Study of the technological process of operation of transplanting machines

Iurie Melnic, Vladimir Badiul, Vladimir Melnic, Mihail Cătană
Technical University of Moldova, 168, Ştefan cel Mare Blvd., Chişinău, Republic of Moldova
iurie.melnic@im.utm.md

Abstract. *The article proposes a classification based on the method of movement of the working parts of the planting apparatus, which identifies three groups of transplanting machines: with the movement of the working parts in a vertical plane, a horizontal plane, and a combined method. The speed of planting seedlings depends on the following main factors: the frequency m of seedling supply, the planting step l, the design of the planting apparatus with seedling holders, the condition of the planting material, as well as the experience and skill of the planting operators. Feeding seedlings into seedling holders or cups of the planting apparatus is limited by the physical capabilities of a person, namely the number of seedlings fed per minute or frequency m. Thus, in order to increase the speed V_m of seedling planting, it is necessary to increase the frequency m of seedling supply. The speed of planting seedlings into cups or seedling holders (the frequency m) actually determines the maximum operating speed of the transplanting machine.*

The study of the technological process of operation of a transplanting machine, as well as a phase analysis of the working process of a carousel-type transplanting machine, makes it possible to better understand ways to improve the design of the machine and its working parts and will make it possible to obtain important decisions on increasing the speed. As a result of a theoretical study of the technological process of a carousel-type transplanting machine, a relationship was obtained between various factors on which the maximum operating speed of planting seedlings depends.

KEY WORDS: *TRANSPLANTING MACHINE, OPERATING SPEED, SEEDLINGS, STEP OF PLANTING SEEDLINGS, CAROUSEL TYPE TRANSPLANTING MACHINE.*

Introduction

The The seedling method of growing vegetable crops is the most effective agrotechnical technique for obtaining high yields in a fairly short time. As a result of the introduction of modern technologies for growing seedlings into production and the creation of increasingly more productive designs of planting machines, the problem of increasing the production of vegetables in open ground can be solved.

Compared to other agricultural machines, transplanters are the least studied. That was also due to the fact that in general the area of plantations of crops cultivated with seedlings (vegetables, tobacco, strawberries, etc.) in the world is insignificant compared to other field crops. Therefore, there are few scientists studying for seedlings transplanting machines, but there are quite a lot of problems to study in this area.

Formulation of the problem

According to several classifications based on the principle of operation [1, 2, 3], machines for planting seedlings are divided into simple, semi-automatic and automatic. The technological process of machines from these categories mainly differs from the method of carrying out operations: manual or automatic. In simple machines, most operations are performed manually and only one or two operations are performed automatically, without the actual participation of the worker.

In automatic transplanters, all operations are performed automatically, but these machines are unaffordable for most farmers due to their high cost. That is why semi-automatic transplanting machines are most widespread, the technological process of which will be discussed below.

Analysis of recent research and publications

The process of planting seedlings using semi-automatic transplanting machines consists of the following main technological operations:

- manual removal of seedlings by the operator from a box or cassette and feeding them into the seedling holder (done manually);
- furrow formation (performed automatically);
- moving and placing seedlings into the furrow opened by the coulter (performed automatically);
- watering seedlings in the furrow with an irrigation system mounted on a tractor (performed automatically);
- planting of plants with soil compaction around the roots of seedlings using compacting wheels (performed automatically).

Depending on the method of movement of the working parts of the planting apparatus, you can get different opportunities for improving these machines.

So, according to the method of movement of the working parts of the planting apparatus, three groups of transplanting machines are distinguished:

- with the movement of the working parts of the planting apparatus in the vertical plane (with a vertical disk) (Fig. 1);
- with the movement of the working parts of the planting apparatus in the horizontal plane (with a horizontal disk) (Fig. 2);
- joint method.

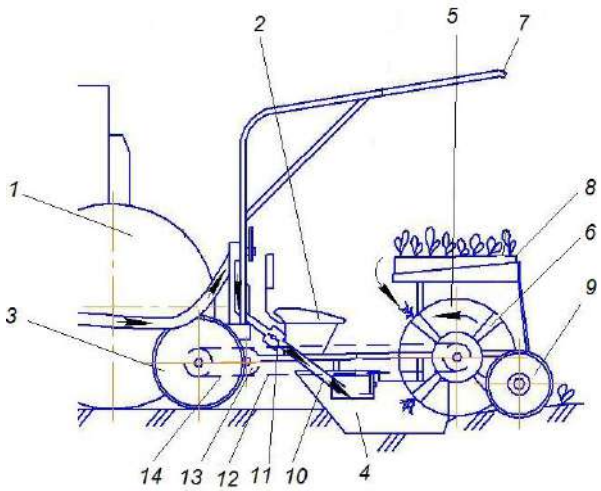

Figure 1. Diagram of a transplanting machine with the movement of the working parts of the planting apparatus in the vertical plane: *1 - tractor; 2 - front seat; 3 - support-drive wheel; 4 - coulter; 5 - vertical planting disk; 6 - seedling holder; 7 - awning; 8 - box with seedlings; 9 - compacting rollers; 10 - irrigation pipe; 11 - dosing device for the irrigation system; 12 and 14 - chain drives; 13 - gearbox.*

Many scientists have dealt with the problems of a comprehensive study of transplanting machines MPR-5, SKN-6A, etc. with a vertical disk on which the seedling holders are attached [1, 2, 3]. The process of operation of such machines is quite well studied both in terms of theory and practice.

However, in recent decades, rapid development of technologies for growing seedlings in cassettes has begun [4, 5]. At the same time, intensification began in improving the designs of carousel-type transplanting machines [6, 7, 8, 9], which are currently the most widespread. Therefore, a more universal and integrated approach is needed to study the technological process of

planting seedlings and analyze the operating process of the considered designs of transplanting machines.

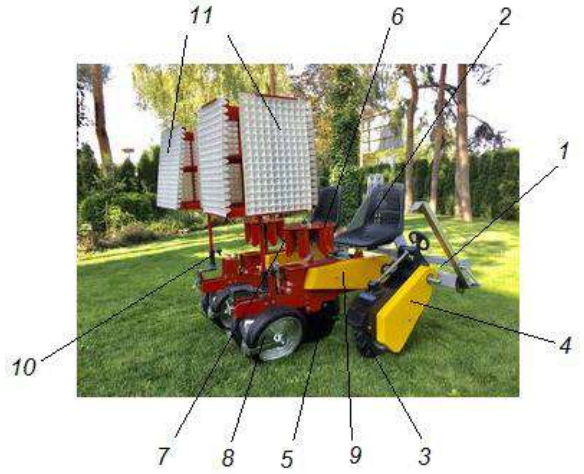

Figure 2. Solan transplanting machine with worker movement organs of the planting apparatus in the vertical plane (with a vertical disk): *1 - frame; 2 - planter operator's seat; 3 - support-drive wheel; 4 - chain drive; 5 - coulter; 6 - horizontal disk of the planting apparatus; 7 - cups; 8 - pressing wheels (rollers); 9 - transmission; 10 – stand for seedlings; 11 - cassettes with seedlings.*

It is known [2, 3, 8] that the speed of planting seedlings depends on many factors, the main ones being: the frequency of supplying seedlings, the planting step, the design of the planting apparatus with seedling holders, the condition of the planting material, as well as the experience or skill of the planting operators, etc.

The seedling planting step is set according to the agricultural requirements for planting the corresponding crop. As the seedling planting step decreases, it is also necessary to reduce the speed of the planting unit. Feeding seedlings into seedling holders or cups of the planting apparatus is also limited by the physical capabilities of a person, namely the number of seedlings fed per minute or frequency *m*. A medium skilled operator can put an average of 35-40 seedlings per minute into a seedling holder or cups [2, 3].

Rezults and discussions

The operating speed of movement of the transplanting machine V_m, provided that $V_m=V_d$, is determined by formula (1) [9]:

$$V_m = \frac{\pi D m}{iz \cdot (1-\varepsilon)} \quad (1)$$

where: D - diameter of the drive wheel;
i - drive gear ratio;
ε - slip coefficient of the drive wheel;
z - number of seedling holders of the planting apparatus;
m - frequency of supplying seedlings in the seedling holder.

Thus, the operating speed of the transplanting machine is determined without directly taking into account the planting step l, however, this indicator can be determined from equation (2):

$$l = \frac{\pi D}{z} \cdot \frac{1}{\lambda} \quad (2)$$

where λ is an indicator of the kinematic operating mode of the transplanter;

$$\lambda = \frac{V_d}{V_m} \quad (3)$$

where V_d is the speed of the disk at the point under consideration located at a certain radius r coinciding with the point on the seedlings in the seedling holder, which, when it enters the furrow, will come into contact with the soil:

$$V_d = \omega \cdot r \quad (4)$$

where: ω - peripheral speed of the planting apparatus disk;
r - the radius to the point in question on the disk.

Then the speed of the transplanter is obtained from formulas (1) and (2):

$$V_m = \frac{60lm}{i(1-\varepsilon)}, \text{ m/s} \quad (5)$$

By inserting formulas (1) and (4) into formula (3), we obtain the indicator of the kinematic operating mode λ:

$$\lambda = \frac{\omega r \cdot i(1-\varepsilon)}{60lm}. \quad (6)$$

Considering that the indicator of the kinematic operating mode λ, provided that $V_m=V_d$, is equal to unity, then from formula (6) it is easy to find the frequency m of supplying seedlings:

$$60lm = \omega r \cdot i(1-\varepsilon)$$

$$m = \frac{\omega r \cdot i(1-\varepsilon)}{60l} \quad (7)$$

From here you can find the dependence of the seedling planting step l on the frequency m of supplying seedlings:

$$l = \frac{\omega r \cdot i(1-\varepsilon)}{60m} \quad (8)$$

So, increasing the operating speed V_m of the movement of the transplanting machine (5) is possible by increasing the frequency m of supplying seedlings into the seedling holder.

Thus, in order to increase the speed V_m of planting seedlings, it is necessary to increase the frequency m of feeding seedlings into the planting apparatus of the machine.

So, you can increase the frequency of supplying seedlings m in the following ways:

1) installation of an additional device between the planter operator and the planting apparatus of the transplanting machine, which facilitated the supply of seedlings and made it possible to increase the pace of work, thereby increasing the frequency m of supplying seedlings into the seedling holder;

2) increasing the number of planter operators on one planting section of the machine;

3) using carousel-type transplanters for planting [7,8];

4) the use of well-trained and experienced planter operators when carrying out work on planting seedlings [8, 10].

It was previously noted that a medium planter operator can put an average of 35-40 seedlings into a planter holder or cup seedlings per minute. This is true for a one-handed planter operator working on a vertical disc transplanting machine.

However, in the case of using carousel-type planting machines and cassette seedlings for planting, the operator has the opportunity to work with both hands at the same timet and then he can put an average of 60 seedlings into the cups of the planting machine. An experienced and well-trained planter operator can put up to 60-80 seedlings per minute into the cups [10].

Consequently, the speed of suplying seedlings into the cups (seedling holders) or the frequency m actually determines the maximum operating speed of the transplanter, which can be found using the following formula [11]:

$$V_{m\max} = 0{,}06ml \quad (9)$$

where: $V_{m\ max}$ - maximum operating speed of the transplanting machine, km/h;
l - step of planting seedlings, m.

For ease of study, you need to convert the speed to m/s, and then:

$$V_{m\max} = 0{,}0167m_{\max}l \quad (10)$$

where m_{max} - maximum frequency of supplying seedlings in the seedling holder.

The time required for one supplying seedling in a seedling holder (cup) is determined from the expression:

$$t_{1\max} = \frac{60}{m_{\max}} \quad (11)$$

where $t_{1\,max}$ is the maximum time for one supplying seedling in a seedling holder, s.

For example, at frequency m=40 seedlings/min you get the time for planting equal to $t_{1\,max}$=1,5 s.

This indicator is very important for studying the phase analysis of the process of operation of transplanting machines, since for carousel-type machines, the time of seedlings falling from the cup into the coulter for the same type of seedlings is a constant value. That directly affects the quality of work performed by the transplanting machine when the speed of the planting unit increases. Substituting formula (10) into (11) you can get:

$$t_1 = \frac{l}{V_{m\,max}}, \text{ s} \quad (12)$$

$$V_{m\,max} = \frac{l}{t_1}, \text{ m/s} \quad (13)$$

For example, with a planting step l = 0,3 m and the maximum time for supplying of one seedling t_1 = 1,5 s, $V_{m\ max}$= 0,2 m/s or $V_{m\ max}$ = 0,72 km/h is obtained.

Then, in production conditions, knowing the planting step l and the capabilities of the planter operator expressed through the frequency m, you can easily determine the maximum operating speed of the transplantng machine:

$$V_{m\,max} = \frac{m_{max}\, l}{60}, \text{ m/s} \quad (14)$$

or

$$V_{m\,max} = 0{,}06 m_{max}\, l, \text{ km/h} \quad (15)$$

Increasing the operating speed V_m of the movement of the transplanting machine is possible by increasing the frequency of supplying seedlings m into the seedling holder. Only by solving this problem using the previously proposed methods you can move on to technical issues of improving the design of the machine and its working parts [13].

Studying the theory of the technological process of operation of a transplanting machine, as well as phase analysis of the working process of a carousel-type transplanting machine, makes it possible to better understand ways of improving the design of the machine, its working parts and will provide important practical solutions to increase its operating speed [14, 15, 16].

Conclusions

1. Transplanting machines are the least studied agricultural machines in theoretical and experimental terms.

2. The rapid development of technologies for growing seedlings in cassettes has intensified the processes of improving the designs of carousel-type transplanting machines, which are currently the most widespread.

3. The speed of planting seedlings depends on many factors, the main ones being the frequency of seedling supply, planting pitch, the design of the planting apparatus with seedling holders, the condition of the planting material, as well as the experience or skill of the planting operators.

4. When working on transplanting machines with a vertical disk, an average-skilled planter operator can place into the seedling holders with one hand an average of 35-40 seedlings per minute. However, in the case of using carousel-type transplanting machines for planting cassette seedlings, the operator has the ability to work with both hands in the came time and then he can put an average of 60 seedlings into the cups of the planting apparatus, and a trained planter operator with experience can put up to 80 seedlings per minute.

5. The study of the technological process of operation of a transplanting machine, as well as a phase analysis of the working process of a carousel-type planting machine, makes it possible to better understand ways of improving the design of the machine, its working parts and will make it possible to obtain important decisions on increasing the speed of the studied transplanting machines.

References

1. CAPROIU, S. Masini agricole de lucrat solul, semanat si intretinerea culturilor. - Bucuresti: Editura Didactica si Pedagogica, 1982. - 242 p.

2. CIUBARIN, M. Rassadoposadocinie mashini. - M: Mashinostroenie, 1972. - 208 p.

3. BALAN, O., NECULAIASA,V. Realizari si tendinte in constructia masinilor de plantat // Lucrari stiintifice, Universitatea Agronomica. Vol. 35. - Iasi: Universitatea Agronomica, 1992. - P. 103-106.

4. BUMACOV, V., R. ROSCA, V. Aspectele tehnologiilor modern de crestere a rasadului. // Lucrari stiintifice, UASM. Vol. 3. - Chisinau: Tipografia UASM, 1995. - P. 105-108.

5. WHITE, R. ROSCA, V. Producerea rasadurilor de legume in palete celulare. - Chisinau: Editura Prometeu, 1999. - 5 p.

6. SCUDELARO, L. Transplanting machine. Patent of invention nr. 4886002, USA, 1989.

7. BOOTS, S. Seedling transplanter. Patent of invention nr. 4290373, USA, 1989.

8. MELNIC, IU. Optimizarea parametrilor constructivi ai sectiei de plantat rasaduri // Lucrari stiintifice, UASM. Vol. 7. - Chisinau: Tipografia UASM, 1999. - P. 230-232.

9. VINEVSKI, E. Элементы научных основ средств механизации посадки рассады табака в поле // Voprosi. Gipotezi. Otveti. Nauka XXI veka: Kolectivnaia monografia. Kniga 8. - Krasnodar: 2014. - P. 204-222.

10. BUMACOV, V. Procesul de lucru si parametrii masinii de plantat rasaduri //Lucrari stiintifice, Vol.4. UASM. - Chisinau: Tipografia UASM, 1996. - P. 349-352.

11. GHEORGHIEV, G., CERNEAC, A. Posadocinie mashini. Spravocinik konstruktora s/h mashin. Vol.2. - M: Mashinostroenie, 1967. - P. 290-316.

12. MELNIC, IU. Повышение рабочей скорости движения рассадопосадочного агрегата. In: Конструювання, виробництво та експлуатація сільскогосподарських машин. *Zbirnic naukovîh praţi,* випуск 39. - Кіровоград, 2009. - P. 356-362.

13. MELNIC, IU. Bumacov, V. Masina de plantat rasaduri. Patent of invention nr. 2371, 29.02.2004, BOPI nr. 2/2004.

14. MELNIC, IU. Фазный анализ рабочего процесса рассадопосадочной машины карусельного типа. Mijnapodna naucino-practicina konferenţia. „Problemî konstruirovannea, virobniţtva ta eksploataţiii siliskogospo-darskoi tehniki". Zbirnic naukovîh praţi. - Kirovograd, 1999. - p.103-107.

15. MELNIC, IU. Повышение рабочей скорости движения рассадопосадочного агрегата. In: Конструювання, виробництво та експлуатація сільскогосподарських машин. *Zbirnic naukovîh praţi,* випуск 39. - Кіровоград, 2009. - с. 356-362.

16. MELNIC, IU., MELNIC, V. Mathematical modeling of the operating system of the carousel type transplanting machine. *III International Scientific Conference "Mathematical modeling", Borovets, Bulgaria, 11-14 decembre 2019.* In: *International Scientific Journal "Mathematical modeling", Vol.3, Issue 4.* 2019. *pp.124-126*, Print ISSN 2535-0986, Web ISSN 2603-2929.