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QUALITY CONTROL INDICATORS OF SOIL RIDGES AT SOWING CULTIVATED CROPS

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Abstract

The initial component of any cultivated crops technology is high-quality preparation of a field in order to create proper conditions for the subsequent seed placement, plant root system's growth and development stimulation. At the same time, any mechanical treatment should not disrupt the optimal soil structure; it should preserve the soil fertility, protect against erosion processes and maintain moisture to the greatest possible extent.

Traditional technologies of growing cultivated crops on a flat field surface have been and remain the most widespread. However, the studies have found that the most promising is the ridge technology. A ridger seeder is developed for implementation of the ridge technology; the ridger seeder's application allows to cost effectively perform presowing cultivation in just one pass, after sowing the seeds to form a soil mound over a stitch of sown seeds, to compact such soil mound on three sides and finally form a soil ridge of a required dimension and density. The tool's flat disk and concave disks of the ridger seeder's ridge forming roller have substantiated approach angles. It has been revealed that structural and operating parameters of the tools with flat discs and the ridge forming roller, as well as physical and mechanical properties of the soil affect the process of forming the soil ridges of required dimension and density at seeding any cultivated crops.

Keywords: Technology, ridger seeder, Cultivated crops, Seeding, Soil ridge, Compacting.

Introduction

The initial component of any cultivated crops technology is high-quality preparation of a field in order to create proper conditions for the subsequent seed placement, plant root system's growth and development stimulation. At the same time, any mechanical treatment should not disrupt the optimal soil structure; it should preserve the soil fertility, protect against erosion processes and maintain moisture to the greatest possible extent [1, 2, 3, 4, 5, 6].

Traditional technologies of growing cultivated crops on a flat field surface have been and remain the most widespread. However, the studies have found that the ridge technology [7] is the most promising; it allows to create favourable temperature, water and air conditions for a quick and simultaneous seed germination. When seeding in the same terms the plants cultivated on ridges develop better than on a flat surface. The plant root system in the soil ridges does not comes out in inter-row grooves, so during the inter-row cultivation, compared to the conventional crops cultivation, the soil can be loosened deeper; it helps preserve it in a loose condition and prevent the soil moisture from evaporation.

Having analyzed the known methods of presowing field treatment and ridge seeding of cultivated crops, it can be concluded that at seeding the soil ridges are formed by a variety of means of mechanization with active and passive tools, in particular, with flat and concave disks. However, the task of qualitative soil ridge formation with such tools is not solved adequately, so the optimal structural and operating parameters of a ridger seeder equipped with new tools are to be justified.

Methods

In order to implement the method of ridge seeding of cultivated crops a ridger seeder [8, 9, 10] (Figure 1) was designed; it simultaneously carries out loosening of soil, destroying of weed plants, forming of wet compacted bed, seeding with a soil mound formed over the sown seeds, formation of a soil ridge of required dimension and density. A standing coulter, two tools with flat discs and a ridge forming roller (Figure 3) are installed on each seeding section (Figure 2) of a ridger seeder.

The tools with flat disks form soil mounds over the sown seeds. The tools on the ridger seeder’s frame are positioned so that the flat discs are directed at an acute angle towards the seeder unit’s movement.

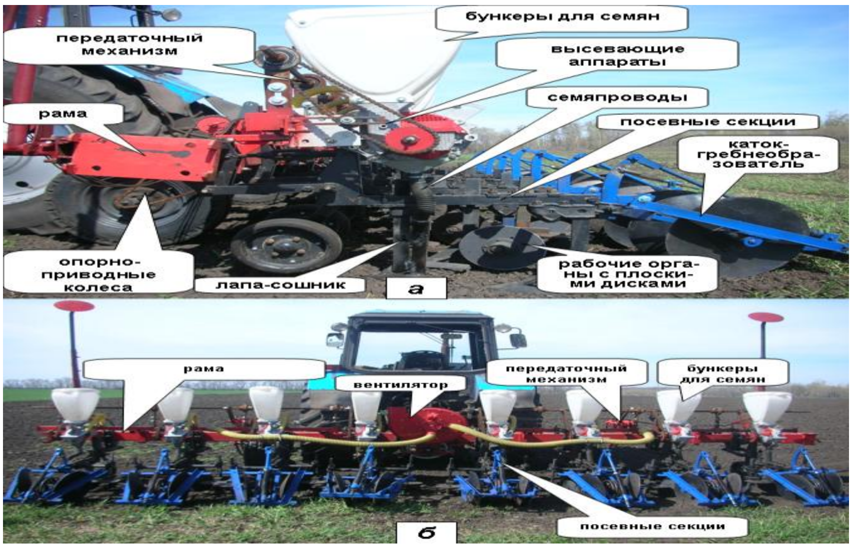
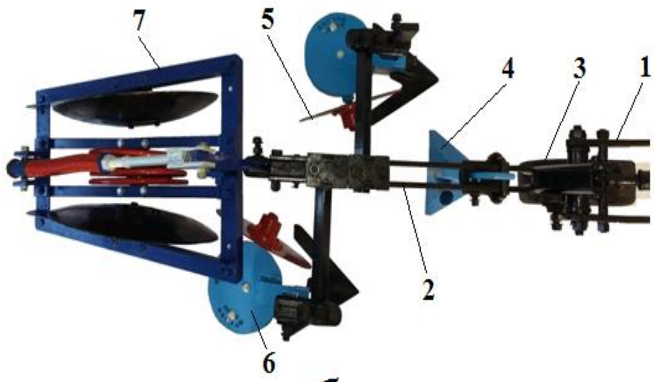


Figure 1. Ridger seeder: *a* – side view; *b* – back view.

a	
передаточный механизм	transmission mechanism
рама	frame
опорно-приводные колеса	main balancing wheels
лапа-сошник	standing coulter
бункеры для семян	seed hoppers
высевающие аппараты	seed-feeding devices
семяпроводы	seed spouts
посевные секции	seeding sections
каток-гребнеобразователь	ridge forming roller
рабочие органы с плоскими дисками	tools with flat disks
b	
рама	frame
вентилятор	blower
передаточный механизм	transmission mechanism
бункеры для семян	seed hoppers
посевные секции	seeding sections

a



б

Figure 2. Ridger seeder’s section: 1 – parallel link motion; 2 – beam; 3 – balancing wheel; 4 – standing coulter;

5, 6 – tools with the right and left flat disks; 7 – ridge forming roller.

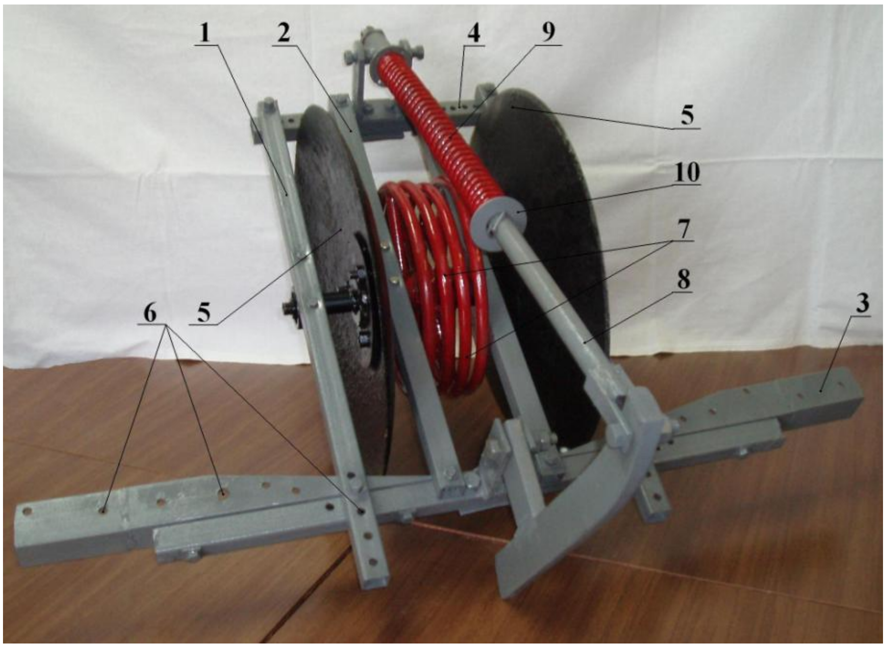


Figure 3. Ridge forming roller: 1 – side beam; 2 – lengthwise beam; 3 – front beam; 4 – back beam; 5 – concave disks; 6 – adjusting holes; 7 – press rings; 8 – boom; 9 – spring; 10 – ring plate.

When driving a seeder unit, the standing coulter wings of the ridger seeder lift a soil layer 2 ... 3 cm thick, move it into different directions, form a bed and then seeds are uniformly placed on a formed bed through the coulter's seeding tube. Using the A-blade's wings, the tools also lift the soil and throw it on the sown seeds by means of the right and left flat disks, and after the soil subsidence over the sown seeds a trapezoidal soil mound with an angle of natural slip γ is formed.The ridge forming rollers compact a soil mound on three sides, and finalize formation of a soil ridge of required geometric parameters and soil density. Moreover, the ridge forming roller's press rings compact the top of the soil mound, and the concave discs - the sides of such soil mound.

Results and Discussion

Geometrical parameters of a soil mound depend on the flat disk diameter d, m, flat disk approach angle α_1, degree, flat disk soil motion depth, h, m, as well as the ridger seeder's speed v, m/s.

The studies to determine the tools' optimal parameters were carried out in a soil box at the soil moisture of 19 ... 23% using the flat disks with a diameter of 0.2; 0.25; 0.3 and 0.35 m. The depth of tools with flat disks was 0.06 m, since the agrotechnical requirements to the presowing cultivation specified it. The search experiments resulted in determination of ranges of the main independent factors relating to the process of forming a soil mound: speed of the ridger seeder's section with tools varied from 1.2 m/s to 2.4 m/s at an interval of 0.4 m/s; flat disks' approach angle towards the seeder's movement - from 5° to 30° at an interval of 5°.

When the soil is moved from the space between rows to the sown seeds, the flat discs should provide the required dimension of a soil mound for its subsequent qualitative compaction. Therefore, coefficient of conformity with the standard $k_{сэ}$ (k_{cs}) allowing the formed soil mound quality to be characterized from the perspective of conformity with its profile established by agrotechnical requirements was accepted as the optimization criterion.

The coefficient of conformity with the standard can be expressed by the following dependence:

$$k_{сэ} = 1 - \left| \frac{S_{эт} - S_{ф}}{S_{эт}} \right|, \qquad (1)$$

where $S_{эт}$ (S_{st}) is a cross sectional area of the standard soil mound, which dimension was specified by the agrotechnical requirements to seeding, m^2; $S_{ф}$ (S_{act}) is a cross sectional area of the soil mound, which was formed after passage of tools, m^2.

After implementation of the experiments and processing of their results with a PC program Statistica, mathematical models were obtained for the soil mound formation in natural values of the factors.

The response surface equations relating to interaction of the ridger seeder's speed v and approach angle α_1 of flat disks with a diameter of 0.2; 0.25; 0.3 and 0.35 m have the following form (equations 2, 3, 4 and 5, respectively):

$$k_{сэ} = 0{,}0994 + 0{,}1358\,v + 0{,}0527\,\alpha_1 - 0{,}0558\,v^2 - 0{,}0002\,v\,\alpha_1 - 0{,}0011\,\alpha_1^2, \qquad (2)$$

$$k_{сэ} = -0{,}655 + 1{,}2591\,v + 0{,}0568\,\alpha_1 - 0{,}2724\,v^2 - 0{,}021\,v\,\alpha_1 - 0{,}0006\,\alpha_1^2, \qquad (3)$$

$$k_{сэ} = -0{,}7615 + 1{,}4606\,v + 0{,}041\,\alpha_1 - 0{,}34\,v^2 - 0{,}0146\,v\,\alpha_1 - 0{,}0005\,\alpha_1^2, \qquad (4)$$

$$k_{сэ} = 0{,}1922 + 0{,}5632\,v + 0{,}0212\,\alpha_1 - 0{,}1635\,v^2 + 0{,}0005\,v\,\alpha_1 - 0{,}0005\,\alpha_1^2, \qquad (5)$$

where $k_{сэ}$ (k_{cs}) is a coefficient of conformity with the standard; v is a ridger seeder's speed, m/s; α_1 is an approach angle of every flat disc, degree.

By differentiating the equations (2-5), coordinates of the extrema were determined, at which the maximum value of an optimization parameter is reached:

from equation (2): v = 1.2 m/s and α_1 = 24 decree, $k_{сэ}$ = 0,81.

from equation (3): v = 1.5 m/s and α_1 = 21 decree, $k_{сэ}$ = 0.89.

from equation (4): v = 1.85 m/s and α_{14} = 14 decree, $k_{сэ}$ = 0.87.

from equation (5): v = 1.76 m/s and α_1 = 22 decree, $k_{сэ}$ = 0.92.

The presented calculations show that the maximum value of the coefficient of conformity with the standard $k_{сэ}$ (k_{cs}) = 0.92 is achieved at a ridger seeder's speed of 1.76 m/s and approach angles of flat disks degrees with a diameter of

0.35 m of α_1= 22.

The response surface that corresponds to the equation (5) is represented in Figure 4.

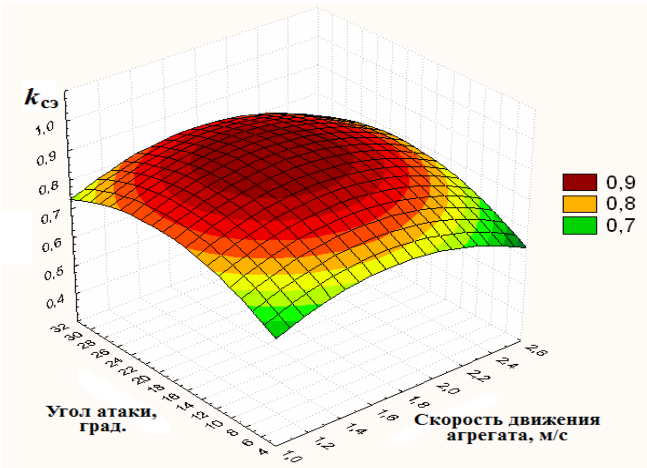


Figure 4. Response surface relating to interaction of the ridger seeder's speed and approach angle of flat disks with a diameter of 0.35 m

Угол атаки, град.	Approach angle, degree
Скорость движения агрегата, м/с	Ridger seeder's speed, m/s

As shown by the ridger seeder's experimental studies, density of the soil mound formed by flat disks ranged from 900 till 1050 kg/m^3.

The combined action of ridge forming roller's press rings and concave discs influences the final formation of a soil ridge over sown seeds of the required soil density. Moreover, at an angle of installation of concave discs towards the ridger seeder's movement (approach angle) α_2 = 0°, the press rings are key players in compacting the ridge soil. However, concave discs (Figure 5) influence the ridge soil density at approach angles of α_2 > 0°.

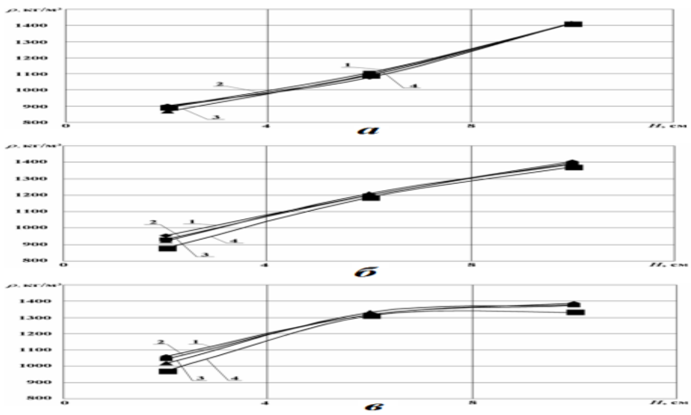


Figure 5. Relationship of soil density in ridge height at the ridge forming roller's speed *v* = 1.75 m/s and spring's compression force at: *a* - α_2 = 0°; *b* - α_2 = 10°; *c* - α_2 = 20°; 1 – F_{spr} = 0 N; 2 – F_{spr} = 80 N; 3 – F_{spr} = 160 N; 4 – F_{spr} = 240 N.

а	a
б	b
в	c
p, кг/м^3	p, kg/m^3
H, см	H, cm

Conclusions

Having analyzed Figure 5, it can be concluded that at every certain velocity of the ridge forming roller the soil density of the ridge top (H = 0…4 cm) decreases with the increased spring's compression force F_{spr} and increases slightly with the increased approach angle of concave disks α_2. This is due to an increase in soil deformation with the press rings, and it results in interspersing of a larger volume of soil between them and additional loosening. Soil density of the ridge top ranged from 832 till 1065 kg/m^3, that corresponds to the agrotechnical requirements to the soil surface after passage of rollers. Soil density in the central part of the ridge (H = 4…8 cm) at α_2 = 0° is mainly influenced by the press rings. However, with increasing the approach angle of concave disks α_2 the soil density increases more intensively, since in this case they play, in comparison to the rings, a major role in increasing the soil density. Under otherwise equal conditions, density increases with the increased ridger seeder's speed as well, but in this case the speed has less influence on the density than concave discs and press rings. The seed bed soil density (H = 8…12 cm) does not change practically, and it is within 1336 and 1450 kg/m^3, since such density is specified during the preliminary (basic and presowing) soil cultivation, and it is finally formed during passage of the ridger seeder's standing coulter. Changed ridge forming roller's structural and operating parameters have no effect on the seed bed soil density. The designed ridger seeder's multiple studies in working conditions showed that at the optimal parameters identified in the laboratory studies the formed soil ridge has the required dimension: soil ridge height was from 6 till 8 cm, width of the upper base of the soil ridge varied from 8 till 10 cm, width of the lower base of the soil ridge ranged from 27 till 32 cm and soil density in the central part of the ridge was from 1095 till 1254 kg/m^3. It meets all agrotechnical requirements to seeding.

In comparison with the traditional cultivated crops technology for a flat field surface, using the proposed ridge technology increased yield of soybean, sunflower and corn by 22, 18 and 44%, respectively.

Summary

Structural parameters of the tools with flat discs and the ridge forming roller, as well as physical and mechanical properties of the soil affect the process of forming the soil ridges of required dimension and soil density at seeding any cultivated crops. At the known ridge dimensions determined by the type of a cultivated crop, the optimal soil density in the ridge (1200 kg/m^3) can be achieved at the ridge forming roller's speed of v = 1.75 m/s, angle of installation of concave discs of α_2 = 10° and spring's compression force of F_{spr}= 185 N.

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