Rate of sowing Norway spruce seeds: the effect of rotation frequency of the sowing machine

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Abstract. The article presents the research results of the sowing process (Norway spruce seeds) using a sowing machine under various modes of its operation. It has been established that the rotation frequency of sowing tools has a significant impact on the sowing rate of Norway spruce seeds and the uniformity of their distribution in the sowing line. The rate of spruce seed sowing and the uniformity of their distribution in the sowing line are determined. It is understood that rotation frequencies of sowing tools are 4.3, 7.0, 10.5 and 14.5 rpm and the forward speed of the unit is 900 m/h. To meet the requirements of growing spruce seedlings according to the generally accepted technology (with a seed sowing rate of about 50 kg/ha (1.5 g/m) the rotational speed of sewing machines should be 10.5 rpm. The rotational speed of sewing machines is recommended to be equal to 7.0 rpm when growing large spruce seedlings in the nursery with a seed sowing rate of about 24 kg/ha (0.7 g/m) Rational modes of operation sewing machines have been substantiated. These modes provide existing and advanced technologies for growing spruce seedlings in forest nurseries.

1. Introduction

Roller-grooved sowing devices are used in modern seed drills for sowing tiny coniferous seeds in forest nurseries. They have a number of significant shortcomings that negatively affect both the quality of sowing and the planting material. The main disadvantage of these sewing machines is damage of seeds during sowing. In addition, roller-grooved sewing machines do not fully meet the requirements of the advanced technology of large spruce seedlings growing. This technology provides even distribution of seeds in the sowing line with a minimum sowing rate of 0.5-1.5 g/m [1-4]. Sewing machines are used in agriculture for vegetable crops sowing. They ensure high-quality sowing. The seeding rate of sowing devices is regulated by changing the rotation frequency [5-9].

A review of modern articles shows that they cannot be used to analyze the work of forest seeders, as they were carried out on seeds of other species other than seeds of spruce. Therefore, it is necessary to conduct special studies, the impact of the operating conditions of seeders on their performance when sowing seeds of spruce. The main indicator of the quality of sowing device is uniform distribution of seeds during sowing and their number per unit length of the sowing furrow or unit area. Studying the possibility of using sowing tools for tiny seeds of conifers and justifying rational modes of their work is of interest calculating and designing seed drills intended for sowing spruce in forest nurseries.

The purpose of the research was to study the effect of rotational speed of sewing machines on the rate and uniformity of spruce seed sowing and justification of their rational modes.
2. Materials and methods

The objects of the research were local seeds of Norway spruce from one batch of 1 (the best) quality class harvested in local territories (Moscow region, Russia). Studies were carried out on spruce seeds sowing using forest mounted modernized planting tool SLN-5A with sowing devices under various operating regimes. The main parts of the seeder are: frame 1, furrow forming roller 2, hopper 3, sowing devices 4, chain transmission 5, gearbox 6, bearing rod 7, seed tubes 8, covering device 9, roller 10, automatic coupling 11, hinge 12, stops 13 and plugs 14 (Figure 1). This seeder provides a 5-row seeding scheme with a spacing between the rows equal to 22.5 cm on a sowing belt (22.5-22.5-22.5-22.5-60 cm) [4]. Furrow forming roller 2 with five rows is designed to drive seeding machines and prepare five sowing furrows with a width of 20 mm and a depth of 20 mm.

![Figure 1. Forest mounted modernized planting tool SLN-5A: (a) side view, (b) view from above; 1 – frame, 2 – furrow forming roller, 3 – hopper, 4 – sowing devices, 5 – chain transmission, 6 – gearbox, 7 – bearing rod, 8 – seed tubes, 9 – covering device, 10 – roller, 11 – automatic coupling, 12 – hinge, 13 – stops and 14 – plugs.](image)

Sowing devices 4 are installed in the bottom of the hopper 3 and are designed to feed seeds from it to the seed furrows using seed tubes 8. These sowing devices are made in the form of coils with a diameter of 60 mm, with studs having 5 mm wide and 5 mm high (Figure 2a and 2b). The studs are located on its periphery in two rows of 12 studs in each row and ensuring a uniform flow of seeds into the sowing line. The drive of the sowing devices 4 with different rotation frequency is carried out from the furrow forming roller 2 through the chain drive 5 and gearbox 6. The seed sowing rate is adjusted by changing the rotational speed of the sewing machines using a multi-stage gearbox 6.

Covering of seeds is carried out by covering device 9, installed along the track of each sowing furrow. It is made in the form of two V-shaped skids with a diameter of 20 mm with a deviation of 15 degrees of their front parts to the direction of the sewing machine movement. In the back the skids join for a value which is slightly larger than the width of the furrows. The skids have rods with a diameter of 4-6 mm in their lower part to ensure the measured amount of soil sent to the sowing line. The roller 10 is designed to compact the soil in the seed covering zone and throughout the seed belt. The hinge 12 is designed to ensure contour following by a sewing machine in the transverse plane. The stops 13 are designed to limit the lateral deviation of the machine when working on falling belts.

The technological process performed by the machine looks as follows. Upon arrival of the machine on the belt with the pre-treated soil, the seeder is moved to the working position. Then, the required rotation frequency of the sowing apparatus is established by selecting the appropriate pair of stars in the gearbox. This frequency provides the required seed rate. During the forward movement of the seed drill, the furrow forming roller ensures the preparation of seed furrows and the rotation of the sowing tools.
The studs of sowing tools capture the seeds from the hopper and send them to the bottom of the seed lines using seed tubes. Covering devices close the seeds with soil in the furrows and press rollers compact the soil in them and on the entire seed belt. The peculiarity of the technological process performed by the sewing machine is simultaneous performance of three agrotechnical operations: sowing seeds, covering them with soil and its compaction.

Figure 2. The coil of sowing device: (a) side view, (b) view from above.

Experimental studies were carried out on medium loamy soils with a moisture content of about 25.4% in the 0-5 cm layer and the soil density equal to 0.74 g/cm³ in the 0-5 cm layer. The pre-sowing tillage was carried out by a rotary machine MRB-1.6 (Russia) by loosening it to a depth of 10 cm with the simultaneous formation of ridges with an average height of 10.8 cm and a width of 115.7 cm.

The mass and quantity of sown seeds were determined. It was made for each of the five sowing devices over 1 m passage length of the seeder with a fivefold repetition of the experiments. The obtained data was processed by the methods of mathematical statistics. During the research, the rotational speed of the sowing tool was: 4.3, 7.0, 10.5 and 14.5 rpm. The experiments were carried out using T-30 tractor (Russia) at a forward speed of 900 m/h.

3. Results and discussion
The main indicator of the quality of sowing device is uniform distribution of seeds during sowing and their number per unit length of the sowing furrow or unit area. The research provides the data on the sowing rate of spruce seeds and the average distance between them in the sowing furrow at different rotation frequency of the sowing tool. Analysis of the obtained data (table 1) shows that the rate of sowing of spruce seeds increases with increasing rotation frequency of sewing machines.

Table 1. Influence of rotational speed of sowing tool on the sowing rate of spruce seeds.

| Rotational speed of the sowing device, rpm | Average sowing rate |
|------------------------------------------|---------------------|
|                                          | kg/ha               | g/m     |
| 4.3                                      | 13.2±0.7            | 0.4±0.02|
| 7.0                                      | 24.4±1.1            | 0.74±0.03|
| 10.5                                     | 36.6±1.9            | 1.11±0.06|
| 14.5                                     | 50.5±2.5            | 1.55±0.08|
The rotational speed increased by 1.6 times (from 4.3 to 7.0 rpm) during changing i.e. the sowing rate increased by 1.8 times (from 13.2 to 24.4 kg/ha or from 0.4 to 0.74 g/m). With an increase in the rotational speed up to 10.5 rpm (1.5 times) the seeding rate increased from 24.4 to 36.6 kg/ha, or from 0.74 to 1.11 g/m, that is, increased by 1.5 times. With a further increase in the rotational speed up to 14.5 rpm (1.4 times) the planting rate of spruce seeds increased from 36.6 to 50.5 kg/ha, i.e., increased by 1.4 times. Thus, the rate of sowing seeds increases with an increase in the rotation frequency of the sowing tool. The dynamics of changes in the rate of sowing seeds reduces with increasing rotation frequency of the sowing tool. The roller pressed the soil in the seed covering zone and throughout the seed belt. The average depth of sowing was 0.9 cm. There were no damages to the spruce seeds during sowing.

Table 2. Influence of rotation speed of sowing tool on the uniformity of spruce seed sowing.

| Number of the sowing tool | Average number of seeds, pieces/m (average distance between the seeds in the sowing furrow, mm) | Frequency of the sowing apparatus, rpm |
|--------------------------|-------------------------------------------------|----------------------------------------|
|                          | 4.3 (12.2)                                      | 7.0 (12.3)                             | 10.5 (13.2)                            | 14.5 (13.2) |
| 1                        | 82.2                                            | 150.8                                  | 223.6                                  | 290.5        |
| 2                        | 81.1                                            | 155.2                                  | 220.2                                  | 304.2        |
| 3                        | 85.4                                            | 154.6                                  | 210.3                                  | 302.3        |
| 4                        | 75.8                                            | 133.4                                  | 220.8                                  | 310.4        |
| 5                        | 81.8                                            | 132.1                                  | 216.1                                  | 295.2        |
| Total                    | 81.3                                            | 145.2                                  | 218.2                                  | 300.5        |

The uniformity of spruce seeds sowing was estimated by the average number of seeds sown per meter of the sowing furrow for the five sowing units and the average distance between the seeds. Analysis of the obtained data (table 2) shows that (with a rotational speed of sewing machines equal to 4.3 rpm) the number of spruce seeds per meter of sowing line changed from 75.8 to 85.4 pcs/m and their average number was 81.2 pcs/m. The average distance between the seeds in the seed furrow was 12.3 mm. With an increase in the rotational speed of sewing machines from 4.3 to 7.0 rpm, the number of sown seeds increased to 132.1 - 155.2 pcs/m. The average distance between seeds in the seed furrow decreased to 6.9 mm. With an increase in the rotational speed of the sewing machines to 10.5 rpm, the number of sown seeds increased to 216.1-223.6 pcs/m. The average distance between the seeds in the sowing furrow decreased to 4.6 mm. With a further increase in the rotation frequency of the sewing machines to 14.5 rpm, the number of sown seeds increased to 290.5-310.4 pcs/m and the average distance between the seeds decreased to 3.3 mm.

Studies of impact of rotation speed of sewing machines on the spruce seed rate and the uniformity of their distribution in the seed furrow show that the planter provides uniform seed sowing of spruce with allowable limits for changing both in the seed rate (from 13.2 to 50.5 kg/ha) and the average distance between seeds in sowing furrow (from 3.3 to 12.3 mm).

4. Conclusion
As a result of the conducted researches of influence of frequency of rotation of sowing devices on norm and uniformity of sowing of seeds of a fir tree, the rational modes of operation of the seeder providing uniform distribution of seeds in a sowing groove are proved. To meet the requirements for the cultivation of spruce seedlings according to generally accepted technology, the rotational speed of the sewing machines should be 10.5 rpm, while the sowing rate of spruce seeds is 50 kg/ha (1.5 g/m). The average distance between them (in the sowing furrow) is 3.3 mm. The rotation speed of the sewing machines should be equal to 7.0 rpm during cultivation of large spruce seedlings in the nursery with a seed sowing rate of about 24 kg/ha (0.7 g/m). With this operation regime, the average distance between the seeds in the sowing furrow is 6.9 mm.
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