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CHANGES IN TEMPERATURE DURING SEEDLING STORAGE IN STYROFOAM MULTIPOTS KEPT ON SHELVES IN OUTDOOR CONTAINERS UNDER DIFFERENT COVER MATERIALS

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Abstract. The aim of this study was to determine changes in temperature found during short-term seedling storage on shelves kept on racks under different cover materials. Analyses assessed the effect of different materials for covering of loading space on interior temperature changes. Collected results were to supply information on the effect of this factor on the quality of seedling material in view of specific conditions produced under the cover. Analyses were conducted under conditions found in the loading space using temperature and humidity sensors by Vaisala. The distribution of sensors at different levels in the loading space and the fact that some of them were coupled with fans enforcing air circulation made temperature measurements possible over a larger space. Results were recorded using a KNE Data Logger, recording the results on the PCMCIA memory card. The device recorded data collected from the measurements taken over any selected period. This facilitated analysis of the effect of a direct impact of external conditions on temperature changes in containers under covering made of different materials. It results from the conducted investigations that air temperature in each measurement site fluctuated. During intensive solar radiation a marked increase in temperature was observed under container covering. It was found that the covering material for the racks has a very big effect on the course of changes in temperature inside the racks.

Key words: agrotextile, Douglas fir, canvas cover, storage, seedlings, frame, transport, temperature

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INTRODUCTION

Transport of seedlings constitutes an important element in the afforestation and regeneration of forests. Although the final effect, i.e. reforestation success, depends on many factors, the shipping of the seedling material and its importance seem to be underestimated, as it is confirmed by scarce literature data concerning this problem. The studies were conducted at the Department of Forest Engineering, the Poznan University of Life Sciences in cooperation with the Industrial Institute of Agricultural Engineering in Poznań that identified this problem [Ratajczak 2010, Dubowski et al. 2009, 2011]. Also American scientists indicated the importance of transport of deciduous tree seedlings in multipots (in Poland incorrectly called containers). They were of an opinion that reforestation success is attainable only when the entire production process is perceived as a series of interdependent operations from the production of seedlings at a nursery to their outplanting, taking into consideration all intermediate procedures and measures. For this reason transport is equally important as any other operation concerning the production process of establishing a new plantation.

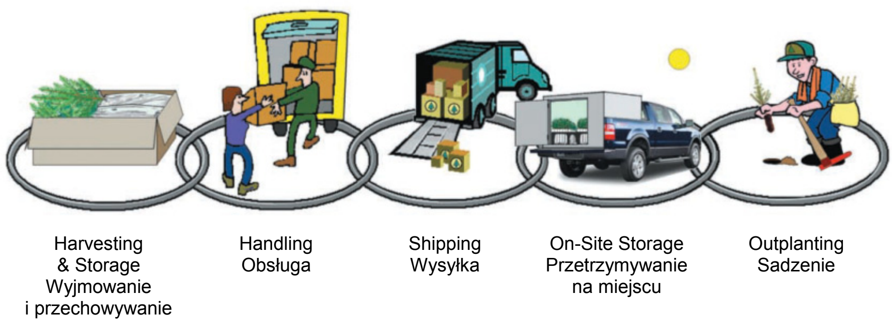

Fig. 1. Chain of dependencies connected with the transport of seedlings composed of interdependent operations [Landis et al. 2010]
Rys. 1. Łańcuch zależności związanych z procesem transportu sadzonek składający się z operacji wzajemnie powiązanych [Landis i in. 2010]

What is the situation in the Polish State Forests, in which annually over 1 billion seedlings are transported? To date no standards have been established, which would concern seedling transport from forest nurseries to the plot allocated to regeneration. In practice it is arranged for the service provider to collect seedlings from the nursery and deliver them to the forest land as they see fit.

An increase in the distance during seedling transport results from changes occurring in the Polish forest nursery production. Thus it has become essential to gather information on the conditions under which storage, shipping and transport of seedlings are performed and their modification depending on the applied measures.

Transport of seedlings in multipots is relatively complicated due to their size. It poses a problem both in case of styrofoam and plastic multipots. To facilitate loading and unloading, as well as their transfer multipots should be transported on special racks (commonly called frames). In turn, due to the changing weather conditions, particularly wind, racks have to be covered with a canvas cover. A unique microclimate is produced under the canvas cover, being a factor influencing the transported seedling material both during the travel and when parking. Covers may be made from different materials, i.e. cotton fabric, rubber, plastic, wood or tin sheets, thus it is essential to determine the generated climatic conditions and their effect on the covered merchandise.

Some authors [Boetzelser 1984] reported that the temperature under a cover during seedling transport does not threaten their survival rates. A greater problem is connected with the stage of seedling loading, which, when executed manually lasts, 1 day.

In turn, Szabla and Pabian [2009] reported that transport of seedlings in multipots on frames from the nursery to their destination may result in their overdrying. What is important, the threat is much lower than in the case of bare-root seedlings; however, the use of fast cars during adverse weather conditions may lead to substrate and seedling overdrying. During transport, particularly at high speeds, freezing may occur and for this reason seedlings should be transported under covers. The load-carrying body closed in this way protects seedlings against the adverse effect of the weather.

The problem of substrate temperature is significant in the case of myccorrhizal seedlings, in which overheating or overdrying of the substrate ball has to be prevented [Kowalski 2007].

No detailed results have been found in available literature concerning changes in temperature occurring under covers during transport. It may be assumed that such studies have not been conducted to date. Similarly, no study results have been found on the effect of long-term seedling storage under covers on their survival rates. This is significant since racks with seedlings, generally designed for the transport of seedlings in styrofoam containers from a forest nursery to the outplanting site may in exceptional cases be used for short-term (several days) storage of loaded seedlings.

This problem is addressed in the studies on the development of transport conditions for seedlings in styrofoam containers in a specially designed semitrailer.

EXPERIMENTAL MATERIAL AND METHODOLOGY

Conducted analyses aimed at the assessment of the effect of the type of material, from which covers (rack covers) are made, on air temperature inside the frame. Used covers were made from agrotextile in three colours: white, green and black, as well as a typical material used in canvas covers, the so-called canvas material.

Analyses were conducted when keeping racks protected with covers, which were placed outdoors, at an eastern warehouse wall so that at 1 p.m. the sun set behind the building wall and from that moment racks were in the shade.

The scope of investigations covered measurements of changes in air temperature recorded continuously using special sensors, with data recording executed every 15 minutes and the recording in the electronic memory conducted for one day.

Styrofoam pots with 1-year old Douglas fir seedlings were placed on four shelves of each rack. Sensors taking measurements were arranged so that a temperature sensor equipped with a fan was placed under the rack ceiling in the immediate contact with the cover. Another thermocouple with a fan was placed in the needles of seedlings on the second shelf. Also on that shelf thermocouples (without fans) were placed in the substrate with seedlings.

Racks were arranged in a row. On the right there was a rack covered with a green agrotextile cover (Z), the middle one – black (C) and white agrotextile (B), while on the left there was a rack covered with a cover made from a silver canvas material (P).

Fig. 2. Measurements of air temperature in racks and containers standing in open space
Rys. 2. Pomiary temperatury powietrza w regałach i pojemnikach stojących na odkrytej powierzchni

Agrotextile covers were produced by STRADOM S.A. from STRADOMAGRO Premium 100 agrotextile, typically used in agriculture, orchard production and horticulture.

According to the manufacturer, STRADOMAGRO agrotextile due to its structure guarantees adequate air circulation and water permeability at one of the highest indexes in commercially available materials (Table 1). This ensures good water permeability (no puddles on mats) and guarantees adequate release of moisture from the subsoil.

To date these textiles have not been used as covers for racks in the transport of seedlings, particularly forest trees.

Canvas materials used in the production of vehicle canvas covers are produced using polyester net covered with PCV. They differ in basis weight, width and colour, while having extremely high rupture and tear strength, as well as resistance to adverse weather conditions (Table 2). This material meets the waterproof and steam tightness requirements, thus a cover produced from such material does not breathe.

Prismatic covers with rectangular bottoms were made to fit ideally the rack size. Each cover was not completely sawn in one of the longer sides to facilitate its placement over the racks. The cover could be tightened using a rubber puller (in the form of strings) pulling together two cover sides. On one of them two rows of typical canvas hooks were attached, while on the other one row of holes was made, through which a row of hooks was protruding. Such a divided wall of the cover facilitated a relatively easy separation of the cover for loading and unloading of the racks of seedlings in styrofoam multipots.

Table 1. Technical parameters of STRADOMAGRO Premium 100 agrotextile (http://www.stradom.com.pl/oferta/Geotkaniny.html)
Tabela 1. Parametry techniczne agrotkaniny STRADOMAGRO Premium 100 (http://www.stradom.com.pl/oferta/Geotkaniny.html)

Item Lp.	Parameter Cecha charakterystyczna	Value of parameter Wielkość parametru
1	basis weight – gramatura	100 $g \cdot m^{-2}$
2	widths – szerokości	1.6 m, 3.2 m 4.57 m, 5.25 m
3	colours – kolorystyka	black, brown, green, white czarna, brązowa, zielona, biała
4	water permeability PN-EN ISO 11058 wodoprzepuszczalność PN-EN ISO 11058	0.026 (+/– 0.05) $m \cdot s^{-1}$
5	UV stabilisation – stabilizacja UV	150 kLy, test according to standard ASTMG 154 – 98: 5 years in central and eastern Europe 150 kLy, test wg normy ASTMG 154 – 98: 5 lat w Europie środkowo-wschodniej
6	packaging – pakowanie	textile on rolls of 100 running metres, packaged in stretch foil or polyethylene foil tkanina nawinięta na rolkach po 100 metrów bieżących, pakowana w folię stretch lub folię polietylenową

Table 2. Basic properties of canvas material
Tabela 2. Podstawowe cechy materiału plandekowego

Item Lp.	Characteristics Cecha charakterystyczna	Value of parameter Wielkość parametru	Standard Norma
1	2	3	4
1	textile – tkanina	100% PES 2 × 1100 dtex	
2	basis weight – gramatura	900 $g \cdot m^{-2}$	DIN EN ISO 2286-2 BS 3424 method 5A BS 3424 metoda 5A
3	composition – skład		
	textile – tkanina	260 $g \cdot m^{-2}$	DIN EN ISO 2286-2 BS 3424 method 5B BS 3424 metoda 5B
	coating – powłoka	640 $g \cdot m^{-2}$ PCV	
4	rupture strength – wytrzymałość na rozrywanie		
	warp – osnowa	4000 N/5 cm	DIN 53 354 BS 3424 method 6A BS 3424 metoda 6A
	weft – wątek	3500 N/5 cm	
5	tearing strength – wytrzymałość na rozdzieranie		
	warp – osnowa	600 N	DIN 53 356 BS 3424 method 7A BS 3424 metoda 7A
	weft – wątek	600 N	

Table 2 – cont. / Tabela 2 – cd.

1	2	3	4
6	PCV adhesion to polyester przyleganie PCV do poliestru	100 N/5 cm	DIN 53 357 BS 3424 method 9B BS 3424 metoda 9B
7	thermal strength wytrzymałość na temperatury	–30°C +70°C	DIN EN 1876-2 BS 3424 method 10 BS 3424 metoda 10

Measurements of temperature were taken using sensors by Vaisala. Some of them were equipped with fans enforcing air circulation in their vicinity in order to measure air temperature over a larger area, and not in the vicinity of the sensor itself. Results were recorded using a KNE Data Loger with 32 signal inputs, which facilitated simultaneous measurements of 32 temperature values. Results were recorded on a PCMCIA memory card, with the capacity of 440 000 records of 32 results in each. Results recorded on the memory card were transferred to the computer and analysed in detail using the Excel programme. Thanks to the graphic tools of that programme they may be presented in graphs.

RESULTS

The analyses showed that fluctuations in soil air temperature on racks kept outdoors were very big. This was particularly evident in the late morning hours and around noon at the direct effect of the solar radiation (Fig. 3).

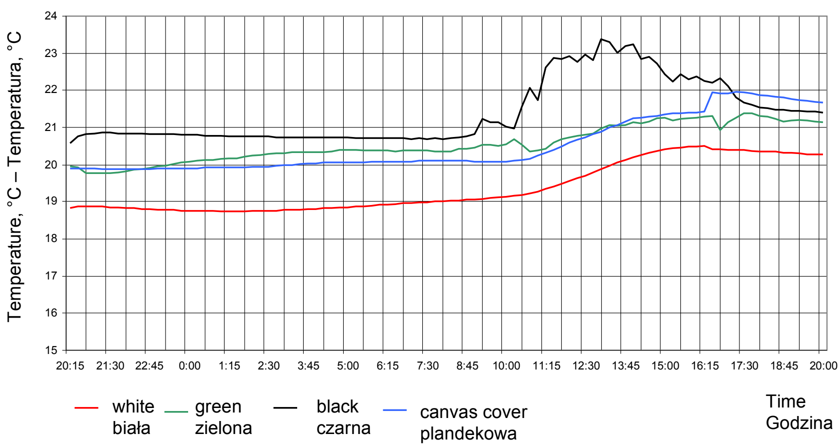

Fig. 3. Changes in soil air temperature in the root balls of seedlings in styrofoam multipots shielded with different materials and kept outdoors

Rys. 3. Zmiany temperatury powietrza glebowego zachodzące w bryłce korzeniowej sadzonki w wielodoniczkach styropianowych, osłoniętych różnymi materiałami, podczas przetrzymywania na dworze

Starting from 9:00 a marked increase was observed in soil air temperature. It was greatest for the rack covered with the black cover, slightly lower for the container covered with the green cover and for the racks covered with the cover made from canvas cover material. At noon hours the temperature under the canvas cover exceeded that under the green canvas cover, to increase rapidly at 4:30 p.m. and exceed the temperature under the black cover. The lowest increments in soil air temperature were recorded in soil with seedlings in styrofoam multipots, in the container under a white cover.

Fluctuations in soil air temperature indicate that despite the low overall heat transfer coefficient of styrofoam, the substrate in multipots made from this material heats up under the influence of long-terms action of the sun. The most intensive heating was observed for the black cover and at a slightly lower level for the green cover, while it was lowest for the white cover and for the canvas material cover. However, for the latter cover a constant increase in air temperature may be observed despite the absence of sunlight operation.

Measurements of air temperature under the ceiling of the tested container covers are given in Figure 4.

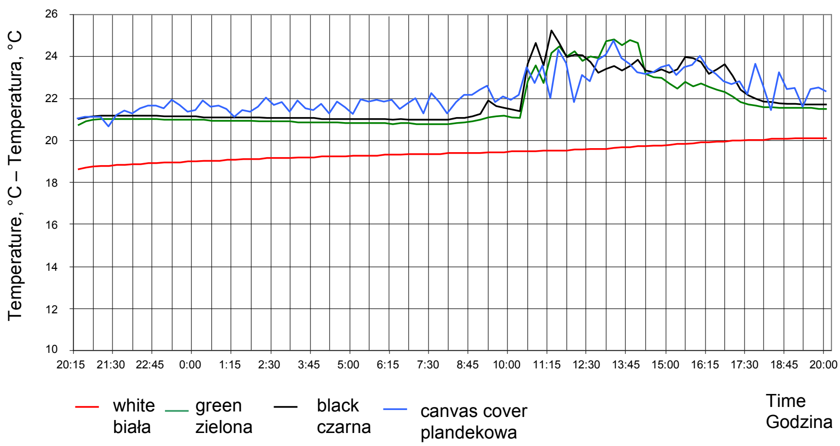

Fig. 4. Changes in air temperature under the ceiling of racks with styrofoam multipots covered with different materials and kept outdoors

Rys. 4. Zmiany temperatury powietrza pod stropem regałów z wielodoniczkami styropianowymi, osłoniętymi różnymi materiałami, zachodzące podczas przetrzymywania na dworze

Also in this case we may observe the effect of solar radiation on changes in temperature. This was particularly evident for black and green covers and for the one made from canvas material. For the canvas cover fluctuations in temperature were conspicuous. Air temperature under this cover fluctuated intensively. Even at night it cooled and heated up, similarly as during the day, which is characteristic of this cover. For the white cover the increase in air temperature under the ceiling was constant and relatively uniform and no effect of sunlight on the intensity of changes was observed.

The course of changes in air temperature in the seedling needle zone was quite similar, with a characteristic increase in temperature at the time of intensive sunlight operation. Temperature in the needles was similar for the black cover and for that made from canvas material. Its minimal increase could be observed even at night. At the time of the initial intensive operation of sunlight a characteristic decrease in temperature may be observed, which after a certain time begins to grow successively even up to late afternoon hours, with no rapid peaks at noon hours, as it could have been observed for white and green covers. In turn, white and green covers cause slightly higher heating of air in needles of seedlings, particularly at noon hours (Fig. 5).

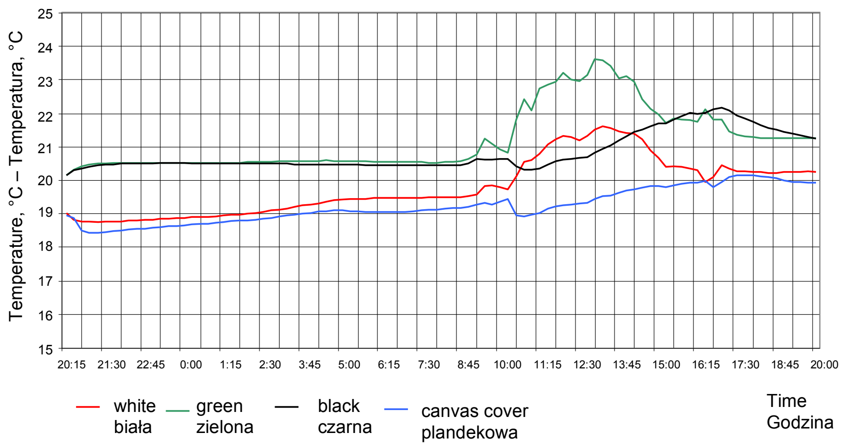

Fig. 5. Changes in air temperature in seedling needles during outdoor storage of styrofoam multipots shielded with different materials

Rys. 5. Zmiany temperatury powietrza w igliwiu sadzonek zachodzące podczas przetrzymywania na dworze styropianowych wielodoniczek osłoniętych różnymi materiałami

DISCUSSION AND RESULTS

A detailed analysis of the results shows that the material, from which rack covers are made has a great effect on the course of interior temperature changes. The cover made from white agrotextile proved to be most effective. The smallest fluctuations in air temperature in each measurement point were recorded inside the rack shielded with the white cover. Similar conclusions were presented by American researchers, who experimentally stated very good insulating properties in covers made from white and silver-coloured Mylar, as it is shown in Figure 6. Irrespective of the used covers, seedlings should always be stored in shaded places [Ratajczak 2010]. As it was correctly observed by Landis et al. [2000], the necessity for seedling storage is not a physiological requirement of plants, but one of the operations in the transfer of seedlings from the nursery to the outplanting site.

The graphic illustration of the results indicates that black and green agrotextile do not protect seedlings as effectively as white agrotextile produced in an identical manner and from the same material. Temperature of the nursery substrate (Fig. 3) and temperature under the ceiling (Fig. 4) reach the highest values in the case of black and green agrotextiles.

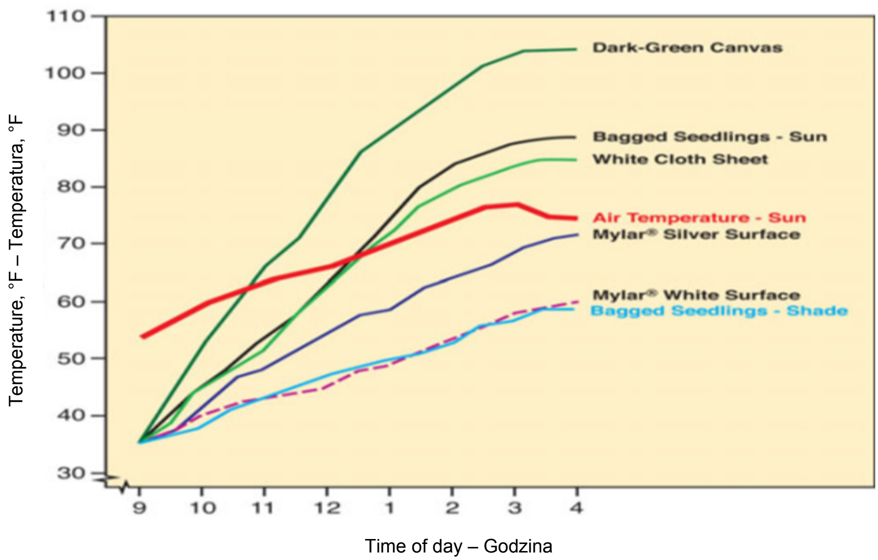

Fig. 6. Changes in air temperature in the vicinity of seedlings during outdoor storage shielded with different materials [DeYoe et al. 1986]
Rys. 6. Zmiany temperatur powietrza w otoczeniu sadzonek, osłoniętych różnymi materiałami, zachodzące podczas przetrzymywania na dworze [DeYoe i in. 1986]: Dark-Green Canvas – ciemnozielona opończa, Bagged Seedlings – Sun – worki z sadzonkami na słońcu, White Cloth Sheet – biała tkanina jako opończa, Air Temperature – Sun – temperatura powietrza w słońcu, Mylar Silver Surface – osłona z srebrnego Mylaru, Mylar White Surface – osłona z białego Mylaru, Bagged Seedlings – Shade – worki z sadzonkami w cieniu

Analyses showed that inappropriate seedling handling has a considerable effect on their quality [Adams and Patterson 2004], while the occurrence of extreme temperatures during seedling storage constitutes one of the three main stress factors to which they are exposed. In this case we have to stress following Paterson et al. [2001] that seedlings produced in a forest nursery and prepared for shipment reach their maximum value at that time point.

Moreover, results of the analyses show that a canvas material cover is more effective in protection against temperature changes. This was also pointed out by DeYoe [1986], who stated that canvas covers provide a much better insulation than standard green cloth. However, water tightness and even steam tightness of the canvas material, particularly during intensive activity of sunlight may produce a disadvantageous microclimate inside the rack. Water vapour heating inside the rack creates the greenhouse effect. Heating-up of seedlings was not observed using available research methods; however, the recorded microclimate may pose a considerable risk for their further viability, which was manifested in needle discolouring. Effects of stress influencing tree seedlings accumulate, causing a gradual reduction of their viability and capacity of appropriate growth after outplanting and as it is confirmed by studies in this respect their effects may be invisible even months after outplanting [Landis et al. 2010].

CONCLUSIONS

Based on the conducted analyses the following conclusions may be formulated:

1. The use of covers made of agrotextile as shields for seedlings in multipots transported on frames relatively effectively protects them against considerable temperature changes inside the loading space and in the nursery substrate.

2. Containers covered with the white agrotextile cover provide the most effective protection of seedlings during long-term outdoor storage.

3. Covers made from black and green agrotextile and particularly from canvas cover material should not be used in a situation of a potential extended parking period or a longer outdoor storage of seedlings.

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ZMIANY TEMPERATURY PODCZAS PRZECHOWYWANIA SADZONEK W WIELODONICZKACH STYROPIANOWYCH W KONTENERACH OSŁONIĘTYCH RÓŻNYMI MATERIAŁAMI WYSTAWIONYMI NA WOLNYM POWIETRZU

Streszczenie. Badania nad opracowaniem nowej koncepcji transportu sadzonek w pojemnikach styropianowych, przewożonych w kontenerach, na specjalnie do tego celu skonstruowanej naczepie, odnoszą się do problemu ze względu na istotny wpływ rodzaju użytego okrycia ładunku. Specyficzny mikroklimat, wytwarzający się w przestrzeni ładunkowej przykrytej opończą, jest czynnikiem w różnoraki sposób wpływającym na przewożony towar zarówno podczas przejazdów, jak i na postoju. Bardzo istotne więc okazuje się zagadnienie warunków klimatycznych wytwarzających się pod opończą w powiązaniu z rodzajem przewożonego towaru. Obejmuje transport sadzonek ze szkółki do miejsca przeznaczenia, przechowywanie na postoju, przygotowywanie do załadunku lub czas po rozładowaniu i opóźnionym wysadzeniu na powierzchni. Powstaje wówczas ryzyko przesuszenia sadzonek bądź ich przemarznięcia. Dlatego niezmiernie istotna staje się technologia transportu sadzonek, począwszy od ich przygotowania na szkółce, poprzez transport na miejsce przeznaczenia i dalsze postępowanie do momentu ich wysadzenia w grunt. Badania nad transportem sadzonek zmierzają do oceny jak rodzaj materiału, z którego są wykonane okrycia przestrzeni ładunkowej, wpływa na zmiany temperatury w jej wnętrzu. Rejestracja pomiarów wykonywanych czujnikiem temperatury i wilgotności firmy Vaisala, w warunkach istniejących w przestrzeni ładunkowej, pozwoliła zaobserwować przebieg zmian warunków, zachodzących pod stropem kontenera służącego do transportu, w igliwiu i w glebie transportowanych sadzonek. Poznanie przebiegu zmian temperatury – w zależności od rodzaju okrycia i okresu przetrzymywania pod okryciem – ma duże znaczenie i pozwala na właściwie dopasowanie elementów składających się na wykonanie całego procesu spedycji. Wyeliminowanie rozpoznanych błędów ma znaczenie dla jakości dostarczonego materiału, związanej z tym udatności zakładanych upraw i płynących z tego korzyści ekonomicznych. Przeprowadzone badania pozwoliły stwierdzić, że materiał, z którego są wykonane osłony kontenerów ma bardzo duży wpływ na przebieg zmian temperatury i wilgotności powietrza wewnątrz przestrzeni ładunkowej.

Słowa kluczowe: agrotkanina, daglezja, opończa, przechowywanie, sadzonki, regały, transport, temperatura

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