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Change In Chemical And Physical Parameters Of Light Chestnut Soil During Cultivation Of Winter Wheat On Precision Farming Site

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Abstract. The aim of the research is to assess the effect of differentiated application of mineral fertilizers and treatment on the change in agrochemical and agrophysical indicators of light chestnut soil during the growing season of winter wheat. The research was carried out in the Almaty region on a rainfed eroded area of the site with an area of 2.5 ha during the cultivation of winter wheat. By the period of harvesting in the phase of full ripeness of winter wheat in all fertilized plots, the supply of easily hydrolyzed nitrogen was medium and increased (41-68 mg/kg). By the end of the vegetative season of winter wheat, its amount on fertilized plots in the unwashed soil of the watershed of the slope of the southern and eastern exposure and in the medium-washed soil of the middle part of the slope of the eastern exposure remained elevated and high - 39-60 mg/kg and 35-54 mg/kg. By the period of winter wheat harvesting, its amount still decreased in the fertilized areas of the field, but insignificantly and remained in the unwashed soil of the watershed of the slope of the southern and eastern exposure at the level of elevated and high supply - 365-435 mg/kg and in the medium-washed soil of the middle part of the slope of the eastern exposure with a medium supply - 224-297 mg/kg. In the phase of milk ripeness of winter wheat, the highest content of productive moisture was observed in the middle part of the eastern slope on chisel cultivation in medium-washed soil - 125.9-128.6 mm and the smallest in the watershed part of the southern slope on subsurface cultivation in unwashed soil - 81.9 -83.9 mm. On the plots with fertilization at a dose of $N_{60}P_{60}$, the best yields of winter wheat variety Talimi 80 were obtained in the middle part of the slope of the eastern exposure on medium-washed soil with chisel cultivation at 30-35 cm - 31.3 dt/ha, subsurface cultivation at 10-12 cm – 31.1 dt/ha, moldboard plowing at 20-22 cm - 28.1 dt/ha.

Keywords: plowing, subsurface cultivation, chisel cultivation, total humus, easily hydrolyzed nitrogen, mobile phosphorus, exchangeable potassium, hardness, yield.

1. Introduction

Winter wheat is one of the most demanding crops for soil fertility. The critical growing seasons that determine the level of yield for winter wheat are September of the previous year - June of the current year (Cherkasov G.N., Sokorev N.S., Voronin A.N., Trapeznikov S.V., 2010). Nutrition of winter wheat is most important in two periods - autumn, immediately after sowing, and early spring, when the growing season resumes. In the first case, a good supply of young plants with phosphorus and a balance of the soil solution for phosphorus, nitrogen and potassium are necessary, and after thawing of the soil in spring at low temperatures, there is a need for nitrogen (Agafonov Ye.V., Gromakov A.A., Maksimenko M.V., 2012; Dabin Z., Pengwei Y., Na Z., Weidong C., Yajun G., 2015).

The consumption of basic nutrients by wheat during its growing season is rather uneven. Studies carried out in the Stavropol region have shown that in the initial period of growth and development (seedlings - tillering), a relatively small amount of nutrients is consumed. Most intensively and a lot of them enter the plant at the stem elongation and at the beginning of earing. During this period, it consumes the main amount of nitrogen, phosphorus and potassium. Despite the relatively low absorption of nitrogen and ash elements by wheat from germination to the end of tillering, at this time the plants are very sensitive to the lack of these elements (Smirnov P.M., Muravin E.A., 1977; Ageyev V.V., 1996; Bobryshev F.I., Voiskovoy A.I., Dubina V.V. et al., 2003).

Wheat synthesizes relatively little biomass in autumn. However, nutrients accumulate very intensively in the first two weeks of growth. By the beginning of steming, plants form 10–15% of the biomass of the maximum amount, but consume already 25–30% of total nitrogen, 20–25% of phosphorus and 25–30% of potassium. Consequently, at the beginning of growth, a sufficiently good supply of plants with nutrients is required. Deficiency of nitrogen and especially phosphorus during this period cannot be compensated by the subsequent improvement of nutrition. Therefore, it received the name "critical" (Gulyakin, I.V, 1977; Podkolzin, A.I, 1997; Yang Z.C., Zhao N., Huang F., 2015).

The elevated nitrogen nutrition of winter wheat in the autumn increases the synthesis of nitrogenous substances, the intensity of respiration and the activity of oxidative enzymes, but reduces the content of sugars, which leads to the premature consumption of the plastic substances of the seed. With this direction of synthetic processes, wheat becomes less winter-hardy, plants become effete, many plants die during overwintering, which subsequently causes strong lodging, which complicates harvesting and causes significant crop losses. To eliminate this negative phenomenon, it is necessary to isolate the nitrogen of fertilizers from the seed (Mineyev V.G., 1973; Ageyev V.V., Chernov A.P., Kuydan A.P. et al., 1999; Babulicov M., Faragov N., 2014; Noack SR, McLaughlin MJ, Smernik RJ, McBeath TM, Armstrong RD, 2014).

Nitrogen consumption by winter wheat plants begins from the first days of life and continues until the end of the grain filling. In the tillering phase, nitrogen consumption is 20–25%, in the period of stemming - earing - 50–55%, flowering - the beginning of waxy ripeness - 5–10% of the maximum amount of nitrogen consumed (Posypanov G.S., Dolgodvorov V.Ye., Korenev G.V., 1997; Sandukhadze B.I., Zhuravlev Ye.V., 2011; Gamzikov G. P, 2013; Cormier F., Faure S., Dubreuil P., Praud S., Le Gouis J., 2013).

Optimization of phosphorus nutrition of plants helps to improve the root system - it branches more strongly and penetrates deeper into the soil. This improves the supply of plants with nutrients and moisture, and also promotes the accumulation of sugars in plants (Agrochemistry and fertilization system, 1979; Sheudzhen A.Kh., Zagorulko A.V., Gromova L.I. et al., 2009; Bairwa RK, Purohit HS, Meena RH, Jain HK, 2013).

The need for phosphorus in winter wheat is noted from germination to full ripeness. It is of particular importance in the biochemical processes occurring in the swelling grain and wheat seedlings.

Phosphorus applied with seeds has a positive effect on plant growth and development, and nitrogen often slows down growth, especially of roots. It is not only a source of energy, but also an element necessary in carbohydrate metabolism, in the accumulation of sugar phosphates, nucleic acids, in the synthesis of nucleoproteins and other complex organic compounds, which are extremely necessary for the enhancement of growth processes. As a result, the plants are well prepared for winter (Podkolzin, A.I, 1997).

Potassium enters plants from the soil from the first days of plant growth to flowering, but its greater consumption is observed in the phase of winter wheat stem elongation and earing (Ageyev V.V., Chernov A.P., Kuydan A.P. et al., 1999;). Strengthens the formation of lateral roots, the growth of thin roots, increases the total absorbing surface of the root system, increases the winter hardiness of plants. Along with calcium and magnesium, potassium affects the dispersion, viscosity, and water content of protoplasmic colloids, increases plant resistance to diseases and lodging (Ageyev V.V., Podkolzin, A.I., Dinyakova S.V., 2007).

2. Methodology

The object of research is a light chestnut eroded soil located on a semi-rainfall rainfed area of 5 ha on the territory of «KazRIAPG» LLP of the Karasay district of the Almaty region. The soil of the experimental site is characterized by a fairly clear differentiation of the profile into genetic horizons with the thickness of the humus horizon (A + B) on average 60-70 cm and the presence of an eluvial carbonate horizon from 70-90 to 110 cm. The granulometric composition is medium loam. The content of total humus in the upper horizon is within 1.6-1.9%, total nitrogen is 0.15%, phosphorus is 0.21%. The soil is supplied with potassium in sufficient measure. The amount of exchangeable bases is 14-18 mg/eq, there is no soil salinity, a dense residue 1.5 m thick does not exceed 0.1%. The groundwater depth is more than 5m and it does not affect the soil-forming process. The parent rocks are loess-like loams and clays. According to the reaction of the soil solution, it is medium alkaline.

The climate of the zone is a moderately arid zone with a sharply expressed continental climate, with large daily fluctuations in air temperature and total annual precipitation. The average annual air temperature is 7-8^{0}C. The average annual precipitation is 415 mm with fluctuations in some years from 300 to 500 mm.

The field area is 5 ha. Accounting area - 2.5 ha. It is divided into 18 counting areas, which covers the watershed and the middle part of the slope. Land area - 7290 m^2. On the plots of the field, 3 methods of basic soil cultivation for winter wheat were used: plowing by 20-22 cm, flat-cutting cultivation by 10-12 cm, chisel cultivation by 30-35 cm. On the plots of the field, nitrogen-phosphorus fertilizers were used at a dose of $N_{30}P_{60}$, $N_{60}P_{60}$ and without them. A winter wheat variety - Talimi-80 was cultivated at the site.

Laboratory-agrochemical studies of soils are carried out according to the following methods: total humus - according to V.I. Tyurin (Practical work on soil science, 1986), labile humus - according to I.V. Tyurin and M.M. Kononova (Practical work on soil science, 1986), nitrate nitrogen - according to Grandval-Lyazhou (Practical work on soil science, 1986), easily hydrolyzed nitrogen - according to V.V. Ponomareva and A.T. Plotnikova (Practical work on soil science, 1986), mobile phosphorus - according to B.P. Machigin (Practical work on soil science, 1986), exchangeable potassium - according to V.P. Protasov (Practical work on soil science, 1986), acid-base equilibrium - potentiometric method (Practical work on soil science, 1986), hardness - electronic hardness meter SC 900 , structural and aggregate composition - according to N.A. Savvinov (Practical work on soil science, 1986), moisture supply - according to Vadyunina (Vadyunina A.F., Korchagina Z.A., 1986). The harvest was taken into account by continuous threshing with a Sampo-130 combine, bringing the grain to 12% moisture content and 100% purity.

3. Results

Earlier, an agroecological assessment of land was carried out at the site, including a landscape-ecological analysis of the territory. This included studies of geomorphological, lithological conditions and soil cover structure. The agronomic assessment of soils determined the study of their morphological, physical, physicochemical properties, erosion and hydromorphism. These works were carried out by soil-geographical and laboratory-agrochemical methods. Field studies were carried out by route method to clarify the content of the identified soil contours, to establish deciphering characteristics of soils. These studies will make it possible to identify the spatial distribution of different soils.

An agronomic assessment of the dynamics of humus, water and nutrient regimes, dynamics of density and structural state of light chestnut soil in rainfed eroded soil of the site was carried out. The yield of winter wheat variety Talimi 80 was determined depending on the use of various doses of mineral fertilizers, methods of soil cultivation, part and exposure of the slope. For the indicated agro-assessment of soils, 144 soil samples were taken, 1620 samples were taken to determine moisture content, 1008 agrochemical analyzes were performed, 752 density determinations, 4320 determinations of the structural-aggregate composition of soils. The evaluation of the obtained data has been carried out.

4. Discussion

Determination of the nitrogen state of the site soil indicates that during the tillering period of winter wheat, the content of easily hydrolyzable nitrogen in the 0-20 cm layer varied within 20-49 mg/kg. After carrying out differentiated top dressings at a dose of N_{30} and N_{60}, its amount in the phase of winter wheat stem elongation increased and amounted to 49-59 mg/kg and 69-80 mg/kg in the unwashed soil of the watershed of the southern and eastern slope against the background of treatments - 49-59 mg/kg and 69-80 mg/kg and to the soil of the middle part of the slope of the eastern exposure - 46-51 mg/kg and 53-76 mg/kg, respectively. On plots without fertilization with the use of basic treatments, the content of easily hydrolyzable nitrogen decreased in the unwashed soil of the watershed of the slope of the southern and eastern exposure - by 9-13 mg/kg and in the medium-washed soil of the middle part of the slope of the eastern exposure - by 11-16 mg/kg (Table 1). By the period of harvesting in the phase of full ripeness of winter wheat in all fertilized plots, the supply of easily hydrolyzed nitrogen was medium and increased (41-68 mg/kg). On plots without fertilization, its amount decreased to a very low level (13-28 mg/kg). In the soil layer 20-40 cm with a low absolute value of the indicator, no regularities in the content of easily hydrolyzable nitrogen were observed.

Table 1 - Dynamics of the content of easily hydrolyzable nitrogen in the light-chestnut rainfed soil of the site during the growing season of winter wheat

Field plots	Depth, cm	Determination term		
		Tillering	Stem elongation	Full ripeness of grain
1	2	3	4	5
Watershed, southern exposure, unwashed, P-20-22 cm, without fertilizers	0-20	49	40	28
	20-40	26	21	18
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{30}P_{60}$	0-20	31	49	41
	20-40	25	31	26
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{60}P_{60}$	0-20	35	69	58
	20-40	22	44	36
Watershed, southern exposure, unwashed, S-10-12 cm, without fertilizers	0-20	44	31	13
	20-40	22	17	9
Watershed, southern exposure, unwashed, S-10-12 cm, $N_{30}P_{60}$	0-20	40	59	49
	20-40	18	39	26
Watershed, southern exposure, unwashed, S-10-12	0-20	36	75	53

cm, $N_{60}P_{60}$	20-40	20	48	40
Watershed, eastern exposure, unwashed, C-30-35 cm, without fertilizers	0-20	45	33	18
	20-40	24	17	13
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{30}P_{60}$	0-20	29	55	44
	20-40	18	33	27
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{60}P_{60}$	0-20	32	80	68
	20-40	24	55	40
Middle part, eastern exposure, medium-washed, P-20-22 cm, without fertilizers	0-20	47	36	27
	20-40	26	18	12
Middle part, eastern exposure, medium-washed, P-20-22 cm, $N_{30}P_{60}$	0-20	20	46	42
	20-40	11	22	25
Middle part, eastern exposure, medium-washed, P-20-22 cm, $N_{60}P_{60}$	0-20	22	53	54
	20-40	15	34	30
Middle part, eastern exposure, medium-washed, S-10-12 cm, without fertilizers	0-20	48	32	20
	20-40	24	23	12
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{30}P_{60}$	0-20	24	46	43
	20-40	10	25	14
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{60}P_{60}$	0-20	27	70	57
	20-40	17	51	39
Middle part, eastern exposure, medium-washed, C-30-35 cm, without fertilizers	0-20	43	32	22
	20-40	19	16	11
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{30}P_{60}$	0-20	25	51	49
	20-40	16	36	27
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{60}P_{60}$	0-20	23	76	57
	20-40	11	54	38

The assessment of the content of mobile phosphorus indicates that in the plots with the application of phosphorus fertilizers in the arable layer of the unhwashed soil of the watershed of the southern and eastern slopes against the background of treatments and in the medium washed soil of the middle part of the slope of the eastern exposure, its amount from the tillering phase to the phase of stem elongation of winter wheat increased to elevated supply - 33-45 mg/kg and 31-44 mg/kg, respectively.

In the unfertilized areas, the content of mobile phosphorus in the phase of stem elongation of winter wheat was in the arable layer of the unwashed soil of the watershed of the slope of the southern and eastern exposure, medium supplied - 16-21 mg/kg and in the medium-washed soil of the middle part of the slope of the eastern exposure, low -13-15 mg/kg (Table 2).

Table 2 - Dynamics of the content of mobile phosphorus in the light-chestnut rainfed soil of the site during the growing season of winter wheat

Field plots	Depth, cm	Determination term		
		Tillering	Stem elongation	Full ripeness of grain
1	2	3	4	5
Watershed, southern exposure, unwashed, P-20-22 cm, without fertilizers	0-20	29	21	10
	20-40	18	13	6
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{30}P_{60}$	0-20	30	38	43
	20-40	19	22	29
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{60}P_{60}$	0-20	25	33	39
	20-40	16	19	21
Watershed, southern exposure, unwashed, S-10-12 cm, without fertilizers	0-20	23	18	13
	20-40	17	13	7
Watershed, southern exposure, unwashed, S-10-12 cm, $N_{30}P_{60}$	0-20	23	37	46
	20-40	16	22	27
Watershed, southern exposure, unwashed, S-10-12 cm, $N_{60}P_{60}$	0-20	21	40	52
	20-40	14	25	31
Watershed, eastern exposure, unwashed, C-30-35 cm, without fertilizers	0-20	19	16	10
	20-40	13	10	7
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{30}P_{60}$	0-20	16	41	55
	20-40	11	26	32
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{60}P_{60}$	0-20	19	45	60
	20-40	13	28	38
Middle part, eastern exposure, medium-washed, P-20-22 cm, without fertilizers	0-20	26	15	12
	20-40	19	11	9
Middle part, eastern exposure, medium-washed, P-20-	0-20	29	36	40

22 cm, $N_{30}P_{60}$	20-40	17	24	27
Middle part, eastern exposure, medium-washed, P-20-22 cm, $N_{60}P_{60}$	0-20	26	31	35
	20-40	17	25	28
Middle part, eastern exposure, medium-washed, S-10-12 cm, without fertilizers	0-20	22	14	8
	20-40	16	12	7
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{30}P_{60}$	0-20	25	42	51
	20-40	17	27	32
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{60}P_{60}$	0-20	20	38	49
	20-40	14	23	27
Middle part, eastern exposure, medium-washed, C-30-35 cm, without fertilizers	0-20	20	13	9
	20-40	16	13	7
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{30}P_{60}$	0-20	17	44	54
	20-40	11	25	29
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{60}P_{60}$	0-20	18	43	53
	20-40	13	29	32

By the end of the vegetative season of winter wheat, its amount on fertilized plots in the unwashed soil of the watershed of the slope of the southern and eastern exposure and in the medium-washed soil of the middle part of the slope of the eastern exposure remained elevated and high - 39-60 mg/kg and 35-54 mg/kg. In unfertilized areas of the field, the content of mobile phosphorus in the studied soils was in the range of 8-13 mg/kg, that is, at the level of low and very low availability. A similar dynamics of the content of mobile phosphorus can be traced in the 20-40 cm layer of the soil, but with reduced indicators.

Analysis of the potassium state of the soil showed that the application of nitrogen-phosphorus fertilizers did not affect the content of exchangeable potassium during the entire growing season of winter wheat. Its amount decreased from the tillering phase to the stem elongation phase of winter wheat on fertilized areas of the field with unreached soil of the watershed of the southern and eastern slopes and medium-washed soil of the middle part of the eastern slope and amounted to 396-459 mg/kg and 255-306 mg/kg, respectively. Also, the content of exchangeable potassium in the unfertilized areas of the field with unwashed soil of the watershed of the slope of the southern and eastern exposure decreased and was at the level of elevated and high supply - 396-453 mg/kg and the medium-washed soil of the middle part of the slope of the eastern exposure with medium and elevated supply - 253-305 mg/kg (Table 3).

By the period of winter wheat harvesting, its amount still decreased in the fertilized plots of the field, but insignificantly and remained in the unwashed soil of the watershed of the slope of the southern and eastern exposure at the level of elevated and high supply - 365-435 mg/kg and in the medium-washed soil of the middle part of the slope of the eastern exposure with a medium supply - 224-297 mg/kg. In unfertilized plots of the field, the content of exchangeable potassium in the studied soils was in the range of 223-432 mg/kg, that is, at the level of medium, elevated and high supply. A similar situation in the content of exchangeable potassium in the soil in the studied areas of the field was observed in a layer of 20-40 cm.

Table 3 - Dynamics of the content of exchangeable potassium in the light-chestnut rainfed soil of the site under the sowing of winter wheat

Field plots	Depth, cm	Determination term		
		Tillering	Stem elongation	Full ripeness
Watershed, southern exposure, unwashed, P-20-22 cm, without fertilizers	0-20	424	396	364
	20-40	392	364	339
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{30}P_{60}$	0-20	426	398	365
	20-40	395	366	340
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{60}P_{60}$	0-20	429	396	368
	20-40	398	366	341
Watershed, southern exposure, unwashed, S-10-12 cm, without fertilizers	0-20	452	434	415
	20-40	430	417	397
Watershed, southern exposure, unwashed, S-10-12 cm, $N_{30}P_{60}$	0-20	455	438	419
	20-40	432	420	402
Watershed, southern exposure, unwashed, S-10-12 cm, $N_{60}P_{60}$	0-20	457	435	416
	20-40	431	420	400
Watershed, eastern exposure, unwashed, C-30-35 cm, without fertilizers	0-20	470	453	432
	20-40	446	424	408
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{30}P_{60}$	0-20	472	453	434
	20-40	447	427	411
Watershed, eastern exposure, unwashed, C-30-35 cm, $N_{60}P_{60}$	0-20	479	459	435
	20-40	450	431	412
Middle part, eastern exposure, medium-washed, P-20-22 cm, without fertilizers	0-20	276	253	223
	20-40	243	225	206
Middle part, eastern exposure, medium-washed, P-20-22 cm, $N_{30}P_{60}$	0-20	277	258	224
	20-40	245	224	210

Middle part, eastern exposure, medium-washed, P-20-22 cm, $N_{60}P_{60}$	0-20	280	255	228
	20-40	251	226	207
Middle part, eastern exposure, medium-washed, S-10-12 cm, without fertilizers	0-20	303	286	267
	20-40	276	263	244
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{30}P_{60}$	0-20	308	288	269
	20-40	280	264	245
Middle part, eastern exposure, medium-washed, S-10-12 cm, $N_{60}P_{60}$	0-20	304	286	272
	20-40	281	267	249
Middle part, eastern exposure, medium-washed, C-30-35 cm, without fertilizers	0-20	328	305	293
	20-40	291	276	265
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{30}P_{60}$	0-20	331	306	297
	20-40	292	279	268
Middle part, eastern exposure, medium-washed, C-30-35 cm, $N_{60}P_{60}$	0-20	343	303	295
	20-40	298	281	270

Determination of soil moisture in a meter layer in the tillering phase of winter wheat indicates that its amounts in all areas of the field were not the same. The value of this indicator depends both on the exposure of the slope and on its parts. So, the largest April moisture reserves were in the middle part of the eastern slope in medium-washed soil on chisel cultivation by 30-35 cm, on subsurface cultivation by 10-12 cm and on plowing by 20-22 cm against the background of using mineral fertilizers on them and without them - 171.3-173.5 mm, 169.2-170.9 mm and 165.5-167.2 mm, respectively. On the watershed section of the slope of the eastern exposure in the unwashed soil with chisel cultivation by 30-35 cm, a significant content of productive moisture was observed in comparison with the areas of the southern slope with subsurface cultivation by 10-12 cm and plowing by 20-22 cm and exceeded by 54.6 -58.1 mm and 60.1-64.0 mm, respectively (Figure 1, 2).

From the tillering phase to the booting phase of winter wheat, there was an increase in the content of productive moisture in the watershed area of the southern exposure slope on ordinary plowing in unwashed soil from 101.5-103.8 mm to 119.7-122.4 mm and in the middle part of the eastern slope on moldboard plowing and shallow subsurface cultivation in medium-washed soils - from 165.5-167.2 mm to 187.2-190.3 mm and from 169.2-170.9 mm to 204.6-206.7 mm, respectively.

In the areas of the watershed part of the southern slope with subsurface cultivation and the eastern slope with chisel cultivation in unwashed soils, a decrease in the amount from 107.4-109.3 mm to 102.2-104.1 mm and from 163.9-165.5 mm up to 119.0-120.3 mm, respectively. A decrease in moisture supply was observed in the area of the middle part of the slope of the eastern exposure on chisel cultivation in medium-washed soil from 171.3-173.5 mm to 145.2-147.5 mm.

In the phase of milky ripeness, due to the consumption of moisture for evaporation and the formation of plant biomass, the reserves of productive moisture significantly decreased in all parts of the field from 102.2-206.7 mm to a poor and satisfactory level - 81.9-128.6 mm. The highest content of productive moisture was observed in the middle part of the slope of the eastern exposure on chisel cultivation in medium-washed soil - 125.9-128.6 mm and the lowest in the watershed part of the southern exposure slope on subsurface cultivation in unwashed soil - 81.9-83.9 mm. In the rest of the field, the reserves of productive moisture were in the range of 86.6-112.1 mm.

Figure 1 - Dynamics of reserves of productive moisture in unwashed light chestnut rainfed soil under winter wheat crops (in a layer of 0-100 cm, mm)

Figure 2 - Dynamics of productive moisture reserves in medium-washed light chestnut rainfed soil under winter wheat crops (in a layer of 0-100 cm, mm)

During the growing season of winter wheat, hardness indicators are important, with which physical conditions can be assessed. Determination of the hardness at the beginning of the growing season of winter wheat showed that the loose soil composition was noted in the middle part of the slope of the eastern exposure on chisel cultivation at 30-35 cm and plowing at 20-22 cm - 805-883 kPa and 923-992 kPa. A loose state was observed in the areas of the middle part of the slope of the eastern exposure after subsurface cultivation by 10-12 cm on medium-washed soil – 1027-1094 kPa and in the watershed part of the slope of the eastern exposure after chisel cultivation on unwashed soil - 1422-1487 kPa. In the areas of the watershed part of the southern slope, after plowing and subsurface cultivation, the unwashed soil was poorly compacted - 1513-1583 kPa and 1635-1691 kPa, respectively.

By the end of the growing season of winter wheat, the soil, due to desiccation from a loose and weakly compacted state, became moderately compacted in the middle part of the slope of the eastern exposure on all treatments of medium-washed soil - 2109-2397 kPa and dense - in the watershed part of the slope of the southern and eastern exposure for all treatments of unwashed soil - 2701-2993 kPa (Table 4).

Table 4 - Dynamics of the hardness of light chestnut rainfed soil of the landfill during the growing season of winter wheat, (layer 0-40 cm)

Field plots	Determination term	
	Spring	Before the harvest
Southern exposure slope watershed, unwashed, P-20-22 cm, without fertilizers	1513	2875
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{30}P_{60}$	1536	2811
Watershed, southern exposure, unwashed, P-20-22 cm, $N_{60}P_{60}$	1583	2845
Southern exposure slope watershed, unwashed, S-10-12 cm, without fertilizers	1691	2993
Southern exposure slope watershed, unwashed, S-10-12 cm, $N_{30}P_{60}$	1635	2967
Southern exposure slope watershed, unwashed, S-10-12 cm, $N_{60}P_{60}$	1667	2912
Eastern exposure slope watershed, unwashed, C-30-35 cm, without fertilizers	1422	2733
Eastern exposure slope watershed, unwashed, C-30-35 cm, $N_{30}P_{60}$	1487	2701

Eastern exposure slope watershed, unwashed, C-30-35 cm, $N_{60}P_{60}$	1443	2768
Middle part of the slope of the eastern exposure, medium-washed, P-20-22 cm, without fertilizers	944	2264
Middle part of the slope of the eastern exposure, medium-washed, P-20-22 cm, $N_{30}P_{60}$	992	2284
Middle part of the slope of the eastern exposure, medium-washed, P-20-22 cm, $N_{60}P_{60}$	923	2225
Middle part of the slope of the eastern exposure, medium-washed, S-10-12 cm, without fertilizers	1094	2356
Middle part of the slope of the eastern exposure, medium-washed, S-10-12 cm, $N_{30}P_{60}$,	1063	2328
Middle part of the slope of the eastern exposure, medium-washed, S-10-12 cm, $N_{60}P_{60}$	1027	2397
Middle part of the slope of the eastern exposure, medium-washed, C-30-35 cm, without fertilizers	883	2109
Middle part of the slope of the eastern exposure, medium-washed, C-30-35 cm, $N_{30}P_{60}$	805	2177
Middle part of the slope of the eastern exposure, medium-washed, C-30-35 cm, $N_{60}P_{60}$	836	2134

Accounting for the yield of winter wheat variety Talimi 80 showed that its formation was greatly influenced by the use of various doses of mineral fertilizers, methods of tillage, parts and exposure of the slope, variety. On the plots with fertilization at a dose of $N_{60}P_{60}$, the best yields of winter wheat variety Talimi 80 were obtained in the middle part of the slope of the eastern exposure on medium-washed soil with chisel cultivation at 30-35 cm - 31.3 dt/ha, subsurface cultivation at 10-12 cm – 31.1 dt/ha, moldboard plowing at 20-22 cm - 28.1 dt/ha. The use of nitrogen fertilizers in a low dose $N_{30}P_{60}$ ensured the yield of winter wheat in the range of 26.1-27.7 dt/ha for all soil treatments. On unfertilized areas of the field, the yield was 26.7 dt/ha for chisel cultivation, 25.9 dt/ha for subsurface cultivation, and 23.1 dt/ha for moldboard plowing. A similar yield of winter wheat of this variety was obtained in the watershed part of the slope of the southern and eastern exposure on unwashed soil, but with lower indicators, which is associated with a lower content of productive moisture (Figure 3, 4).

Two-factor analysis of variance according to ANOVA for winter wheat yield

Effect	Sum of squares (SS)	Degree of freedom	Medium square (MS)	F-criterion	P
Intercept	37509.23	1	37509,23	42603,95	0,000000
Washout	68.01	1	68,01	77,24	0,000000
Tillage	101.14	2	50,57	57,44	0,000000
Fertilizers	156.54	2	78,27	88,90	0,000000
Error	42.26	48	0,88		

With two-factor analysis of variance and the F-criterion, it can be seen that the change in the yield of winter wheat is most influenced by mineral fertilizers, the second most important should be soil washout and the third - tillage. The analysis of variance carried out indicates that reliable indicators were obtained in the experiment.

Figure 3 - Yield of winter wheat Talimi 80 on unwashed light chestnut rainfed soil

Figure 4 - Yield of winter wheat Talimi 80 on medium-washed light chestnut rainfed soil

5. Conclusion

Thus, on the plot with fertilization at a dose of $N_{60}P_{60}$, the best yield of winter wheat variety Talimi 80 was obtained in the middle part of the slope of the eastern exposure on medium-washed soil with chisel cultivation at 30-35 cm - 31.3 dt/ha. Research should be continued with the use of increased rates of mineral fertilizers in order to develop methods for optimizing nitrogen and phosphorus nutrition of intensive varieties of winter wheat in the technologies of their cultivation in the southeastern regions of Kazakhstan due to the variability of soil fertility and the variability of weather conditions.

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