Technická univerzita vo Zvolene
Fakulta techniky
Katedra environmentálnej a lesníckej techniky

MOBILNÉ ENERGETICKÉ PROSTRIEDKY – HYDRAULIKA
– ŽIVOTNÉ PROSTREDIE
– ERGONÓMIA MOBILNÝCH STROJOV

Vedecký recenzovaný zborník

MOBILE ENERGY SYSTEMS - HYDRAULICS - ENVIRONMENT
- ERGONOMICS OF MOBILE MACHINES

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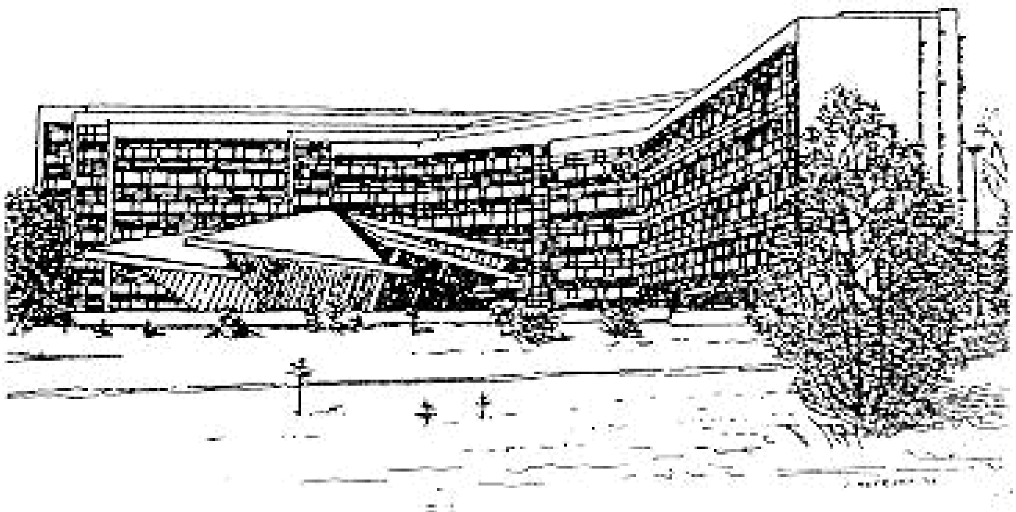

Zvolen, 2023

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KATEDRA ENVIRONMENTÁLNEJ A LESNÍCKEJ TECHNIKY

Mobilné energetické prostriedky – Hydraulika
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Obsah

4. ZÁVER

V príspevku sme sa zamerali na zhodnotenie využitia teleskopického manipulátora v poľnohospodárstve na nami vybranom podniku. Výskum a zber údajov prebiehal počas celého roka 2018. Po zhodnotení výsledkov sme zistili že manipulátor počas roku 2018 odpracoval spolu 2952,5 h. V rámci uvedeného časového rozpätia sa spotrebovalo 11 716 l nafty. Zaevidovali sme až 27 rozličných pracovných úloh, ktoré stroj počas roka vykonal. Najväčšie zastúpenie tvorili práce pri kŕmení hovädzieho dobytku a to až 73 % z celkového pracovného času. Práci so slamou a senom prislúchalo 10% a nakladacím prácam v rastlinnej výrobe 7 %. Ostatné práce súviseli s nakladaním v živočíšnej výrobe (6 %), pričom servisné úkony činili 1%. Zvyšok tvorili iné pracovné činnosti. Z hľadiska hodnotenia mesiacov, najväčšie zastúpenie využitia bolo v auguste (300,5 h) a najmenej vo februári (211 h). Sezónnosť ako dôležitý faktor poľnohospodárstva nemal značný vplyv na náš manipulátor, pričom ale nemožno poprieť, že najviac práce mal stroj počas jarného, letného a jesenného obdobia. Na základe tohto možno tvrdiť, že manipulátor je vybraným podnikom dostatočne využívaný.

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MODERN CONTROL OF PHYSICAL PARAMETERS OF SUBSTRATES IN CONTAINER NURSERIES

Mariusz KORMANEK - Jacek BANACH - Łukasz MATEUSIAK - Sylwester TABOR - Stanisław MAŁEK

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ABSTRACT: An important problem of container forest nursery is to ensure uniform, favourable growth conditions for the cultivated plants. This can be achieved by ensuring similar physical parameters of the substrate used for growing seedlings in individual cells of the container. Measuring the physical parameters of substrates as well as those related to nursery production is difficult and often time-consuming, but currently easily available measurement, control and monitoring systems enable progress in these issues as well. The work presents three new prototype solutions for measurement stations for controlling the physical parameters of substrates and parameters related to nursery production. The first measurement station is a multipenetrometer, which is used to control the substrate density in many cells after filling the containers with substrate on the production line. The second station is used to measure the rate of water leakage from container cells, which is related to the retention of water in container cells after the irrigation process. The third station measures the resistance to pulling seedlings out of container cells, which is particularly important in the context of newly emerging automated afforestation planters. The presented stations can be used to control current production, control the quality of the substrate supplied for production, the quality of substrate preparation for filling containers, but they also allow obtaining information necessary when developing new substrate compositions or designing machines related to the planting process.

Key words: container, forest nursery, physical and mechanical parameters, measuring system,

1. Introduction

Forest container nursery is the production of high-quality planting material on a specially composed substrate placed in the cells of a nursery container. The volume, shape and number of cells in the container are related to the plant species and the requirement to obtain the highest possible efficiency from a unit of production area [Szabla and Pabian *2003*]. For this reason, the size of the cells is usually small, and water and nutrients are supplied mainly through irrigation systems and foliar fertilization systems, and/or by adding fertilizer to the substrate. Therefore, the nursery substrate is important, mainly its physical parameters and its chemical composition [Rolbiecki *et al. 2010*; Leciejewski *2011*]. The substrate used in Poland for the production of seedlings is prepared from high sphagnum peat, with a small addition of other components, e.g. perlite, vermiculite. High peat is characterized by high porosity and water capacity, high sterility and low mineral content, which facilitates the determination of fertilizer doses [Szabla and Pabian *2003*]. Recommended parameters for the peat-perlite substrate most commonly used in Poland are total porosity 70–93% by volume, water capacity 73% by volume. and air 20–25% by volume, available water 48% by volume, wet weight 864 kg $\cdot$ m^{-3} [Cabrera and Johnson *201*4, De Boodt and Verdonck *1972*, Fernandes and Cora *2004*; Szabla, Pabian *2003*]. Inappropriate physical parameters of the substrate are difficult to correct, and the main problem is too low or too high air capacity levels, which are related to the substrate density [Allaire *et al. 1996*]. As is known, the degree of compaction and settlement of the substrate in container cells is greater when using thicker elements constituting the substrate, with a more varied volume density of components or with more intensive irrigation. The change in compaction over time is the result of the movement of small substrate particles from the upper level of the cell to the lower one and the decomposition of organic matter. The increase in density is also influenced by the development of roots, while increasing the permeability of the substrate, which facilitates the diffusion of gases [Allaire *et al. 1996*; Mathers *et al. 2005*; Evans and Gachukia *2007*; Altland *et al 2011*].

Measuring the density of the substrate in container cells, the most commonly used method, involves taking the entire substrate from the container cell and determining the bulk density. When it is necessary to perform a quick control measurement of compaction, the bulk density parameter is difficult to use, but it can be replaced by an easily measurable parameter, which is compactness (penetration resistance). Compactness is considered a measure of soil compaction and is used in many areas of the economy such as civil engineering, agriculture and forestry, as well as in the military [Kremer et al. *2007*; Wang *2009*; Lee *et al. 2019*, Kormanek and Dvorak *2021*; *2022*, Kormanek *et al. 2023*]. Compactness determines the ratio of the resistance generated when pressing the penetrometer cone to the area of its base. The compactness is influenced primarily by the granulometric composition, structure, bulk density and moisture of the nursery substrate [ASAB *1998*, Kees *2005*, De Moraes *2014*].

The compaction of the substrate is closely related to the rate of water outflow from the container cell, which affects the retention of water and water with fertilizer in the substrate. This parameter is difficult to measure, especially with many low-volume cells are located in a small container space.

Another important parameter that is important at the end of the seedling production process, related not only to the substrate, but also to the shape of the cell and the material from which the container is made, is the resistance to pulling the grown seedling out of the container cell. This parameter affects the amount of energy needed to pull out the seedlings, but also the aspect of damaging containers, especially those made of porous material (styrofoam), into which the root system may grow, or damage to the root systems.

The aim of the work was to present new design solutions of three prototype measurement stations, which are intended to support the optimization of production in container nurseries by measuring the compactness of the substrate, the rate of water leakage from the substrate, and the resistance of pulling the seedling out of the container cell.

2. Prototype Measuring Stations

The presented prototype technical solutions of the stations were created as part of the tasks in the NCBiR research project 1/4.1.4/2020 implemented by a consortium including the University of Agriculture in Krakow and Bioaktyw Sp. z o. o. The main topic of the project is the development of a new substrate recipe for use in container production.

2.1 Station for measuring the compactness of the substrate in the container

To determine the level of substrate density in many container cells, a new, prototype solution of the measurement station, the so-called Multipenetrometer for containers was proposed [P.441918 *2023;* Kormaek *et al.2023*]. The device allows for quick control of the compactness of the substrate in a nursery container, performed simultaneously in several cells, which accompanies the process of filling the containers on automated lines for filling the substrate (Figure 1). The station consists of a frame (1) to which a movable base (2) in the form of a flat steel plate is attached and a fixed upper steel plate (3) on which strain gauge sensors (4) are mounted in various places. The sensors are influenced by the insertion rods (5) ended with indenters (penetrometers) in the form of cones (6). On the basis of the station (2), a nursery container (7) is placed. The base plate is mounted on linear bearings (8) moving on guide shafts (9), and its movement is caused by the drive screws (10). On the upper plate (3), the strain gauge sensors (4) are influenced by the insertion rods (5), ending with cones (6), during the upward movement of the movable plate (1) and the container (7). The rotation of the propellers (5) is caused by chain gears (11), which is driven by an electric motor (12) with a reducer (13). The speed of introducing cones (6) into the cells is regulated by the rotational speed of the electric motor (12) controlled by the inverter. The up and down movement of the plate is limited by limit sensors (14) connected to the system controlling the direction and operation of the drive motor (12). The force of pressing the cones (6) into the substrate in the container cells (7), measured by strain gauge sensors (4), is transmitted after amplifying to a multi-channel recorder and then to a computer for processing and archiving measurement data. The measurement at the station involves placing the container (7) on the movable plate (2) and then performing the measurement by causing it to move upwards, which causes the individual penetrometric cones (6) to sink into the ground located in the container cells. In the prototype solution, a single V150 and V300 Styrofoam container from Marbet (dimensions: length 650 mm, width 312 mm) or three HikoV120SS or V265 containers (dimensions: length 352 mm, width 216 mm) placed on a moving plate were used to measure compactness in 15 cells at once.

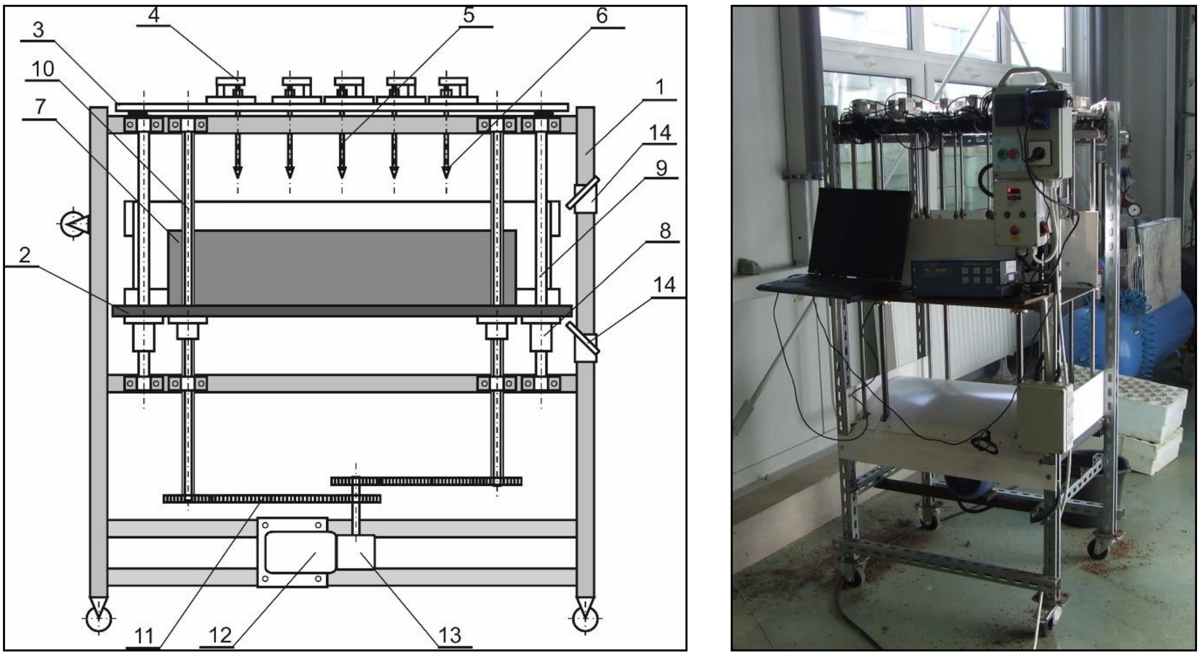

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Figure 1. Prototype Multipenetrometer station for measuring substrate compactness in nursery containers [P.441918 *2023*], station diagram -a, measurement in the container -b. Fig. and photo: M. Kormanek

1 - movable base frame, 2 - movable plate, 3 - upper plate, 4 - strain gauge sensors, 5 - insertion rods, 6 - conical indenters, 7 - nursery container, 8 - linear bearings, 9 - guide rollers, 10 - drive screws, 11- chain gears, 12- electric motor, 13- reducer, 14- limit switches;

As a result of the measurement at the Multipenetrometer station, each of the measurement sensors provides a relationship between the force of pressing the cone and the depth of penetration of the penetrometric cone into the substrate located in the container cell. An example of this relationship for the V150 container is shown in Fig. 2.

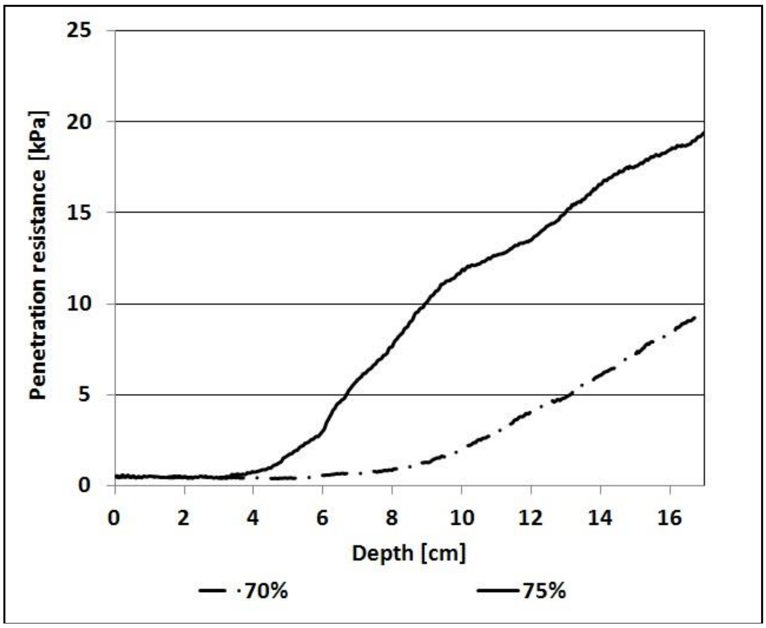

Figure 2. Substrate penetration resistance as a function of the penetration of the penetrometer into the V150 Marbet container cell, at various substrate moisture levels when filling the containers.

2.2 Station for measuring the rate of liquid drainage from container cells

A prototype measurement station was used to measure the outflow of liquid from the substrate located in the container cells (Fig. 2) [P.443675 *2022*]. It is an automated measuring device that allows you to measure the outflow of liquid from the substrate filling many container cells at the same time. The station consists of a main frame (1) in which the lower (2) and upper (3) tanks are installed. In the central part of the frame, a horizontal fixed frame is mounted (4), into which a replacement drain plate is inserted (5), on which the tested container (6) is placed. The drain plate has drain pipes installed, which drain the liquid from the bottom of the individual cells of the container. From the top, the container is pressed by a movable frame (7) mounted on linear bearings (8) moving on vertical guide rollers (9). The pressure of the frame is caused by compression springs (10), the tension of which is caused by a lever mechanism (11). Water is supplied to the upper frame (7) from the upper tank (3) through adjustable spray nozzles (12). An overflow hole is made on the side of the upper frame (7), which establishes a constant water level above the upper surface of the container (6). The excess liquid from the overflow hole flows to the lower tank (2). Water is pumped into the upper tank (3) by a pump (13) from the lower tank (2), where excess water is drained to the lower tank (2). From the individual drain stubs on the drain plate, the liquid is fed through the settling filters (14) via solenoid valves (15) to the lower tank or via solenoid valves (16) to measuring containers (17) mounted on strain gauge weighing sensors (18). Information about the mass of incoming water from the strain gauge sensors (18) is transferred to the recording system equipped with the station. The measurement at the station involves placing the container (6) on the drainage plate (5) and clamping the movable frame (7) on the container (6) thanks to a lever mechanism (11) with a pressure spring (10). Then the container is flooded with water from the top and the liquid percolates through the individual cells of the container (6). The liquid flowing from the cells of the container can be directed thanks to electro valves (15) to the lower tank (2) or thanks to electro valves (16) to measuring containers (17) placed on weighing sensors (18). In the prototype solution, in a single V150 and V300 Styrofoam container from Marbet or in three HikoV120SS or V265 containers placed on a drainage plate, the outflow is measured simultaneously on 15 load cells. Measurements can be performed in containers filled with substrate, as well as with plants growing in the container.

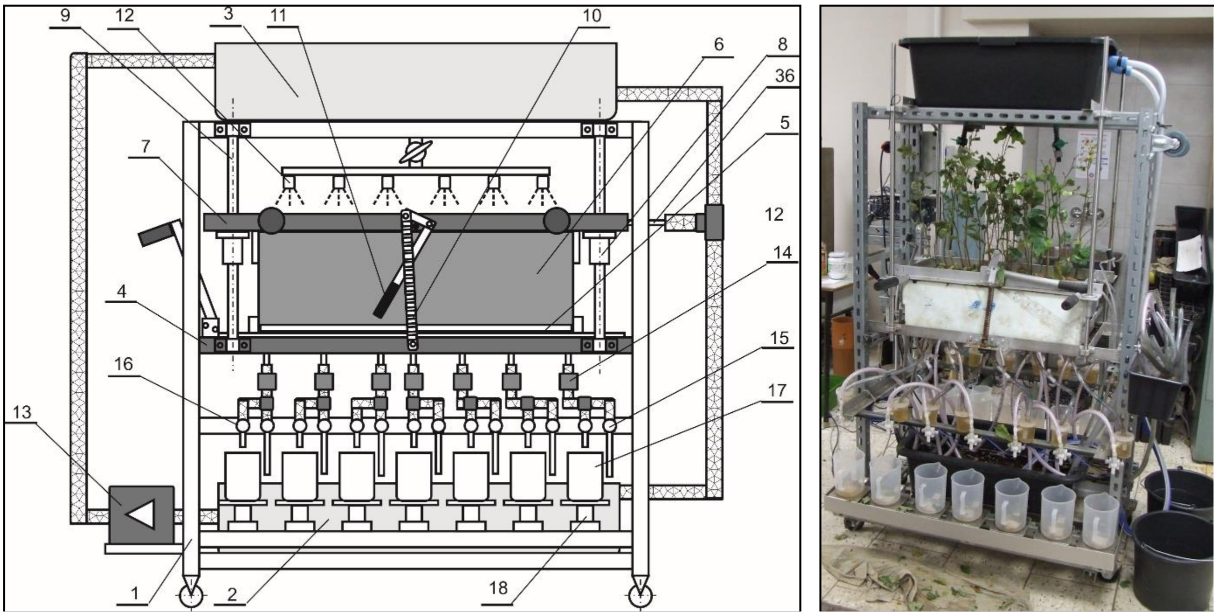

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Figure 3. Prototype station for measuring the rate of water leakage from a nursery container [P.443675 *2022*], diagram of the station -a; measurement in the container -b. Fig. and photo: M. Kormanek

1- main frame, 2- lower tank, 3- upper tank, 4- fixed frame, 5- drain plate, 6- container, 7- movable frame, 8- linear bearings, 9- guide rollers, 10- compression springs, 11- lever mechanism, 12- spray nozzles, 13- pump, 14- settling filters, 15, 16 solenoid valves, 17- measuring containers, 18 strain gauge sensors

As a result of the measurement at the station for measuring the rate of water leakage from the container, the dependence of the increase in liquid weight over time is obtained from each of the measurement sensors. An example of this relationship for a V150 Styrofoam container is shown in Fig. 4.

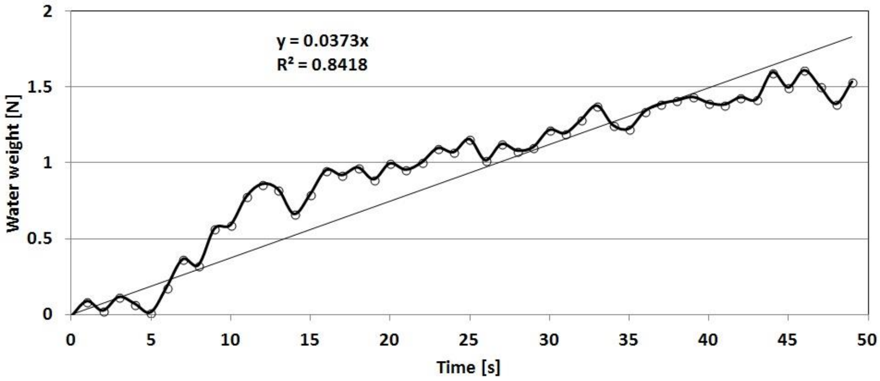

Figure 4 The increase in the weight of water as it percolates through the substrate in the cell of the V150 Marbet container

2.3 Station for measuring the resistance of pulling seedlings out of the container

A prototype measurement station was used to measure the resistance of pulling seedlings out of the container (Fig. 5) [P.441918 *2023*]. The station consists of a main frame (1) on which a stationary base plate (2) is mounted, on which a nursery container (3) with seedlings (4) is placed. The container (3) is attached to the base plate (2) using two horizontal flat bars (5) through which vertical threaded rods screwed into the plate pass base and tightened from above with wing nuts. At the top of the frame (1), X-axis guide rollers (6) are mounted in holders, on which linear bearings are mounted, in holders (7), on which rectangular support plates (8) are mounted, to which Y-axis guide rollers (9) with linear bearings in holders are mounted (10), attached to the base plate (11). The base plate (11) is moved in the horizontal plane manually and, thanks to the guide rollers and linear bearings in the holders of the drawout is measured. The location of the base plate is determined by the racing rope (12), which is led through the guide roller (13) and wound on the rope winch drum (14). The rotation of the rope winch drum (14) is caused by the electric motor via an angle gear reducing the rotational speed of the engine. At the end of the winding rope there is a self-clamping handle (15), which is mounted on the root collar of seedling (4). The rope winch drum (14) together with the electric motor, gear and guide roller are mounted on the winch plate (16), which is connected to the base plate via a shaft and bearings (17), which allow the winch plate (16) to freely deflect in relation to the base plate (11). The movement of the winch plate (16) in relation to the base plate (11) is limited by the bending strain gauge (18). During pulling seedlings (4) out from container (3), the force in the hoisting rope is transferred to the strain gauge sensor (18), from which the variable voltage, depending on the value of the resistance force in racing the seedlings, is transferred to the strain gauge amplifier, and then to the analog-to-digital converter and the microprocessor system recording the force values. Measurement of the vertical displacement of the seedlings (4), during the process, it is pulled out of the container using a rotary encoder mounted on the drum shaft of the rope winch. The station allows for measurement of any seedling within the container, measurement in any type of container, measurement at a constant speed of racing the seedling, and registration of the pulling resistance seedlings in the device's memory as a function of the vertical displacement of the seedlings, which allows for the analysis of the process and the evaluation of the seedlings. An example of this relationship for the V150 container is shown in Fig. 3.

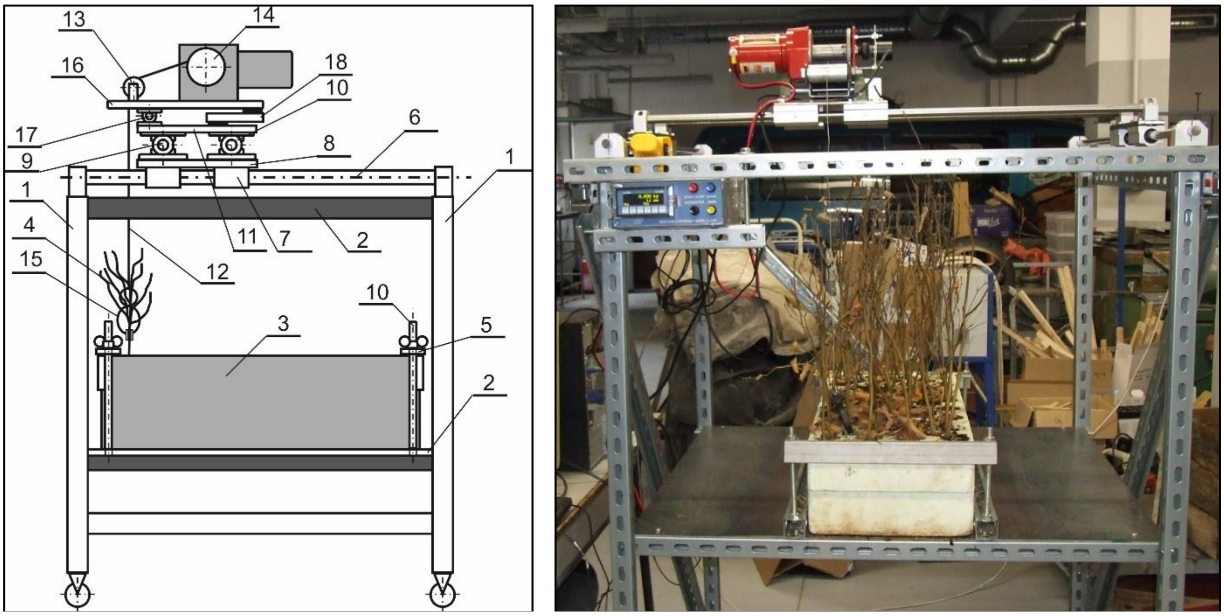

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Figure 5. Prototype stand for measuring the resistance of pulling seedlings out of a container [P.445111 *2023*]

1- main frame, 2- base plate, 3- container, 4- seedling, 5- flat bars, 6- X-axis guide rollers, 7- linear bearings, 8- support plates, 9- Y-axis guide roller holders, 10- linear bearings 11- base plate, 12- rope 13- roller, 14- winch drum, 15- self-clamping handle, 16- winch plate 17- shaft and bearings, 18- strain gauge. Fig. i fot.: M. Kormanek

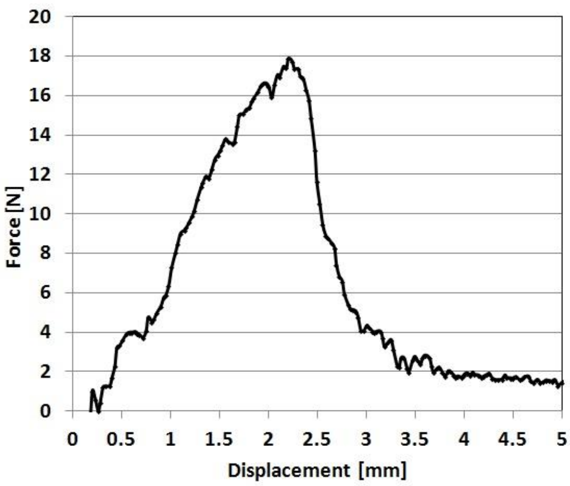

Figure 6. Resistance to pulling out a beech seedling from a V300 Marbet container

3. DISCUSSION

The presented technical solutions of prototype measurement stations can be used at various stages of nursery production:

- Due to the quick measurement (approximately 1 minute), the Multipenetrometer allows you to control the process of filling containers on the container filling line. If there is a significant variation in the compactness parameters within the containers or if the compactness parameters are too high/low, adjustments can be made to the settings of the units filling the container with substrate on the automated line. The device also allows us to draw conclusions about the quality of the substrate itself, its preparation (mixing, moistening) and the work of teams of employees operating the automated line.

• The station for measuring the rate of water leakage from container cells, due to the long measurement time, allows for control before the start of the production cycle or during production of the quality of materials supplied for production (homogeneity of the material in terms of granulometric composition or structure), the quality of containers prepared for sowing, as well as supports the process of optimizing the use of water and fertilizers.

• A station for measuring the force of pulling seedlings out of the container beyond control at the end of production (overgrowth of the substrate lump with roots, roots growing into the container, wear of the containers over time), allows obtaining information important when designing feeding systems in judging machines.

All of the presented solutions for measurement stations allowed, in the ongoing NCBiR project 1/4.1.4/2020, to verify the suitability of the newly developed substrate for use in container forest nurseries.

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