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Relief, physico-mechanical and technological properties of soil in the cotton growing area

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Abstract. The aim of the study is to study and analyze the physical, mechanical and technological properties of the soil of the cotton growing zone. The results of determining the relief of cotton fields, physical, mechanical and technological properties of takyr soils and gray soils, and the most common in areas of cotton cultivation are presented. It was found that before plowing, cotton fields have a pronounced uneven relief, characterized by the presence of ridges and irrigation furrows. The average height of the ridges in fields with row spacing of 90 and 60 cm is 17.1 and 12.8 cm, respectively. The physical-mechanical and technological properties of the soil of the arable and sub-arable layer of a cotton field along the track of wheels differ significantly from the soil between rows without a track of wheels and a ridge: the density of the soil along the track of the wheels of light gray soils reaches 1.78 g/cm^3, and of takyr soils - 1.51 g/cm^3, which is respectively more than the density of the ridge soil by 0.24 and 0.16 g/cm^3; the resistance of light gray soils to shear is 1.4 and 1.2 times greater than to rupture and torsion, and takyr soils - 1.33 and 1.15 times, respectively; density, hardness and resistance of the soil to various deformations has a maximum value in layers of 15-25 cm along the track of the tractor wheels.

1. Introduction

Agronomic Old-irrigated soils of Central Asia were formed and cultivated over the centuries through the use of artificial irrigation and organic fertilizers. They are characterized by the presence of a powerful agro-irrigation layer. Depending on the region, the thickness of this layer reaches 1-2, and in some places it is 3 m or more [1, 2]. These soils are generally homogeneous in texture - medium loamy and clayey soils prevail. The most common types of soils in Uzbekistan are sierozem, meadow and takyr soils. In the basins of Zarafshan and Surkhandarya, meadow soils occur on low river terraces and river deltas. Light gray soils are widespread in the Syrdarya and Kashkadarya regions, in the middle part of the Zarafshan valley and in the Fergana valley. According to the mechanical composition, they are classified as medium loamy. Typical gray soils occupy areas of high river terraces, foothill plains and low foothills. Takyr soils are mainly distributed in the Kashkadarya region. They have a high sandiness, the sum of fractions of more than 0.05 mm in some horizons reaches 55%. The content of the dusty fraction (0.05-0.01 mm) ranges from 14 to 33%. Takyr soils are

heavy loam in texture, tend to clod formation and are characterized by high density from 1, 12 to 2.13 g/cm^3 [2].

The development of new technologies and technical means in the cotton growing zone, providing high quality soil cultivation with minimal energy consumption, is impossible without determining the patterns of changes in the physical and mechanical properties of the soil in the arable and subsoil layers, which have developed during the cultivation and harvesting of agricultural crops [1-15].

Of greatest interest are the studies of the physical and mechanical properties of soils carried out by Mansurov [5]. He studied the moisture, density, hardness of the arable layer, resistance to rupture, compression and friction of the upper horizon of takyr soils and light gray soils. He found: the resistance of soils with an increase in soil moisture significantly decreases, with an increase in the moisture content of the takyr soil from 3 to 18%, the compression force decreases 10.8 times; resistance to breaking and compression of light gray soils is much higher than that of takyr soils; the breaking force during soil compression is 5-6 times higher than the breaking force. Researches Ishpulatov, Mamatov and Mirzaev [6, 16, 17] found that the interval of physical ripeness in the plow horizon of light gray soils is 13-18%, and takyr soils 14-20%. He notes that the maximum compaction (up to 1.50-1.5 g/cm^3) and the greatest hardness are achieved in the middle (10-20 cm) and lower (20-30 cm) parts of the arable horizon. Mamedkuliev [8] studied the density, moisture, hardness of the soil in the vertical and longitudinal directions at a depth of 60 cm (every 10 cm) before and after the technological operations of cotton cultivation. The results obtained by him in experiments for three years show that at a depth of up to 20 cm over these years the longitudinal hardness of the soil changes insignificantly, at a depth of 20-40 cm there is a slight increase and a noticeable increase at a depth of 40-60 cm. Muradov , Bibutov , Mamatov, Mirzaev [9 , 10 , 18-20] came to the conclusion that the soil in the subsurface horizon (at a depth of 50 - 60 cm) in comparison with arable has a lower moisture content, greater hardness and high coefficients of friction of the soil against the metal. The analysis of the research shows that in the cotton growing zone, the resistance of the arable and subsoil layers to rupture and shear has not been sufficiently studied. The torsional resistance of the soil has not been studied. When studying the physical and mechanical properties of cotton soils, their heterogeneity in different row spacings and in the row spacing under the action of irrigation and running machines of tractors was not taken into account.

The aim of the study is to study and analyze the physical, mechanical and technological properties of the soil of the cotton growing zone.

2. Methods

We have studied the relief of cotton fields, the physical and mechanical properties of takyr soils and gray soils, and the most common in the areas of cotton cultivation. The study of soil compaction in the fields after the cotton harvest was carried out in the farms of the Kashkadarya region of the Republic of Uzbekistan. The region belongs to the zone of subtropical deserts. The climate is sharply continental, extremely dry, with high summer temperatures. The sum of effective temperatures for the growing season of cotton is 2606 ^{0}C. In winter and spring, very little atmospheric precipitation falls. The soils are mainly takyr and sierozem.

3. Results and Discussion

One of the main factors affecting the performance of arable machines is the relief of the fields. When plowing cotton fields, the work of the plowing unit takes place under conditions of a pronounced relief, since on the surface of the field there are artificially created irrigation furrows and ridges with a certain row spacing (60 or 90 cm). The uneven terrain, acting on the working plowing unit through the support devices, causes its oscillations and entails uneven tillage in depth, deterioration of its dynamic performance. In order to find ways and means of combating the negative influence of the relief on the operation of arable machines, it is necessary to comprehensively study its characteristics.

We carried out a study of the surface relief of the cotton field before the main tillage. Profiling of the surface of the rows was carried out in cotton fields sown with a row spacing of 60 and 90 cm. In this

case, measurements in the transverse direction were carried out every 5 cm in a checkerboard pattern over the entire field. As a result of grouping all the ordinate values corresponding to each abscissa, the average cross-sectional profile of the row spacing of the cotton field was determined, the standard deviation of the average profile and the coefficient of variation were determined. Figure 1 shows profiles with a minimum 1, average 2 and maximum 3 ridge heights of the surface of cotton fields from cotton crops with row spacing of 60 and 90 cm.
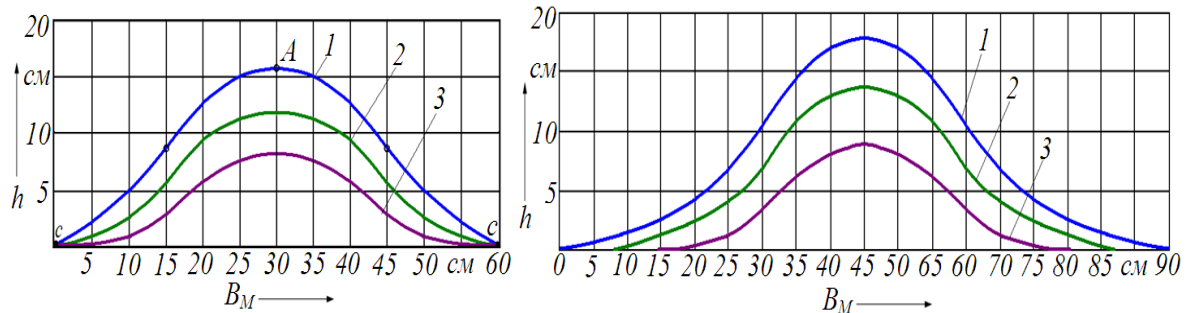

Figure 1. The surface profile of the row spacing of a cotton field with a width of 60 cm (*a*) and 90 cm (*b*), depending on the height of the ridge *h*: 1 - maximum; 2 - medium; 3 - minimum

As can be seen from the graphs, respectively, the minimum height of the ridge was 7.2 and 9 cm, the average height was 12.8 and 17.1 cm, and the maximum height was 17.7 and 23 cm. It should be noted that the furrows of the row spacing along the track of the tractor wheels have a depth of on average, 8-10 and 13-15% more than in row spacings without wheel marks. The standard deviation of the mean profile was 3.93 and 4.21 cm, the coefficient of variation was 21.8 and 24.6%.

Soil moisture and density are important indicators of the physical and mechanical properties of the soil, which predetermine its technological properties - hardness, soil resistance to various deformations.

The density and moisture content of the soil was determined by the method of samples using the Litvinov device. To determine the compaction of the soil of the arable layer, before the main processing, samples were taken in the fields of cotton cultivated on takyr soils with a row spacing of 60 cm.

When choosing a place for sampling, we took into account the fact that during the growing season of cotton, some areas of the field are exposed to repeated effects of the running machines of tractors, and some are not. Therefore, the soil density in row spacings 90 cm wide was measured at point *A* (Figure 2) of the ridge (in the area of cotton roots), at point *B* - in the middle of the slope and in the middle of the row spacing (along the bottom of the irrigation furrow). Point *A* was taken as the reference point for the depth of the horizon. At the same time, the depth of the location *h of* the slope surface at point *B* was 15 cm, and the height of the ridges in the row spacing of 90 cm and 60 cm, respectively, was 20 and 10 cm. The soil density in the row spacing of 60 cm was measured at the ridge and in the middle of the row spacing.

All operations for the cultivation and harvesting of cotton sown with a row spacing of 60 cm are carried out with 4-row machines. At the same time, every two row spacing out of four are not affected by the running devices.

Studies have established (Figure 3 *a*) that the soil density of the ridge, slope and the middle of the row spacing differs significantly. In the upper horizon of the ridge (0-10 cm), the soil is loose, its density is 1.18 g/cm^3. The upper soil horizon of the slope and the bottom of the furrow is constantly loosened during inter-row cultivation. In addition, after the last irrigation, cracks form in this horizon. All this leads to a decrease in the soil density of this horizon. The maximum density in the ridge of the takyr soil reaches 1.44 g/cm^3 in the horizon of 10-20 cm. This layer during the entire growing season of cotton is not exposed to the influence of loosening working organs, as well as the protective zone. The

soil of this horizon is compacted due to lateral propagation of soil deformation under the influence of tractor wheels due to the concave shape of the row spacing. In the horizons 20-30, 30-40 and 40-50 cm, the soil density decreases. The minimum value is 1.35 g/cm^3 in the 30-40 cm horizon. In the underlying soil horizons, an increase in soil density occurs, reaching 1.44 g/cm^3 in the 60-70 cm horizon.
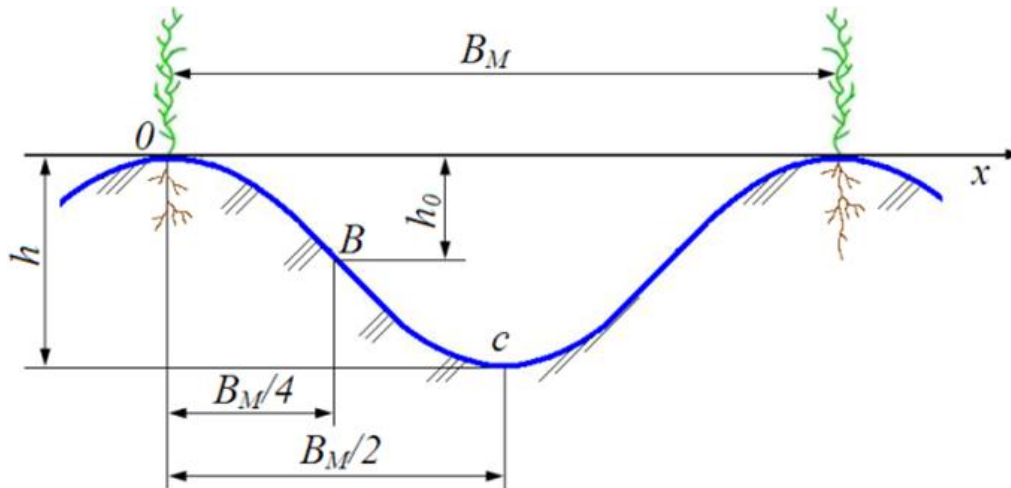

Figure 2. Aisle profile

In the slope and in the middle of the row-spacing, the greatest soil compaction occurs in the 35-45 cm horizon, which is 15-25 cm from the soil surface. The density in this slope horizon is 1.51 g/cm^3, furrows are 1.46 g/cm^3, which is greater than the density of the ridge soil, respectively, by 0.16 and 0.11 g/cm^3.
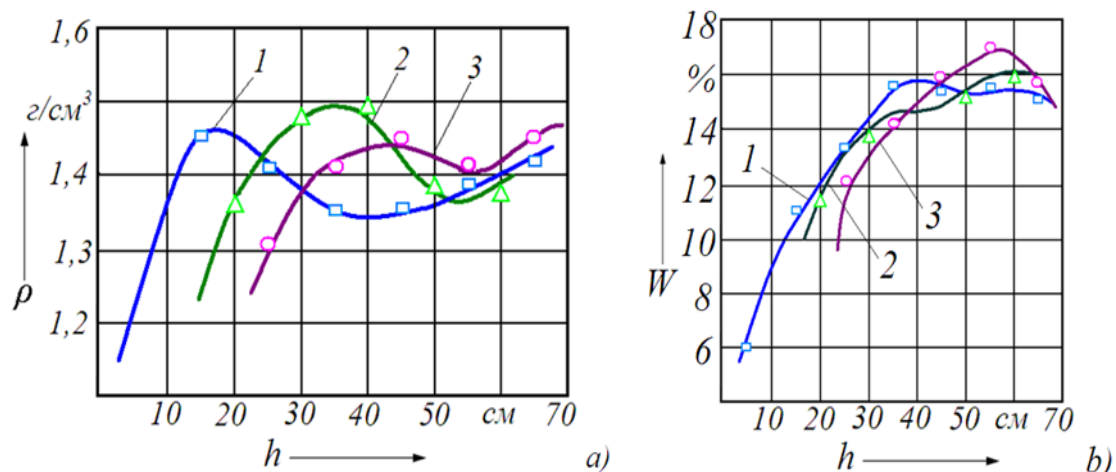
Figure 3. Dependences of the density (*a*) and moisture (*b*) of the takyr soil on the depth of the horizons: 1 - on the ridge; 2 - on the slope; 3 - in the furrow

The data obtained show (Figure 4 *a*) that the light gray soil in the middle of the row spacing along the wheel track is strongly compacted. The density of the soil along the track of the wheel in the horizon of 20-30 cm (from the surface of the soil 10-20 cm) is 1.78 g/cm^3, which is respectively more by 0.24 and 0.19 g/cm^3 the density of the soil of the ridge and furrow, unaffected by the wheel. The soil density on the ridge and in the middle of the furrow, unaffected by wheels, is almost the same.

The moisture *W of the* takyr and light gray soil in the arable layer increases with the depth of the horizons *h* , and in the subsoil layer slightly decreases, since the subsoil absorbs water much less.

Soil hardness is one of the important indicators of technological properties, which predetermines the value of the traction resistance of tillage machines, the depth of the working bodies, the degree of soil crumbling and the uniformity of the tillage depth.

Soil hardness was determined by a Revyakin hardness tester with a conical tip, the base area of which is 1 cm^2. Soil hardness in row spacings 90 cm wide was measured on the ridge, in the slope (with an offset from the row by 15 and 30 cm) and in the middle of the row spacing (Table 1). Soil hardness in row spacings 60 cm wide was measured on the ridge and in the middle of the row spacing (Table 2). The soil moisture between the rows is shown in Figure 5 *b*.
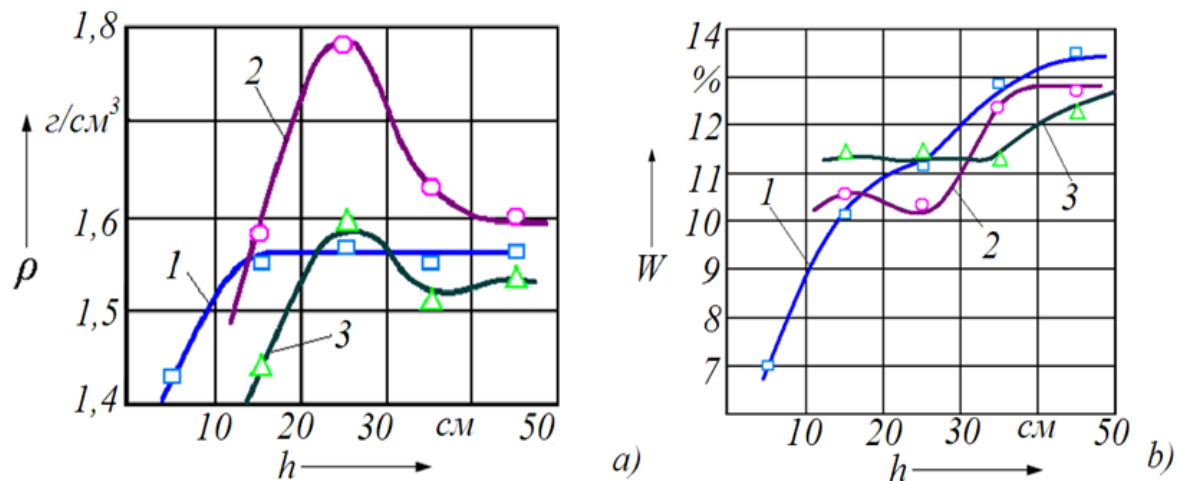

Figure 4. Dependences of the density (*a*) and moisture (*b*) of the soil of light gray soils on the depth of the horizons: 1 - on the ridge; 2 - in a furrow without wheel marks; 3 - in the furrow along the track of the wheels

Table 1. Hardness of takyr soil between rows of cotton, MPa

Soil layer, cm	Distance from the axis of the row (ridge) to the measuring point of the row spacing along the wheel track, cm				Mid furrow without wheel marks
	0	15	30	45	
5	0.06	0.15	2.74	2.93	1.98
10	0.46	1.33	3.56	3.55	2.86
15	2.73	2.65	3.7	3.8	2.88
20	3.25	3.53	3.8	3.96	3.22
25	3.0	3.63	3.75	3.85	3.31
30	3.1	3.65	3.75	3.8	3.38
35	3.35	3.65	3.70	3.7	3.5
40	3.55	3.7	3.75	3.75	3.61
45	3.58				
50	3.6				

It has been established (Table 2) that the hardness of the ridge, slope and the middle of the row spacing of takyr soils differs significantly. In the middle of the furrow in the 0-30 cm layer, the soil hardness is on average 1.69 times higher than in the ridge of the row spacing. The maximum hardness in the 0-30 cm layer of the ridge falls at a depth of 20 cm. In the middle of the row-spacing, the greatest increase in soil hardness is observed in the 15-25 cm layer. At a depth of 20 cm, the soil hardness in the middle of the row is 1.22 times greater than that of the soil of the same horizon in the ridge. The hardness of the soil increases significantly in the furrows along the wheel track. So, in

an impassable row-spacing in a layer of 0-30 cm, it ranges from 1.98 to 3.33 MPa, which is 0.58-0.95 MPa less than the hardness of the soil along the track of the wheel.

Table 2. Soil hardness of light gray soils, MPa

Soil layer, cm	Row spacing ridge	Middle of the furrow in the wheel track	Mid furrow without wheel marks
5	1.8	3.7	2.10
10	3.35	3.8	2.22
15	3.4	3.85	2.22
20	3.4	3.91	3.25
25	3.65	4.10	3.60
30	3.65	4.10	3.62
35	3.66	4.10	3.65
40	3.74	3.85	3.75

In the 0-30 cm layer, the soil hardness in the middle of the furrow along the track of the wheels of light gray soils is 1.37 and 1.22 times greater than the soil hardness, respectively, of the ridge and the middle of the furrow of the impassable row-spacing (Table 2).

Analysis of the measurement results shows that the hardness of the arable and sub-arable horizons in the middle of the row-spacing and takyr soils and light gray soils is greater than the hardness of the soil of the ridge and row-spacing without wheel marks.

The soil resistance to various deformations was determined on the ridge and in the middle of the furrow of the cotton row spacing 90 cm wide (Table 3) and 60 cm (Table 4 , 5 and 6), as well as in the field from under corn (Table 7).

Table 3. Resistance of the takyr soil of the arable layer various deformations

Soil layer, cm	Humidity,%	Density, g/cm³	Gap, kPa	Torsion, kPa	Shift, kPa
0-10	12.39	1.38	47.17	49.46	61.51
	6.28	1.18	5.56	7.11	7.56
10-20	14.11	1.40	58.98	60.49	72.72
	10.74	1.36	28.9	39.1	47.05
20-30	12.36	1.46	51.99	59.42	69.11
	13.9	1.40	40.69	47.6	57.9
30-40	14.81	1.41	48.88	54.98	63.5
	16.11	1.35	46.3	50.4	62.4
40-50	-	-	-	-	-
	13.71	1.34	44.0	49.5	61.3
50-60	-	-	-	-	-
	14.95	1.36	47.9	54.75	62.9

Note: The numerator is the soil resistance of the middle of the row spacing, the denominator is the soil resistance of the ridge

Analysis of the experimental data shows (Table 3) that in the 0-30 cm layer of takyr soils during shear deformation, an effort is required greater than in the case of rupture and torsion deformation, respectively, by an average of 1.4 and 1.2 times. The resistance of the soil in the middle of the furrow along the track of the wheels to shear, torsion and rupture is 1.63, 1.54 and 1.54 times higher, respectively, than with deformation of the soil on the ridge. In a layer of 15-25 cm, the resistance of the soil to various deformations has a maximum value. For example, in the 15-20 cm layer of the furrow, the forces of soil deformation to shear are 1.33 times greater than in the 0-5 cm layer.

As can be seen from Tables 4, 5 and 6, in the 0-30 cm layer of light gray soils during shear deformation, a force is required greater than in the case of deformation by rupture and torsion, respectively, on average 1.33-1.40 and 1.15-1.21 times. The soil resistance of the middle of the furrow along the wheel track to shear, torsion and rupture is 1.39, 1.32 and 1.38 times, respectively, than the middle of the furrow without a wheel track. The soils of the ridge have resistance to shear, torsion and rupture, respectively, 1.77, 1.71 and 1.69 times less than soils in the middle of the row spacing along the wheel tracks. The soil resistance to various deformations has a maximum value in the 15-20 furrow layer and in the 25-30 cm ridge layer.

Table 6 shows that the resistance of the subsurface soil layers in the middle of the furrow along the wheel track to rupture, torsion and shear is greater than when the soil is deformed on the ridge and in the middle of the furrow without a wheel track.

Comparative analysis of the results shows that the resistance of the soil to various deformations of light gray soils is greater than that of takyr soils. With a decrease in moisture, the resistance of the soil to deformation increases sharply. For example, in a layer of 10-20 cm, the resistance of light loamy takyr soils with a moisture content of 9.01% (Table 7) to shear and torsion is 1.15 and 1.1 times higher, respectively, than average loamy takyr soils with a moisture content of 14.11%.

Table 4. Resistance of light (medium loamy) gray soils various deformations on the ridge of the row spacing

Layer, cm	On the crest				
	Humidity,%	Density, g/cm^3	Resistance on		
			gap, kPa	torsion, kPa	shift, kPa
0-5	8.27	1.45	9.66	10.15	14.8
5-10			18.6	21.2	29.6
10-15	10.27	1.56	38.12	41.3	50.3
15-20			55.24	61.6	72.6
20-25	11.07	1.54	56.28	64.1	76.4
25-30			53.44	66.71	78.2
30-35	12.9	1.55	48.79	56.54	67.5
35-40			49.1	57.23	69.3
40-50	13.95	1.56	56.2	61.2	70.1

Table 5. Resistance of light (medium loamy) gray soils various deformations in the middle of the row-spacing furrow along the wheel track

Layer, cm	The middle of the furrow on the wheel track				
	Humidity,%	Density, g/cm^3	Resistance on		
			gap, kPa	torsion, kPa	shift, kPa
0-5	10.68	1.53	57.5	61.8	76.5
5-10			60.1	65.9	81.2
10-15	10.24	1.79	72.4	79.1	97.5
15-20			78.3	86.4	104.2
20-25	12.74	1.62	74.7	81,7	98.1
25-30			67.4	78.1	87.5
30-35	12.62	1.60	57.1	42.4	79.3
35-40			58.3	73.4	79.5
40-50					

Table 6. Resistance of light (medium loamy) gray soils various deformations in the middle of the row spacing without wheel marks

Layer, cm	Mid furrow without wheel marks					
	Humidity,%	Humidity,%	Density, g/cm^3	Resistance on		
				gap, kPa	torsion, kPa	shift, kPa
0-5	8.27	11.33	1.46	28.1	43.4	51.5
5-10				44.3	51.8	59.4
10-15				56.1	62.1	71.2
15-20	10.27	11.18	1.49	58.3	63.4	71.4
20-25	11.07	11.11	1.49	57.9	62.5	72.5
25-30				50.2	59.8	68.1
30-35	12.9	12.13	1.54	51.3	61.2	67.3
35-40				56.0	62.7	68.2
40-50	13.95					

Table 7. Resistance of light loamy takyr soils to various deformations

Soil layer, cm	Humidity,%	Gap, kPa	Torsion, kPa	Shift kPa
0-5	7.56	43.1	57.53	58.93
5-10	7.74	48.41	58.33	66.85
10-15	8.9	53.24	69.5	79.54
15-20	9.13	58.81	70.12	80.13
20-25	9.38	45.3	62.5	71.24
25-30	9.59	25.44	34.11	38.31
30-35	9.88	1.73	1.85	2.45

4. Conclusions

1. Before plowing, cotton fields have a pronounced uneven relief, characterized by the presence of ridges and irrigation furrows. The average height of ridges in fields with row spacing of 90 and 60 cm is 17.1 and 12.8 cm, respectively.

2. The physical-mechanical and technological properties of the soil of the arable and sub-arable layer of the cotton field along the track of the wheels differ significantly from the soil between the rows without a track of wheels and a ridge: the density of the soil along the track of the wheels of light gray soils reaches 1.78 g/cm^3, and of takyr soils – 1.51 g/cm^3, which is respectively more than the density of the ridge soil by 0.24 and 0.16 g/cm^3; the resistance of light gray soils to shear is 1.4 and 1.2 times greater than to rupture and torsion, and takyr soils - 1.33 and 1.15 times, respectively; the density, hardness and resistance of the soil to various deformations has a maximum value in layers of 15-25 cm along the track of the tractor wheels.

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