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Design parameters of furrow forming and compacting roller of the combined seeder STS-80

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Abstract. *A turf seed drill (STS-80) has been designed, in which the seeds from the sowing machines are sent to the soil through seed pipes. The size of the seeds is relatively small, therefore it is a requirement for them to be sown at a depth between 0.5 cm and 1.5 cm. The drill allows the following operations to be performed simultaneously: soil furrowing, seed sowing, and soil compaction with a compaction roller. The structure of the individual bodies that make up the aggregate is essential for the smooth running of the work process. Two rollers have been developed, which allow the providing of the necessary agro-technical requirements for sowing grass seeds. The role of the roller mounted in the front part of the drill is to make furrows in the soil at a depth of 1.5 cm, where the grass seeds fall. The roller, located in the rear of the unit, dulls the surface of the soil after the seeds enter it. This creates additional dynamic force, which increases the degree of soil compaction and the intensity of destruction of soil aggregates at a certain mass of the roller.*

Keywords: compaction roller, furrow roller, grass seeds, seed drill, soil

Introduction

The main trend in modern machine-technological solutions in ornamental gardening is aimed at the development of mechanized equipment, which will be able to provide the necessary agro-technical requirements. The development of such equipment is of extreme importance so that the necessary conditions for optimal plant development could be met (Karadocheva, 2002; Nosnikov and Asmolovsky, 2009).

An important technological operation in the production of grass turf is the planting of seeds in the soil (Kaprenko and Halanski, 1989; Karadocheva, 2002). Due to the different parameters of the components of the mixture - size, shape, smoothness, the unit that performs the sowing is required to be specialized. To solve this problem we developed the combined grass drill STS-80, which is equipped with furrow-forming and compacting rollers, which play an important role when the grass seeds are being laid in the soil. The purpose of the furrow-forming roller here is to create a furrow in the soil at a certain depth, which is in accordance with the agro-technical requirements for sowing grass mixtures. At the same time, the compaction roller compacts the surface layer of the soil and this action destroys the soil aggregates and creates favorable conditions for the collective germination of the seeds (Hristova, 2018).

Some authors (Kurdyumov et al., 2016; Sharonov et al., 2017) in their research also substantiate the design parameters of compaction rollers, which are used for pre-sowing treatment or after sowing crops. Kurdyumov et al. (2019) justify the optimal basic design parameters of a soil compaction roller containing new working bodies, which include, in particular, annular compaction elements. Golubev (2004) substantiates the technological and design parameters, as well as the modes of operation of the tillage roller, which provides increased quality and reduced energy consumption for the implementation of the technological process of pre-sowing tillage for small seed crops.

This development aims to present the design and technical parameters of furrow-forming and compacting rollers, which are important elements of the combined drill STS-80 created by the author's team.

Material and methods

The object of development is the substantiation and construction of furrow-forming and compacting rollers (Kurdyumov and Zykin, 2007; Zykin, 2013; Kurdyumov et al., 2014; Semenikhina, 2015).

The planting of very small seeds of ornamental grass species at a small depth (0.5-1.5 cm) is one of the main agro-

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technical requirements, which is essential for obtaining an even and dense turf. Based on these conditions, a furrow-forming roller was constructed as an integral part of a seed drill for grass mixtures. Figure 1 presents the structure of the drum of the roller on which the grooving discs are mounted.

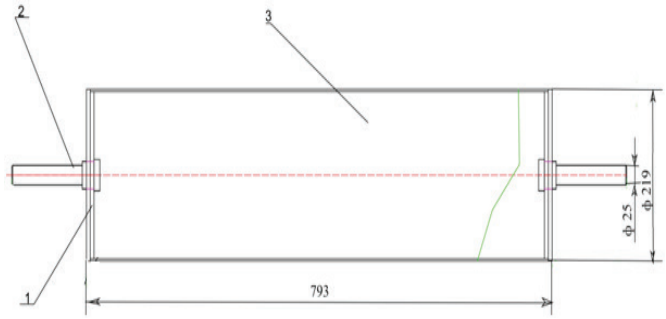

Figure 1. General view of the roller without mounted sector discs: 1- side roller, 2- axis, 3- hollow cylinder

To meet the agro-technical needs for the sowing of grass mixtures, on the working surface of the furrow-forming roller alternating smooth and serrated sector discs are mounted at a certain distance from each other. They form the seed furrows along the bed during the movement of the specialized seeder STS-80, and the loose soil sliding from the walls of the furrows covers the seeds (Hristova, 2018). The made furrow-forming roller with toothed and smooth disks, providing the agro-technical requirements at sowing of grass seeds, is presented on Figure 2.

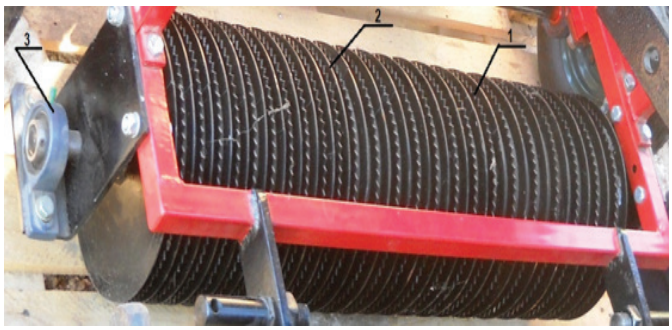

Figure 2. Furrow-forming roller: 1- toothed sector discs, 2- smooth sector discs, 3- bearing body

To compact the soil bed of seeds each sowing operation must end with the rolling of the sown soil surface. Rolling is an operation that improves the contact of seeds with the soil and thus provides conditions for co-germination and germination (Turbin and Lurie, 1967; Nosnikov and Asmolovsky, 2009). The smooth roller designed for the seed drill is shown on Figure 3.

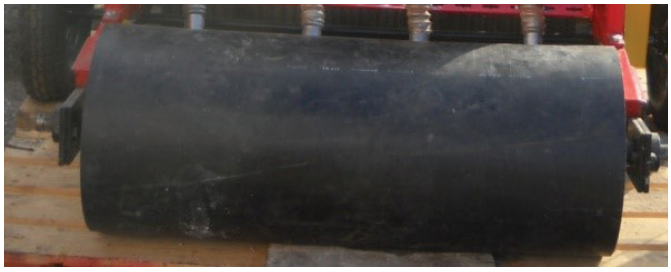

Figure 3. Smooth roller

Results and discussion

When the furrow-forming roller moves on the soil surface, the sector discs compact the soil to a certain depth, destroy the soil aggregates, and then form the seed furrows into which the seeds fall. To achieve the effect of using this roller, before planting the seeds, the optimal diameter of the roller, the height of the discs, and the distance between them must be selected. If the parameters are not picked appropriately the agro-technical requirements for the sowing of grass mixtures at a depth of 0.5 to 1.5 cm will not be fulfilled.

The sector discs mounted on the grooved roller are two types: smooth and serrated. They are located at a distance of 10 mm from each other and the height of the sector is 20 mm (Figure 4). These dimensions are consistent with the formation of narrow row rows, so as to correspond to the required average feeding area of the ornamental grass species we use - 1.0 cm^2. In preliminary experiments, this roller with the constructed sector disks shows stable work ensuring quality flow of the furrowing process (Hristova, 2018).

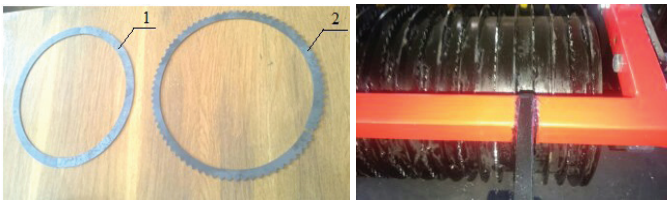

Figure 4. Sector disks: 1- smooth sector discs, 2- serrated sector discs

When the roller rolls, a soil edge is formed in front of it the height of which depends on the depth of sinking of the sectors and the diameter of the hollow cylinder (Figure 5). For normal operation of the roller, the angle α of the range of the roller the rim must not be more than 20° (Sharonov et al., 2017).

In this case, the soil edge in front of the roller is small, therefore we can express it with the following dependence:

$$\cos\alpha = 1 - (2.h.D^{-1}), \quad (1)$$

Where: D is the diameter of the hollow cylinder, mm;
h - the depth of sinking of the sectors, mm;
α - the angle of the range of the roller rim, °.

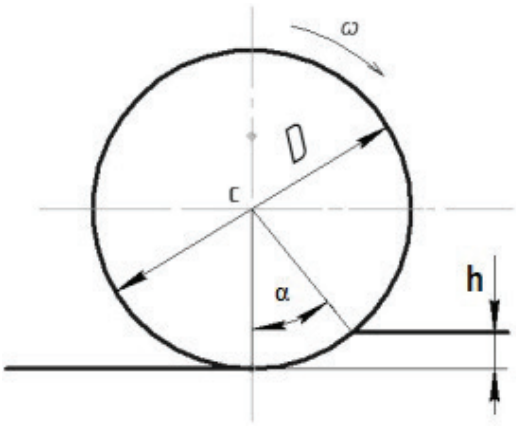

Figure 5. Justification of the minimum radius of the roller

Taking into account the depth of the hollow cylinder and

the angle of the range of the wreath, we can determine the diameter of the cylinder by the following formula:

$D_b = 2.h.(1-cos\,\alpha)^{-1}$, (2)

Where: D_b is the diameter of the furrow-forming roller, mm.

It is also taken into account that the diameter of the roller influences the traction resistance of the sowing unit, and with the increase of the diameter, its mass also increases. Thus, for the diameter of the furrow-forming roller of the specialized seeder STS-80 – D_b = 225 mm is assumed.

For the compacting (smooth) roller the agro-technical requirement is in force that its weight does not exceed 50-70 kg/m, and for the diameter, the following condition should be fulfilled: $D_г \geq$ (33 to 55) h, m, where h is the depth of the trail, which is left. The smooth roller designed for the needs of the lawn seed drill and its parameters are shown on Figure 6:

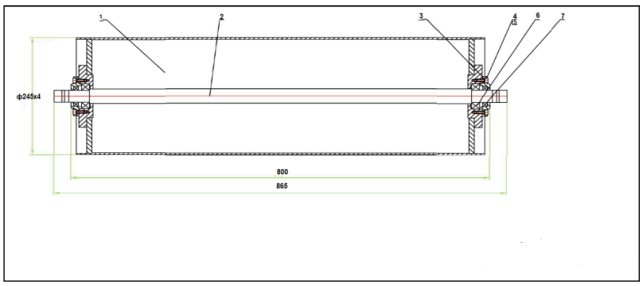

Figure 6. Tamping roller: 1- drum, 2- axis, 3- flange, 4 and 5 connecting bolts, 6- bearing, 7– bearing

The traction force ($F_{t.f.}$) for moving the furrow-forming roller on a flat surface is found as follows (Sharonov et al., 2017):

$$F_{t.f.} = \sqrt{\frac{G^4}{K.B.D^2}} \quad (3)$$

Where: K is the coefficient of volume crushing of the soil, N/m^3

G - the weight of the roller, N;

B - working width of the roller, m;

D - diameter of the roller, m.

Given that the drill has two rollers, the traction (resistance) force can be calculated using the following formula:

$$F_{t.f.} = \sqrt{\frac{G_1^2}{K_1.B.D_1^2} + \frac{G_2^4}{K_2.B.D_2^2}} = \sqrt{\frac{1}{B.D^2}\left(\frac{G_1^4}{K_1} + \frac{G_2^4}{K_2}\right)} \quad (4)$$

Where K_1 and K_2 are the coefficients of volume crushing of the soil, respectively of the furrow-forming and smooth roller, N/m^3.

Therefore, the effort to move the roller depends on the roller's mass, width, and diameter of the cylinders, as well as on the properties of the soil.

Conclusion

From the justification of the performed constructive research work for the furrow-forming and compacting roller as working bodies of the combined seeder STS-80, intended for sowing of grass mixtures were: (i) Justification technical parameters of the furrow-forming roller, it is constructively developed, as its working width is 793 mm, diameter without mounted sector disks Φ 219 mm; (ii) The distance between the serrated and smooth sector disks - 10 mm, as well as their height, which is 20 mm, has been established; (iii) The complex dimensional characteristics of the compaction of the roller are substantiated, its construction has been developed, its length is 800 mm, diameter - Φ 245 mm.

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