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ANALYSIS OF THE DEWINGING PROCESS ON SCOTS PINE SEEDS WITH SMALL-SIZED DEWINGER

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ABSTRACT

In recent years, in Bulgaria there is a tendency to reduce the yield of seeds of conifers. This implies a more efficient use of machines with less power and performance. The forest seed producing stations in the country are equipped with small-sized dewingers "Unitech", but at this stage we still lack research and data to work with seeds of Scots pine. In the present work, a study has been conducted and an analysis has been made on the dewinging process of the Scots pine seeds (*Pinus silvestris L.*) with a small-sized paddle dewinger "Unitech". As a result, functional dependencies have been identified, which express the relationship of the rotation speed of the working bodies and the duration of the process on the quality of the harvested seeds and the operating performance of the machine. On this basis, the optimal process parameters have been established and specific modes of dewinging of Scots pine seeds have been proposed. The obtained results have an applied science nature in the field of forest seed production and the design of machines for dewinging of seeds.

Key words: forest seed production, small-sized dewinger, technological parameters, Scots pine.

1. INTRODUCTION

The seed dewinging in the forest seed stations in Bulgaria is done with paddle dewingers. They have better performance characteristics as it goes for the dewinging of seeds of conifers, compared to the brush dewingers (Gunev and Lyubenov 1973, Buszewicz and Gordon 1973, Lanquist 1980, Marinov 2006). A small series of small-sized paddle dewingers "Unitech" for use in the seed producing station and seed control stations (Fig. 1) was produced in Bulgaria for the dewinging of small batches of seeds of coniferous species. These machines are designed on the basis of the small-sized dewinger "Lilliput", produced by the German company "Streckel & Schreder". Given the downward trend in seed yield in recent years in Bulgaria, these machines are a current solution for our current seed production (Lowman 1975, Lowman and Casavan 1978). Studies with a similar small-sized dewinger have been conducted in the forest seed station in Batak for dewinging of seeds of pine and spruce (Marinov *at al*. 2008), but there is still no data on the dewinging process of seeds of Scots pine, which is one of the main coniferous species in the country.

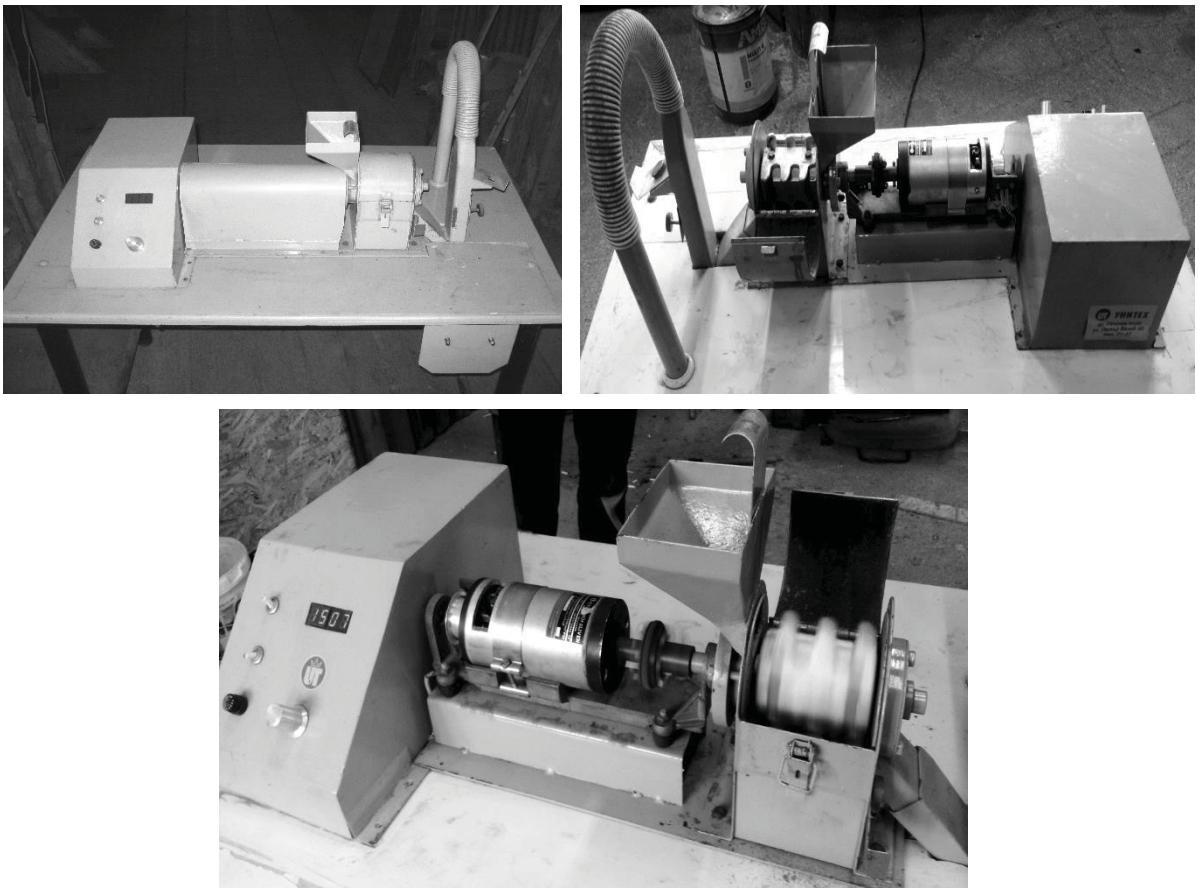

Figure 1: Pictures of the small-sized paddle dewinger „Unitech“

The aim of the study is to establish the influence of a small-sized paddle dewinger on the quantitative and qualitative indicators of the dewinging process and to identify the most effective processing modes for the seeds of Scots pine (*Pinus silvestris L.*).

Object of the study is the small-sized paddle dewinger "Unitech", part of the equipment of the Forest Seed Producing Station in Razlog. The study is focused on the qualitative and quantitative indicators of dewinging process of the seeds of the Scots pine. The Scots pine cones are harvested in the region of State Forestry "Razlog" and State Forestry "Eleshnitsa".

Place of the study is Forest Seed Producing Station in Razlog. The seed control samples are graded in the laboratory of Seed Control Station in Sofia.

The obtained results will be used for:

1. Finding the relationship between the qualitative and quantitative indicators of the process, at different technological modes.

2. Determining of the functional modes of the dewinger for obtaining high-quality seeds.

3. Establishment of recommended and optimal processing modes of the Scots pine seeds.

2. METHODS AND MATERIALS

To conduct the study, a special methodology for studying the paddle dewingers is used (Marinov and Lyubenov 2007). Object of the research is the technological process of dewinging with a small-sized paddle dewinger "Unitech" in the regional Forest Seed Station in Razlog. The study is focused on the seeds of the Scots pine harvested in the region of State Forestry Eleshnitsa and State Forestry Razlog. The purpose of the study is achieved through experimental study of the

main parameters (factors) influencing the process.

Input parameters. The input parameters of the researched object are variable and constant. Constant parameters are the constructional characteristics of the machine and the type of seed. Variable parameters are manageable and unmanageable. The last belong to the group of the interfering factors. The manageable parameters form the input manageable factors of the study. The larger number of factors requires a large number of experiments and the larger amounts of valuable seeds. In order to reduce the total number of experiments, some of the factors are kept at the same level. For this purpose, the humidity is kept within $W = 7{,}5 \div 9$ %, which provide favorable conditions for the method to work. Other important factors for the process are the clearance between the tooth crest and the inner walls of the drum and the degree of fullness of the drum. During the study, the clearance is maintained at 2.5 mm, thereby preventing the risk of crushing of larger seed. From the studies carried out on the operation of these types of dewingers, it has been found that, in order to ensure optimal operation of the process, the drum must be filled with seed up to 75 % of its free internal volume (Gunev and Ljubenov, 1983). There is risk for damaging of the seeds and overload of the machine at a higher level of filling. At a lower filling level, the lapping effect on seeds is weaker, which requires an extension of the process and leads to a reduction in the operating performance. To provide such a filling level of the drum of the "Unitech" dewinger, 87 g seeds of Scots pine were used. To conduct the study two factors for control were selected, that meet the requirement for interoperability, manageability and independence. These are:

X_1 – the rotation speed the working bodies of the dewinger, min^{-1};

X_2 – the duration of the seed processing, min.

In order to limit the influence of interfering factors, such as impurities in the seeds, they need to be removed before carrying out the experimental observations.

Output parameters. The output parameters are selected in accordance with the assigned tasks and comply with the requirements of the production process. They are directly related to the qualitative and quantitative indicators of the process. For this purpose, the following 4 examination parameters are chosen:

Y_1 – level of the dewinging of the seeds, %;

Y_2 – germination of the seeds, %;

Y_3 – mechanical damage to the seeds, %.

Y_4 – operating productivity, $kg.h^{-1}$

The quality indicators of the seeds Y_1 Y_2 and Y_3 can be evaluated by quantitative measurement. The degree of dewinging Y_1 is a key indicator for assessing the performance of the machine. The germination (viability) of seeds Y_2 is a main criterion in determining their quality. Micro damages and overheating of the seeds during processing, lowers their germination. As a studied parameter, this parameter is very important and gives a qualitative assessment of the performance of the machine. It expresses in percentage terms the number of rotting seeds, damaged due to the impact of the working bodies, compared to the total number of examined seeds. Mechanical damage Y_3 express in percentage terms the mass of crushed and broken by the machine seeds to the total weight of the treated seed. The operating performance Y_4 is defined as the ratio between the mass of the dewinged seeds and the time required for their processing.

Study conditions. The dewinging is done at a seed humidity of W = 7.5–9 %, which is favorable to the dry method of work.

In order to maintain the humidity, the seeds are kept in the boiler room. After each test monitoring, the machine is cleaned of the remaining seeds and impurities. Sample drawing of seed control samples are taken at the entrance and exit of the machine, according to the methodology BIS 1953:99. To prevent suction of seeds, broken by the machine, the pneumatic aspirator is switched off during the experiments.

Methods and means of measurement. To determine the quality indicators, seed control samples are compiled, before and after the experimental observations. The quality of the seeds is determined in accordance with BIS 208:99, and the samples are tested according to the procedure described, in BIS 1953:99.

The level of dewinging Y_1 is determined by the formula,

$$Y_1 = \frac{m_O}{M}.100,\% \qquad \textbf{(1)}$$

where m_o is the mass of the dewinged seeds, g;

M – the total mass of the seeds in the seed-control sample, g.

Germination Y_2 is determined after reduction of the rotting, non-dewinged seeds from the control sample at the entrance and exit of the machine, by the formula:

$$Y_2 = 100 - \frac{n_3}{N - n_{ПР}}.100,\%, \qquad \textbf{(2)}$$

where n_3 is the reduced number of the rotting, dewinged seeds in the examined sample;

N – the total number of the examined seeds;

$n_{ПР}$ – the number of the empty seeds.

The mechanical damage on the seeds Y_3, caused by the machine during the dewinging process is determined by the formula,

$$Y_3 = \frac{m_{МП}}{M}.100,\% \qquad \textbf{(3)}$$

where $m_{МП}$ is the reduced mass of the damaged by the machine seeds, g.

The operating productivity Y_4 is determined by the formula,

$$Y_4 = \frac{V}{t},\ \text{kg.h}^{-1} \qquad \textbf{(4)}$$

where V is the quantity of the processed seeds, kg;

t – time (duration) of the experiment, h.

The moisture content of the seeds is determined by the analytical method, by drying the samples in an oven thermostat at a temperature T = 103 °C ± 2 ºC (BIS 1953: 99). The duration of the process is measured with a stopwatch with accuracy up to 1s. The mass of seeds is weighed with an electronic scale with accuracy up to 0,01 g.

Plan for conducting the experimental tests. The experimental observations are carried out according to a test plan. The study is managed by two input factors:

1) Processing time of the seeds – t;

2) The rotation speed of the shaft with the working bodies or dewinger shaft revolutions – n. The experiment is conducted by planning of five levels of modification factors (Table 1).

Table 1: Testing plan

Processing time – *t*, [min]	2, 4, 8, 12, 16
Dewinger shaft revolutions – *n*, [min^{-1}]	450, 600, 750, 900, 1050

Duration of the study and number of observations. The study duration is determined in accordance with the test plan. The time for each test is an input parameter of the study. The number of the observations for each test is directly related to the total duration of the study. The larger number of experimental observations gives more accurate information on the measured object, but also requires more tests, which requires the use of

a greater amount of valuable seeds. Considering the results from our previous studies (Marinov at al. 2009), it was decided that 3 observations for each test to be conducted.

Drawing and analysis of results. After completion of the experimental observations, the average values of the studied parameters are determined. These results are used to build functional graphic relationships, which show the change of the studied parameters, depending on the rotation speed of the working bodies and the duration of the process. On that base, an analysis of the results is made and optimal working modes of the machine are proposed.

3. RESULTS AND DISCUSSION

3.1. Results from the study

The study was conducted according to the approved methodology. To determine the extent of dewinging, germination and mechanical damage, the seed control samples are tested and graded in the laboratory of forest seed control station in Sofia. The operation modes of dewinging are determined by the rotation speed the shaft, leading the working and the time for seed processing, according to the test plan. The moisture content of the seeds is maintained within W_a = 7.5 ÷ 9 %, and the drum is filled 75 %. The average values of the obtained results for the quality of the seeds are presented in Table 2.

Table 2: Scots pine indexes for quality on dewinging process

Input parameters		Output parameters		
X_1, Shaft revolutions, n [min^{-1}]	X_2, Processing time, t [min]	Y_1 Dewinging level [%]	Y_2 Germination [%]	Y_3 Mechanical damage [%]
	2	72.10	100.00	0.04
	4	78.90	100.00	0.07
450	8	89.30	100.00	0.14
	12	96.20	99.50	0.23
	16	100.00	98.50	0.35
	2	81.80	100.00	0.08
	4	87.20	100.00	0.12
600	8	94.30	99.50	0.21
	12	98.20	98.50	0.33
	16	100.00	97.00	0.47
	2	87.90	100.00	0.13
	4	92.50	99.50	0.18
750	8	96.90	98.50	0.28
	12	99.30	97.00	0.43
	16	100.00	95.00	0.62
	2	91.80	99.50	0.19
	4	94.70	99.00	0.25
900	8	98.50	97.50	0.38
	12	100.00	95.50	0.55
	16	100.00	93.00	0.77
	2	94.90	99.00	0.29
	4	97.40	98.50	0.35
1050	8	99.50	96.50	0.49
	12	100.00	94.00	0.69
	16	100.00	90.50	0.95

The operating productivity of the machine as a 4th examined parameter Y_4 at a constant mass of the seeds and a different duration is presented in Table 3.

Table 3: Operating productivity

Processing time – t, [min]	2	4	8	12	16
Operating productivity – Y_4, [kg.h^{-1}]	2.63	1.31	0.66	0.44	0.33

Based on the obtained results, graphical relationships, depicted in Figures 2, 3, 4 and 5, are constructed. The constructed dependencies express the correlation between the quality of the harvested seeds and the operating productivity of the machine, relative to the rotation speed of the working bodies or the shaft revolutions [n] and the duration of the processing [t], at various levels of the examined entrance input parameters.

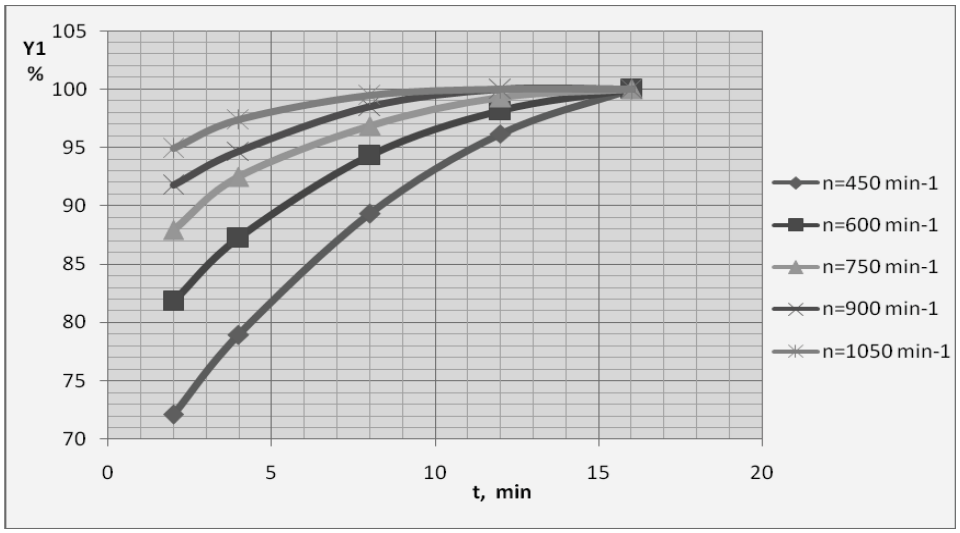

Figure 2: Variation of the level of dewinging Y_1 at Scots pine seeds, dependence on the shaft revolutions [n] and the processing duration [t]

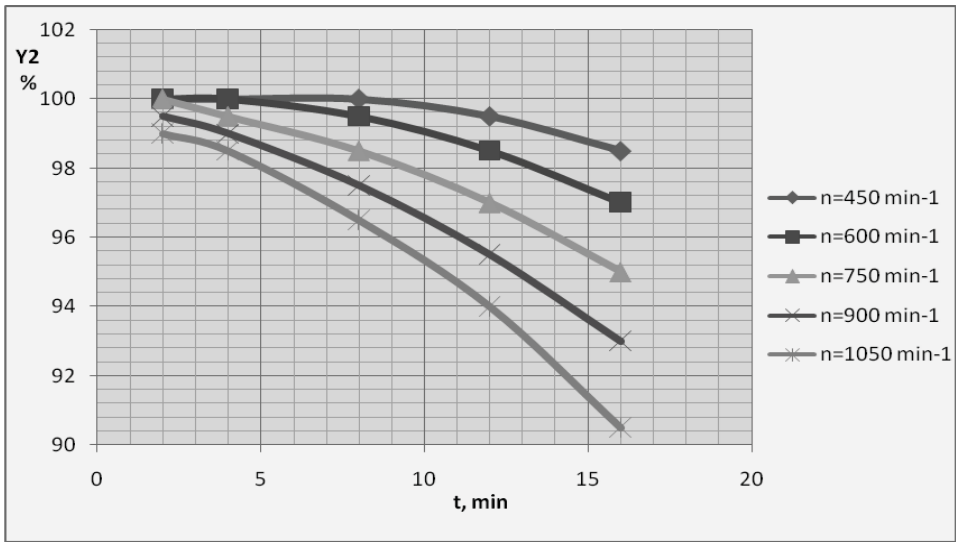

Figure 3: Variation of the germination Y_2 at Scots pine seeds, dependence on the shaft revolutions [n] and the processing duration [t]

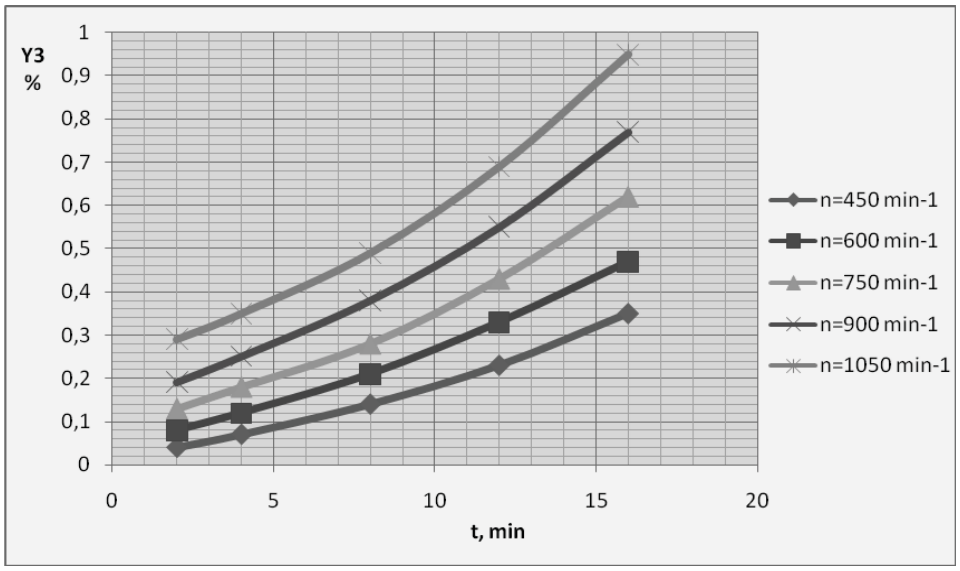

Figure 4: Variation of the mechanical damages Y_3 at Scots pine seeds, dependence on the shaft revolutions [n] and the processing duration [t]

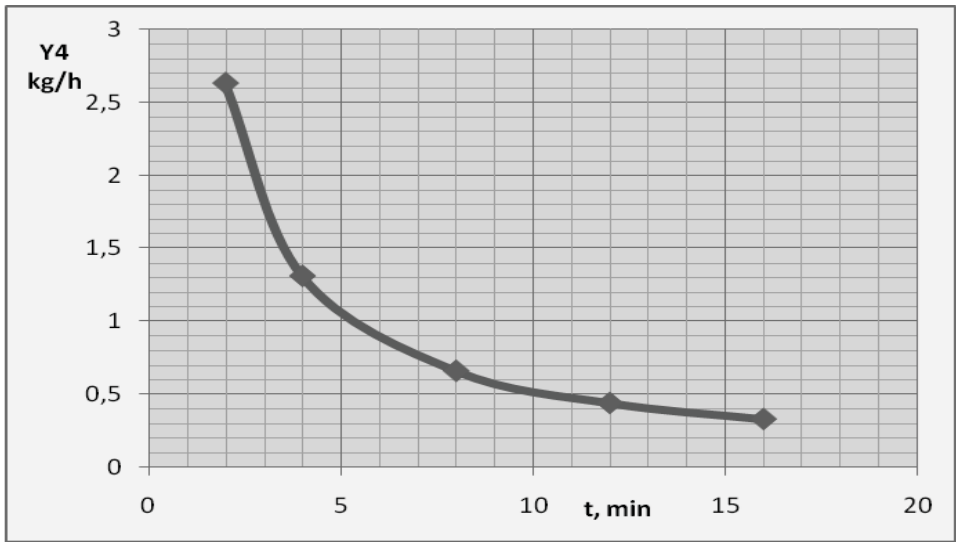

Figure 5: Variation of the operating productivity Y_4 at Scots pine seeds dewinging, dependence the processing duration [t]

3.2. Analysis of the results and discussion

The increase of the rotation speed of the working bodies the process duration, increases in proportion to the level of dewinging – Y_1 (Fig. 2). This fact stems from the more intense and longer-lasting effects on the seeds. The graph of Fig. 2 shows that in order to achieve the minimum level of first quality at 95 % level of dewinging, at the lowest shaft speed n = 450 min^{-1} for the Scots pine, a minimum of 11 minutes to processing time is required. Under this condition, the productivity of the machine is lower – Y_4 = 0.48 $kg.h^{-1}$ (Fig. 5). At the highest observed speed of the shaft – n = 1050 min^{-1}, only 2 minutes to achieve the desired level of dewinging is necessary, thereby achieving the highest productivity of the machine – Y_4 = 2.63 $kg.h^{-1}$ dewinged seeds.

The increase in the speed of the working bodies can lead to an undesired increase in the damage to the seed and to reduce their propagation characteristics. Using paddle dewingers, it is accepted that the maximum

limit of mechanical damage to $Y_{3max} = 0.5$ %. The graphical correlations in Fig. 4 show that at a speed of n = 1050 min^{-1}, the maximum processing time should not exceed 8 minutes. As the speed decreases, the time increases.

The increased friction and heat lead to the appearance of microscopic tearings of the mucilage and lowering the germination qualities of the seeds. This is seen in the graphics in Fig. 3. At lower shaft rotation of the working bodies, up to n = 750 min^{-1} , during the first 4 to 8 minutes, the micro damages are not observed, while at higher speeds – over n = 900 min^{-1} damages are observed even at the shorter processing times.

The operating productivity of the dewinger at a 75 % filling of the drum with 87 g of seeds, depends on the duration of the process. The productivity may be determined by the graphical correlation in Fig. 5. It can be increased by increasing the operating speed and shortened dewinging time.

The choice of an optimal mode is determined by the need for seed yield with high propagation characteristics. For the extraction of first quality seeds of Scots pine, certain restrictions in the levels of variation of the examined output parameters are required. According to the established rules and requirements for seed production of Scots pine (BIS 208: 99 and BIS 1953: 99), the minimum level of dewinging must be not less than 95 %. This makes it necessary to introduce a restrictive level of dewinging, which will be expressed by the condition: $Y_1 \geq 95$ %. The mechanical damage, caused by the machine, according to the accepted rules in the seed yield, must not be larger than 0.5 %, which requires the introduction of a restrictive condition: $Y_3 \leq 0.5$ %. For the production of Scots pine seeds with first quality, their germination shall not be less than 90 % or the condition: $Y_2 \geq 90$ % must be met. The damage of healthy seeds, caused by the machine, reduces their germination and propagation characteristics of the seeds produced.

The analysis leads to the conclusion that in order to identify optimal modes for the technological process, it is necessary to introduce certain restrictive conditions. These conditions for degree of dewinging and mechanical damage are: $Y_1 \geq 95$ % и $Y_3 \leq 0.5$ %. In order to establish the germination, there can be introduced more flexible restrictions that include more levels of $Y_2 = 90$ % to $Y_2 = 100$ %, thereby reducing the participation of non-viable seeds in the supplied batch. Only the rotting should be referred as non-viable seeds, since the empty seeds are subsequently released into the air channel of the pneumatic aspirator. If the number of these seeds is denoted with $n_{Звход}$, and the total number of examined seeds with N, the non-viable seeds (C) are determined by the formula

$$C = \frac{n_{Звход}}{N}.100,\% \qquad \textbf{(5)}$$

If several restrictive levels for the presence of non-viable seeds, prior to processing, such as: $C = 0$ %; 4 %; 8 %, 9 % and 10 % are introduced, then the allowable micro damages, caused by the machine, will be limited, respectively, to 10 %; 6 %; 2 %; 1 % and 0 %. These restrictive conditions will be expressed by the following equations:

$$Y_2 \geq 90\ \%;\ Y_2 \geq 94\ \%;$$
$$Y_2 \geq 98\ \%,\ Y_2 \geq 99\ \%$$
$$\text{и } Y_2 = 100\ \%. \qquad \textbf{(6)}$$

The boundary times for defining the duration of the seed processing may be established from these restrictive conditions. At a nominal shaft rotation speed of the working bodies, the values of these times are determined by the relationships in Figures 2, 3 and 4 in accordance with the graph-analytical method. The results obtained are shown in Table. 4.

Table 4: Limited parameters for Scots pine seeds processing duration at 1-quality production

Shaft revolutions n, [min^{-1}]	Duration of the processing time – t, [min]						
	Dewinging level Y_1, [%]	Germination Y_2, [%]					Mechanical damage Y_3, [%]
	$Y_1 \geq 95$ %	$Y_2 \geq 90$ %	$Y_2 \geq 94$ %	$Y_2 \geq 98$ %	$Y_2 \geq 99$ %	$Y_2 = 100$ %	$Y_3 \leq 0.5$
450	$t \geq 11.4$	$*t_{max} \rightarrow 30$	$*t_{max} \rightarrow 25$	$*t_{max} \rightarrow 17$	$t \leq 14.0$	$t \leq 8.0$	$*t_{max} \rightarrow 25$
600	$t \geq 8.8$	$*t_{max} \rightarrow 25$	$*t_{max} \rightarrow 21$	$t \leq 13.5$	$t \leq 10.2$	$t \leq 4.0$	$t \leq 16.5$
750	$t \geq 6.3$	$*t_{max} \rightarrow 22$	$t \leq 17.5$	$t \leq 9.5$	$t \leq 6.5$	$t \leq 2.0$	$t \leq 13.5$
900	$t \geq 4.1$	$t \leq 18.5$	$t \leq 14.5$	$t \leq 6.8$	$t \leq 4.0$	$*t_{max} \rightarrow 1.0$	$t \leq 10.8$
1050	$t \geq 2.0$	$t \leq 16.5$	$t \leq 12.0$	$t \leq 5.1$	$t \leq 2.0$	$*t_{max} \rightarrow 0.5$	$t \leq 8.1$

** Note. Minimum and maximum times in Table 4 indicated by the symbols "tmin →" and "tmax →" tend to values that are outside the scope of the trials. They are determined by graphical upgrade of the resulting dependencies and are presented as approximate estimates.*

The obtained results are used to establish effective performance dewinging modes. Based on the results obtained and the graphical dependencies from Fig. 5, the operating productivity of the machine is determined.

. DETERMINING OF FUNCTIONAL MODES

The technological modes of a dewinger "Unitech" are managed by the speed of the rotation of the shaft of the working bodies and the duration of the process. In order to yield quality seeds, it is necessary to know what the percentage of non-viable (rotting) seeds in the batch for dewinging – C % is. Many suitable modes can be identified from the obtained results in Table 4. In order to reduce their number, recommended boundary levels for some of the output parameters can be entered. The degree of dewinging is fixed at two levels: a lower level – $Y_1 = 95$ % and an upper level – $Y_1 = 100$ %. Modes of mechanical losses over $Y_3 > 0.5$ % are excluded. On this basis, using the graphical relations in Fig. 2, 3, 4 and 5, ten values for establishing the boundary functional modes of a "Unitech" dewinger can be determined. The results are shown in Table 5.

Table 5: Working regimes for Scots pine seeds dewinging

Shaft revolutions, [min^{-1}]	Dewinging level, [%]	Processing time, [min]	Germination reducing, [%]	Operating productivity, [kg.h^{-1}]
450	95	11.4	0	0.47
	100	16.0	1.5	0.33
600	95	8.8	0.5	0.58
	100	14.8	3.8	0.37
750	95	6.3	1.0	0.87
	100	12.8	3.0	0.39
900	95	4.1	1.0	1.28
	100	10.5	3.5	0.50
1050	95	2.1	1.0	2.61
	100	8.1	3.5	0.64

We can define 3 basic modes for laboratory and industrial dewinging of Scots pine seeds – „A", „B" and „C" from the so determined functional modes.

Laboratory mode – "A".

This mode is suitable for work in the laboratory and Forest Seed Control Stations. The rotation speed of the working bodies is n = 450 min^{-1}, and the processing time is t =

11.4 min. In this mode, there is no seed damage and reduced seed germination (Y_2 = 100 % и Y_3 = 0.21 %). The dewinging level is Y_1 = 95 %, and the operating productivity is W_h = 0.47 kg.h^{-1}.

Light operating mode – "B".

This mode is suitable for use in Forest Seed Producing Stations when the harvest of seeds is with low germination qualities. The rotation speed of the working bodies is n = 600 min^{-1} and the processing time is t = 8.8 min. In this mode, a germination decrease with 0.5 % (Y_2 = 99.5 % и Y_3 = 0.21 %) is accepted. The dewinging level is Y_1= 95.1 %, and the operating productivity – W_h = 0.58 kg.h^{-1}.

Intensive operating mode – "C".

This mode is suitable for use in Forest Seed Producing Stations when the harvest of seeds is with high germination qualities. The rotation speed of the working bodies is n = 1050 min^{-1} and the processing time is t = 2.1 min. In this mode, a germination decrease with 1 % (Y_2 = 95 % и Y_3 = 0.29 %) is accepted. The dewinging level is Y_1= 96 %, and the operating productivity – W_h=2.61 kg.h^{-1}.

CONCLUSION

The present study is the first in Bulgaria on the dewinging of the seeds from Scots pine with a small-sized paddle dewinger "Unitech", produced in Bulgaria. As a result, original results are obtained, from which the following important conclusions and recommendations can be made:

1. The functional relations to determine the qualitative and quantitative process parameters have been established. With their help, appropriate technological modes for dewinging of Scots pine seeds can be established.
2. The boundary and optimal modes of the technological process have been established.
3. The functional modes for yield of first quality seeds have been established.
4. Recommended technological modes for dewinging of Scots pine seeds in laboratory and production conditions have been defined.

The obtained results have an applied science nature in the field of forest seed production and the design of machines for dewinging of seeds. They can be used by Forest Seed Producing Stations and Seed Control Stations for determining of optimal work modes for Scots pine seed processing with a small-sized dewinger “Unitech”/”Lilliput”.

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