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Soil preparation machine parameters for the cultivation of cucurbitaceous crops

D Chuyanov[2,3]*, G Shodmonov[2], I Avazov[1], N Rashidov[2] and S Ochilov[1]

[1]Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Tashkent, Uzbekistan
[2]Karshi branch of Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, Karshi, Uzbekistan
[3]Karshi Engineering Economic Institute, Karshi, Uzbekistan

ikrom_0878@mail.ru

Abstract. The combined machine allows qualitatively preparing the soil for sowing melon crops with minimum energy consumption. The efficiency of the combined machine depends on the type, location of the tiller relative to the body, and its parameters. The purpose of the study is to justify the type and parameters of the tiller combination machine to prepare the soil for sowing melon crops. In researches methods of classical mechanics are applied. The construction of the combined machine with soil cultivators is given. Based on the theory of soil destruction wedge determined the main parameters of the soil tinker. Experimental research of different types of soil cultivators is carried out. it is established that at the performance of soil cultivator of the combined unit in the form of a three-sided wedge with an inclined stand, the minimum longitudinal distance from a ploughshare of the case to soil cultivator is 52.7 cm, transverse distance from the field cut of the hull to the tiller bit is 15 cm, width and length of the tiller bit is 5 and 14 cm respectively, cutting angle of the bit is 18 degrees, quality crushing of sub-powder soil layers with minimum energy consumption is provided.

1. Introduction

It is known that the main task of soil tillage is to regulate its density, as it is the density that significantly affects the yield of crops, particularly melons. In the process of the influence of working bodies of agricultural machinery and propellers of mobile agricultural machinery on the soil there are changes in its density. In Uzbekistan, due to repeated passes of machine and tractor units across the field, soil density in some cases increases by 1.4-1.56 times and reaches 1.6-1.7 g/cm^3 [1-7]. The reduction of soil fertility and the productivity of melon crops are connected with this phenomenon.

Problems of qualitative preparation of soil for sowing melon crops are considered in many scientific works [1-19]. Researches on the creation of machines for melon cultivation, substantiation of designs, and parameters of their working bodies were carried out by V.G.Abezin [20], A.D.Em, V.N.Zhukov [21], V.I.Malyukov [22] and others. V.G.Abezin [20] substantiated and developed working tools for pre-sowing tillage and sowing of melon seeds. Studies by A.D.Em and V.N.Zhukov [21] are mainly aimed at the development of machines for inter-row cultivation of melon seeds. Ya.P.Lobachevsky [13], F.M.Mamatov, I.T.Ergashev [15], B.S.Mirzaev [2, 3, 9] have studied sub-pathic loosening of soil, thorium of interaction of the hull and soil reconsolidator with soil at reservoir rotation within the limits of own furrow. In these studies the issues of substitutional loosening of the soil during the preparation of the soil for sowing of melons in one pass of the unit have not been considered. These deficiencies can be remedied by developing a soil tiller for the machine to prepare the soil for sowing the melon crops in a single pass of the unit.

The purpose of the study is to justify the optimal design of the combined machine for preparing the soil for sowing melon crops.

2. Materials and Methods

The combined machine (figure 1) for preparing the soil for sowing melon crops consists of a disk knife 1, flat knife 2, right and left-winging screw bodies 3 and 4, screw guide plates 5, soil cultivators 6, mounted on the stand of the bodies and the roller 7. Roller 7 is hinged to the frame. Soil trenches 6 are of "paraplau" type [2, 8].

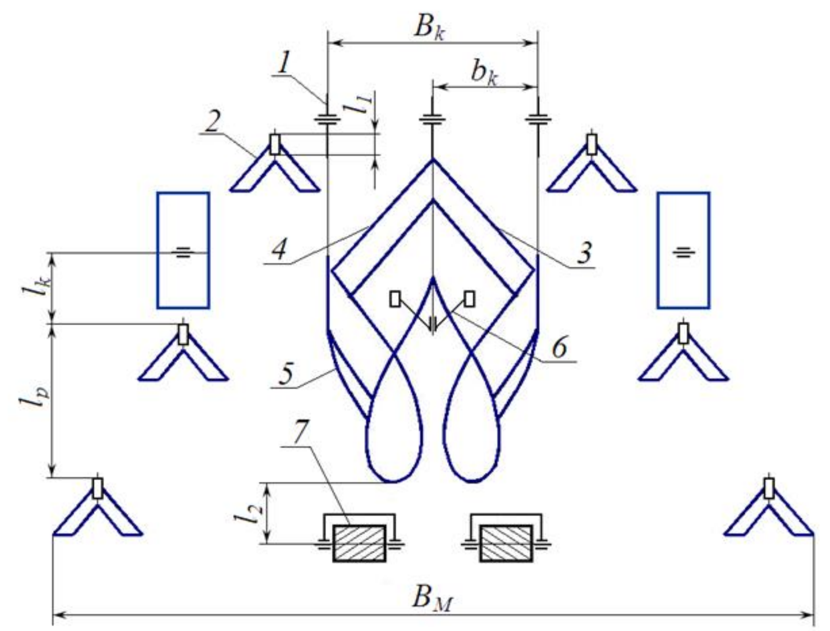

Figure 1. Scheme of the combined machine:
1 – disc blade; 2 – flat cutter; 3 and 4 – right and left turn housings;
5 – guide plates; 6 – soil tiller; 7 – roller

In the process of the unit operation, the planes 2 loosen the soil between the adjacent seeding zones, right and left wrapping hulls 3 and 4 together with the guide plates 5 wrapping layers of the seeding zone with a width of up to 1.05 m relative to each other, form a preliminary watering furrow. In the process of layer turn over the soil dredgers 6 loosen the sub-powder soil layers and the roller 7 prepares for sowing the soil of the sowing zone.

3. Results and Discussion

Researches of F.M.Mamatov and I.T.Ergashev [14, 15] have established that at the turn of layers within the limits of their furrows there are no open furrows behind the hulls, it, in turn, creates certain difficulties at the installation of soil cultivators behind the hulls for sub-powder loosening of the soil.

The analysis of the formation turnover process has shown (figure 2) that at the sub-pitch loosening of the soil at the formation turnover relative to each other from 0 to $\pi/2-\varphi$ without transverse movement of the centers of their gravity the deformed soil with soil trenches prevents the implementation of the technological process. On this basis, the minimum distance from the body stubble to the tiller is determined by the following expression.

$$l_{1\min} = a_c tg\frac{1}{2}\left(\alpha+\phi+\phi_1\right)] + (b_n - a_c ctg\psi_1) ctg\gamma \qquad (1)$$

Calculations performed by expression (8) at b_n=b_k=52.5 cm; a_c=15 cm; α=25º; φ=30º; φ_1=40º and γ=45° showed that l_1=52.7 cm.

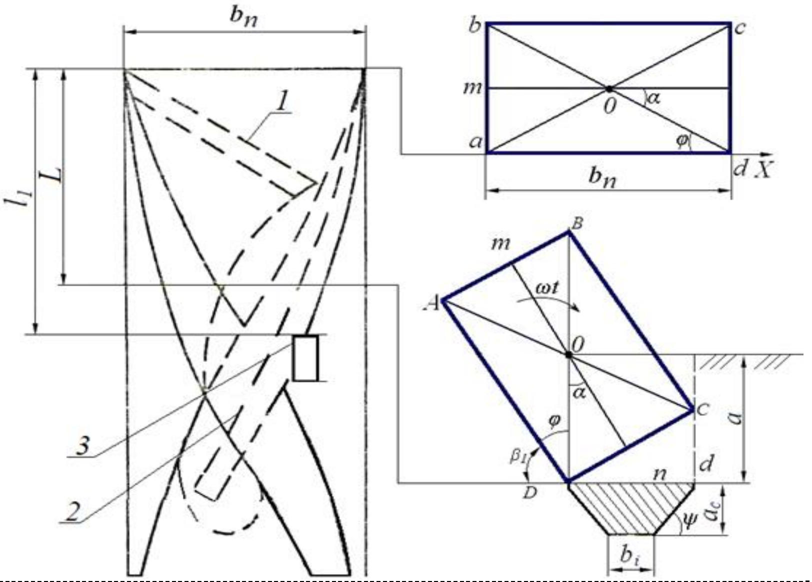

Figure 2. Scheme for determining the location of the dredger behind the body: 1 is body; 2 is plough; 3 is soil tiller

It has been established [15, 23], that at formation rotation within the limits of its furrow it is possible to carry out plowing only with a soil dredger with inclined tillage. The main elements of the tiller are tine and chisel.

Based on previous studies, we accept the angle of inclination of the tiller trestle in the vertical transverse plane β_k=45°, and the angle of inclination in the vertical longitudinal plane β_b=18°.

The main parameters of the bit are the geometric shape of its working surface, crushing angle, angle of bit installation relative to the direction of movement, and its length.

To exclude the influence of deformed soil on the formation turnover, we take the form of a drill bit with an inclined strut as a trihedral wedge.

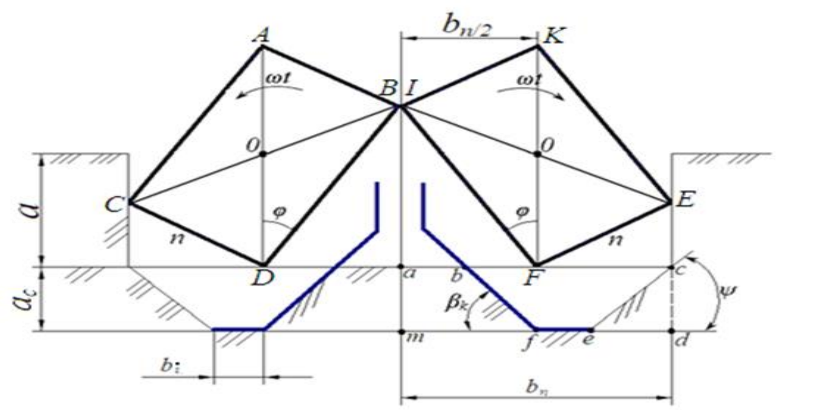

Figure 3. Scheme for determining the location of the plow harvester transversely

We define the width of the bit by the following expression

$$b_i = 0.65b_n - 2a_c ctg\psi_1 \quad (2)$$

In terms of (9) at b_i=52.5 cm; a_{cmax} =15 cm and ψ_1=45° the bit width should be at least 4.12 cm. We accept 5 cm.

The length of the working damage of the bit is determined from the condition of ensuring sufficient loosening and destruction of the soil on the following expression

$$L_i \geq \sqrt{\frac{2\tau a_c[b\sin\psi + a_c tg(\frac{\pi}{4}+\frac{\phi_1}{2})\sin\gamma]\sin(\varepsilon+\psi)\sin\varepsilon\cos\frac{1}{2}(\phi+\phi_1-\varepsilon)}{q_0(1+K_V V)\,b\cos[\frac{1}{2}(\varepsilon+\phi+\phi_1)]\sin\varepsilon\sin\gamma\sin^2\psi}}\cdot\frac{\sin\psi}{\sin(\alpha+\psi)} \quad (3)$$

At [τk]= 2.104 Pa; φ=30º; φ_1=40º; q_0=2.5.107 N/m^3 ; K_V =0.1; a_c=0.15 м; b_i=0.05 m and ψ=45° on expression (10) for loosening the bottom of the furrow to a depth of 10-15 cm the length of working surface of the bit should be not less than 125 mm.

For the definition of traction resistance of a soil dredger with a bit in the form of a trihedral wedge the following expression is received

$$R_{px} = \frac{b_i}{\sin\gamma_3} t_n \sigma_o \sqrt{1+f^2}\cos(\gamma_3+\phi) + \frac{\tau a_c}{\sin\gamma_3\sin^2\psi}\times$$

$$\times[b_i\sin\psi + a_c ctg\frac{\phi_1}{2}\sin\gamma_3][\cos\psi_1\sin\gamma_3 + f\sin(\varepsilon+\psi_1)\times$$

$$\times\cos(\arcsin tg\alpha_1\cos\varepsilon)\cos(arctg\frac{(1-\cos\varepsilon)tg\gamma_3}{1+tg^2\gamma_3\cos\varepsilon})] + \rho g(1+\frac{W}{100})a_c b_i(\frac{b_i ctg\gamma_3}{2}+$$

$$+\frac{l_i}{\cos\alpha_1})(tg\alpha_1\cos\varepsilon + f\cos\gamma_3)\sqrt{1-(tg\alpha_1\cos\varepsilon)^2}\cos[\arg tg\frac{(1-\cos\varepsilon)tg\gamma_3}{1+tg^2\gamma_3\cos\varepsilon}]+$$

$$+\frac{1}{2}\rho(1+\frac{W}{100})a_c(a_c\cos\gamma_3 ctg\psi_1 + 2b_u)V^2\sin\gamma_3\cos\psi_1(1-i_{\max})[\sin\gamma_3\cos\psi_1+$$

$$+f\sin(\varepsilon+\psi_1)\cos\arcsin(tg\alpha_1\cos\varepsilon)\cos arctg\frac{(1-\cos\varepsilon)tg\gamma_3}{1+tg^2\gamma_3\cos\varepsilon}]+$$

$$+\sigma_0 t_n\frac{l_m}{\cos\beta_b} + ql_m t_m^2 + \frac{pfb_m}{\sin\beta_b}[2(a_c-h_i) - \frac{t_m}{\sin\beta_f}] \quad (4)$$

where, ε is the angle of bit entry into the soil, degree; α_1 is the angle of bit crushing, degree; bi is bit width, m; ac is the depth of bit burial into the soil, m; li is the length of the tetrahedral part of the bit, m; ψ_1 is the angle of soil chipping in the transverse direction, degree; γ_3 is angle of bit blade installation relatively to the direction of movement, degree; τ is specific resistance of the soil to shear, Pa; *KV* is coefficient taking into account the change of coefficient of volumetric soil buckling as a function of speed; *V* is the speed of movement, m/s; i_{max} is coefficient of maximum soil shrinkage; l_m is the length of the blade of the post, m; p is specific pressure of the soil on the inclined part and side surfaces of the post, Pa; hi is bit height, m; β_t is the angle of the post sharpening, degree; βb is the angle of the post inclination in the vertical longitudinal plane, degree.

Analysis of this expression shows that traction resistance of the soil former depends on its parameters (t_m, h_i, α_1, γ_3, β_b, β_f, t_n), depth of tillage (ac), physical-mechanical properties of the soil (σ_0,

τ, φ, φ_1, ρ, W, q, f) and speed of the machine. Performed calculations by expression (11) at σ_0=.44·106Pa; τ =2·104Pa; f=0.5774; φ=30°; φ_1=40°; ρ=1520 kg/m^3; W=14%; t_p=0.001 m; b_i=0.05 m; t_m=0.015 m; h_i=0.008 m; l_i=0.14 m; q=1.5.107 N/m^3; p=1.64·102 Pa; α_1=18°; γ_z=45°; β_b=18°; β_f=25°; B_t=0.08 m; t_t=0.015 m and a_c=15 cm have shown that at 2-2,5 m/s the traction resistance of the soil sinker will be 1.71-1.82 kN.

For studying of influence of the type of a soil graver on machine performance indicators soil gravers of following kinds have been made: 1) a soil graver with a two-sided wedge-shaped bit; 2) a soil graver with a three-sided wedge-shaped bit; 3) a soil graver in the form of a half-pit. A universal lancet cultivator foot was used as a semi-paddle. Thus the width of the working width of a half leg made 125 mm, a crushing angle 30°, the angle of a solution of a leg 30°. Parameters of soil cultivators with two-sided and three-sided wedge-shaped bits: the thickness of the inclined stand 1.5 cm, the width of the stand 8 cm, angle of sharpening of the stand 25°, length of the bit 14 cm, width 5 cm, angle of crushing of the bit 18°, angle of installation of a blade of the bit concerning a direction of movement 45°.

According to the results of experimental studies, the installation of soil cultivators in the form of semi-layers on the bodies worsens their performance. At the same time the depth of weed planting decreases by 3.1 cm and the completeness of planting – by 4.1%. Thus, the installation of soil cultivators in the form of semi-layers harms the technological process of hulls. Installation on bodies of soil cultivators with a bit in the form of a double-sided and trihedral wedge improves their performance. If the average square deviation of the working width and a working depth of the bodies without a soil tiller is 4.2 and 3.7 cm respectively, the average square deviation of the working width in 1 and 2 versions is 2.5 and 2.3 cm, and the average square deviation of the working depth is 1,8 and 1,9 cm respectively. In all variants installation of soil cultivators lead to an increase in traction resistance of the machine. From Figure 4 it is visible, that traction resistance of all soil cultivators in the function of the speed of movement changes by the law of convex parabola. The traction resistance of a semi-pump type soil tiller is 9.6-10.8 % higher than that of a double wedge type drill. The smallest traction resistance and the best quality of loosening of the soil sinker are received at work with the three-sided wedge type bit.

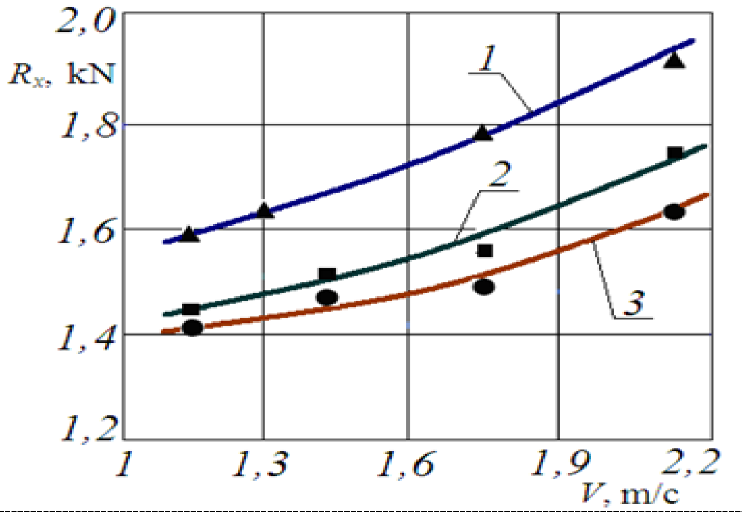

Figure 4. Graphs of dependence of traction resistance of soil cultivators: R_x on its type and speed of movement V (a_c=12 cm): 1 is soil cultivator as a half-piece; 2 is soil cultivator with a three-edged wedge-shaped bit; 3 is soil cultivator with a three-edged wedge-shaped bit.

Soil dredgers with trihedral wedge chisel mounted on the frame stand loosen the subsoil layer (figure 2). Thus the width of the loosened strip makes b_p=33.2 – 35.3 cm. It provides moisture accumulation mainly in the zone of plant root system development.

Thus, the installation of soil cultivators with chisels in the form of a three-sided wedge on the bodies of the combined unit provides high-quality loosening of the sub-powder soil layer at the level of agrotechnical requirements with the lowest energy consumption. At the same time agrotechnical parameters of bodies of this variant completely correspond to requirements.

4. Conclusions

It is established that at the performance of the soil sinker of the combined unit in the form of a three-sided wedge with an inclined rack, the minimum longitudinal distance from a ploughshare of the case to the soil sinker 52.7 cm, Transverse distance from the field cut of the body to the bit of the soil softener is 15 cm, width, and length of the bit of the soil softener is 5 and 14 cm respectively, the angle of crushing of the bit 18° provides quality crushing of sub-powder soil layers with minimum energy consumption.

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