to the planting machines are met.

II. Frequency planting quality index is partially comes outside the limits, by means of a value corresponding to a low working speed variant, corroborated with increased wheel slip planter; the solution to fix it is choosing a range of working speeds higher and reducing planter wheel slip by improving anti-slip profiles.

III. Planting depth has one value which exceeding the imposed rule, generated by a fault of planting, which by its nature could induce a major deviation in the values numbers, so that it can be considered to be a random isolated phenomenon.

IV. Due to the checking of the majority of the required planting indicators for plug seedlings transplanting, the achieved automatic transplanter is comparable to other existing planting machines.

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ASPECTE PRIVIND AUTOMATIZAREA PLANTĂRII RĂSADURILOR

Dezvoltarea unei tehnologii de producere şi plantare automată a răsadurilor cu substrat nutritiv

(Rezumat)

Automatizarea plantării răsadurilor în legumicultură este o soluție pentru creşterea productivității, înlocuirea forței de muncă, parametri de calitate ridicați, autonomie mare de lucru şi reducerea costurilor lucrării, comparativ cu plantarea cu maşini cu operatori umani.

Maşina automată de plantat răsaduri realizată permite studierea procesului de lucru pe un canal de sol, în scopul determinării parametrilor constructivi, funcționali şi energetici ai maşinii. Monosecția de plantare realizată, datorită verificării într-o proporție covârşitoare a cerințelor agrotehnice pentru plantarea răsadurilor cu substrat nutritiv şi în unele cazuri, prin depăşirea lor substanțială, poate fi considerată conformă normelor impuse maşinilor de plantat existente în exploatare.