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ECHIPAMENT PENTRU MANAGEMENTUL COVORULUI VEGETAL ÎN POMICULTURĂ, CU COMANDĂ SENZORIALĂ CU LIDAR
EQUIPMENT FOR VEGETATION MANAGEMENT IN ORCHARDS, WITH SENSORIAL CONTROL USING LIDAR

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Abstract

The development of Agriculture 4.0 is a current and future concern, which has also been extended in the field of equipment intended for maintenance work in fruit plantations. The achievement of high-performance equipment, in the context of climate changes, can ensure the timely and high-quality completion of the works in the fruit plantations, but also ensure the protection of the trees, to increase the life span and fruiting period of the fruit trees. From all of this, the research team carried out applied research for the development of an integrated technology and technical equipment for mowing the floor vegetation in orchards. Integrating high technology into the maintenance technology of orchards, plant material can be obtained that will form the basis of mulch production, which will be used in organic fertilization technologies of orchards/vineyards. The development of Agriculture 4.0 is a current and future concern, which has also been extended to the field of machinery for maintenance work in orchards. The realization of high-performance machines, in the context of climate changes, can ensure the timely and quality completion of the works in the orchards, but also the protection of the trees, to increase the life span and fruiting period of the trees. The research team carried out applied research for the development of an integrated technology and technical equipment for mowing the orchard floor vegetation. The advantage of this technology, which integrates LiDAR technology, is the fact that the tree trunks will not be damaged, so the potential for diseases to occur in the bark of the trees decreases, favouring the obtaining of rich fruit harvests.

Cuvinte cheie: pomicultura, covor vegetal, comanda senzoriala, LiDAR
Key words: pomiculture, floor vegetation, sensory command, LiDAR

1. Introduction

Orchard floor vegetation management has gained great importance, because it is no longer recommended to plough and incorporate the vegetable remains, resulting from mowing, but to leave the soil grassy or to mow the vegetable mass and use it in the form of mulch. Reasons for applying mulch include conservation of soil moisture, improving fertility and health of the soil, reducing weed growth, and enhancing the visual appeal of the area. Many materials are used as mulches, which are used to retain soil moisture, regulate soil temperature, suppress weed growth, and for aesthetics (Turgeon et al., 2009) They are applied to the soil surface, (Upadhyaya et al., 2007), around trees, paths, flower beds, to prevent soil erosion on slope. Mulch layers are normally 2-5 cm or deeper when applied (Pittenger, 2002; Murdoch Books, 2004). Mulches of manure and compost will be incorporated naturally into the soil by the activity of worms and other organisms. The process, when applied correctly, can improve soil productivity. Mulch helps conserve moisture, 10 to 25 percent reduction in soil moisture loss from evaporation. Mulches help keep the soil well aerated by reducing soil compaction that results when raindrops hit the soil. They also reduce water runoff and soil erosion. Mulches prevent soil and possible fungi from splashing on the foliage, thus reducing the likelihood of soil-borne diseases. They help maintain a more uniform soil temperature (warmer in the winter and cooler in the summer) and promote the growth of soil microorganisms and earth worms (Lal et al, 2012).

2. Material and methods

In the last period, many companies carried out researches for the development of mowing machines. Over time, different mowing machines have been developed, such as reel mowers, rotary mowers, and flail mowers. Rotary mowers have become the most widespread for their great versatility

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and easy maintenance. Modern rotary mowers can be equipped with battery-powered electric motors and precise settings, such as blade rpm.

Pirchio et al. evaluated the differences in power consumption of a gasoline-powered rotary mower and a battery-powered rotary mower (Pirchio et al., 2019). Other researchers analysed the mower machines, after their cutting apparatus and their work width. They presented and analysed technical characteristics of mowers, which influence their economic performances. From the economic point of view, considering the engine mowers, it was concluded that the mowers with 2 knives have a better work capacity, at the same width of mowed furrow, compared to borne mowers (Dumitru M., 2015).

Some researchers studied the trend in the development of mowers. They concluded that the mounted triple mower combinations reach a working width of 10,00 m; while trailed-mounted triple mower combinations or self-propelled mower must be chosen for greater working widths. Depending on the conditions it is possible to achieve very large area capacity in the range of 10 to 20 ha/h. The increase of working speed is achieved by improving systems for the reduction of contact pressure of the mower on the ground and topsoil contour adaptation. The reduction of fuel consumption can be achieved by reducing the number of passes, using automatic steering system and by changing the mower blades regularly (Fabijannic at al., 2013)

Some researches focused on the power sources for mowers, the newest being powered by the solar energy, electric mowers having the advantage of a low operating cost (Soyoye B.O., 2021). Besides, the pollution will be avoided. Most mowers are powered with gasoline engine and operating cost for such mowers is higher than for the electric powered ones.

Chinese researchers developed a cutting and sweeping device for grass in orchards. The Design-Expert 13 software and the response surface methodology of a Box–Behnken Design (BBD) were utilized to design the experiments. They focused on an analysis of the coupling simulation results, particularly the number of broken bonding links and the power. The main influencing factors that were selected for this analysis were the forward velocity, the cutting blade rotational speed, and the number of cutting blades. The set ranges for these factors were as follows: the forward velocity ranged from 0.6 to 1.4 m s−1, the rotational speed of the cutting blade from 540 to 850 rpm, and the number of cutting blades from 17 to 29 (Shuai Shen et al., 2023).

Simulation of front-end-mowers adjustment to soil surfaces was studied. Mower suspension can help to provide an optimal quality of adjustment to different soil surfaces. Suspension device efficiency is essentially determined by the quantity of contamination found among forage as well as by sward damages. Multibody-simulation models of tractor, front-end-mower and soil surface represent the mechanical system. Tastings were necessary for validating the simulated results of position and acceleration from tractor and mower components. The quality of adjustment to the soil was tested with different front-end-mowers and artificial or natural obstacles (Eberle, 1998).

Our research team proposed to integrate the knowledge acquired in other projects in the field of Agriculture 4.0, in order to design a piece of equipment that can perform mowing in the interval between rows of trees as well as between trees in a row, the novelty consisting of the integration of a LiDAR system, which ensures the withdrawal of the arm to avoid the contact with the trunk and a safe protection of the trunk of the trees, thus ensuring the health of the plantations.

For developing a new mower which can be considered as part of Agriculture 4.0, first the constructive solutions existing on the market at the present time were analysed, the research team developing new solutions for the mowing device.

Many companies such as Kuhn (Franta), Fisher (Australia), Fieldmaster (New Zealand), Tehnos (Slovenia), Rasco (Croatia), Perfect van Wamel (Netherlands), Gason (Australia), Jar-Met (Poland) etc., developed different kind of mowers.

Some of them have a fixed working width, Figs. 1, 2, carrying out the work of mowing between rows of trees, or between rows of vines, others have a variable working width, Fig. 3, depending on the distance between the rows.

There are mowers attached in front of the tractor or to the rear on the 3-point linkage. These mowers are intended for mowing between rows of trees, being equipped with disc knives.

All these types of mowers have a mechano-hydraulic transmission, the main action being taken from the tractor's power take-off shaft, with a power shaft, transmitted to the rotor with blades through a gear drive. The extension of the working width can be done with the help of a hydraulic transmission, the movement being made with the help of a hydraulic cylinder.

In Figs. 4, 5, 6, can be seen mowers which cut the grass between the rows and also between the fruit trees in the same row, around the trunks.

There are rotary mowers with swing arm(s) for orchards and vineyards, models with 1 or 2 swing arms. Some orchard mowers have a large offset and a swing-arm; this combination makes the mowing of grass and weeds in between trees very easy; furthermore, it is possible to mow far from the tractor track because of the large offset. The mower in Fig. 4 is equipped with two rotors with overlapping blades. The motion from the central part to the sides rotors is transmitted by a belt transmission. Because of sturdy Vbelt drive system, the heavy cutting blades spin very fast, so the swing-arms have a high working capacity.

As soon as the swing-away blade of the orchard mower touches the tree-trunk, it swings back; when doing so, the swing-arm, which is supplied with a rubber strip, goes around the tree without damaging it. When the arm has passed the tree, it swings back on the tree row thanks to a spring mechanism. The heavy cutting blades mow tough grass and other plants as well.

The mower presented in Fig. 5 can be equipped with a hydraulic feeler system for orchards with young trees; the feeler registers the presence of a tree and directs a hydraulic cylinder that makes sure that the blade disc mows around the tree without touching it.

The disadvantage of these machines is the fact that the mowing between the trees is controlled by an elastic element that comes into contact with the tree. Repeated contact can lead to the destruction of the tree's bark and the appearance of diseases, endangering the existence of the tree and affecting its life span.

Starting from these conclusions, the research team has carried out applied research for the design, construction and testing of a mower for cutting grass in orchards or vineyards, between tree rows and also between trees in the same row, using sensors, in the context of Agriculture 4.0. The equipment integrated the LiDAR technology, "**L**ight **D**etection **A**nd **R**anging", which consists in determining ranges by targeting the tree trunks and measuring the time for the reflected light to return to the receiver. LiDAR can operate in horizontal or vertical direction, in a defined angle range. LiDAR uses ultraviolet, visible, or near infrared light to image objects. It can target a wide range of materials, in our case, the target being the tree trunks, LiDAR operating in horizontal plane, at a defined height over the ground.

The LIDAR system has the ability to measure very quickly (thousands of points per second) the distance between the sensor and the objects around it, which allows obtaining a volume of 3D points that, by applying appropriate algorithms, makes possible the reconstruction and digital description of the structure trees with high accuracy. For these reasons, LIDAR systems could become one of the most widely used sensors for the geometric characterization of tree crops.

The purpose of the conducted research was to increase the protection of the tree trunks during the mowing work around the trunk, increasing the lifespan of the orchard, by avoiding the occurrence of diseases generated by the successive contact of the equipment with feelers or rubber bandages, which will implicitly lead to the increase fruit production in orchards. Computerized design can be extremely useful in the application of the constructive solutions defined by the team of researchers, allowing the simulation of movement and the identification of interactions with a destructive effect, between the component parts of the machine. In this way, the construction of the equipment can be optimized and the time required for the design can be reduced.

Description of software used

The software used was 3D SOLIDWORKS, which allowed the three-dimensional creation of the model, which has been the basis for the construction of the parts and component assemblies. This software can reduce the time for development, reduce the investments and improve the quality of the final product. Test projects can be tested under real-world conditions, by simulation of the working process. 3D SOLIDWORKS ensures product quality while reducing prototyping and physical testing costs. Process simulation has gained increasing importance, its role being very important for obtaining reliable equipment, but with reduced consumption of raw materials and materials used in the construction of the equipment.

3. Results and discussions

Using SOLIDWORKS software, the execution documentation has been generated. The designs have been used for the physical construction of the equipment.

The equipment consists of welded assemblies and elements in series production (gear motor, belt transmission, bearings, wheel, electro-hydraulic distributor, hydraulic cylinders, hydraulic components, removable fasteners: screws, nuts, washers, flat washers Grower and so on). The main part is the LiDAR, which it is different from the constructive solutions currently in production. The machine has an adjustable height of mowing. Crushed grass is left on the ground as organic fertilizer.

The equipment is mainly composed of a central mower, which cut the grass between rows of trees and a swinging mower, articulated to the central mower, which mows between trees per row. The equipment also includes a mechanical transmission, consisting of a cardan shaft with a safety coupling and a conical group. Its role is to actuate the rotor with blades, from the composition of the central mower.

The EIPP equipment also includes a hydraulic transmission, composed of 2 electro-hydraulic distributors, one rotary hydraulic motor and a double-action hydraulic cylinder. One of the distributors controls the movement of the rotor with blades, and the second distributor controls the position of the mower in relation to the central mower and the rows of trees, by means of the double-action hydraulic cylinder. The rotational movement given by the hydraulic motor is amplified 2.5 times with the help of a trapezoidal belt transmission, and is transmitted to the rotor with blades from the swinging mower.

The equipment also includes the command-and-control part of the swinging mower arm, which consists of a control box located in the tractor, which commands the switching of the first distributor in one of its 2 positions, and another command, which is given by a LiDar sensor that detects the trunk of the tree, transmits the information to the control box, which transmits the signal to the second distributor, activating the hydraulic cylinder. The return to the initial position is done by a traction spring, when the signal transmitted by LiDar ceases.

The equipment for mowing in fruit plantations, with laser trunk detection, Fig. 9, is mainly composed of the following main parts: a central mower, composed of a welded frame *1*, for attachment to the tractor, a case *2*, welded to the frame *1*, made of welded tubes and plates, a primary rotor consisting of a plate, *3*, on which some articulated knives are fixed, *4*, an assembled rotor fixed with a parallel wedge on the axis of a conical group *5*, a power shaft with safety coupling, *6* and conical group, *5*, AND a swinging mower, which has an arm, *7*, articulated to the central mower, a rotor equipped with 3 articulated knives, *8*, fixed to a disk, *9*, a belt transmission, consisting of a belt wheel, *10*, fixed to the shaft of the rotary hydraulic motor, *14*, by a parallel wedge, another belt wheel, *11*, fixed with a parallel wedge on the rotor shaft *9*, a transmission belt, *12*, a housing welded to the arm, *13*, in which the rotor *9* is mounted, with a cylindrical joint by radial-axial bearings, mounted on the shaft rotor, respectively in the housing of the swing mower, a hydraulic transmission consisting of a rotary hydraulic motor, *14*, a hydraulic cylinder, *15*, a distributor by two sections, *16*, with electric control, some hydraulic hoses and fittings and an automation system control, mounted on an adjustable support, *17*, fixed to the central mower, composed of a control box, *18*, a LiDAR laser radar, *19*. The working principle is presented in Fig. 10.

LiDAR is setup to detect the tree trunk in a defined range, depending of the distance between trees on the row. When the LiDAR (L) detects the trunk, a signal is transmitted to the control box, which, by an electric signal transmitted to the distributor acts the hydraulic cylinder and the swinging mower, CP, is moved behind the central mower, CC, avoiding the contact with the trunk.

After the signal transmitter by the LiDAR cesses, the swinging mower returns to the working position, for mowing between trees in a row, or around the trunk of trees. This working principle protects the tree trunks, avoiding the damage of the tree trunk bark. In Fig. 10, is presented the physical model of the equipment.

Preliminary results were obtained at the stationary tests of the mower. The constructive parameters have been checked, to compare the design with the physical construction. The experiments have been carried out on the experimental orchard, at INMA Bucharest.

Measurements were made of the main constructive dimensions of the experimental model and of the subassemblies, the overall dimensions, functional dimensions, the cutting height have been measured. Measurements of the equipment weight have been made. Also, the rotational speed of the rotors, cutting width has been measured. The measured values obtained at the stationary tests are presented in Table 1.

3. Conclusions

The mowing equipment, symbol EIPP-0, corresponds to the requirements imposed by the design theme, the constructive parameters proposed by the initial requirements have been achieved;

The mowing equipment obtained by the above research, designed for cutting grass or other plants in orchards/vineyards farms, will contribute to the improvement of the equipment for agricultural works, integrating sensors, software, in accordance with Agriculture 4.0;

Researches will be conducted for experimental tests in real conditions and the results will be presented in a new article.

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References

1. Dumitru M., 2015. Technical-economic analysis on forage mowers. Scientific papers-series management economic engineering in agriculture and rural development. Vol.15, Issue 4: 53-58.
2. Eberle C., 1998. Simulation of front-end-mowers adjustment to soil surfaces. Conference: Agricultural Engineering. Volume 1449: 183-187. https://www.mdpi.com/2077-0472/13/12/2276.
3. Kosutic S., 2013. The trends in the development of mowers. Actual tasks on agricultural engineering. 41st International Symposium on Agricultural Engineering. Vol.41, Pages 153-163.
4. Lal Rattan, Stewart B.A., 2012. Soil Water and Agronomic Productivity. CRC Press. pp. 461. ISBN 978-1-4398-5079-4.
5. Pirchio M., Fontanelli M., Labanca F., Sportelli M., Frasconi C., …& Grossi, N., 2019. Energetic Aspects of Turfgrass Mowing: Comparison of Different Rotary Mowing Systems. Agriculture. Vol.9, Issue 8. DOI10.3390/agriculture9080178.
6. Pittenger R. Dennis, 2002. California Master Gardener Handbook. UCANR Publications. pp. 567–. ISBN 978-1-879906-54-9.
7. Shuai Shen, Yichuan He, Zhihui Tang, Yameng Dai, Yu Wang, Jiaxin Ma., 2023. Development of an Orchard Mowing and Sweeping Device Based on an ADAMS–EDEM Simulation. Agriculture. Volume 13, Issue 12: 2276. https://doi.org/10.3390/agriculture13122276.
8. Soyoye B.O., 2021. Development and Performance Evaluation of a Solar Powered Lawn Mower. Turkish Journal of Agricultural Engineering Research. 2(2): 348-3622. https://doi.org/10.46592/turkager.2021.v02i02.009
9. Turgeon J. Alfred, McCarty Lambert Blanchard, Christians Nick Edward, 2009. Weed control in turf and ornamentals. Prentice Hall. pp. 126. ISBN 978-0-13-159122-6.
10. Upadhyaya K. Mahesh, Blackshaw E. Robert, 2007. Non-chemical Weed Management: Principles, Concepts and Technology. CABI. pp. 135. ISBN 978-1-84593-291-6.
11. ***, 2004. Vegetable Gardening: Growing and Harvesting Vegetables. Murdoch Books. pp. 110–. ISBN 978-1-74045-519-0.
12. ***, 2008. RHS A–Z encyclopedia of garden plants. United Kingdom: Dorling Kindersley. pp. 1136. ISBN 978-1405332965.
13. https://www.kuhn.com/en/crop/flail-mowers/orchard-vineyard-flail-mowers
14. https://www.fischeraustralis.com.au/orchard-mowers/
15. https://www.perfectvanwamel.com/en/sectors/orchards-and-vineyards/mowing/around-trees-vines/
16. https://fieldmaster.co.nz/vineyard-orchard-mowers
17. https://en.tehnos.si/flail-mowers-for-orchards-and-vineyards
18. https://gason.com.au/product/wing-deck
19. https://jagoda.com.pl/mowers-shredders/under-tree-mower-lucek/
20. https://jarmet.pl/en/products/orchard-mowers-2/

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Tables and Figures

Fig. 1. RN series

Fig. 2. T series

Fig. 3. VT-series

Fig. 4. Compact mowers with small width

Fig. 5. Mower with 2 swinging arms

Fig. 6. Mower with 1 swinging arm

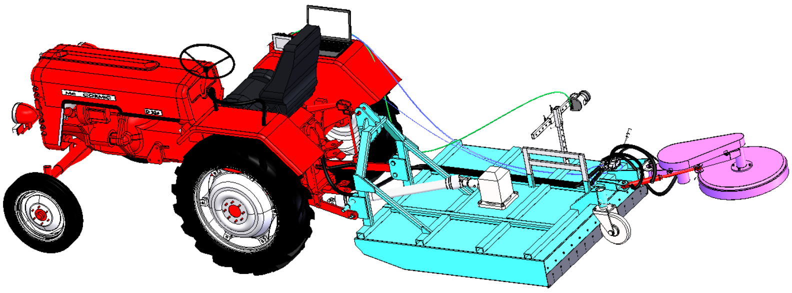

Fig. 7. Technical equipment for cutting grass in aggregate with the tractor

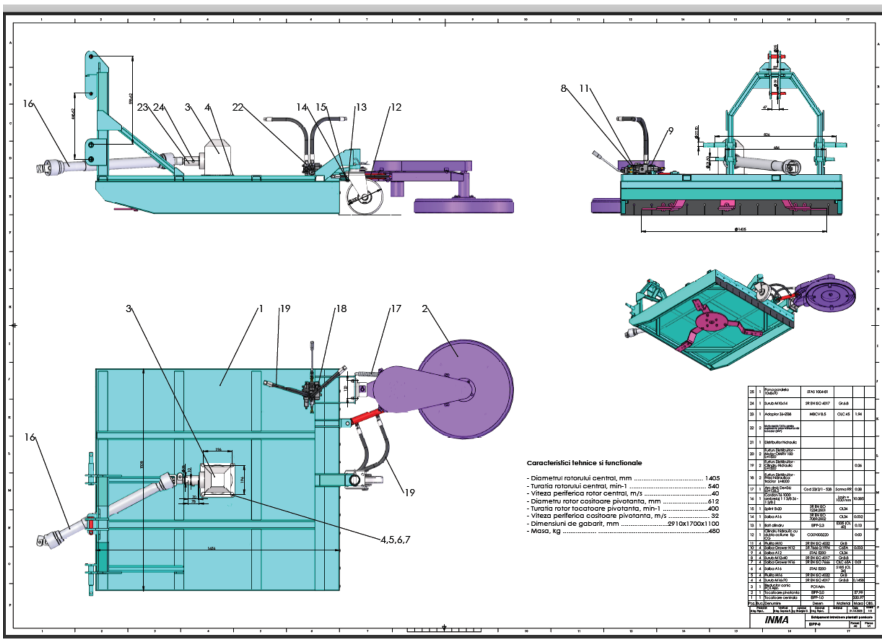

Fig. 8. Technical plan of the mower

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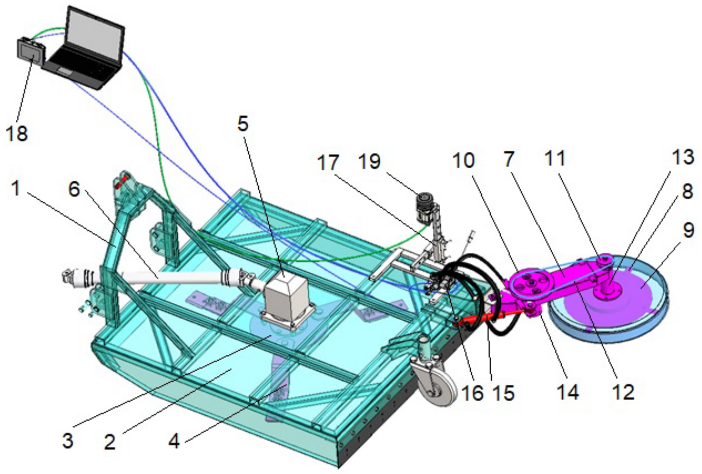

Fig. 9. Mowers equipped with LiDAR

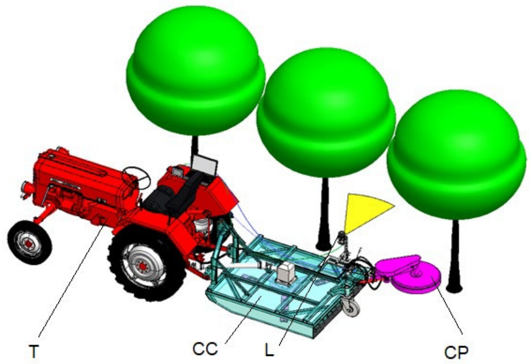

Fig. 10. Working scheme of the mower provided with LiDAR

Fig. 11. Orchard mower with LiDAR technology

Fig. 12. Aspects during stationary testing

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Table 1. Measurement results

Characteristics	Value
Overall dimensions, mm - length - width - height	 3730 1770 2540
Cutting width, mm	1400…2470
Cutting height, mm	40…90
Diameter of the main rotor, mm	1400
Number of blades of the main rotor, mm	3
Diameter of the second rotor, mm	610
Number of blades of the second rotor, mm	3
Rotational speed of the main rotor, rpm	530
Weight, kg	490