The Influence of Suspension Plough Support Wheel Diameter and Width on Its Performance Indicators

Abdusalim Tukhtakuziev[1][a], Abdurakhmon Rasuljonov[1][b], Sherzod Barlibaev[2][c], Dilfuza Karimova[3][d] and Madina Turdiyeva[3][e]

[1]*Scientific-Research Institute of Agricultural Mechanization, Samarkand str. 41, Yangiyul dis., Tashkent reg., Uzbekistan*

[2]*Tashkent Institute of Irrigation and Agricultural Mechanization Engineers, National Research University, K. Niyazi str. 39, Tashkent, Uzbekistan*

[3]*Andijan Institute of Agriculture and Agrotechnology Oliygoh str. 1, Kuyganyor, Andijan, Uzbekistan*

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Abstract: The article presents the results of theoretical and experimental studies conducted on the study of the influence of the diameter and width of the support wheel of the suspension plough on the driving depth and its stability, and on the basis of this, to determine their optimal values. In theoretical studies, it was noted that the stability of the driving depth at the level of requirements is mainly ensured by the correct choice of the diameter of the plough support wheel and the width of it, and for a three-body suspension plug, their value is not less than 35 and 16 cm, respectively. In order to verify these obtained results, we prepared a three-body suspension plough and conducted experimental studies using it. For conducting experimental studies, the base wheels with the diameter and the width of the beam at 5 cm intervals from 30 cm to 50 cm and from 10 cm to 30 cm, respectively, were prepared. In experimental studies, the influence of the diameter of the plough support wheel and the width of its furrow, the driving depth, its mean square deviation, the vertical pressure force exerted by the support wheel on the soil, and the plow's traction resistance were studied. In order to reduce the influence of various variable factors on the obtained results, the experiments were carried out on specially prepared agro-funds, that is, they were first plowed, then leveled and fully irrigated. Based on the results of experimental studies, the following can be noted: in order for the plough to work stably at the specified depth, the diameter of the support wheel should be at least 40 cm, and the width of the rim should be at least 20 cm. These results fully correspond to the results of theoretical studies.

1 INTRODUCTION

It is known that the depth of cultivation and its stability are the main performance indicators of all soil tillage machines. If the tillage depth is at the required level and its stability is ensured, i.e. it is uniform development and ripening of crops and a high yield will be achieved, otherwise, crops will develop and ripen unevenly, productivity will decrease. This situation has been proven in many studies conducted in Uzbekistan and foreign countries. For this reason, there are strict requirements and restrictions on the depth of cultivation and its deviation from the specified for each tillage machine (Tukhtakuziev & Rasuljonov, 2020a; Tukhtakuziev & Rasuljonov, 2020b; Turdaliev et al., 2022; Djurayev et al., 2022).

The depth of tillage and its stability and impact on the development and productivity of cotton and grain crops have been studied. It was noted by them that the change of the tillage depth from the set acceptable value to one side or the other will lead to a 12-15 percent decrease in crop yield (Norchayev et al.,

[a] https://orcid.org/0009-0003-4950-4840
[b] https://orcid.org/0000-0003-4669-9526
[c] https://orcid.org/0009-0004-5991-7425
[d] https://orcid.org/0009-0007-5214-000X
[e] https://orcid.org/0000-0008-1033-1247

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2021; Mukhamedov et al., 2020; Umurzakov et al., 2022; Tukhtakuziev et al., 2023).

The above indicates that it is an important issue to ensure that the tillage depth of soil tillage machines is uniform at the required level.

This article presents the results of theoretical and experimental studies on the influence of the diameter and width of the suspension plough support wheel on the stability of the plowing depth, and based on this, their optimal values that ensure the evenness of the plowing depth are at the required level.

2 MATERIALS AND METHODS

It is known from the literature (Sineokov & Panov, 1977; Mamatov, 2007; Norchayev et al., 2021; Norchayev et al., 2022; Saidova et al., 2024) that the following condition must be met for the suspension plough to sink to a specified depth and to run stably (uniformly) at this depth:

$$Q_Z = Q_M \qquad (1)$$

Where Q_Z - vertical pressure force applied to the soil by the support wheel of the plough, kN;

Q_M - the optimal value of the vertical pressure force applied to the soil by the support wheel of the plough, which ensures the stability of the working (plowing) depth, kN.

when the condition (1) $Q_Z < Q_M$ is met, the base wheel of the plough is constantly pressed against the field surface, as a result, the plough sinks to the specified depth and works without changing the plowing depth. $Q_Z > Q_M$ otherwise, the support wheel of the plough cannot adequately adjust to the unevenness of the field surface, and too much energy is spent pulling the plough

When the condition (1) is fulfilled, the change of plough plowing depth during the working process is mainly due to the change of the depth of immersion of the support wheel into the soil. Based on this, we will study the depth of immersion of the plough support wheel into the soil during the work process. In this case, we consider that the supporting wheel of the plough is rigidly knotted, that is, it does not deform.

Let the support wheel of the plough move along the field and create a track at the depth h0 (Fig. 1). We separate the elementary surface dS=Bтdl (where Bт is the width of the plough base wheel, m; dl - the elemental cross-section separated from the plough base wheel, m) from the part of the base wheel axle in interaction with the soil. The elementary reaction force of the soil acting on this surface is equal to:

$$dN = pB_m dl, \qquad (2)$$

where p - relative pressure of the soil on the axis of the plough support wheel, Pa;

As is known from the literature (Sharov, 1964; Sablikov, 1968; Klenin & Sakun, 1994), the relative pressure of the soil on the base wheel width, taking into account the speed of the unit:

$$p = \frac{p_m}{\cos\alpha} = \frac{q_0 h'\left(1 + k_n V^2\right)}{\cos\alpha} \qquad (3)$$

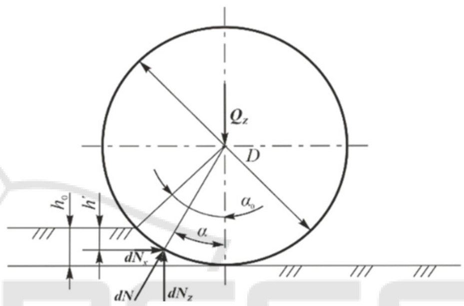


Figure 1: The scheme for determining the depth of immersion of the plough support wheel into the soil.

where p_m- relative resistance of the soil to vertical crushing, Pa;

q_0 - static volume compression coefficient of the soil, N/m^3;

h ‘- vertical deformation of the soil at the considered point, m;

k_n- proportionality coefficient, s^2/m^2;

α- the central angle determining the location of the elemental surface separated from the part of the base wheel bearing in contact with the ground relative to the vertical diameter of the base wheel.

Taking into account expression (3), expression (2) is written as follows:

$$dN = \frac{q_0 h' B_m \left(1 + k_n V^2\right) dl}{\cos\alpha} \qquad (4)$$

Based on the scheme in figure 1:

$$h' = \frac{D}{2}\left(\cos\alpha - \cos\alpha_0\right) \qquad (5)$$

$$dl = \frac{D}{2} d\alpha \tag{6}$$

where α_0 - the angle of the base wheel sinking into the ground, °;

$d\alpha$ - elementary angle, °.

Taking expressions (5) and (6) into account, expression (4) becomes:

$$dN = \frac{q_0 B_m D^2 \left(1 + k_n V^2\right)\left(\cos\alpha - \cos\alpha_0\right)}{4\cos\alpha} d\alpha \tag{7}$$

dN divide into vertical dN_Z and horizontal dN_X components. The sum of the vertical components is equal $\sum dN_Z$ to the vertical compressive force Q_Z exerted by the supporting wheel on the soil, i.e.:

$$Q_Z = \sum dN \cos\alpha = \int_0^{\alpha_0} \frac{q_0 B_m D^2 \left(1 + k_n V^2\right)\left(\cos\alpha - \cos\alpha_0\right)}{4} d\alpha \tag{8}$$

Integrating the right side of the expression (8), we get the following result

$$Q_Z = \frac{q_0 B_m D^2 \left(1 + k_n V^2\right)\left(\sin\alpha_0 - \alpha_0 \cos\alpha_0\right)}{4} \tag{9}$$

From the schematic in Fig.1

$$\sin\alpha_0 = \frac{2\sqrt{Dh_0 - h_0^2}}{D} \tag{10}$$

$$\alpha_0 = \arcsin\frac{2\sqrt{Dh_0 - h_0^2}}{D} \tag{11}$$

$$\cos\alpha_0 = \frac{D - 2h_0}{D} \tag{12}$$

Taking these expressions into account, expression (9) becomes:

$$Q_Z = \frac{q_0 B_m D \left(1 + k_n V^2\right)}{4}\left(2\sqrt{Dh_0 - h_0^2} - \left(D - 2h_0\right)\arcsin\frac{2\sqrt{Dh_0 - h_0^2}}{D}\right). \tag{13}$$

$Q_Z = Q_M$ = 3,5 kN (for a three-mouldboard suspension plough) (Klenin & Sakun, 1994), q_0 = 1.75·107 N/m^3 (Mamatov, 2007), k_n= 0.08 (Shiryaev, 1988) assuming V= for speeds of 6 and 9 km/h using the numerical solution method according to the expression (13), graphs of the change in the depth of the plough support wheel into the soil h_0 were constructed depending on D and B_m (Fig. 2). It can be seen from the obtained data that as the width and diameter of the wheel width increased, the depth of its immersion in the soil decreased, and therefore, the actual working depth was closer to the specified working depth.

Figure 2: 1, 2 - the speed of movement is 6 and 9 km/h, respectively Graphs of the change of the depth of the plough support wheel into the soil depending on its diameter (a) and the width of the bridge (b).

3 RESULTS AND DISCUSSION

The increase in speed from 6 km/h to 9 km/h also reduced the ground contact depth of the main wheel. According to existing agrotechnical requirements, the deviation of plowing depth from the specified should not exceed 2 cm. For this, the graphs presented in Fig. 2 show that the diameter of the plough support wheel should not be less than 35 cm and the width of its width should not be less than 16 cm.

Experimental studies were conducted in order to verify the results obtained in the conducted theoretical studies and to determine the influence of the width and diameter of the plough support wheel on its performance. In order to conduct experimental studies, a three- mouldboard suspension plough was developed in the "Soil Cultivation Machines" laboratory of SRIAM to be aggregated with wheeled tractors of class 3-4 (Fig. 3).

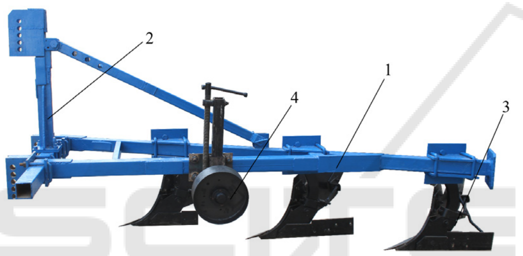


Figure 3: Overview of suspension plug. Frame 1; 2nd suspension device; 3rd corps; 4th base wheel

Experimental studies were carried out in agro fund specially prepared to create the same working conditions throughout the field, i.e. first plowed, then leveled and thoroughly irrigated. The soil of the field where the experiments were conducted is gray soil of medium-heavy, slightly mechanical composition, and underground water is located at a depth of 10-12 m. Before conducting the experiments, the moisture, density and hardness of the soil in layers of 0-10, 10-20, 20-30 and 30-40 cm was defined according to GOST 20915-11 “Testing of agricultural machinery. Methods for determining test conditions” (GOST 20915-11, 2013). According to the obtained results, in the 0-10-20, 20-30 and 30-40 cm layers, they are 15.7, 17.3, 18.1 and 18.9 percent, respectively, and their hardness is 1.57, 3.19, 3.45 and 4.21 MPa and the density was 1.33, 1.42, 1.57 and 1.61 g/cm^3.

For conducting experimental studies, base wheels with a diameter and a width of 5 cm at an interval of 30 cm to 50 cm and 10 cm to 30 cm were prepared (Figures 4 and 5).

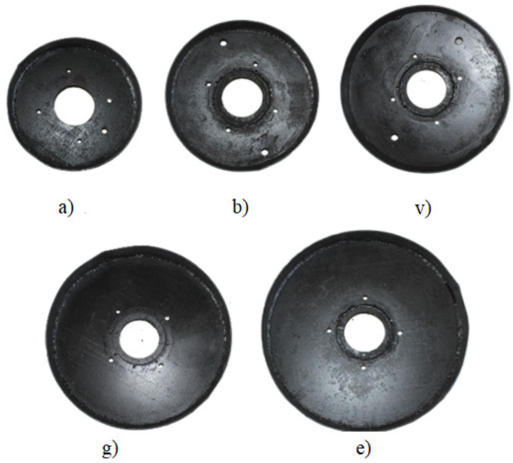


Figure 4: Support wheels with a diameter of 30 (a), 35 (b), 40 (v), 45 (g) and 50 (e) cm.

In the experiments, the plowing depth is 35 cm, the vertical distance from the base plane of the suspension plough to the lower suspension points and the vertical distance between its upper and lower suspension points are 80 cm and 90 cm, respectively, the longitudinal distance from the edge of its first mouldboard share to the axis of the supporting wheel is 80 cm, and the aggregate speed of movement was set at 6 and 9 km/h. The driving depth and its mean square deviation, as well as the traction resistance of the suspension plough and the vertical pressure force exerted by the support wheel on the soil were taken as the main indicators.

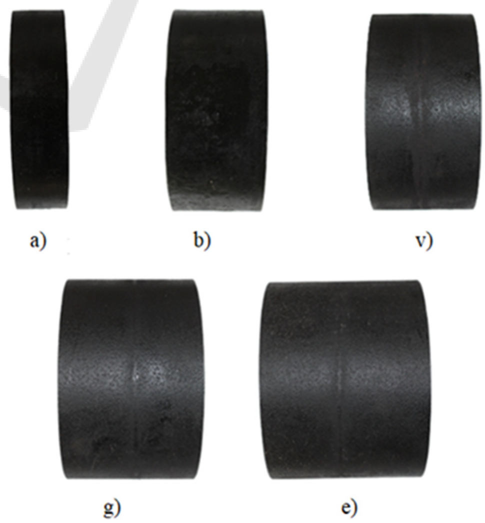


Figure 5: Support wheels with a diameter of 10 (a), 15 (b), 20 (v), 25 (g) and 30 (e) cm.

Plowing depth UzDSt 3355:2018 "Testing of agricultural machinery. Machines and weapons for deep tillage. Test program and methods" (GOST 20915-11, 2013). In this case, the plowing depth was determined after each pass of the plough along the edge formed by the final casing using an edge gauge. For each option, 50 measurements were made in four repetitions (twice in this direction, twice in this direction). The measurement error was 0.5 cm.

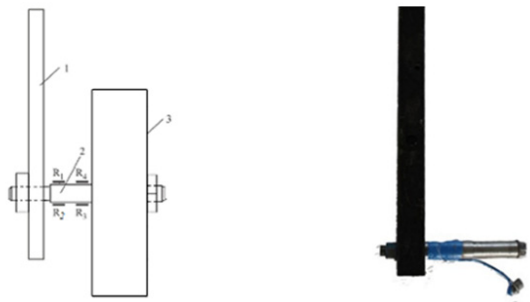
Plough tensile strength UzDSt 3193:2017 "Testing of agricultural machinery. It was determined using tensometric fingers (Fig. 6) according to the method of energy assessment of machines" (Dospekhov, 1979; O‘zDSt 3193, 2017; O‘zDSt 3355, 2018; Alimova et al., 2023).

1 2 3

Figure 6: General view of the fingers.1st upper index finger; 2, 3 lower right and left tensofingers.

The vertical compressive force applied to the soil by the support wheel was also determined using the tensometry method. In this case, the axle with the strain gauges glued was used (Fig. 7). During tensometry, IP-238M measuring equipment was used to record signals from strain gauges. Before and after the experiments, the tension fingers and the bullet to which the strain gauges were glued were calibrated. The data obtained in the experimental studies were processed by the methods of mathematical statistics (O‘zDSt 3193, 2017) and the arithmetic mean values and mean square deviations of the indicators were determined. In experimental studies, the plough was aggregated with a New Holland T 7060 tractor. The results obtained in experimental studies are presented in Tables 1 and 2.

From the results presented in Table 1, it can be seen that the plowing depth and its mean square deviation decreased with the increase in the diameter of the plough support wheel. When the diameter of the base wheel increased from 30 cm to 50 cm, the plowing depth decreased from 35.8 cm to 35.1 cm and from 35.7 cm to 34.9 cm at speeds of 6 and 8 km/h, respectively, its root mean square deviation ± Decreased from 1.24 cm to ± 1.06 cm and from ± 1.29 cm to ± 1.07 cm. The reason for this is that an increase in the diameter of the support wheel leads to an increase in the surface of its interaction with the soil, and as a result, the depth of immersion of the support wheel into the soil decreases. This causes the plowing depth and its root mean square deviation to decrease and match the target.



a) b)

Figure 7: Tensometric axis installation scheme (a) and general view (b) 1st column; 2nd strain gauge glued axis; 3rd base wheel.

Table 1: The plowing depth of the diameter of the suspension plough support wheel and its root mean square deviation, the vertical pressure force exerted by the support wheel on the soil and its traction effect on resistance.

Diameter of suspension plough support wheel, cm	Powing depth and its mean square deviation, cm		Vertical compressive force exerted by the support wheel on the soil, kN	Pulling resistance of suspension plough, kN
	$M_{ўр}$	$\pm\sigma$		
V=6 km/h				
30	35,8	1,24	3,73	28,7
35	35,5	1,13	3,62	28,1
40	35,3	1,10	3,54	27,7
45	35,2	1,07	3,49	27,2
50	35,1	1,06	3,41	26,9
V=8 km/h				
30	35,7	1,29	3,67	29,4
35	35,4	1,21	3,54	28,7
40	35,2	1,14	3,48	28,1
45	35,1	1,09	3,39	27,8
50	34,9	1,07	3,31	27,5

According to the results of the experimental research, it should be noted that when the diameter of the base wheel increased from 30 cm to 40 cm, the mean square deviation of the plowing depth at both speeds decreased rapidly, and when it increased from 40 cm to 50 cm, its rate of decrease decreased.

Table 2: The plowing depth and root mean square deviation of the width of the suspension plough support wheel, the vertical compressive force exerted by the support wheel on the soil and its effect on traction resistance.

The width of the axle of the suspension plough support wheel, cm	Plowing depth and its mean square deviation, cm		The vertical compressive force of the support wheel is applied to the soil, kN	Pulling resistance of suspension plough, kN
	Mўр	±*σ*		
V=6 km/h				
10	37,1	1,51	3,85	31,1
15	35,9	1,33	3,69	28,9
20	35,4	1,15	3,52	27,9
25	34,9	1,05	3,42	27,1
30	34,5	1,02	3,29	26,5
V=9 km/h				
10	36,8	1,58	3,73	31,9
15	35,9	1,39	3,59	29,5
20	35,1	1,17	3,43	28,7
25	34,7	1,10	3,32	28,3
30	34,3	1,06	3,18	27,8

For example, when the diameter of the base wheel increased from 30 cm to 40 cm, the mean square deviation of the plowing depth decreased by ± 0.11-0.17 cm, and when it increased from 40 cm to 50 cm, it decreased by ± 0.03-0.05 cm. This indicates that the diameter of the support wheel should be at least 40 cm in order for the plough to work stably at the specified depth.

An increase in the diameter of the suspension plough support wheel from 30 cm to 50 cm reduces its traction resistance from 28.7 kN to 26.9 kN at a speed of 6 km/h and from 29.4 kN to 27.5 kN at a speed of 8 km/h came This is due to the fact that the plowing depth decreases with the increase in diameter.

An increase in the diameter of the suspension plough support wheel from 30 cm to 50 cm led to a decrease in the vertical pressure force exerted by it on the soil, that is, this force decreased from 3.73 kN at a speed of 6 km/h to 3.41 kN at a speed of 8 km/h. Reduced from 3.67 kN to 3.31 kN. This is due to the reduction of the vertical distance between the base wheel axis and the instantaneous center of rotation of the plough.

At the diameter values of 35-45 cm, the pressure force applied to the soil by the support wheel was at the required level (3.5 kN).

From the results presented in Table 2, it can be seen that the plough depth and its mean square deviation decreased with the increase in the width of the support wheel hub. When the wheelbase width increased from 10 cm to 30 cm, the plowing depth decreased from 37.1 cm to 34.5 cm and from 36.8 cm to 34.3 cm at speeds of 6 and 9 km/h, respectively. Decreased from ± 1.51 cm to ± 1.02 cm and from ± 1.58 cm to ± 1.06 cm. However, the rates of reduction of plowing depth and root mean square deviation decreased with increasing wheelbase width. For example, at a speed of 6 km/h, when the width of the support wheel hub increases from 10 cm to 20 cm, the plowing depth decreases by 1.7 cm and its root mean square deviation decreases by ± 0.36 cm, when it increases from 20 cm to 30 cm, these indicators are suitable were 0.9 cm and ± 0.13 cm, respectively. At a speed of 9 km/h, these changes were 1.7 cm and ± 0.41 cm and 0.8 cm and ± 0.11 cm, respectively.

When the width of the wheel hub is less than 15 cm, the suspension plough is sunk deeper than specified, that is, the plowing depth is greater than the specified 35 cm, and when it is greater than 20 cm, the plug is sunk to the specified depth.

An increase in the width of the wheelbase from 10 cm to 30 cm led to a decrease in the traction resistance of the suspension plough, that is, the traction resistance of the plough decreased from 31.1 kN to 26.5 kN at a speed of 6 km/h, to 31.9 at a speed of 9 km/h. reduced from kN to 27.8 kN. This is explained by the fact that an increase in the width of the wheel hub causes a decrease in the depth of its immersion in the ground.

An increase in the width of the suspension plough support wheel from 10 cm to 30 cm has led to a decrease in the vertical pressure force exerted by it on the soil, that is, this force is from 3.85 kN at a speed of 6 km/h to 3.29 kN at a speed of 9 km/h and decreased from 3.73 kN to 3.18 kN. This can be explained by the fact that an increase in the width of the support wheelbase has led to a decrease in the plowing depth. In the range of 15-25 cm values of the base wheel axle, the pressure force exerted by it on the soil was at the required level (3.5 kN).

Therefore, in order for the suspension plough to work stably at the specified depth and for the vertical pressure force applied to the soil by the support wheel to be at the required level, its width should be at least 20 cm. The results obtained in experimental studies showed that the results obtained in theoretical studies are correct.

4 CONCLUSIONS

On the basis of the above, it is possible to draw the following conclusion: in order for the suspension plow to work stably at the specified depth, the diameter of the supporting wheel and the width of the beam should be at least 40 cm and 20 cm, respectively.

REFERENCES

Alimova, F.A., Saidova, M.T., & Primkulov, B.Sh., 2023. Pneumatic feed mechanism for accurate sowing of bare cotton seeds. *IOP Conference Series: Earth and Environmental Science*, *1231*(1), 012012. https://doi.org/10.1088/1755-1315/1231/1/012012.

Djurayev, A.D., Alimukhamedov, Sh.P., Turdaliev, V.M., Sheraliev, I.I., & Sherboev, M., 2022. Vibrational motion of soil-compaction tools in agriculture. *Russian Engineering Research,* 42, 969–971. https://doi.org/10.3103/S1068798X22100094.

Dospekhov, B.A., 1979. Methodology of field experience. Moscow: Kolos, p. 416.

GOST 20915-11, 2013. Testing of agricultural machinery. Methods for determining test conditions. Moscow: Standartinform, p. 23.

Klenin, N.I. & Sakun, V.A., 1994. Agricultural and reclamation machines. Moscow: Kolos, p. 751.

Mamatov, F.M. 2007. Wood roasting machine. Tashkent: Fan, p. 338.

Mukhamedov, Z., Turdaliev, V.M. & Kosimov, A.A., 2020. Kinematic nonuniformity of the rotation of a toothed belt transmission with a composite pulley. *Russian Engineering Research,* 40, 705–709. https://doi.org/10.3103/S1068798X20090130.

Norchayev, D.R., Xaliqulov, M.A., Shermuxamedov, X.P., & Ibragimova, G.N., 2021. Test results of the new Root Crop Harvester. *IOP Conference Series: Earth and Environmental Science,* 868(1), 012059. https://doi.org/10.1088/1755-1315/868/1/012059.

Norchayev, D.R., Xaliqulov, M.A., Turkmenov, X.I., Shermuxamedov, X.P., & Ibragimova, G.N., 2022. Acceptable solutions for harvesting root crops in the soil climate of the Republic of Uzbekistan. *IOP Conference Series: Earth and Environmental Science*, 1076(1), 012029. https://doi.org/10.1088/1755-1315/1076/1/012029 .

O‘zDSt 3193: 2017. The countryside is covered with machinery. He is a source of energy.” Tashkent, p. 21.

O‘zDSt 3355: 2018. The countryside is covered with machinery. A machine for deep drawing of pipes and pipelines. Synovlarning guidelines and methodology. Tashkent, p. 70.

Sablikov, M.V., 1968. Agricultural machines. Part 2. Fundamentals of theory and technological calculation. Moscow: Kolos, p. 296.

Saidova, M., Tursunbaev, S., Boltaeva, M., & Isakulova, N., 2024. Comparison of pneumatic sowing machines by the number of seeds in the slots of the discs and the distance between the slots. *BIO Web of Conferences,* 105, 01004. https://doi.org/10.1051/bioconf/202410501004.

Sharov, N.M., 1964. On the uniformity of the stroke depth of a mounted plow with an increase in the speed of movement of the unit. *Proceedings of the MIISP*, 25-37.

Shiryaev, A.M., 1988. Near-sowing soil compaction. Mechanization of agriculture. Moscow, 3, p. 33-35.

Sineokov, G.N. & Panov, I.M., 1977. Theory and calculation of tillage machines. Moscow: Mashinostroenie, p. 328.

Tukhtakuziev, A., & Rasuljonov, A.R., 2020a. Ensuring the stability of the processing depth of suspended soil mounted machines. *IOP Conference Series: Earth and Environmental Science*, 614(1), 012156. https://doi.org/10.1088/1755-1315/614/1/012156 .

Tukhtakuziev, A., & Rasuljonov, A., 2020b. Results of laboratory and field experiments on an experimental mounted chisel cultivator. *Effectiveness of Innovative Technological and Technical and Social and Water Management*, 112-115.

Tukhtakuziev, A., Rasuljonov, A.R., Turkmenov, H.I., Irgashev, A.A., & Barlibaev, S., 2023. Ensuring the stability of the suspended chisel-cultivator processing depth. *E3S Web of Conferences*, 390, 01038. https://doi.org/10.1051/e3sconf/202339001038.

Turdaliev, V.M., Alimukhamedov, S.P., Mukhamedov, Z., Komilov, S.R., 2022. Measuring the variable center distance in a chain transmission. *Russian Engineering Research,* 42 (Suppl 1), 57–59. https://doi.org/10.3103/S1068798X23020259.

Umurzakov, A.K., Turdaliev, V.M. & Khakimov, U.A., 2022. Low-power hydraulic motor for mobile micropower stations and pumps. *Russian Engineering Research,* 42(8), 791–793.