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IRRIGATION AND MINERAL FERTILIZER EFFECTS ON PHYSICAL PROPERTIES OF LIGHT CHESTNUT SOIL USED IN THE CULTIVATION OF SUGAR BEET (*BETA VULGARIS* L.)

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SUMMARY

This work studied the effect of irrigation and mineral fertilizers on the physical properties of light chestnut soil used in cultivating sugar beet (*Beta vulgaris* L.). The experiment happened in 2021 on an irrigated field with an area of 2 ha in the territory of the Kazakh Research Institute of Agriculture and Plant Growing, District Karasai, Almaty region, Kazakhstan. A sugar beet hybrid (obtained from domestic selection 'Aksu' and foreign selection 'Yampol') cultivation used four levels of mineral fertilizers, i.e., 0:0:0 (control), 90:90:60, 120:120:90, and 150:150:120 NPK kg ha^{-1}. During the sugar beet growing season, all periods of observations recorded an increase in the bulk density in the upper, middle, and lower soil layers, from 1.14–1.27 g/cm^3 to 1.31–1.48 g/cm^3. The content of agronomically valuable aggregates in 0–10 cm, 10–20 cm, and 20–30 cm soil layers decreased from the germination phase to harvesting of sugar beet in extensive technology (10.0%–15.7%) and intensive technologies (2.3%–13.1%). In these soil layers, the number of water-stable aggregates decreased from the beginning of renewal to the end of the growing season of sugar beet in technology without the use of fertilizers (2.9%–6.4%) and in technologies with the application of mineral fertilizers (1.6%–7.6%). In the soil layers, the noted highest content of productive moisture occurred in the phase of closing the leaves in the rows with the extensive technology of sugar beet cultivation (51.5–213.2 mm). Irrigation during the sugar beet growing season reduces the content of agronomically-valuable and water-stable aggregates in soil layers to the minimum values for harvesting in technology without the use of fertilizers (50.5%–54.4% and 12.9%–14.2%) and technology with the use of mineral fertilizers (52.3%–54.4% and 10.9%–13.5%), respectively.

Keywords: Sugar beet (*B. vulgaris* L.), light chestnut soil, soil layers, soil aggregates, mineral fertilizers, productive moisture, bulk density

Key findings: During the growing season of sugar beet, an increase in bulk density in the upper, middle and lower layers of the soil was observed for all observation periods from 1.14-1.27 g/cm3 to 1.31-1.48 g/cm3. The content of agronomically valuable aggregates in the soil layers of 0-10 cm, 10-20 cm and 20-30 cm decreased from the germination phase to the harvesting of sugar beet by extensive technology (10.0-15.7%) and intensive technology (2.3-13.1%).

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INTRODUCTION

In the present era, frequent and prolonged droughts seriously undermine food security worldwide. However, ensuring food security is impossible without improved irrigated agriculture since most of the agricultural land is in arid areas, belonging to the zones of unstable agriculture in Kazakhstan and other regions of the world (Kenenbayev *et al.,* 2016; Abekova *et al*., 2022; Bastaubayeva *et al*., 2022; Kenenbayev and Yesenbayeva, 2022). The Southeastern region of Kazakhstan comprises the largest zone of irrigated agriculture, and the area of irrigated land exceeds one million hectares.

The Almaty region has unfavorable soil and climatic conditions; thus, one of the regions where irrigation is the most important stabilizing factor in crop production. With crop cultivation and irrigation technologies, it is possible to ensure high productivity and yields 2–3 times higher than the yield obtained in rainfed lands (Kublanov *et al.,* 2017; Zhaksybayeva *et al.,* 2021). Violation of ecological stability, the development of irrigation erosion, the rise in groundwater, and the occurrence of secondary soil salinization, which occur on irrigated lands, interlinked with a decrease in the technical level of irrigation systems, imperfection of irrigation equipment, and improper utilization of irrigation regimes (Nemeata-Alla and Helmy, 2022).

Long-term improper agricultural use of irrigated lands contributes to the deterioration of their physical condition. It results from an increase in the anthropogenic load on the soil, its over-compaction with agricultural machinery, a decrease in the content of organic matter, the high frequency of crop rotations with tilled crops, and the occurrence of erosion processes. The improvement of the physical properties of the soil needs focus to restore the productivity of irrigated lands. Soil properties play an immense role in its fertility—determines the resistance of soils to degradation, the growth and development of crops, and obtaining high and stable yields (Papish *et al.,* 2016; Bastaubayeva *et al*., 2022).

Soil physical properties comprised a set of properties that characterize the physical state of the soil and its relationship to various tangible influences (granulometric composition, the specific gravity of the solid phase, soil density, porosity, soil hardness, structural-aggregate composition, air, water, thermal, electrical, and radioactive properties). Moisture is one of the vital and highly variable components required of the soil (Borodin and Krylach, 2008; Bazykina and Boiko, 2010; Błaszkiewicz and Sztukowski, 2019; Bastaubayeva *et al*., 2022). With the influence of water, weathering processes, humification, and mineralization of organic residues occur. Cultivated plants receive water only from the soil or through it. The provision of crops with moisture has a decisive influence on the growth and development of plants. The studies of many scientists have established the impact of the physical conditions of the soil on crop productivity (Pronko *et al.,* 2022).

Soil-physical features have a significant impact on crop yield. The various factors' influence share breaks down into soil moisture content (33%), thermal conductivity (25%), the sum of temperatures in the 0–50 cm layer (17%), and soil surface temperature (12%) (Shorina, 2013). The destruction of the structure during irrigation leads to soil compaction. The most dynamic is the density of the soil. So, according to Belkov (1989), in podzolized and leached chernozems of the Kuibyshev region, the density in the upper layer increases by 0.1–0.2 g/cm^3 after each irrigation. In old-irrigated areas, a sharp increase in density by 0.2–0.4 g/cm^3 surfaced at a depth of 50–80 cm of the redistribution of the clay fraction. The density of the solid phase is the most stable, with a slight enhancement by 0.09–-0.06 g/cm^3 in the humus horizon (decrease in humus and removal of the clay fraction) and somewhat more in the horizon of the irrigation eluviation by 0.06–0.1 g/cm^3. Decline in the reserves of productive moisture in the tilled layer by the period of increased leaf growth to 20 mm, the plant's use of nutrients becomes hard, decreasing the efficiency of mineral fertilizer use (Grigorieva and Zubchenko*,* 1973).

On ordinary chernozems of the Kuban, under the influence of four-year irrigation, the soil density increased in the upper layer (0–10 cm) by 0.06 g/cm^3 and reached 1.40 g/cm^3 at a depth of 50 cm. The same trend was also expressed in the long-term irrigated area (14 years). Compaction often occurs in the first few years of irrigation and later does not increase but gradually stabilizes (Pinchuk *et al*., 2017; Papish *et al*., 2016). In ordinary chernozems of the steppe Trans-Urals, long-term irrigation (14–15 years) led to the compaction of arable and sub-arable horizons. At the same time, its maximum value at a depth of 60–70 cm reached 1.51 g/cm^3 (Suyundukov, 1995, 2001). It was also long-established that the longer the irrigation period, the more compacted the arable horizon and the deeper this compaction manifests itself in the soil profile (Kukoba and Balyuk, 1983; Korolev *et al.,* 2012).

Thus, on the chernozems of Southern Right-Bank Ukraine on the Lower Dniester irrigation system, where irrigation has flowed out for four years, the non-irrigated and irrigated soils revealed a significant difference for the bulk density at a depth of 30–40 cm (Poznyak and Turus, 1975). With eight-year irrigation, a reliable change in profile compaction can be traced to a depth of 60 cm and a decrease in porosity by 2.0%–2.2% in the upper horizons and by 4%–5% in the lower ones. The utmost decrease in porosity occurs at a depth of 40–70 cm, which is consistent with the results of the soil granulometric composition, indicating the maximum content of silt particles at the same depth (Suyundukov, 1995, 2001). Sugar beet responds to practices that contribute optimal indicators of soil density, making more demands on soil aeration (Uvarov *et al*., 2006).

Sugar beet is a principal crop and plays a vital role in the economy of 52 countries in temperate zones, particularly in Central and South Europe (Stevanato *et al.,* 2019). However, in many regions, sugar beet production became increasingly challenging. A report stated there is an increased requirement for water in Europe for cultivating sugar beet (Shrestha *et al.,* 2010; Supit *et al.,* 2010). This demand will likely intensify more with climate change and global warming (Gornall *et al.,* 2010; Mirzaev *et al.,* 2019). This crop's ability to store a lot of sucrose in its roots emphasizes its importance for agriculture (Choluj *et al*., 2004; Bouras *et al.,* 2021). Sugar beet is a source to produce sugar (McGrath and Townsend, 2015). It has uses in many different production processes, and although not primarily used as a source of sucrose, it has relatively diverse uses (Mall *et al.,* 2021). According to FAO (2022) report, the world's sugar beet production reached approximately 253 million tons. The latest study aimed to elucidate the effects of irrigation and mineral fertilizers on the physical properties of light chestnut soil used in sugar beet (*B. vulgaris* L.) cultivation.

MATERIALS AND METHODS

Material

The research on sugar beet took place in 2021 at the Kazakh Research Institute of Agriculture and Plant Growing, District Karasai, Almaty region, Kazakhstan. The territory used the Southern part of the Southeastern region for experimental purposes. Cultivation of sugar beet hybrid (obtained from domestic selection 'Aksu' and foreign selection 'Yampol') received four mineral fertilizers, i.e., 0:0:0 (control), 90:90:60, 120:120:90, and 150:150:120 NPK kg ha^{-1}. The fertilizers used in the experiment consisted of ammonium nitrate, ammophos, and potassium chloride. The experiment used plots of 620 m^2 with three replications. The placement of options was systematic, i.e., single-tier plot placement.

The experimental field soil composition is as follows: light chestnut, medium-thick, low-humus, and medium-loamy granulometric, with a slight predominance of coarse dust and silt fractions. The structure of the arable layer was lumpy-granular. The content of structural units (> 0.25) was 10%–30%, determined according to the method of Savvinov and Filippova (1940). In the irrigated areas, the content of humus in the upper layer (0–30 cm) was 1.91%–2.4% according to Tyurin (1939), alkaline hydrolyzable nitrogen % according to Kornfield (1938), mobile phosphorus and exchangeable potassium according to B.P. Machigin, respectively at 11–19 mg kg^{-1} and 230–275 mg kg^{-1} of soil, pH (7.9–8.4), the sum of exchangeable bases of soil (12–14 meq/100 g), carbonates represented by calcium (12.0 mg.-eq.), as well as, magnesium with a lesser extent (2.5 mg.-eq). The total nitrogen, phosphorus, and potassium contents in the soil were 0.15%, 0.21%, and 1.67%, respectively.

Methods

Agrophysical studies proceeded in the Laboratory of Soil Science and Agro-Chemistry according to generally accepted methods, i.e., moisture availability - according to A.F. Vadyunina and Z.M. Korchagina (GOST 28268-89), soil density - according to A.N. Kachinsky (GOST 27593-88), and structural-aggregate composition - with a sieve analyzer, (GOST 27593-88). Statistical analysis, including analysis of the variance of the recorded data, employed the method of Dospekhov (1984).

In the germination phases, closing of leaves in rows and before the sugar beet harvesting, the soil samples were taken from a depth of 0–100 cm in various layers, 0–10, 10–20, 20–30, 30–40, 40–50, 50–60, 60–70, 70–80, 80–90, and 90–100 cm. The obtained results established the dynamics of productive moisture reserves during the growing season of sugar beet. In the above phases of the sugar beet vegetation, the acquired soil samples used cutting cylinders to a depth of 0–30 cm in layers of 0–10, 10–0, and 20–30 cm to determine the volumetric mass of the soil. Determining the variation in the soil density during the vegetative season of the crop ensued. Soil structure, considered a less dynamic indicator than productive moisture, received an evaluation in two terms. In the germination phase and before harvesting the sugar beet, acquiring soil samples from a depth of 0–30 cm in layers of 0–10, 10–20, and 20–30 cm determined the structural and aggregate composition of the soil. It established the dynamics of the content of agronomically valuable and water-stable aggregates in the growing sugar beet period.

RESULTS AND DISCUSSION

Soil moisture

Soil moisture is the main requirement and condition for the continuity of life of higher plants. It is involved and has a vital role in the movement of various substances within the soil profile, with genetic soil horizons isolated and some elements even removed from the soil profile. The physical properties of the soil largely depend on the state of soil moisture (Ivanov and Banov, 2020; Harutyunyan *et al.,* 2022). As observed, irrigation had a higher effect on the moisture content of the soil. However, to a lesser extent affected the fertilization level. Thus, the noted highest reserves of productive moisture in the arable soil layer (0–20 cm) in the sugar beet shoots phase resulted from cultivation with extensive technology, i.e., the level of fertilization had the lowest effect on soil moisture. Mineral fertilizers did not differ significantly for the values of this indicator and varied in the range of 26.4–31.1 mm. In the deep soil layers of 0–40 and 0–100 cm, a different trend surfaced with a significant difference in the indicators of productive moisture. Except for the 0–20 cm depth, increasing the rates of fertilizer resulted in greater levels of soil moisture in the soil profile (Table 1).

At the row-closing phase in sugar beet, soil moisture reserves gained enhancement after irrigation to a depth of one meter. In the 0–20 cm soil layer, the advantage of the technology without fertilizers in comparison with the technology with mineral fertilizers in terms of moisture content remained and was higher by 3.3–6.9 mm. On the contrary, in the subsurface and meter soil layers, the moisture content was higher by 9.6–14.9 mm in technology with mineral fertilizers than without fertilizers. During summer, the sugar beet used large amounts of water so that at harvesting time, the moisture content in the soil decreased, showing the difference in the reserves of productive moisture under sugar beet that remained, with slightly lower moisture reserves observed with the use of mineral fertilizers (118.1–121.6 mm) compared with the technology with no fertilizers used (124.3 mm) (Table 1).

Soil density

In the spring season of sugar beet, observations on the seedling phase revealed that the lowest soil density occurred in the soil layers 0–10, 10–20, and 20–30 cm with extensive technology (Table 2). In technology with mineral fertilizers, an increase of 0.01–0.04 g/cm^3 emerged in the soil density. In summer, at the row-closing phase and after irrigation, the soil density sharply increased in all technologies with and without fertilizers ranging from 1.22–1.37 g/cm^3. In the technology without the use of fertilizers compared with intensive technologies, the soil density increased in the layers 0–10, 10–20, and 20–30 cm, by 0.03–0.06, 0.01–0.04, and 0.01–0.05 g/cm^3, respectively. An increase in soil density occurred during the transition in the 0–10 to 10–20 cm soil layers, with little change reported in the soil layer of 20–30 cm in the above technologies (Khitrov *et al.,* 2019; Lebbos, 2021).

During the sugar beet harvesting period, in technology without fertilizers and with a mineral fertilizer system, the increase in soil density was even more noticeable and went beyond the optimal (1.31–1.48 g/cm^3). In extensive technology, the high indicators of soil density remained by the end of the growing season, and in technology with mineral fertilizers, the values of these indicators were lower. In technologies without

Table 1. Influence of irrigation and mineral fertilizer systems on the dynamics of productive moisture content in soil layers in extensive and intensive technologies of sugar beet cultivation (mm).

Mineral fertilizer system	Terms of definition								
	Seedling phase			The closing phase of leaves in rows			Before harvesting		
	Soil layers (cm)								
	0-20	0-40	0-100	0-20	0-40	0-100	0-20	0-40	0-100
Extensive - No fertilizer	33.2	55.8	158.7	51.5	84.6	213.2	24.9	54.8	124.3
Mineral - 90:90:60 NPK	27.9	60.9	173.4	48.2	75.0	205.7	22.1	52.4	121.6
Mineral - 120:120:90 NPK	26.4	67.2	185.7	46.1	72.8	197.4	20.7	51.9	119.5
Mineral - 150:150:120 NPK	31.1	72.1	186.8	44.6	69.7	188.5	19.2	49.6	118.1
NSR05 (Smallest difference between averages)	6.5	13.4	26.1	7.1	11.9	20.9	6.6	6.1	6.8

Table 2. The influence of irrigation and mineral fertilizer systems on the dynamics of the density of the addition of soil layers in extensive and intensive technologies for the cultivation of sugar beet (g/cm^3).

Mineral fertilizer system	Terms of definition								
	Seedling phase			The closing phase of leaves in rows			Before harvesting		
	Soil layers (cm)								
	0-10	10-20	20-30	0-10	10-20	20-30	0-10	10-20	20-30
Extensive - No fertilizer	1.14	1.17	1.23	1.28	1.37	1.31	1.37	1.41	1.48
Mineral - 90:90:60 NPK	1.16	1.18	1.26	1.23	1.34	1.30	1.34	1.40	1.46
Mineral - 120:120:90 NPK	1.15	1.19	1.24	1.25	1.36	1.29	1.31	1.40	1.43
Mineral - 150:150:120 NPK	1.15	1.21	1.27	1.22	1.32	1.30	1.32	1.39	1.46
NSR05 (Smallest difference between averages)	0.01	0.02	0.05	0.06	0.06	0.01	0.03	0.01	0.03

fertilizers, significant differences resulted in the soil density with a soil layer of 0--10 cm (0.03–0.06 g/cm^3), 10–20 cm (with less difference of 0.01–0.02 g/cm^3), and a slight difference in the soil layer of 20–30 cm (0.02–0.05 g/cm^3) (Table 2).

Soil structure

Soil structure is one of the most important indicators of the agrophysical characteristics of the soil profile. It has a greater influence on parameters, such as, water movement in the soil profile, heat transfer, aeration, density, and ultimately effective fertility (Bastaubayeva *et al*., 2022). This research also studied the structural-aggregate state of a 30 cm soil layer. In the sugar beet seedling phase, the content of agronomically valuable aggregates of the upper, middle, and lower soil layers in the technology without the use of fertilizers were slightly higher than in the technology using mineral fertilizers by 0.8%–2.9%, 0.7%–3.0%, and 0.9%–3.2%, respectively. At a depth of 10–20 cm, a decline in the value of this indicator and a nonsignificant difference in extensive and intensive technologies occurred. In the lower soil layer (20–30 cm), the number of structural aggregates was the smallest in technology with fertilizers used (61.2%–63.5%) compared with the technology with no fertilizer.

The maximum values of such soil aggregates displayed in the upper soil layer (0–10 cm) without fertilization (66.2%). At the harvest period, the content of agronomically valuable aggregates was lower in technology without fertilizers (10.0%–15.7%) compared with the technology with mineral fertilizers (3.3%–13.1%). The structural-aggregate composition of the irrigated light chestnut soil in the soil layer of 0–30 cm undergoes significant changes, especially in the beginning years. The strength of aggregates was greater than 10 mm, while the content of fractions was less than 0.25 mm. The largest share of the macro-structure (0.25–10 mm) showed in the upper soil layer (0–10 cm) with all levels of fertilization (55.1%–57.9%). For the soil layer of 10–20 cm, a decrease transpired in the agronomically valuable fraction in technology without fertilizers (0.5%) and technology with mineral fertilizers (0.5%–2.1%). In general, the observations for both technologies showed a low number of structural aggregates in the soil layer of 20–30 cm relative to the soil layer of 10–20 cm (Table 3).

Table 3. Influence of irrigation and mineral fertilizer systems on the dynamics of the content of agronomically valuable aggregates in soil layers in extensive and intensive technologies of sugar beet cultivation (%).

Mineral fertilizer system	Terms of definition					
	Seedling phase			Before harvesting		
	Soil layer (cm)					
	0-10	10-20	20-30	0-10	10-20	20-30
Extensive - No fertilizer	66.2	65.5	64.4	54.4	53.9	50.5
Mineral - 90:90:60 NPK	65.4	64.8	63.5	56.6	56.1	54.7
Mineral - 120:120:90 NPK	63.3	62.5	61.2	57.9	55.8	52.3
Mineral - 150:150:120 NPK	64.9	63.6	62.1	55.1	54.2	52.4
NSR05 (Smallest difference between averages)	6.9	4.9	4.9	4.5	5.4	5.0

Table 4. Influence of irrigation and mineral fertilizer systems on the dynamics of the content of water-stable aggregates in soil layers in extensive and intensive technologies of sugar beet cultivation (%).

Mineral fertilizer system	Terms of definition					
	Seedling phase			Before harvesting		
	Soil layers (cm)					
	0-10	10-20	20-30	0-10	10-20	20-30
Extensive - No fertilizer	19.3	18.8	17.1	14.2	13.7	12.9
Mineral - 90:90:60 NPK	18.5	18.0	16.6	13.5	12.4	11.6
Mineral - 120:120:90 NPK	17.8	17.1	15.9	13.0	11.9	11.1
Mineral - 150:150:120 NPK	17.2	16.7	15.1	12.7	11.3	10.9
NSR05 (Smallest difference between averages)	2.5	2.5	2.8	2.2	2.9	2.4

In the present results, the different levels of mineral fertilizers have no significant impact on the water-stable aggregates of soil layers, i.e., 0–10, 10–20, and 20–30 cm. In the seedling phase, in the soil layers, the content of water-stable aggregates was the highest in the extensive technology compared with the intensive technology by 0.5%–2.1%. The highest content of water-stable aggregates emerged in the upper soil layer (0–10 cm) in both technologies but much higher with extensive technology (19.3%). A decrease in the number of water-stable aggregates by 0.5% and 0.5%–0.7% was manifested in technology without mineral fertilizer with the transition from a soil layer of 0–10 cm to a layer of 10–20 cm. A similar trend resulted for the soil layer of 20–30 cm, where the content of water-stable aggregates in technology with mineral fertilizers decreased by 1.2%–1.6%. Likewise, technology without mineral fertilizers had a decrease in the soil by 1.7%.

The latest results also revealed that irrigation reduced the water-stable aggregates. Before harvesting of sugar beet, the content of water-stable aggregates decreased in technology without fertilizers and in technology with mineral fertilizers in a soil layer of 0–10 cm (by 5.1% and 4.5%–5.0%), 10–20 cm (by 4.1% and 5.2%–5.6%), and in a soil layer of 20–30 cm (by 4.2% and 4.2%–5.0%). At the same time, the advantage of extensive technology in the content of water-stable aggregates remained in comparison with intensive technology. Notably, the regularity of the decrease in the number of water-stable aggregates in the soil layers of 10–20 and 20–30 cm relative to the upper layer remained and amounted to 0.5% and 1.3%, respectively, in technology without fertilizers, and 1.1%–1.4% and 1.8%–1.9% in technology with fertilizers (Table 4).

The conduct of a correlation-regression analysis of the dependence of productive moisture in the soil under sugar beet sowing on the dynamics of soil density and the content of agronomically valuable aggregates and water-stable aggregates in the germination phase and before harvesting the crop established the average correlation relationships under irrigated conditions.

The parameters determined for the germination phase were:

$$a, b_1, b_2, \text{ and } b_3$$

Where,

b_1 = 177.81

b_2 = -2.22

b_3=-2.7

$a = \bar{y} - b_1 \bar{x} - b_2 \bar{z} - b_3 \bar{c}$ =176,15−177,81*1,19+2,22*63,9+2,7*17,32=362,65

Before harvesting:

b_1 = 19.61
b_2 = -0.69
b_3 = 2.1
$a = \overline{y} - b_1\overline{x} + b_2\overline{z} - b_3\overline{c}$ =120,87−19,61*1,39+ 0,69*54,47-2,1*12,5=104,95

Where,
a - argument
b_1 - is the coefficient of soil density
b_2 - is the coefficient of agronomically valuable aggregates
b_3 - is the coefficient of water-stable aggregates
$\overline{y}$ – is the arithmetic mean of productive moisture,
$\overline{x}$ – is the arithmetic mean of soil density,
$\overline{z}$ – is the arithmetic mean of agronomically valuable aggregates,
$\overline{c}$ – is the arithmetic mean of water – stable aggregates.

Regression equations for the germination phase were compiled:

$$Y = 362.65 + 177.81X - 2.22Z - 2.7C$$

Before harvesting beets:

$$Y = 104.95 + 19.61X - 0.69Z + 2.1C$$

Where,
Y is productive moisture in the soil under sugar beet sowing (mm)
X - is the soil density value (g/cm3); content (%)
Z - is an agronomically valuable aggregate
C - is the water-stable aggregates

Thus, an average positive relationship between productive moisture and soil density resulted, and at the same time, noting a tendency for a decrease in the closeness of this relationship from the germination phase to the harvesting of sugar beets: from 0.48 to 0.30. The significance of productive moisture lies in the fact that many properties that determine the soil fertility level depend on it, including agronomically valuable and water-stable aggregates. Statistical analysis proceeded according to Dospekhov (1984). An average negative correlation stemmed between agronomically valuable aggregates of the 0–30 cm layer and productive moisture. However, for the germination phase, the correlation coefficient (r) was -0.44 and decreased at the end of irrigation before the sugar beet harvest (-0.37).

Amid the content of productive moisture and water-stable aggregates in the seedling phase, an inverse relationship appeared: An increase in productive moisture materialized with a decrease in water-stable aggregates (r = −0.40). At the end of irrigation, a positive average correlation between these traits came about (r = 0.64) (Table 5).

Table 5. Correlation coefficients of productive moisture with the physical properties of the soil.

Productive moisture, soil layers (cm)	Density	Agronomically valuable aggregates	Water resistant aggregates
Phase shoots 0–100	0.48	− 0.44	− 0.40
Before harvest 0–100	0.30	− 0.37	0.64

CONCLUSIONS

The noted maximum reserves of productive moisture in the meter soil layer occurred in the row-closing phase of sugar beet after irrigation in technology without fertilizers (213.2 mm). The soil moisture content at crop harvesting in the fertilizer treatments was lower by 2.7–6.2 mm than with the extensive technology. During the growing season of sugar beet, an increase in soil density showed, reaching the highest values of this indicator by harvesting in technology without fertilizer and in technology with mineral fertilizers, in a soil layer of 0–10 cm (1.37 and 1.31–1.34 g/cm^3), 10–20 cm (1.41 and 1.39–1.40 g/cm^3), and 20–30 cm (1.48 and 1.43–1.46 g/cm^3). From sugar beet germination to the harvesting phase, a decrease in the content of agronomically valuable aggregates in the soil under the influence of irrigation in technology without fertilizers emerged by 15.6%–21.6% and in intensive technology by 11.5%–14.6%. In the soil, the noted highest content of water-stable aggregates appeared during the resumption of the vegetation of sugar beet in technology without fertilizers (17.1%–19.3%) and was higher than the technology with fertilizers (0.5%–2.1%). By harvest time, the amount of these aggregates decreased by 4.2%–5.1% in the technology without fertilizers and by 4.2%–5.6% in the technology with mineral fertilizers due to irrigation.

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