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CHANGES IN HUMIDITY DURING OUTDOOR STORAGE OF SEEDLINGS IN STYROFOAM CONTAINERS ON RACKS COVERED WITH DIFFERENT MATERIALS

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Abstract. The study was to provide information on changes in humidity during short-term storage of seedlings on shelves in containers covered with different materials. Collected results made it possible to specify how the type of material of loading space coverings influences changes in the interior humidity. This made it possible to determine the effect of this factor on quality of seedling material under the specific conditions produced under the covering. Analyses in the loading space were conducted using temperature and humidity sensors by Vaisala, recording humidity changes for conditions found under the covering. Sensors were placed under different levels in the loading space. Some of them were equipped with fans enforcing air circulation, facilitating measurements of humidity over a larger space. Using a KNE Data Logger measurements were registered and the results were recorded on a PCMCIA memory card. Measurements were taken over a 24-hour period, facilitating analyses of the effect of a direct action of external conditions during the day and night on changes in humidity in containers covered with coverings made from different materials. It results from the conducted analyses that humidity changes occurred in each of the measurement points. These changes were more marked during intensive operation of sunlight, when a distinct drop in humidity was observed under loading space coverings. It was stated that the material, from which rack coverings were made, has a significant effect on the course of changes in interior humidity, which could have a significant effect on the quality of stored seedlings.

Key words: Douglas fir, covering, agrotextile, short-term storage, transport, seedlings, racks, humidity

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INTRODUCTION AND AIM

Transport of seedlings in the process of afforestation and forest regeneration constitutes an important element in the operation chain in this technological sequence. It needs to be stressed that reforestation success is influenced by the entire technological process in the reforestation production. It is not only the material used in reforestation that is important and it is not only the fact whether it meets quality standards in visual inspection that we need to focus on. Conditions under which it was stored upon completion of its production in a forest nursery and under which it was transported onto the regeneration plot determine its viability and chances for adequate reforestation success. The final effect obviously depends on many factors. However, it is the transport of seedling material that seems to be underestimated, as evidenced by the very limited resources on this subject in research and literature sources, and which – despite changing conditions under which it is presently provided – has an undisputed considerable impact. Studies were conducted at the Department of Forestry Engineering, the Poznań University of Life Sciences in cooperation with the Industrial Institute of Agricultural Engineering in Poznań in view of the need to investigate this problem at present conditions [Dubowski et al. 2009, 2011]. Analysis of this subject also showed that American researchers point to all actions performed in relation with operations from the beginning of works at the nursery and ending with outplanting. It clearly results from their observations that transport and storage of seedlings constitute important elements in the chain of dependencies in the seedling transport process [Landis et al. 2010].

The State Forests transport over different distances more than 1 billion seedlings produced for their needs connected with artificial forest regeneration. There are no standards or principles under which conditions this transport should be provided. Applied solutions frequently result from the approach to this problem developed in current practice. This is performed using their own resources, as convenient for the service provider, which accepts seedlings from the nursery and delivers them to the forest area as they see fit.

The presently observed direction of changes in the Polish model of forest nursery production clearly indicates a trend towards an increase in the distances over which seedlings are transported. Thus their forwarding and shipment gain in importance, which makes it absolutely essential to gather information on its performance and on what elements we need to focus to achieve assumed objectives. Storage conditions and transport of seedlings are modified depending on the used resources.

Transport of seedlings in multipots is connected with certain complications due to the relatively large area occupied by the root ball, which results first of all from the size of multipots adapted to the requirements of forest nursery production. This pertains both to styrofoam and plastic multipots. They are transported on special racks (frames) facilitating their efficient loading and unloading. In view of changing weather conditions, particularly wind, during their shipment they are protected by a covering. The specific microclimate produced over such a loading space is a factor influencing in various ways the transported load, both during travel and when parking. Coverings are made from diverse materials, e.g. cotton textiles, rubber, plastics, wood or metal sheets, which makes it crucial to gain insight into the conditions found under the covering.

Kowalski [2007] stated that it is unacceptable to inappropriately handle the seedling material, particularly to store it under conditions potentially leading to root-ball overdrying.

Szabla and Pabian [2009] also reported that during transport of seedlings on racks from the nursery to their destination they may be overdried. For this reason the loading space of vehicles used in seedling transport needs to be covered.

Studies focused on the effect of the type of used load covering on the transported seedling material in order to develop a new approach to the transport of seedlings in styrofoam containers placed on racks (frames) on a specially designed semi-trailer.

No reports have been found in the available literature related to investigations concerning changes in humidity observed under covering (commonly, but erroneously called canvas cover) during transport, which indicates that such studies have not been conducted to date. Analogously, no results have been obtained on research concerning the effect of long-term seedling storage under covering on their survival rates. From the point of view of the analysed problem it is essential considering that under exceptional conditions racks with seedlings are used for short-term storage (several days) prior to their outplanting.

Seedlings on racks are not always prepared for transport from the nursery in tightly closed, roofed facilities. Conditions, under which seedlings are prepared for shipment, kept before being transported and stored until outplanting may vary greatly: it may be in the rain, i.e. high humidity, and in dry air, in windless weather and at intensive movements of air masses.

EXPERIMENTAL MATERIAL AND THE SCOPE OF STUDY

Analyses aimed at the assessment of the effect of cover type on changes in humidity inside the racks, in which multipots with 1-year old Douglas fir seedlings were placed on four shelves. Seedlings of Douglas fir were produced in a 1-year long production cycle using styrofoam boxes by ROBIN (France) of 650 × 312 mm and 200 cm^3 round cells tapering towards the bottom. Used coverings were made from agrotextile coming in three colours: white, green and black, as well as typical covering material (commonly, but erroneously called vehicle canvas covers), the so-called canvas cover material.

The scope of investigations described in this paper covered measurements of changes in humidity taken using special sensors by Vaisala, registered in a continuous manner, with the recording of results averaged at every 15 minutes and data recording in the electronic memory on memory cards, registered for 1 day.

METHODOLOGY

Analyses were conducted during storage of 1-year old Douglas firs shielded with coverings made from different materials, stored outdoors at an eastern wall of a warehouse so that at 1 p.m. the sun set behind the building wall and from that moment racks were in the shade.

Styrofoam containers with seedlings were placed in racks on shelves. Humidity sensors were arranged so that a sensor equipped with a fan was mounted under the ceiling in the immediate contact with the covering. Another thermocouple with a fan was placed in the needle zone of seedlings placed on the second shelf. Also on that shelf thermocouples (without fans) were placed in the substrate with seedlings.

The rack on the left was covered with a covering made from white agrotextile (B), the central one with black agrotextile (C), while the right – with green agrotextile (Z). Properties and structure of agrotextiles used in the analyses were presented in a paper by Mordas et al. [2012]. A rack covered with a canvas covering (P) was placed in the central row on the right. Technical parameters of this material were also reported in a publication by Mordas et al. [2012].

According to the manufacturer of the STRADOMAGRO agrotextiles they guarantee adequate water permeability thanks to their structure, and thus they have one of the highest indexes offered on the market. This is due to the ideal water penetration (no puddles on mats) and it also guarantees adequate release of moisture fro the substrate.

STRADOMAGRO agrotextiles are applied in forest and ornamental plant nursery production, rack and soil cultivation, in orchard production, in strawberry growing and establishment of gardens and green areas. To date the manufacturer did not consider the use of these textiles as coverings for racks in the transport of seedlings, particularly forest trees.

Materials commonly referred to as canvas cover materials used in the production of vehicle covers are produced on the basis of a polyester net covered with PCV and they differ in terms of basis weight, width and colours. They have exceptionally high tear and rupture strength, as well as resistance to adverse weather conditions. They meet waterproof requirements and they are not permeable to vapour.

Coverings were prismatic with a rectangular bottom so that they fit the shape of the racks and their size fit accurately that of the racks. They were installed by pulling onto the metal rack structure from the top. At such a placement of the covering its bottom constituted the ceiling of the rack. The lower shelf in the racks (shelf 1) was a shield against intensive exchange of air or temperature from the bottom.

A covering set (made from either white, green or black agrotextile, or from a canvas material) was modified so that one of the longer sides was not sown along all its length and it was attached to the rest of the cover by pulling two cover walls together using a rubber string. On one of the walls a row of typical canvas cover hooks was adequately attached to the covering wall. In the other, parallel wall one row of holes was made, through which a row of hooks was extended.

Encircling the hooks with the rubber string resulted in the attachment being relatively tight (thanks to the overlapping of both fabric layers), elastic and first of easy to provide. Such a divided covering wall facilitates relatively easy partition of the covering for loading and unloading of styrofoam containers with seedlings.

Measurements were taken using thermocouples (sensors of humidity) by Vaisala. Some of them were equipped with fans, which enforced air circulation in their surroundings. These measurements of humidity need to be taken over a larger area and not only in the immediate vicinity of the sensor. Some of them were not equipped with fans. Results were recorded using a KNE Data Logger with 32 signal inputs, i.e. facilitating a simultaneous measurement of up to 32 humidity values. The frequency of measurements was arbitrary, ranging from every 5 s to any frequency, while the recorded value is averaged by the device within the tested time interval. Results are recorded on a PCMCIA memory card, on which 440 000 rows of results with 32 results in each row may be recorded.

Sensors were arranged in all the four racks (under the white, green and black covering, and for comparative purposes under the canvas cover material) under the ceiling of racks (immediately at the upper covering wall). In those places sensors with fans were placed, which task was to enforce a jet of air and measurements of its greater volume. Thermocouples mounted in the needle zone of seedlings in styrofoam containers placed on the second shelf in the same racks were also equipped with fans. In order to investigate the distribution of moisture content and substrate overdrying at individual racks covered with selected materials, thermocouples without fans were mounted in the substrate.

Humidity was measured under the ceiling of the rack covered with the tested materials and in the needle zone, while moisture content was recorded in soil of root-ball seedlings grown in styrofoam containers placed on shelves in racks covered with different types of coverings and kept outdoors. The objective was to verify which changes in humidity take place in individual places when a styrofoam container is exposed to the long-term action of weather factors, i.e. sunlight, wind or rain.

Fig. 1. Racks covered with different coverings during outdoor storage of Douglas fir seedlings (photo R. Wojtkowiak)
Rys. 1. Stelaże osłonięte różnymi opończami podczas przechowywania sadzonek daglezji na wolnym powietrzu (fot. R. Wojtkowiak)

RESULTS

In the course of the conducted investigations it was found that changes in root ball moisture content in racks standing outdoors were conspicuous. Observed changes initially indicated a downward trend in moisture content, followed by stabilisation of this parameter (Fig. 2).

In the rack covered with a black covering initially slight changes were observed in soil moisture content with a marked reduction in moisture content in the noon and afternoon hours, when the effect of sunlight was observed. The greatest stability, resulting from the maintenance of an almost identical soil moisture content, was found for a rack covered with the green material. In turn, similar results were observed in racks covered

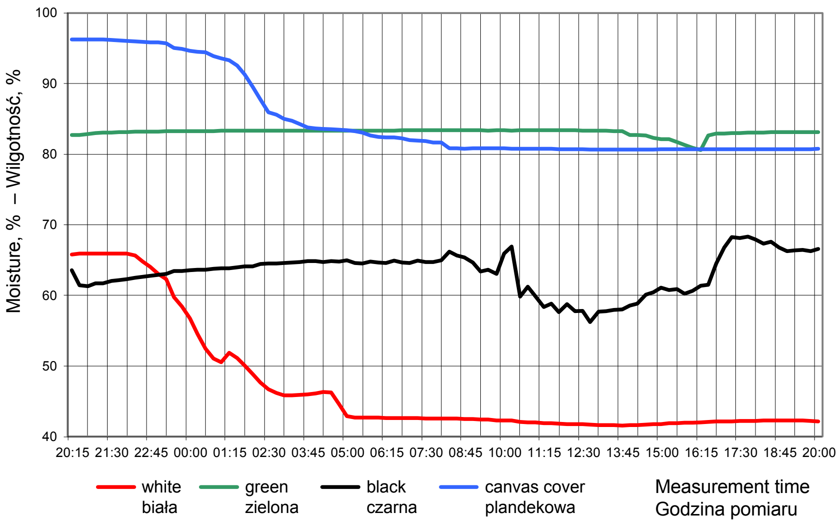

Fig. 2. Changes of moisture content in root balls of Douglas fir seedlings occurring during outdoor storage of styrofoam multipots kept on racks covered with different materials

Rys. 2. Zmiany wilgotności bryłki korzeniowej sadzonek daglezji zachodzące podczas przetrzymywania na wolnym powietrzu wielodoniczek styropianowych na stelażach osłoniętych różnymi materiałami

with canvas material covering and the white covering material, manifested in the course of changes in soil moisture content with an initial decrease and next the maintenance of constant moisture levels.

Observed changes in soil moisture content indicate a reduction progressing in time, i.e. a phenomenon occurring during storage of seedling material kept under cover.

The situation was different for the course of moisture content changes in needles of seedlings in racks covered with different types of coverings and kept outdoors (Fig. 3).

The course of recorded changes is similar when using all types of coverings. A characteristic finding was connected with a reduction of moisture content at the time of intensive sunlight operation and even shortly after sunset. We need to stress here similar courses of moisture content for black and green coverings.

Similar results were found when observing humidity under the ceiling of racks covered with black, green and canvas covers (Fig. 4). In this case the effect of sunlight was also conspicuous, as in the period from 10:30 to 4:30 a considerable decrease was recorded in humidity and maintenance of its low level. Among the applied rack covers the canvas material used as covering caused the greatest amplitude of changes in humidity under the ceiling.

Considerable losses of humidity (Fig. 4) could have influenced the observed discolouring of needles in seedlings stored in styrofoam containers kept on shelves in racks covered with black, green and canvas materials (Fig. 5) over a longer time period.

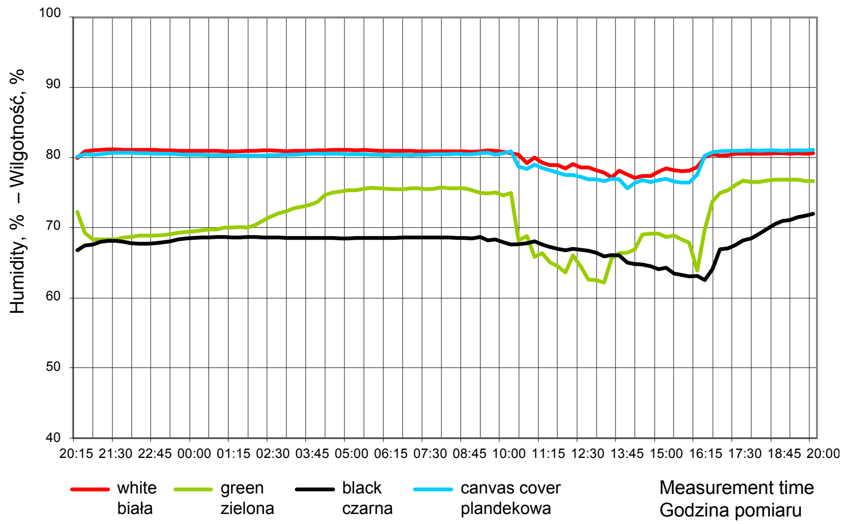

Fig. 3. Changes in humidity in the needle zone of Douglas fir seedlings occurring during outdoor storage of styrofoam multipots covered with different materials

Rys. 3. Zmiany wilgotności powietrza w strefie igliwia sadzonek daglezji zachodzące podczas przetrzymywania na wolnym powietrzu wielodoniczek styropianowych osłoniętych różnymi materiałami

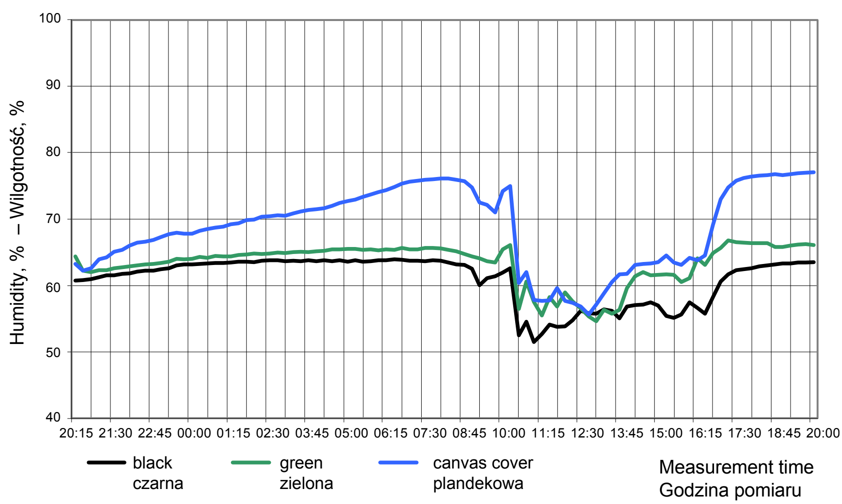

Fig. 4. Changes in humidity under the ceiling of racks holding Douglas fir seedlings during outdoor storage of styrofoam multipots covered with different materials. Humidity was not recorded under white covering

Rys. 4. Zmiany wilgotności powietrza pod stropem stelaża z ustawionymi sadzonkami daglezji zachodzące podczas przetrzymywania na wolnym powietrzu wielodoniczek styropianowych osłoniętych różnymi materiałami. Nie zarejestrowano wilgotności pod opończą koloru białego

Fig. 5. Discoloured needle endings in Douglas fir seedlings as a result of their storage under black covering (photo R. Wojtkowiak)
Rys. 5. Odbarwione końcówki igieł sadzonek daglezji w wyniku ich przetrzymywania pod czarną opończą (fot. R. Wojtkowiak)

DISCUSSION AND RESULTS

Based on these analyses it may be stated that the material, from which rack covers were made, had a considerable effect on changes in humidity in their interior. Covering made from white agrotextile had the best properties. Humidity inside a rack covered with the white cover material was most stable. No marked discolouring was observed in needles of the examined seedlings during long-term storage of seedlings in styrofoam containers on shelves of racks covered over a longer period (3 days) under this covering.

Also a relatively high amount of sunlight penetrates through the canvas material, from which coverings of e.g. lorries are made. PCV coating of canvas covers has a low capacity to reflect selected light lengths. Covering made from canvas material has a better protection potential against changes in humidity, which was confirmed by DeYoe et al. [1986] indicating very good insulation properties of this material. However, during intensive heating as a result of the action of sunlight a highly adverse microclimate is formed inside the rack covered with a covering made from this material. Its waterproofing capacity and even steam tightness are advantages in the case of maintenance of a relatively constant humidity or protection against penetration of moisture inside. However, as a result of a lack of such an exchange, particularly at an increase in temperature, intensive heating of water vapour inside the rack is observed. In this way a greenhouse effect is created. It was aptly observed by Ratajczak [2010] that irrespective of the type of used coverings seedlings need to be always stored in shaded places. Although no seedling scalding was observed due to the relatively short observation period, the microclimate produced under such conditions shows that it may pose a considerable threat to their further viability, which was manifested in needle discolouring. These changes may have a negative effect on seedling survival rates at later dates, since studies conducted on the subject show a lack of effects of stress factors immediately after outplanting, which the seedling material was exposed to [Landis et al. 2010].

This is also confirmed in other studies, which show that inappropriate seedling handling has a considerable effect on their quality [Adams and Patterson 2004].

CONCLUSIONS

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

1. Coverings made from agrotextile relatively effectively protect seedlings against changes in humidity/moisture content during their outdoor storage in the summer period.
2. Racks covered with a white agrotextile covering provide the most effective protection for Douglas fir seedlings during their further outdoor storage.
3. Coverings made from black and green agrotextile and from canvas cover material should not be used in the case of a potential longer parking or probable outdoor seedling storage extended over a longer period.

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ZMIANY WILGOTNOŚCI PODCZAS PRZECHOWYWANIA SADZONEK W POJEMNIKACH STYROPIANOWYCH W KONTENERACH OSŁONIĘTYCH RÓŻNYMI MATERIAŁAMI WYSTAWIONYMI NA WOLNYM POWIETRZU

Streszczenie. Transport sadzonek, ze względu na istotny wpływ rodzaju użytego okrycia przestrzeni ładunkowej, jest bardzo istotnym zagadnieniem w procesie odnawiania lasu poprzez sadzenie. Z punktu widzenia hodowcy materiał użyty do odnowień powinien spełniać określone normy jakościowe oraz cechować się dużą żywotnością. Warunki, w jakich odbywa się transport nie są bez znaczenia, dotychczas nie prowadzono jednak szczegółowych badań odnośnie zmian wilgotności zachodzących pod opończami podczas transportu, a także ich wpływu na materiał sadzeniowy. Osłonięcie przestrzeni ładunkowej opończą wpływa w różnoraki sposób na transportowany towar, nie tylko podczas przejazdów, lecz również na postoju (ze względu na klimat, który może się wytwarzać pod opończą). W takich warunkach dochodzi do zmian wilgotności i temperatury powietrza, co stwarza ryzyko przesuszenia sadzonek bądź „zaparzenia" ich pędów w wyniku niekorzystnego oddziaływania obu tych czynników. Zbadanie przebiegu zmian wilgotności w zależności od rodzaju zastosowanego okrycia – w trakcie przechowywania sadzonek podczas całego procesu załadunku, transportu i rozładunku łącznie z okresem przestojów – umożliwia podjęcie właściwej decyzji co do wyboru materiału, z którego będzie wykonana opończa. Wyniki badań pozwoliły ustalić, że materiał, z którego produkuje się okrycia ładunków ma bardzo duży wpływ na przebieg zmian wilgotności powietrza wewnątrz przestrzeni ładunkowej. Ponadto zastosowanie niewłaściwego materiału doprowadziło do uszkodzenia pędów sadzonek, powodując ich odbarwienia. Nie zaobserwowano zaparzania się sadzonek, ale występujące warunki mogły stworzyć duże zagrożenie dla żywotności materiału sadzeniowego. Transport sadzonek drzew leśnych – z uwagi na rozwój i zmiany w podejściu do produkcji sadzonek, ale również i modelu szkółkarstwa leśnego – z pewnością wpłynie istotnie na głębsze zainteresowanie się tą tematyką. Zbadanie pewnego zakresu tego zagadnienia, wbrew pozorom istotnego i złożonego, wskazuje na dalszą potrzebę analizowania tematu. Wiadome jest, że sadzonki transportowane w warunkach niewłaściwych, nawet po kilku latach od założenia, w wyraźny sposób obniżają jakość oraz udatność uprawy. Zbadany aspekt warunków wilgotnościowych w przestrzeni ładunkowej, zmieniających się w zależności od rodzaju zastosowanego okrycia, ze względu na wydłużanie się odległości transportowych, czyli również czasu przewozu, wpływa znacząco na konieczność dokładnego rozpoznania zagadnienia.

Słowa kluczowe: daglezja, wielodoniczki, opończe z agrotkaniny, przechowywanie, transport, stelaże, sadzonki, wilgotność

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