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AGRICULTURAL FOOD ENGINEERING

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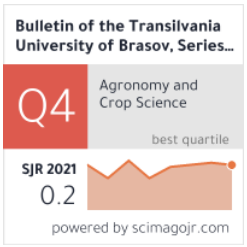

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PECULIARITIES OF REPRODUCTION OF *PINUS NIGRA* ARN. IN UKRAINE

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Abstract: *The article analyzes the peculiarities of black pine reproduction and identifies the most promising methods of propagation for the territory of Vinnytsia city (Ukraine). Having analyzed the germination capacity of the black pine seed material, we found that the percentage of seed germination ranged from 38% (courtyards) to 70% ("Podillya" botanical garden). Examining the duration of black pine seedlings emergence, we found that in almost all objects of the city the largest number of seedlings were established on the 7th day (about 35 pcs.), then the process declined, and the smallest number appeared on the 13th day (about 5-7 pcs.). Studying the black pine propagation by cuttings, we found that when fed with two different rooting stimulants, the best result was obtained with the application of Korenevin (48 pieces), and a slightly lower acceptance rate was demonstrated with the use of Epine (about 34 pieces).*

Key words: *seed and vegetative method, grafting, propagation by cuttings, rooting stimulators.*

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1. Introduction

A distinctive feature of modern landscaping of cities and villages is the use of many varieties of grass and wood species, whose area of natural distribution is a completely different geographical part of the planet [2, 3], [14]. Such species are called alien ones. Almost all ornamental plants in Ukraine are introducers that are well adapted to the conditions into which they have been once successfully transplanted [18]. The plants mainly retain the features of their natural habitats, although their external appearance may become modified [7], [9-11]. Such species have become an integral part of the structure of both urban and rural areas landscaping [17].

The use of various species and cultivars in the landscaping of urban areas is becoming increasingly important. Currently in Ukraine, in order to create various kinds of flower and decorative formations, not only plantations characteristic of the particular area are used, but species such as *Weigela*, *Deutzia*, *Ginkgo biloba*, Vinegar tree, *Catalpa*, etc. are also introduced. Black pine (*Pinus nigra* Arn.) belongs to such introduced representatives [6].

A lot of biologists and other scientists, both Ukrainian (S.A. Adamenko, S.A. Makarynska, V.P. Shlapak, M.A. Kokhno, V.Ya. Zayachuk) and foreign (A. Rehder, W. Dallimore, M. Vidakovic, K.I. Christensen) were involved in studying the peculiarities of the development and reproduction of black pine. In their works the main aspects of the black pine seasonal rhythm of development, specific features of reproduction and use in landscaping are outlined [4], [6], [15, 16]. However, peculiarities of the development and reproduction of black pine for the conditions of Vinnytsia region of Ukraine have not been fully investigated.

The aim of this research is to identify the most promising methods of propagation of black pine reproduction for the territory of Vinnytsia city (Ukraine).

2. Materials and Methods

Seasonal rhythms of growth and development of black pine were studied with the use of V.M. Nilov's method of phenological observations in botanical gardens. Fixation of the beginning and the end of the studied process was performed visually [1].

In order to fully assess the process of development and growth of the genus under study, the onset of phenophases in its representatives was observed: the beginning of the phenophase (manifestation of certain signs or processes in at least 15% of plant organs), mass onset – manifestations in more than 60% of organs, and completion – when 90-95% of the studied object organs enter the process [8].

The dynamics of seasonal growth of shoots was studied using A.A. Molchanov and V.V. Smirnov's method [5]. Linear gain was measured every 10 days. The height of the plants was recorded using a Suunto altimeter with an accuracy of 0.5 m, and the height of the small plants – using a rail with up to 0.1 m accuracy [12].

3. Results and Discussion

The existence continuum of a plant of one or another life form occurs only due to the emergence of new generations. This process is possible due to the ability of organisms to reproduce [13]. As the

level of introduced plants application grows, the investigation of the biological mechanisms of their natural propagation, the improvement of the existing and the development of new methods of reproduction become more and more relevant.

Many years' experience in introduction of woody plants have shown that seed propagation increases the resistance of new generations of introducers to adverse environmental factors and plays a special role in their acclimatization and distribution in new areas. For some species that are almost incapable of vegetative regeneration, this is the only possible way to procreate. Seed reproduction of most tree species remains the main method due to technological simplicity, the possibility to mechanize the process and overall cost savings [7]. In the process of seed propagation the number of new plants increases, and young organisms acquire new features not characteristic of the parent plants. In order to consider this issue in detail, the characteristics of the fruiting organs of the plant need to be studied first. The fruits of black pine, the cones, are characterized by an ovoid shape and a brownish shiny color (Figure 1).

a) b)

Fig. 1. *Cones of black pine: a) closed form; b) cone with open scales*

Unopened cones 5-9 cm long and 2-3.5 cm wide, when opened, increase up to 4-8 cm in diameter. The apophyses are ventricose, with a sharp transverse keel, rounded at the top, shiny, grayish-brown. Rounded woody scales, thickened at the top, fit snugly together. In this way they protect the seeds from the penetration of pests and adverse weather conditions. Inside the cone, under each scale, there are two chambers containing one seed each [10].

It is known that the size of cones varies greatly and is not identical even in the crown of one and the same tree. The size of cones differs depending on the geographical origin, weather conditions, age of plantations that produce them (with the increase in tree age, the size of cones decreases). Thus, in our research it was determined that younger specimens usually have smaller cones than those found in older trees [11].

As a result of our research, conducted not only in "Podillya" botanical garden,

but in other locations of Vinnytsia city, the average main biometric indicators of the *Pinus nigra* Arn. carpellate cones were determined. The data are presented in Table 1.

After examining the biometric indicators and seed quality, it was found that the greatest number of quality seeds (25.5%) was formed in ”Podillya“ botanical garden and the smallest number – in the Druzhby Narodiv Park (15%). Thus, we can say that the cones of black pine trees that grow in the Druzhby Narodiv Park and in the private courtyards of the city have less productive capacity than those in the ”Podillya“ botanical garden and in the forest park area. This, certainly, is conditioned by the individual features of these areas [10].

We conducted a study of biometric indicators of seed material of black pine from various territorial sites of Vinnytsia. The results are presented in Table 2.

Table 1

Biometric indicators of black pine cones on the territory of Vinnytsia

Location of plantations	**Cone size**				**Cone mass**		**The number of fertile scales**	
	length		width					
	mean±standard error [cm]	CV* [%]	mean±standard error [cm]	CV* [%]	mean±standard error [g]	CV [%]	mean±standard error [pcs.]	CV* [%]
“Podillya”botanical garden	9.1±0.35	12.5	4.9±0.23	14.3	12.3±0.20	11.2	30.2±0.25	12.3
Druzhby Narodiv Park	8.4±0.22	14.4	6.9±0.21	17.5	15.9±0.33	16.1	39.3±0.56	15.2
Vinnytsia forest park zone	8.7±0.23	9.7	5.8±0.27	16.8	15.2±0.18	9.8	49.9±0.54	9.9
Private courtyards	7.5±0.31	12.9	4.9±0.36	17.9	13.8±0.22	16.7	39.8±0.31	13.5

Note: ** Coefficient f variation; Source – formed on the basis of own research.*

Table 2

Biometric parameters and quality of Pinus nigra seeds in various growing conditions

Location of plantations	**The number of seeds in fertile zone of the cone**					
	well-filled		**empty**		**underdeveloped**	
	average [pcs.]	CV* [%]	average [pcs.]	CV* [%]	average [pcs.]	CV* [%]
“Podillya”botanical garden	25.5±0.31	39.8	9.7±0.21	20.2	4.3±0.21	40.0
Druzhby Narodiv Park	15.0±0.24	20.8	16.2±0.35	25.3	6.5±0.23	53.9
Vinnytsia forest park zone	20.1±0.21	33.7	11.4±0.33	22.4	5.4±0.15	43.9
Private courtyards	17.2±0.12	22.6	16.1±0.15	27.1	7.1±0.24	50.3

Note: ** Coefficient f variation; Source – formed on the basis of own research.*

As in previous research, the biometric performance of black pine tree seeds growing in “Podillya” botanical garden and in the forest park area is better than in those growing in the Druzhby Narodiv Park and in the private courtyards. Therefore, sowing of identical material resulted in obtaining different number of

seedlings (Figure 2). The percentage of black pine seeds germination ranged from 38% (private courtyards) to 70% ("Podillya" botanical garden). This is due to the fact that germination of any seed usually depends on its quality, method of collection, storage, sowing, germination conditions, and care. That is why selection of quality seeds is an important aspect for this method of propagation. For this purpose, we conducted a comparative characterization of biometric indicators of seed material from different territorial sites in Vinnytsia city.

Thus, after sowing selected stratified seed material, the highest percentage of seedlings emerged on the 7th day (Figure 3).

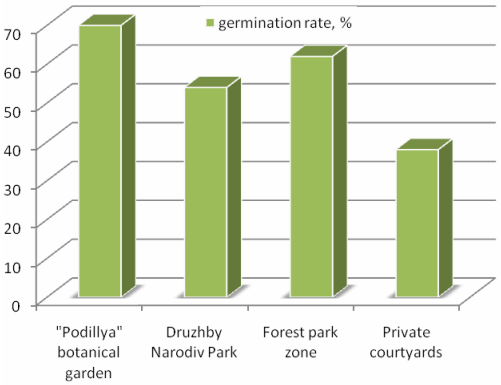

Fig. 2. *Percentage of seed germination of black pine in conditions of Vinnytsia*

It should be noted that at the early harvesting of black pine cones, seed germination rate will be quite low. That is, it indicates that the seeds must be fully mature.

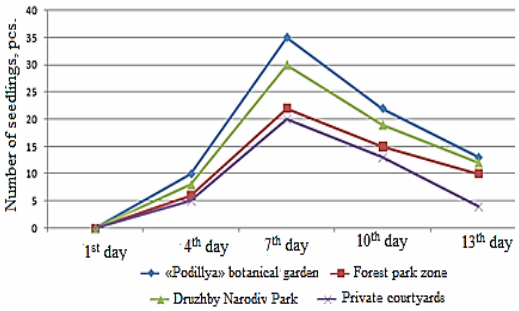

Fig. 3. *Comparative graphs of black pine seedlings emergence*

The peculiarity of young black pine seedlings is that they look like «umbrellas» (Figure 4), and at abundant close sowing can create a kind of «rug». Depending on the number of seeds germinated on the 20th day, the appropriate class of quality is set – 1st, 2nd or 3rd (according to the State Standard of Ukraine 14161-86).

That is why most *Pinus nigra* seed samples meet the 2nd or the 3rd quality class.

Thus, it was established that the highest sowing quality had the seeds collected in plantations of "Podillya" botanical garden and the lowest – those collected in private courtyards of the city.

In spring, the prepared seeds, sown in moist and well-warmed soil, germinate in 12-18 days.

Fig. 4. *Black pine seedlings*

In this case, the soil from the time of sowing to the moment of seedling emergence is less compacted, the risk of damage to the seeds and seedlings by rodents and low winter temperatures, as well as spring frosts, is lower.

With this in mind, an experiment in sowing seeds at different terms, from early spring to the first decade of October, was set up. The seeds were sown to different depths – from 0.5 to 3 cm (Table 3).

Table 3

Influence of terms and depth of planting on germination of the black pine seeds sown on the open ground

Sowing terms	**Depth of planting [cm]**					
	0.5	1	1.5	2	2.5	3
27.03	38.6	55.2	63.3	51.9	48.2	39.6
05.04	55.3	74.5	80.1	68.4	52.7	48.4
15.05	42.8	59.9	70.4	54.7	43.9	38.1
07.06	35.7	48.3	51.3	37.3	30.1	33.5
09.07	22.5	30.9	31.6	21.8	17.8	10.7
11.08	9.0	21.2	27.4	19.3	16.7	8.8
15.09	17.1	39.8	50.6	29.6	36.2	9.3
10.10	36.9	47.5	58.3	42.4	38.2	31.2

It is established that the best time for sowing seeds is the first decade of April. Sowing at a later and earlier date significantly reduces the rate of germination. The lowest open ground germination rate was observed at summer sowing.

The depth of seeds burying affects their germination and seedling development. With deep planting, they are well provided with moisture, but it is harder for the seedlings to break through the soil layer, so they come to the surface later, and at very deep planting, they may not emerge at all. At surface sowing, the seeds may get into over dried layer of soil and die. On light and loose soils (sandy loams and light sandy soils) the humidity of the upper layers is unstable, and it is easier for the seedlings to break through, so on these soils the depth of seed burying should be greater than on heavy ones [10].

According to the literature, the recommended depth of planting *P. nigra* seeds is 0.5-1.5 cm for the forest zone, and 1.0-1.5 cm for the forest-steppe and steppe zone.

This is confirmed by our research as well. When seeds were sown to a greater or lesser depth, a decrease in germination rate was observed.

But the disadvantage of this sowing method is that most germinated seedlings cannot compete with higher herbaceous plants and in the first year most young

seedlings die. Therefore, for the most efficient selection of planting material, black pine should be grown in artificial conditions of protected ground.

The next stage of our research was to study the vegetative propagation of black pine in "Podillya" conditions. Vegetative propagation is more effective for introduction, because it saves costs compared with the seed cultivation of new species. In addition, the plant does not pass through the most critical initial stages of ontogenesis. Since in natural conditions conifers are propagated mainly by seeds, the methods of their vegetative propagation are not so well developed as for the other groups of plants. In this case, the offspring may not inherit some valuable traits, especially important in reproduction of exotic decorative forms [7].

Usually black pine does not reproduce vegetatively. However, there are recorded successful experiments in different countries, which prove the possibility of grafting, budding, and propagation by cuttings.

The above mentioned methods of vegetative propagation have been known since 1820. But these methods are almost never used, as in order to obtain truly elite plantations of black pine, mainly seed propagation is applied.

In vegetative propagation of black pine by grafting, other species of pine are usually used as seedling stocks. But this method is mainly practiced abroad. We obtained information about individual facts of successful grafting from foreign publications studying this issue (Table 4).

Table 4

The results of using Pinus nigra as a seedling stock for other species and forms or the Pinus L. genus

Seedling	Budwood (variety, cultivar)	Terms of grafting	Accept. rate [%]	Growth [cm]	V [%]
Pinus nigra Arn.	*Pinus sylvestris*	03.04	90.1	3.2	9.5
		12.07	79.5	3.0	13.2
		07.09	11.7	2.8	21.8
	Pinus nigra	03.04	94.3	2.9	9.8
		12.07	90.5	2.9	12.3
		07.09	13.4	2.6	19.4
	Pinus sylvestris "Fastigiata"	04.04	73.5	2.1	7.9
		11.07	60.7	2.0	12.3
		08.09	10.8	2.0	17.2
	Pinus mugo "Winter Gold"	04.04	67.8	0.9	10.0
		11.07	53.2	0.7	13.4
		08.09	9.7	0.3	22.9
	Pinus mugo "Mops"	04.04	53.4	1.9	13.4
		11.07	50.2	2.0	14.2
		08.09	8.6	1.6	24.1
	Pinus nigra "Pyramidalis"	04.04	89.6	2.0	10.2
		11.07	82.2	1.9	10.1
		08.09	12.8	1.3	14.7

After conducting an autumn inventory, it turned out that the best results demonstrated spring grafting (first decade of April). Here, the acceptance rate of the studied samples ranged from 94.3% (*P. nigra*) to 53.4% (*P. mugo* "Mops").

To determine the potential for possible vegetative propagation of black pine in conditions of Vinnytsia, we used the method of propagation by cuttings. When doing this, it is not advisable to immerse the branch directly into the soil, as it may negatively affect the acceptance and rooting of the plant.

A light partial shade will be comfortable for the cuttings rooting, so they should be sheltered from direct sunlight. Watering should be moderate, whenever required. The film should be removed regularly in order to aerate the sprouting pine cuttings. Closer to August, the planted pine cuttings from the roots. In full, the rooting process lasts between 1.5 and 4 months.

For better rooting, we used two different preparations: "Korenevin" and "Epin" (Figure 5).

Based on the obtained data we found that of two different rooting stimulators, Korenevin demonstrated the best result (48 pieces), and a slightly lower acceptance rate was observed when using "Epin" (about 34 pieces out of the 100 planted cuttings).

According to the research results in the conditions of the South-East of Ukraine on the state enterprise "Zmievskoe LG" in the study biometric indicators and quality of seeds, the author [16] found that the diameter and length of pine cones fluctuated within 2.72 cm and 5.64 cm, respectively. The average weight was 11.58 g. Studying the morphometric parameters of black pine cones at different sites in Vinnytsia (Centre of Ukraine), we found that the average diameter of cones ranges between 4.9 and 6.9 cm and the length from 7.5 to 9.1 cm. As we can see, the seed organs of black pine which were formed in the conditions of the Vinnitsa region are characterized by the best dimensional qualities, which in the future will contribute to the formation of a large amount of high-quality seed material.

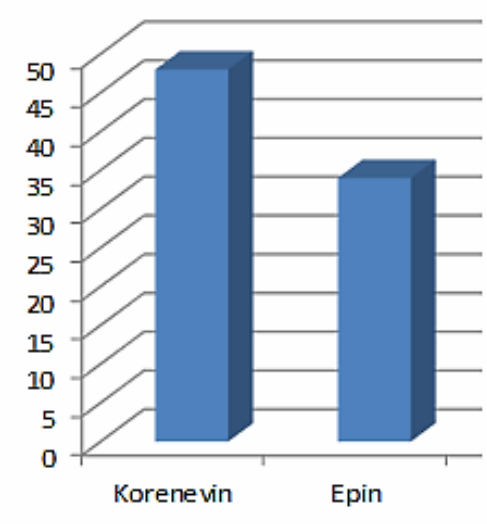

Fig. 5. *Quantitative ratio of rooted cuttings of black pine when using comparative "Korenevin" and "Epin" stimulants*

4. Conclusions

As a result of our research, we can state the following:

1. Reproduction of black pine is best done by seed, because its seeds have a sufficient level of germination and acceptance.
2. After examining biometric indicators and seed quality, it was found that the largest number of quality seeds was mostly formed in "Podillya" botanical garden and made up 25.5%,

and the smallest number was obtained in the DruzhbyNarodiv Park – 15%.

3. The percentage of black pine seeds germination ranges from 38% (private courtyards) to 70% ("Podillya" botanical garden).
4. Analyzing the duration of the process of black pine seedling emergence, we found that in almost all objects of the city the largest number of seedlings began to come up on the seventh day (about 35 pcs.), then the trend declined and the smallest number of seedlings appeared on the 13th day (about 5-7 pcs.).
5. Studying the vegetative propagation of black pine, we found that the "Korenevin" rooting stimulator demonstrated better acceptance rate (48 pieces) than that observed by using "Epin" (about 34 pieces out of the 100 planted cuttings).

References

1. Ermakov A., Arasimovich V., Jarosh N. et al., 1987. Metody biokhimichesk ogoissledovaniya rastenij (Methods studies biochemically plants) [in Ukrainian]. In: Agropromizdat, Leningrad, 430 p.
2. Hrushetskyi S., Yaropud V., Kupchuk I. et al., 2021. The heapparts movement on the share board surface of the potato harvesting machine. In: Bulletin of the Transilvania University of Braşov. Series II: Forestry, Wood Industry, Agricultural Food Engineering, vol. 14(63), no. 1, pp. 127-140. DOI: 10.31926/but. fwiafe.2021.14.63.1.12.
3. Kaletnik G., Honcharuk I., Yemchyk T. et al., 2020. The world experience in the regulation of the land circulation. In: European Journal of Sustainable Development, vol. 9(2), pp. 557-568. DOI: 10.14207/ejsd.2020.v9n2p557.
4. Kovalevskyi S.B., 2010. Intensyvnist osvitlennia v kulturakh sosny zvychainoi (Intensity of illumination in cultures of scots pine) [in Ukrainian]. In: Scientific Bulletin of NULES of Ukraine, vol. 152, pp. 208-214.
5. Kupchuk I., Yaropud V., Hraniak V. et al., 2021. Multicriteria compromise optimization of feed grain grinding process. In: Przegląd Elektrotechniczny, vol. 97(11), pp. 179-183. DOI: 10.15199/48.2021. 11.33.
6. Makarynska S.A., Shlapak V.P., 2010. Pryrodnyi areal sosny chornoi (*Pinus nigra* Arn.) taposhyrenniayii v umovakh introduktsii (Natural habitat of black pine (*Pinus nigra* Arn.) and its distribution in the conditions of introduction) [in Ukrainian]. In: Scientific Bulletin of the National Forestry University of Ukraine: coll. Scientific and technical work, vol. 20(12), pp. 39-45.
7. Mazur V., Didur I., Tkachuk O. et al., 2021a. Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. In: Scientific Horizons, vol. 1(24), pp. 54-60. DOI: 10.48077/scihor.24(1).2021.54-60.
8. Mazur V., Tkachuk O., Pantsyreva H. et al., 2021b. Quality of pea seeds and agroecological condition of soil when using structured water. In: Scientific Horizons, vol. 24(7), pp. 53-60. DOI: 10.48077/scihor.24(7). 2021.53-60.
9. Mazur V., Tkachuk O., Pantsyreva H. et al., 2021c. Ecological suitability peas (*Pisum sativum*) varieties to climate

change in Ukraine. In: Agraarteadus: Journal of Agricultural Science, vol. 32(2), pp. 276-283. DOI: 10.15159/jas.21.26.

10. Mazur V.A., Pantsyreva H.V., Mazur K.V. et al., 2019. Influence of the assimilation apparatus and productivity of white lupine plants. In: Agronomy Research, vol. 17(1), pp. 206-219. DOI: 10.15159/ar.19.024.
11. Mazur V.A., Pantsyreva H.V., Mazur K.V. et al., 2020. Agroecological prospects of using corn hybrids for biogas production. In: Agronomy Research, vol. 18(1), pp. 177-182. DOI: 10.15159/AR.20.016.
12. Palamarchuk V., Krychkovskyi V., Honcharuk I. et al., 2021. The modeling of the production process of high-starch corn hybrids of different maturity groups. In: European Journal of Sustainable Development, vol. 10(1), pp. 584-598.
13. Palamarchuk V., Telekalo N., 2018. The effect of seed size and seeding depth on the components of maize yield structure. In: Bulgarian Journal of Agricultural Science, vol. 24(5), pp. 785-792.
14. Puyu V., Bakhmat M., Pantsyreva H. et al., 2021. Social and ecological aspects of forage production reform in Ukraine in the early 21st Century. In: European Journal of Sustainable Development, vol. 10(1), pp. 221-228. DOI: 10.14207/ejsd.2021.v10n1p221.
15. Shlapak V.P., Makarynska S.A., Shlapak V.V., 2011. Porivnialna kharakterystyka morozostiikosti okremykh vydiv rodu *Pinus* L. (Comparative characteristics of frost resistance of individual species of the genus *Pinus* L.) [in Ukrainian]. In: Scientific Bulletin of the National Forestry University of Ukraine, vol. 21(1), pp. 18-22.
16. Solomakha N.H., 2009. Shcheplennia vydiv rodu *Pinus* L. na *P. rallasiana* D. Don. v umovakh Pivdennoho Skhodu Ukrainy (Vaccination of species of the genus *Pinus* L. on *P. pallasiana* D. Don. In the conditions of the South-East of Ukraine) [inUkrainian].In: Forestry and Agroforestry, vol. 115, pp. 71-74.
17. Telekalo N., Melnyk M., 2020. Agroecological substantiation of *Medicago sativa* cultivation technology. In: Agronomy Research, vol. 18(4), pp. 2613-2626. DOI: 10.3390/su9030349.
18. Varchenko O., Krysanov D., Shubravska O. et al., 2020. Supply chain strategy in modernization of state support instruments for small farms in Ukraine. In: International Journal of Supply Chain Management, vol. 9(1), pp. 536-543.