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Control of forest pathogens present in forest crops in the current climatic context

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Abstract
The creation of artificial stands that are structurally stable and resistant to biotic agents involves the production of seedlings in an intensive regime (grow tent), where their development conditions are optimized, while creating premises to produce infections with various pathogens. Thus, continuous monitoring of the crops is required to have healthy and vigorous seedlings.
To control soil pathogens, a spruce crop was installed in the grow tent located at the Lechința Experimental Base (Bistrița-Năsăud County), in which both synthetic and biological fungicides were tested.
If, in the past, crop monitoring was done through field observations, nowadays, technological progress allows the rapid detection of disruptive biotic or abiotic factors by using digitalization, placing a surveillance camera with infrared vision (IR) connected to a wireless router for remote monitoring in real time of the crop installed within the grow tent.
Data logger sensors were also placed to determine soil temperature (at -6 cm), at soil level (0 cm), at 12 cm and at 1.3 m height, respectively soil moisture and at 1.3 m height.
Of the products tested, the synthetic fungicide based on fluopicolide 62.5 g/l + propamocarb hydrochloride 625 g/l and the biological one based on *Bacillus amyloliquefaciens* strain FZB2 offered the most effective protection against the "seedling damping off" disease caused by *Fusarium spp* and *Pythium spp*.
From the observations made during 2024, it results that an average temperature between 15°C and 25°C in the air, associated with the range of 16 °C and 20°C in the soil and a relative humidity in the air above 75% respectively 30-35% in the soil, maintained between 4 and 6 consecutive days, led to the occurrence of the "seedling damping off " disease in spruce, which allows us to state that the onset of infections occurs within these climatic ranges.

Keywords: grow tent, fungicides, sensors

Introduction

The creation of artificial stands of structurally stable coniferous trees resistant to biotic agents involves the production of seedlings in an intensive (grow tent) regime, in which their development conditions are optimized, while creating, at the same time, premises to produce infections with various pathogens. Thus, continuous monitoring of crops is required to have healthy and vigorous seedlings under current climate dynamics [2,12].

The effects of climate change are increasingly felt, influencing temperatures and precipitation both in the growing season and annual averages, their impact having a significant effect on the production of seedlings, as well as on the spatial incidence of diseases [11,24,19].

The negative effects of environmental factors are felt in Romanian forests, being like those in most European countries, with more areas being reported with a poor vegetation condition, especially that caused by diseases that have begun to become frequent [14-20]. The pathogens in growing tents, being in constant evolution, adapting to environmental conditions as well as to anthropogenic influences, require permanent monitoring for effective control. In parallel with the evolution of pathogens, various technical monitoring and control solutions are continuously developed, on the one hand based on new, non-polluting, and non-toxic synthetic products, and on the other hand by implementing new climate monitoring and image tracking technologies in various color spectra [9].

Complex research on the production of seedlings in relation to the incidence of diseases has been carried out over time to obtain vigorous seedlings and, implicitly, qualitative stands [7].

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The main factors that favor the activity of pathogenic organisms, such as microclimate conditions and the sensitivity of forest species, must be monitored carefully to limit the damage caused by diseases [5, 17].

With the tightening of environmental protection protocols, a wide range of products used in the control of the disease "dumping off" no longer correspond to the new trends in environmental protection, thus requiring studies on the adaptation of new fungicides to the needs of silviculture, in accordance with the evolution of pathogens. These involve combining laboratory studies with those on monitoring the behavior of pathogens in the field [13,16]. For this reason, it is necessary to test new products approved in the agricultural field for their use in the control of the "dumping off" disease, considered one of the greatest phytosanitary risk factors that can significantly decrease the production of coniferous seedlings suitable for planting [10, 15], and can progress rapidly, causing significant damage [21, 22]. This pathology is caused by a wide spectrum of pathogens from the genera *Fusarium spp., Alternaria spp., Pythium spp., Rhizoctonia spp., Botrytis spp.*, etc. [1,6].

The present paper proposes the testing of cutting-edge antifungal products in the control of the "dumping off" disease in coniferous crops installed in grow tents. Also, modern technologies were implemented to monitor microclimatic factors through sensors and crop evolution using IR spectrum cameras.

Material and Method

The works involved the placement of an experimental spruce culture in the grow tent at the Lechința Experimental Base, during 2024, within an experimental block structured in 4 repetitions and 8 variants, of which 7 treated variants, 6 with products in two concentrations/product, and one with a single concentration, as follows:

V1 - Taegro (1x1013 UFC/kg *Bacillus amyloliquefaciens* - FZB24) 0,375 g/0,6 L water/1,6 sqm;
V2 - Infinito (fluopicolid 62,5 g/l + propamocarb clorhidrat 625 g/l) 1,4 ml/0,6 L water /1,6 sqm;
V3 - Carial Star (250g/l mandipropamid + 250g/l difenoconazol) 0,6 ml/0,6 L water /1,6 sqm;
V4 - Fytosave (12.5g/l chito-oligozaharide-oligogalacturonane) 1,6 ml/0.6 L water /1,6 sqm;
V5 - Taegro(1x1013 UFC/kg *Bacillus amyloliquefaciens* - FZB24)0,35 g/0,6 L water /1,6 sqm;
V6 - Infinito (fluopicolid 62,5 g/l + propamocarb clorhidrat 625 g/l)1,3 ml/0,6 L water /1,6 sqm;
V7 - Carial Star (250g/l mandipropamid + 250g/l difenoconazol) 0,5 ml/0,6 L water /1,6 sqm;
V8 – Control untreated.

Used doses:

- Taegro (1x1013 UFC/kg *Bacillus amyloliquefaciens* FZB2): 0,0625% - 375 g/600 L water/ 1 ha, 0,0583% - 350 g/600 L water/1ha;
- Infinito (fluopicolid 62,5 g/l + propamocarb clorhidrat 625 g/l): 0,233 % - 1400 ml/ 600 L water / 1 ha, 0,216% - 1300 ml/600 L water/1ha;
- Carial Star (250 g/l mandipropamid+250 g/l difenoconazol): 0,1 % - 600 ml/600L water / 1 ha, 0,0833% - 500 ml/600L water/1ha;
- Fytosave (12.5g/l COS-OGA - chito-oligozaharide-oligogalacturonane): 0,266% - 2000 ml/750 L water/1ha.

using an infrared (IR) vision surveillance camera, which was connected to a wireless router for remote monitoring in real time. To record climatic data, data logger devices were placed in the soil and air, which record temperature and humidity (fig. 1). These refer to soil temperatures (°C) at 6 cm depth, at the soil The monitoring of the crop was done surface (0 cm), at 12 cm, and at 1.3 m height, as well as humidity in the soil and at 1.3 m height

The crops were monitored until the end of the vegetation period, following the general health status, and at the first symptoms observed, the affected seedlings were extracted.

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Figure 1. Location of equipment within the solar system: 1. Surveillance camera; 2. Data logger at 1.3 m; 3. Data logger in the ground

Results and Discussion

The surveillance camera, and particularly the infrared function, monitored the moment of emergence and the subsequent evolution of the seedlings. Thus, in the spruce crop, the first seedlings were observed on May 3, 2024, with a germination duration of 14 days (Fig. 2).

Figure 2. Images of seedling emergence and "dumping off"

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With the infrared (IR) function, due to the specificity of the spectrum used, healthy plants can be more easily differentiated from the soil (Fig. 3).

Figure 3. IR image

In addition to monitoring with the surveillance camera, data on environmental climatic factors were tracked through repeated readings of sensors placed both in the soil and in the air (fig. 4).

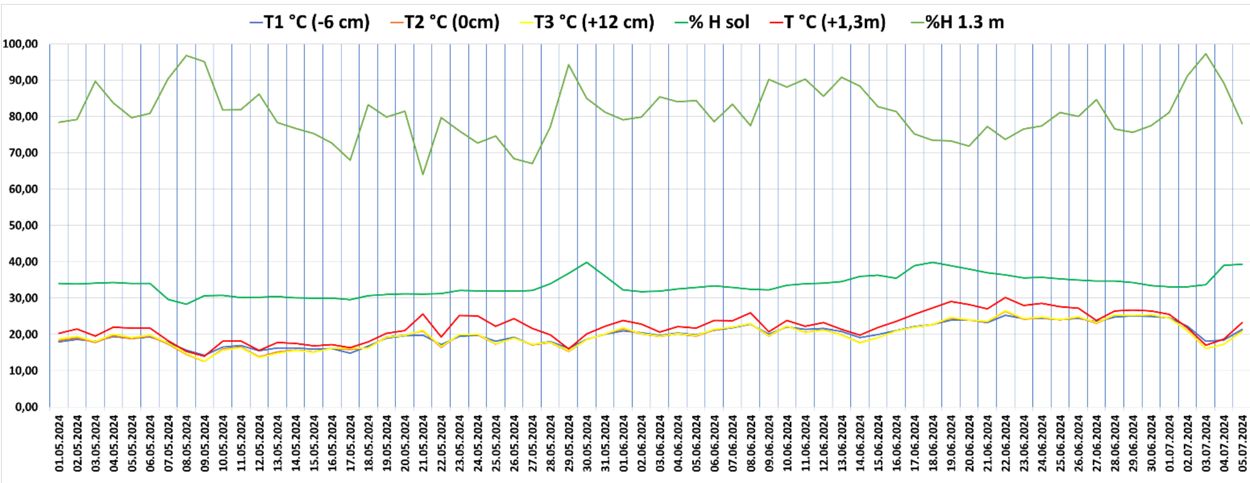

Figure 4. Main daily climatic characteristicsfrom 1.05 to 5.07.2024

Temperatures fluctuated, with the minimum recorded on May 9 and the maximum on June 22. The average throughout the period was approximately 20 degrees Celsius, both in the soil and in the air. The average soil humidity was around 33%, recording a maximum on May 30 and June 18. Compared to the soil humidity, the air humidity underwent significant fluctuations, with a minimum recorded on May 21 and a maximum on July 3 and an average humidity of approximately 80%.

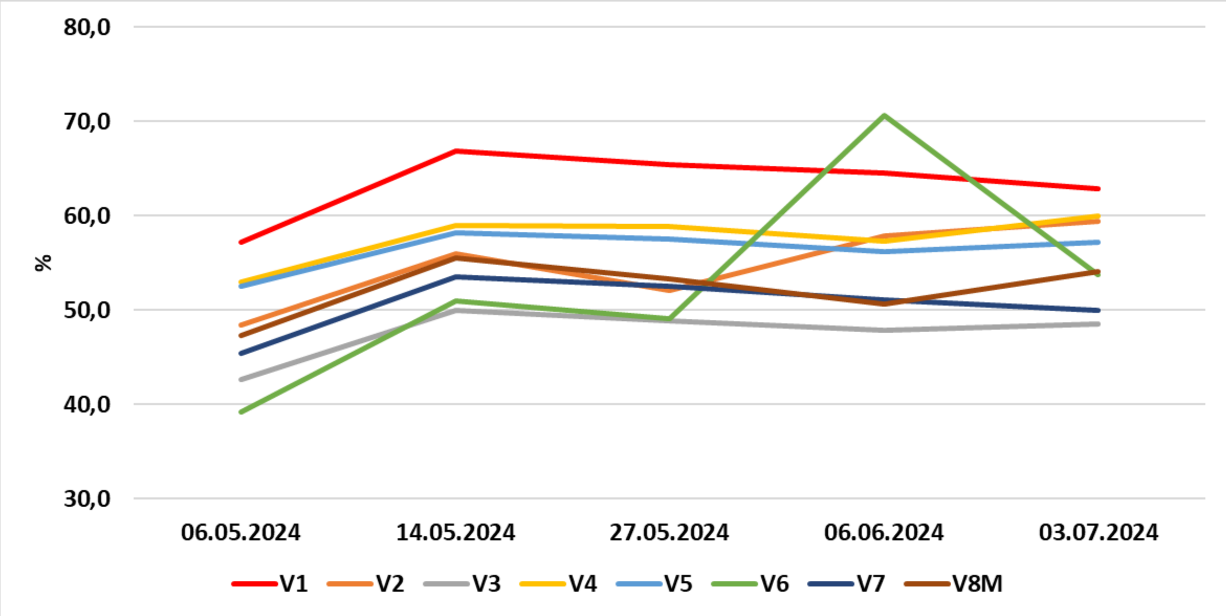

Figure 5. Spruce seedling emergence and survival (maintenance)

The first emerged seedlings were observed on May 6th, with mass emergence being reached on May 14th, the highest percentage recorded in variant V1, which was treated with Taegro (1x1013 CFU/kg *Bacillus amyloliquefaciens* strain FZB2) at a concentration of 0.0625%.

In the variants V2 and V6 treated with the fungicide Infinito (fluopicolide 62.5 g/l + propamocarb hydrochloride 625 g/l), in addition to protection against the "dumping off" disease, it had a secondary effect as a growth stimulant, with a maximum recorded on June 6 in variant V6. After this date, in Variant V6, the emergence trend was decreasing, compared to V2, which was increasing until the end of the emergence period.

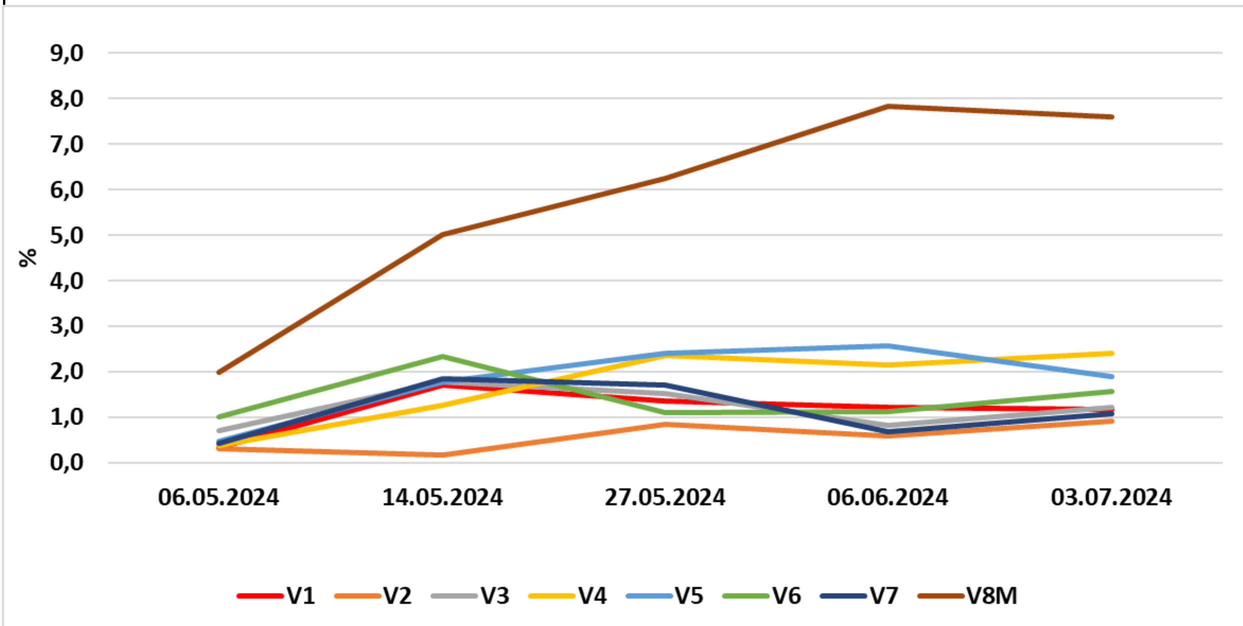

Figure 6. Dynamics of seedlings "dumping off"

Seedling mortality was observed starting from May 6, simultaneously with the first emergence, with a maximum recorded in all treated variants on May 14 except V2, which recorded the maximum on May 27.

In the untreated control variant, seedling drop had an upward trend, from 2% (first inventory, on May 6) to a maximum of 7.6-7.8% affected seedlings (in the last records, from June-July). The treatments had a favorable effect, keeping losses constantly lower than in the untreated variant.

The disease had a faster evolution in the first weeks, especially in variant V6, treated with fluopicolide + propamocarb hydrochloride 0.216%, with 2.3% affected seedlings.

Until July 3, when the last fallen seedlings were observed, in the variants treated with lower concentrations (V4 chito-oligosaccharides-oligogalacturonans 0.200% and V5 fluopicolide + propamocarb hydrochloride 0.216%), the disease caused slightly greater damage. The best protection was provided by the variants with higher concentrations: V2 treated with fluopicolide + propamocarb hydrochloride 0.233%, followed by V1, treated with B. amyloliquefaciens 0.0625%, with losses of fallen seedlings of 2.7% and 5.9%, respectively.

The highest mortality (recorded in the treated variants) was in the first weeks after germination, when the average temperature was 16-18°C in the soil and 16-24°C in the air, and the air humidity was between 75 and 85%.

We note that seedlings are extremely sensitive to lodging during this period; as they develop, they become more tolerant to the disease, and after about two months, the root lignification process begins, which gives seedlings increased resistance to lodging/rot [3, 18].

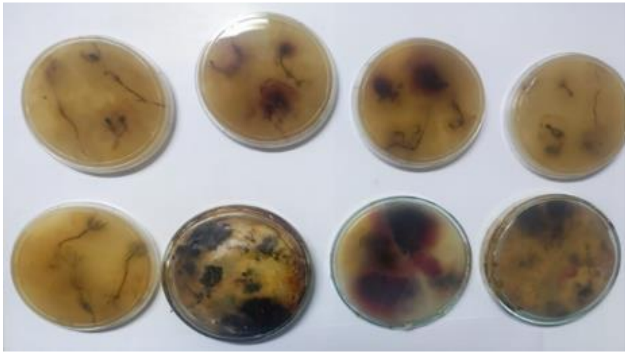

Figure 7. Spruce seedlings on culture medium

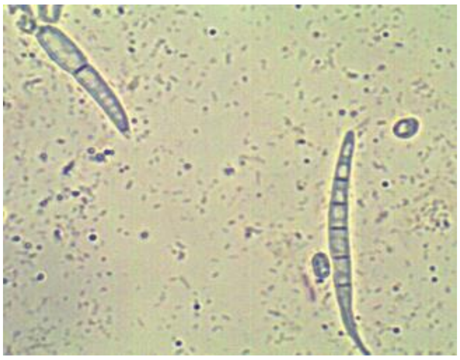

Figure 8. *Fusarium spp*. spores, microscopic view

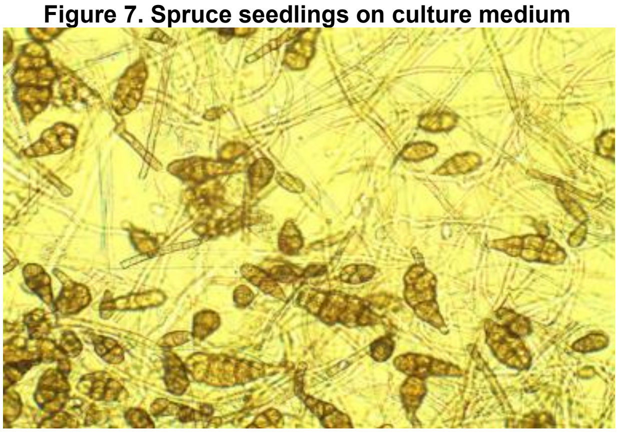

Figure 9. *Alternatia spp*. spores, microscopic view

Figure 10. *Pythium spp*. microscopic view

The disease remained active in the first two months, a period in which soil moisture was over 30% and average air temperatures were between 16°C and 25°C. The "dumping off" disease, in the treated variants, is kept under control by the action of fungicides, except for variant V6, treated with Infinito 0.216% - 1300 ml/600 L water/1 ha. In this case, the lower concentration does not seem to provide sufficient protection of the seedlings. The fungicides used in the study to combat the "damping off" disease had a good yield, with the biological fungicide based on *Bacillus amyloliquefaciens* strain FZB24 being noted, which had a better yield compared to the synthetic fungicides used. Abbas et al. [1] states that *Bacillus spp*. has a significant role in controlling the disease caused by Rhizoctonia solani. Xu et al. [23] reached the same conclusion regarding *Bacillus amyloliquefaciens* in controlling the pathogen *Fusarium oxysporum*.

Samples of biological material were collected from the culture, representing affected seedlings, for laboratory analysis to determine the spectrum of pathogens that led to the disease "dumping off". Following the analyses carried out by subculture procedures on CGA (potato-glucose-agar) culture medium, respectively by digital microscope, pathogens of the genus *Fusarium, Pythium, and Alternaria* were identified (fig. 7-10).

Conclusions

The study focused on the application of experimental treatments with new substances, used in agriculture, to control the disease "dumping off", caused by the spectrum of pathogens of the genera *Fusarium, Pythium, and Alternaria*, which affects spruce crops in forest grow tents. 4 fungicides were used, of which two were biological, the best results being obtained with the synthetic fungicide Infinito (fluopicolide 62.5 g/l + propamocarb hydrochloride 625 g/l) in a concentration of 0.233% and the biological fungicide Taegro (1x1013 CFU/kg *Bacillus amyloliquefaciens* strain FZB2) in a concentration of 0.0625%.

Also, by using the camera with the infrared (IR) function, it was possible to identify the moment of emergence of the first seedlings and the fall of the affected ones, and from the analysis of the data obtained through climate sensors, it was noted that an average temperature between 15°C and 25°C in the air and 16°C and 20°C in the soil, associated with a relative humidity in the air above 75% and 30-35% in the soil, maintained for 4-6 consecutive days, led to the appearance of the "dumping off" disease within the installed crop.

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