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FRICTION COEFFICIENTS SEEDS ANALYSIS OF SOME CONIFEROUS TREE SPECIES

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Abstract

In this paper an experimental study is exposed which has been conducted for determining the angles and the friction coefficients of seeds of some coniferous tree species. These parameters are used in the design and construction stages of forest planters and seeding machinery. These parameters can also be applied in the technological research of many forestry processes such as: dewinging, cleaning, sorting, seeds sowing etc. The object of research are seeds of some of the main coniferous tree species which are a subject of economic activity in our country – Scots pine (*Pinus sylvestris* L.), Black pine (*Pinus nigra* Arn.), Norway spruce (*Picea abies* Karst.) and Macedonian pine (*Pinus peuce* Griseb.). As a result of this study, the angle parameters and the friction coefficients of the studied seeds have been established. Results can be used in the design of forestry machinery and in the research of technological processes connected to the movement and processing of seeds.

Key words: friction coefficients, *Pinus silvestris, Pinus nigra, Picea abies,* seeds.

Introduction

The technological properties of forest seeds and their mixtures are the basis for design of seed production and forestry machines. The production of conifer tree seeds requires a longer production process, in which specialized machinery is used. This requires knowledge of the characteristics and properties of the seed material obtained in Bulgaria.

During the process of movement of seeds and mixtures friction occurs in the working bodies of the machinery. The amount of friction depends on the friction properties of these materials. The objective indicators to measure this friction are the angle of friction on the machinery surface and the angle of repose. The friction coefficients for determining the structural and technological parameters of the machinery and processes are a function of these indicators. The friction coefficients on the machinery surface are used to determine the parameters of hopper-, feeder- and transporting equipment, for calculating the resistance and productivity of the process etc. The coefficients of internal friction of the seed materials, expressed by the angle of repose, serve to determine the type of sowing devices, the filling devices' parameters, the forces

of friction between seeds in the process of their treatment etc.

In our country there are studies on the technological properties of seed materials from the main coniferous species (Vasilev 1964; Marinov 1996, 2007). In regard to the friction coefficients these studies lack information or this information is insufficient. Results, regarding the friction coefficients of forest seeds on various surfaces, referring to local tree species, are known to us from foreign sources (Sviridov 1987).

It can be deducted from the literature and analysis reference, that the study of angle and friction coefficients of seeds and mixtures of the major part of our country's coniferous species, presents a particular interest with a scientific and practical character.

The aim of this work is to study and determine the friction coefficients of seeds and mixtures of the main conifers in Bulgaria.

Tasks of the study. The following main tasks must be solved in order to achieve the target:

1. Determining the friction angle of seeds and mixtures on a smooth steel surface;

2. Determining the angles of repose and the coefficients of internal friction of the seed materials.

The object of the study are seed materials from Scots pine, black pine, Norway spruce and Macedonian pine from the region of the Western Rhodopes, Rila, Pirin and Osogovo mountains.

The subject of the study is the angles of friction of seeds with wings, pure seeds and technological seed mixtures, pounded wings and impurities in dewinging machines.

Material and Methods

The test materials are provided by the state forestry seed stations in the towns of Razlog and Samokov. The study has been conducted at the laboratory "Forestry machines" at the Department of Technology and Mechanization in Forestry at the University of Forestry in Sofia. The study materials are derived from seed crops and seed production orchards in the Western Rhodopes, Rila, Pirin and Osogovo mountains. The Scots pine and the Norway spruce are from the territory of the state forestry stations in the towns of Razlog, Blagoevgrad, Garmen, Mesta, Samokov and Yakoruda, the black pine – from Osogovo, Simitli, Razlog and Katuntsi and the Macedonian pine is from Razlog, Gotse Delchev and Yakoruda.

The humidity of seeds during the testing is maintained between 8–10%, same as in the machinery rooms and the seed storage rooms. The studied samples are compiled through the separation of samples from different lots, in accordance with the methods and means, provided by the state standard and international regulations (BSS 1999, EN ISO 8402 1996, ISO 3534-1 1996). The humidity is determined by an analytical method using a thermostatic desiccator (BSS 1999). The tests are conducted with winged and dewinged seeds, technological mixtures and impurities in the dewingers.

The friction coefficients on a metal surface are defined by the friction angle of the test materials on an inclined

surface (Nartov et al. 1981, Sviridov 1987). A special device with a mobile arm, with an attached steel plate, has been used for this purpose. The test samples are being placed on that plate and thus, the elevation angle of the arm, where the particles at rest begin to move, is being determined. The friction angle of the test samples on a metal surface is determined by the size of this angle. The friction coefficient is expressed by the formula:

$$f = tg\alpha \quad (1),$$

where α is the friction angle.

The angles and coefficients of internal friction of the test materials are defined by their angle of repose with the horizontal surface. In order to determine this angle of repose, one of the accepted practice devices is used (Nartov et al. 1981). A funnel, which is mounted on a stand, is used for this purpose. The test materials are poured into the funnel on a horizontal plane. Thus a bulk figure is formed which has the shape of a cone, the forming wall of which concludes with the horizontal plane an angle, equal to the angle of repose. The angle of repose is determined with stilts. The coefficient of internal friction is expressed by the formula:

$$\mu = tg\varphi \quad (2),$$

where φ is the angle of repose.

The friction angles and the repose are determined by an optical universal octant „Carl Zeiss Jena“ with an accuracy of 0.5 degrees.

Results and Discussion

Between 150 and 220 samples from each of the 22 studied groups are used in the tests. Results from the measurements are processed by the Descriptive Statistics methods. Calculations are made using the computer program “Statistika 7” from StatSoft. The results are subjected to a statistical verification and analysis in accordance with the mathematical models and modus (Tasev 2010). The more important numerical characteristics are presented in a tabular form. With respect to the angle of repose of seeds and technological mixtures, these characteristics are presented in Table 1 and 2 and the characteristics of the angle of friction on a metal surface of winged and de-winged seeds and technological mixtures of seeds and impurities – in Table 3.

Histograms and curves of distribution of the random variables are drawn based on the obtained data. They are presented in a graphic form on Fig. 1–7.

Table 1. Angle of repose of pure (dewinged) seeds.

Seeds	Mean X	Med. Me	Mode Mo	Min X_{min}	Max X_{max}	Std. Dev. S	Coef. Var. V, %	Skewness Ka	Kurtosis Ke
Scots pine, φ	29.70	29.50	29.50	27.00	32.00	0.8783	2.9569	-0.2440	0.6006
Norway spruce, φ	33.15	33.00	33.00	30.50	35.50	1.0245	3.0906	-0.1149	-0.4025
Black pine, φ	26.48	26.50	26.5	24.00	29.00	0.9799	3.7008	-0.0955	-0.2221
Macedonian pine, φ	28.04	28.00	28.00	25.50	30.50	0.9539	3.4017	-0.0110	-0.1978

Table 2. Angle of repose of technological seed mixture in dewinger.

Technological seed mixture	Mean X	Med. Me	Mode Mo	Min X_{min}	Max X_{max}	Std. Dev. S	Coef. Var. V, %	Skewness Ka	Kurtosis Ke
Scots pine, φ	42.95	43.00	Multiple	38.00	49.00	1.8938	4.4093	0.5605	0.1776
Norway spruce, φ	48.43	48.00	48.00	44.00	53.00	1.4654	3.0255	-0.0071	0.1724
Black pine, φ	37.32	37.25	37.00	32.00	43.00	1.7704	4.7443	0.2319	0.3841
Macedonian pine, φ	41.52	41.50	41.50	37.50	46.00	1.4548	3.5040	0.2891	0.5759
Impurities, φ	56.74	56.50	56.50	54.00	60.00	1.0688	1.8840	0.3002	0.2059

Table 3. Angle of friction on steel surface of seeds with wings, pure (dewinged) seeds and technological seed mixture and impurities in dewingers.

Seed materials	Mean X	Med. Me	Mode Mo	min X_{min}	max X_{max}	Std. Dev. S	Coef. Var. V, %	Skewness Ka	Kurtosis Ke
Scots pine – seeds with wings, α	29.65	29.50	30.00	27.00	32.00	0.8920	3.0080	-0.1352	0.3931
Scots pine – pure seeds, α	24.65	24.50	24.50	22.00	27.50	0.9070	3.6799	0.0276	0.8046
Scots pine – tech. seed mixture, α	27.57	28.00	28.00	24.00	31.00	1.2994	4.7137	-0.1417	0.0529
Norway spruce – seeds with wings, α	36.11	36.00	36.00	33.50	38.50	0.8723	2.4154	-0.1996	0.3628
Norway spruce – pure seeds, α	30.61	30.50	30.50	28.00	33.00	0.8835	2.8858	-0.0940	0.5205
Norway spruce – tech. seed mixture, α	33.50	33.00	33.00	30.00	37.00	1.3357	3.9867	0.1255	0.2477
Black pine – seeds with wings, α	28.02	28.00	28.00	25.50	30.50	0.8419	3.0052	-0.1777	0.4007
Black pine – pure seeds, α	22.58	22.50	22.50	20.00	25.00	0.8040	3.5608	-0.3038	0.9157
Black pine – tech. seed mixture, α	26.42	26.00	27.00	23.00	30.00	1.3858	5.2453	-0.1199	-0.1531
Macedonian pine – seeds with wings, α	25.70	25.50	25.50	23.00	28.50	0.8340	3.2452	-0.1195	1.2742
Macedonian pine – pure seeds, α	20.65	20.50	21.00	18.00	23.00	0.7770	3.7623	-0.3502	1.1780
Macedonian pine – tech. seed mixture, α	24.39	24.00	24.00	21.00	28.00	1.3314	5.4581	-0.1024	0.0119
Impurities, α	34.61	35.00	35.00	31.00	38.00	1.2430	3.5907	0.0211	0.0719

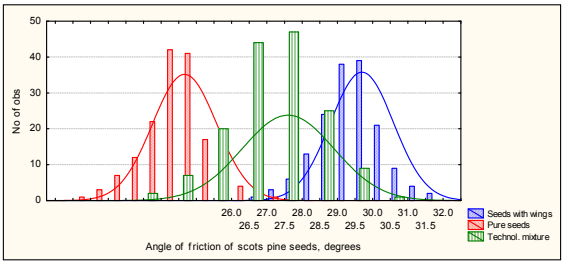

Fig. 1. Histograms of angle of friction of Scots pine (*Pinus sylvestris*) seeds.

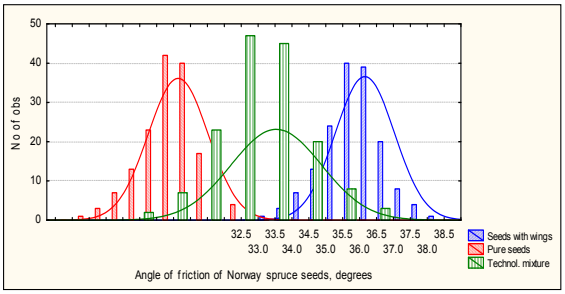

Fig. 2. Histograms of angle of friction of Norway spruce (*Picea abies*) seeds.

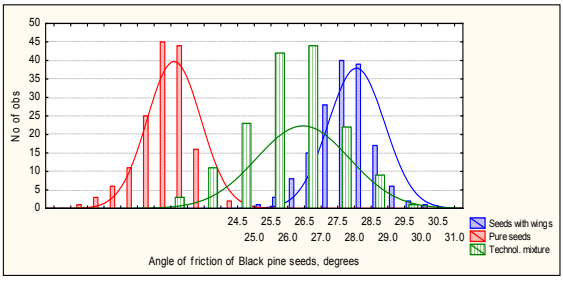

Fig. 3. Histograms of angle of friction of Black pine (*Pinus nigra*) seeds.

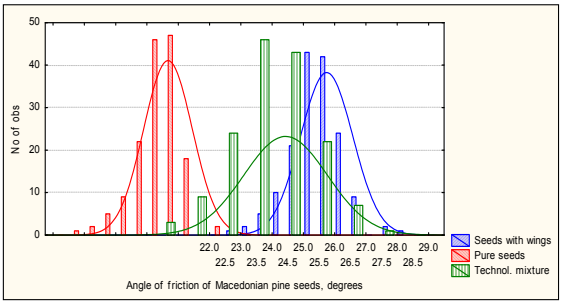

Fig. 4. Histograms of angle of friction of Macedonian pine (*Pinus peuce*) seeds.

The friction angles and the repose are indicated on the X-axis and the number of the objects (samples) is indicated on the Y-axis. The respective curve of the normal distribution is drawn for each of the studied groups. Using the graphical-analytical method, different levels can be determined by these graphs, when there are some set restrictive conditions.

A verification has been made for determining the type of distribution of the angles of friction in accordance with the known laws of distribution of random variables. The verification showed that for all studied cases, the estimated coefficients of variation with respect to Table 1, 2 and 3, are less than 0.3 or V $<$30%. This gives us grounds to assume that the studied variables have a normal (Gaussian) distribution (Tasev 2010). From the obtained average values of friction angles, in accordance with formulas (1) and (2), the average values of respective coefficients of friction of the studied seed materials have been also defined. The coefficients of friction on a steel surface are presented in Table 4 and the coefficients of internal friction – in Table 5.

In determining the geometrical parameters of the hopper – and feeder devices of the machinery it is appropriate to use the maximum values of the angles of friction and repose, Xmax from Table 1, 2 and 3. This will ensure the full fluxion of the materials into the devices with gravitational power.

The angle of repose of the seeds with wings for all the four tree species is greater than 70°, which assigns them to the group of non-fluxion (plastic) bulk materials. When working with such seeds it is necessary the hopper devices of the machines to be fitted with a mechanism for coercive filling.

The technological mixtures in the dewingers include mainly seeds from the processed lots that are between 65–75% of the total weight, pounded wings – about 20–30% and needles and cone scales – less than 5%. To determine the geometrical parameters of these machines, the average values of friction angles are used and for determining the parameters of the process their friction coefficients are mainly used.

The angles of repose and friction of the pure seeds are used for the design of hopper devices, sowing devices and seed tubes for forest seeders. The friction coefficients, obtained as average values of these angles, are used for determining the technological and production parameters of the sowing process.

The group of impurities is formed by the technological mixture in the dewingers while the pure seeds are separated, i.e. this group includes pounded wings, needles and cone particles. Because of the fact that the differences in the angular parameters are very small for the different tree species, the tables show their average values. The friction coefficients of this group are mainly used in the cal-

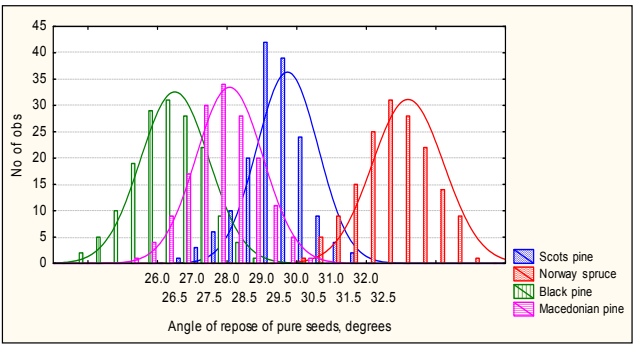

Fig. 5. Histograms of angle of repose of pure (dewinged) seeds.

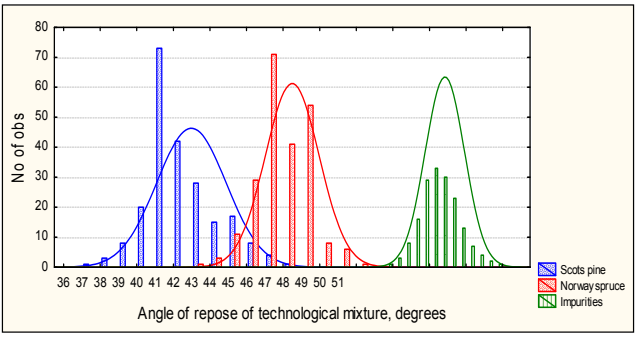

Fig. 6. Histograms of angle of repose of technological seed mixture and impurities.

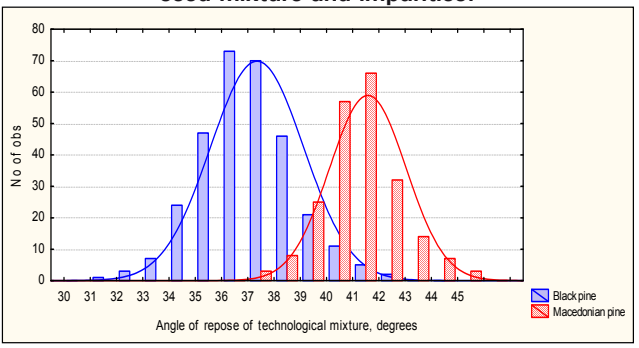

Fig. 7. Histograms of angle of repose of technological seed mixture.

Table 4. Friction coefficients of seed materials on steel surface.

Seed materials	Scots pine	Norway spruce	Black pine	Maced. pine	Impurities
Seeds with wings, f	0.5692	0.7295	0.5322	0.4813	–
Dewinging seeds, f	0.4589	0.5916	0.4159	0.6769	–
Technol. seed mixture, f	0.5221	0.6620	0.4968	0.4534	0.6901

Table 5. Coefficients of internal friction of seed materials.

Seed materials	Scots pine	Norway spruce	Black pine	Maced. pine	Impurities
Dewinging seeds, μ	0.5704	0.6531	0.4981	0.5326	–
Technol. seed mixture, μ	0.9309	1.1275	0.7623	0.8853	1.5247

culation and design of some seed cleaning machines and pneumatic transport systems.

Conclusions

This study has a scientific hand a practical character. Thanks to this study the existing knowledge on the physical-mechanical and technological properties of seed materials from our main coniferous species have been enriched and further developed. The following main results of this study can be pointed out:

1. The friction angles and coefficients of the studied seed materials on a smooth steel surface are determined;

2. The angles of repose and coefficients of internal friction of pure seeds and technological mixtures in the dewingers are determined;

3. The type of distribution and the numerical characteristics of the angular parameters of the studied seed materials as random variables with a normal distribution law are determined.

The results are intended for research in the field of forest seed production and the sowing process. Seed cleaning machines, dewingers, transporting and sowing machines can be designed and constructed with the help of these results. They also define some technological parameters of the processes in the respective area of application.

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