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BIOGEOCHEMISTRY OF MANGANESE (Mn) IN SOILS OF THE ZARAFSHAN VALLEY

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Annotation. This study examines the influence of soil properties – such as humus content, pH, nutrient content, and granulometric composition – on the trace element manganese in the soils of the Zarafshan Valley. The primary objective is to explore the quantitative and qualitative changes in manganese levels in soil and to analyze the correlations between manganese and key soil characteristics. Samples were collected from the arable layer of 17 sections along the Zarafshan River, spanning from the Jomboy district to the Olot district. A total of 3-7 replicate samples were analyzed. The data analysis employed various statistical models, including linear, inverse, parabolic, and hyperbolic relationships, to examine the correlation between manganese and the soil indicators. The analysis revealed a linear relationship between assimilable manganese and most soil indicators, with the strongest correlation ($r > 0.7$) observed between granulometric composition, pH, and water-soluble boron (B). The relationship between mobile phosphorus and manganese was hyperbolic, with phosphorus levels up to 25-26 mg/kg positively affecting manganese, while higher levels had a negative impact.

Key words: available manganese, coefficient of correlations, coefficient of migration, soil environment, total manganese.

Аннотация. В данном исследовании изучается влияние свойств почвы, таких как содержание гумуса, pH, содержание питательных веществ и гранулометрический состав, на содержание микроэлемента марганца в почвах долины реки Зарафшан. Основная цель – изучить количественные и качественные изменения уровня марганеца в почве и проанализировать корреляции между марганцем и ключевыми характеристиками почвы. Образцы были отобраны из пахотного и падпахотного слоя 17 участков вдоль реки Зарафшан, охватывающих районы от Джамбай до Алат. Всего было проанализировано 3-7 повторных образцов. При анализе данных использовались различные статистические модели, включая линейные, обратные, параболические и гиперболические зависимости, для изучения корреляции между марганецом и показателями почвы. Анализ выявил линейную зависимость между усвояемым марганцем и большинством показателей почвы, при этом наиболее сильная корреляция ($r>0,7$) наблюдалась между гранулометрическим составом, pH и водорастворимым бором (B). Зависимость между подвижным фосфором и марганцем

имела гиперболический характер: уровни фосфора до 25-26 мг/кг оказывали положительное влияние на марганец, а более высокие уровни оказывали отрицательное воздействие.

Ключевые слова: доступный марганец, коэффициент корреляции, коэффициент миграции, почвенная среда, общий марганец.

Annotatsiya: Ushbu tadqiqot Zarafshon vodiysi tuproqlaridagi gumus miqdori, pH, ozuqa moddalar miqdori va granulometrik tarkib singari tuproq xususiyatlarining marganets mikroelementi tarkibiga ta'sirini o'rganadi. Asosiy maqsad tuproqdagi marganetsning miqdor va sifat o'zgarishlarini o'rganish, marganets va tuproqning asosiy xususiyatlari o'rtasidagi bog'liqlikni tahlil qilishdir. Zarafshon daryosi bo'yidagi Jomboydan Olotgacha bo'lgan hududlarni qamrab olgan 17 ta tuproq kesmasining ustki ostki qatlamidan namunalar olindi. Jami 3-7 ta takroriy namunalar tahlil qilindi. Ma'lumotlar tahlilida marganets va tuproq xususiyatlari o'rtasidagi bog'liqlikni tekshirish uchun turli xil statistik modellar, jumladan chiziqli, teskari, parabola va giperbola tahlillari ishlatilgan. Tahlil o'zlashtiriluvchan marganets va tuproq xususiyatlarining ko'pchiligi o'rtasida chiziqli bog'liqlik aniqlandi, eng kuchli korrelyatsiya (r>0,7) granulometrik tarkib, pH va suvda eruvchan bor (B) o'rtasida kuzatildi. Harakatchan fosfor va marganets o'rtasidagi munosabatlar giperbola ko'rinishida: 25-26 mg/kg gacha bo'lgan fosfor darajasi marganetsga ijobiy ta'sir ko'rsatdi, yuqori daraja esa salbiy ta'sir ko'rsatdi.

Kalit so'zlar: o'zlashtiriluvchan marganets, korrelyatsiya koeffitsienti, migratsiya koeffitsienti, tuproq muhiti, yalpi marganets.

Introduction

Microelements participate in important biological functions in the structure of a living organism and perform specific tasks in vital processes. Microelements act as components of biologically active substances - proteins, enzymes [32; p. 285-299].

If enzymes are considered catalysts, then microelements can be called catalysts of catalysts [42; p. 720].

Microelements are directly involved in various metabolisms in plants, including respiration, photosynthesis, protein, carbohydrate, and other metabolism [52; p. 464-482], and oxidation-reduction processes in the soil [58; p. 483-494].

Therefore, when applied to the soil as fertilizer, they not only increase crop yields, but also improve their quality, and also accelerate the formation of crop branches, budding, flowering, and early ripening of the crop [56; p. 8-14].

Microelements accelerate plant development, germination and crop formation, carbohydrate synthesis and movement, and protein and fat metabolism [18; p. 4-7].

Due to metabolic disorders caused by a deficiency or excess of micro-elements, humans, animals, and plants are subject to specific diseases [54; p. 57].

Micronutrient deficiencies cause defects in the growth and development of agricultural crops, delaying their development, reducing their resistance to adverse conditions (low or high temperatures, drought, etc.), and increasing their susceptibility to diseases and pests [36; 5-22., 14; 72-73].

It has been established that the main patterns of microelement distribution depend on the geomorphological characteristics of the area, the mineralogical and granulometric composition of the soil, and in addition, the amount of microelements depends on the agrochemical properties of the soil and the absorption complex [8; p. 81].

Manganese (Mn) is an important micronutrient for plant growth and development in metabolic processes in a plant cell. Mn is one of the most abundant metals in soil and comprises about 0.1 % of the Earth's crust [4; p. 1-40].

The mobility of manganese increases from soils with an alkaline reaction to neutral and further to acidic soils [2; p. 300., 9; p. 196-208., 53; p. 397-409]. Its solubility depends on soil redox condition,

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pH, organic matter, clay fraction etc. Solubility of Mn in soils generally decreases with the increasing pH due to adsorption-precipitation, i.e., oxidation-reduction reactions [53; p. 397-409]. Although Mn belongs to the class of low toxicity for soil living organisms [49; p. 3-24], an excess of available manganese in the soil can lead to its actual and potential toxicity to plants, while an increase in soil pH due to liming can lead to Mn unavailability to plants [2; p. 300].

The amount of mobile manganese in the soil and its assimilation depend on the amount of humus [3; p. 487-495., 7; p. 34], the composition of the parent rock from which the soil is formed [9; p. 196-208., 53; p. 397-409., 58; p. 483-494., 61; p. 199-206], the granulometric composition of the soil [2; p. 300., 46; p. 254., 58; p. 483-494., 62; p. 1170-1178], the level of its supply with microelements [2; p. 300., 10; p. 2006-2020], the oxidation-reduction conditions in the soil [15; p. 23-35., 17; p. 56., 31; p. 45., 33; p. 135-144., 41; 470-481., 47; p. 120., 58; p. 483-494], environmental reaction [15; p. 23-35., 31; p. 45., 41; p. 470-481., 47; p. 120., 57; p. 367-373., 58; p. 483-494], in addition, the amount and rate of mineral and organic fertilizers used [11; p. 125-136., 12; p. 904-917., 20; p. 634-640., 40; p. 1075-1076] has been confirmed in a number of scientific studies.

Manganese is not found free in nature. It is a component of many minerals. The most common of them are pyrolusite – MnO_2, psilomelane – $mMn*MnO_2*nH_2O$, braunite – $3Mn_2O_3*MnSiO_3$, manganite – $Mn_2O_3*H_2O$, gaussmanite – Mn_3O_4, rhodochrosite – $MnCO_3$, vernadite – MnO_2*H_2O, rhodonite – $MnSiO_3$, etc. In addition, manganese is a component of about 150 compounds – sulfides, oxides, carbonates, silicates, borates, sulfates, especially phosphates [62; p. 1170-1178., 65; p. 352].

Manganese is involved in soil formation, in particular, in the synthesis of humus, the formation of clays, the process of gleying, and the formation of illuvial layers. Another characteristic feature of manganese is its relatively greater accumulation in layers rich in iron [61; 199-206., 65; p. 352].

Manganese can change its valence from Mn^{2+} to Mn^{4+} depending on environmental conditions [5; p. 14-38].

In the deep layers of the soil, manganese is present as the Mn^{2+} ion in the form of isomorphic mixtures with aluminosilicates, ferrosilicates, etc. In the oxidized region, it occurs mainly in the form of Mn^{4+} [5; p. 14-38., 27; p. 252., 63; p. 663-675].

Mn^{2+} is very mobile in the soil, has a strong migratory property, and is present in an assimilable form (water-soluble and exchangeable). In a weakly alkaline environment, Mn2+ is oxidized, initially forming Mn^{3+}, Mn^{4+}. The dynamics and migration of the compounds depend on the solubility of its compounds, which, depending on the pH of the soil solution, is associated with their hydration process, oxidation-reduction conditions, and oxidation rate [5; p. 14-38., 19; p. 423-426., 27; p. 252.,).

In the water table zone of hydromorphic soils and slightly above it, in oxygen barriers, manganese is oxidized and precipitates in the form of black colloidal minerals, i.e. pyrolusite, psilomelane, manganite [65; p. 352]. These precipitates are observed in layers of 85-130 cm and, in their turn, act as a sorption barrier for Cu, Zn, and other microelements, causing their accumulation in this layer.

In anaerobic and acidic environments, manganese solubility increases sharply. In weakly acidic and neutral environments, some microorganisms oxidize manganese. Under anaerobic conditions, some bacteria use manganese (II) oxide as an oxygen source [13; p. 17-20]. As a result of the death and mineralization of microorganisms, Mn in their residues is converted back to Mn^{2+} in a form that is available to plants. In the conversion of Mn^{4+} to Mn^{2+}

in the soil, reduction processes should prevail over oxidation in the soil, which increases the amount of organic matter and increases the activity of micro-organisms. The greatest accumulation of Mn^{2+} in the upper soil layer is associated with its "rising" from somewhat deeper layers upward through the root system (especially legumes and woody plants) [27; p. 252., 58; p. 483-494., 59; p. 285-308].

The exchangeable, reduced, and water-soluble forms of manganese in the soil change throughout the growing season. When the soil is heavily saturated with moisture, water-soluble and exchangeable manganese increases. Changes in the reaction of the environment in the soil change the soil microflora, as well as moisture and air permeability. All this affects the oxidation-reduction process, which determines the amount of available and mobile forms of manganese in the soil [35; p. 195-203].

Manganese fixation is very rapid in the gray soil region. When water-soluble manganese ($MnSO_4$, $KMnO_4$) is applied to the soil, it quickly converts to the water-insoluble MnO_2 form within the second day. In gray soils, the pyrolusite-MnO_2 form constitutes 50-95% of the total manganese [16; 399-407., 48; p. 100].

An important factor determining manganese migration in soil under irrigated farming conditions is irrigation water, which contains CO_2 and manganese up to 0.2 mg/l, and which ensures high soil solubility [48; p. 100; 67; p. 759-770].

Manganese deficiency in plants is observed primarily in carbonate, strongly alkaline, and other soils with a pH above 6.5 [23; p. 38-44., 28; p. 4-6], since in this environment manganese is in the form of a poorly soluble compound [55; p. 552], in addition, manganese deficiency is usually observed in times of moisture deficiency, in drought years, and on light soils, primarily carbonate soils [34; p. 5-8].

In cases where manganese is deficient in the soil, the ratio of elements in the nutritional balance is disturbed, since it acts as an antagonist in the selective absorption of ions from the external environment, such as calcium. Manganese also plays an important role as an element regulating the process of reutilization [21; p. 15-19., 55; p. 552].

Manganese accumulates more in the humus layer of the soil and in illuvial horizons. The manganese content is much higher in hydromorphic soils of Central Asia. Manganese is less mobile in alkaline and carbonate soils [64; p. 572], and manganese deficiency is especially pronounced in soils with a high content of soluble iron compounds [55; p. 552].

It has been found that the most available manganese accumulates in the 0-40 cm layer of alluvial swamp soils with a medium loamy granulometric composition and accounts for 89-72% of the total amount [31; p. 45., 44; p. 40-49].

Plants absorb not only water-soluble and exchangeable Mn, but also secondary carbonate compounds of manganese, newly precipitated hydroxides, and various other compounds [27; p. 252., 65; p. 352].

According to A.A.Karimberdiyeva [22; p. 123-124], who conducted experiments on gray soils of Uzbekistan, the total manganese content depends on the degree of hydromorphism of the soil. In typical gray soils with old irrigation, its content varies from 517 to 618 mg/kg along the soil profile, while in old irrigation meadow soils it fluctuates from 578 to 687 mg/kg. It was found that the amount of available manganese is much higher than the permissible amount and in both soils its content is about 23% of the total content. It was also noted that manganese accumulates in the lower layers.

According to S.K.Rasulov [51; p. 125-128], the soils of the Zarafshan oasis contain manganese-405; copper-21; zinc-2; and cobalt-9 mg/kg.

In the light gray soils of the Samarkand oasis, the total manganese

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content was found to be in the range of 1100.0-1450.0 mg/kg, and the available manganese content was 189.6-400.2 mg/kg. Manganese was unevenly distributed in the examined soil profile, and its highest content was found to be in the upper, i.e. humus-containing accumulative layer and depended on the parent soil type [24; p. 101-102].

The total amount of manganese in the granulometric composition of typical gray soils increases according to the law, depending on their dispersion. It is the lowest in the fine sand fraction, 2-3 times higher in the medium dust fraction and 7 times higher in the clay fraction, amounting to 1000-1570 mg/kg [50; p. 105-106].

Carbonate soils are deficient in available manganese [45; p. 179], and in irrigated cotton-growing regions, its content of 80-100 mg/kg ensures optimal growth and development of cotton [27; p. 252., 42; p. 720].

The area of Uzbek soils lacking manganese is 250-280 thousand hectares [43; p. 29].

MATERIALS AND METHODS

The Zarafshan Valley is characterized by a wide variety of natural and geographical conditions. The natural and geographical conditions and soil properties of the valley have been described in detail in a number of works [25; p. 9., 26; p. 288., 29; p. 351., `66; p. 237-238].

The Zarafshan Valley is mainly composed of Tertiary sedimentary rocks overlain by Quaternary alluvial rocks. Soil formation in the valley occurred in Quaternary rocks. Based on their genesis, the rocks are divided into loess, alluvial, proluvial, and alluvial-proluvial deposits [30; p. 45.

The Zarafshan Valley is divided into two sharply different landscape and geographical regions according to its natural conditions. The first is the eastern part - foothills, steppes and loess plains, the second is the western part - desert. They differ sharply according to their hydrogeological and land reclamation conditions. The soils of the Samarkand oasis belong to the first region, and the soils of the Bukhara and Karakul oases belong to the second region. In addition, the Zarafshan Valley is divided into four geomorphological regions, which differ significantly in the structure of the relief and the nature of the Quaternary deposits: 1) Samarkand Basin, 2) Bukhara subaerial delta, 3) Karakul subaerial delta, 4) Navoi-Kanimekh oasis [1; p. 5-11].

In conclusion, the Zarafshan Valley has a complex geological and geomorphological structure, various soil covers, and consists of mountainous, hilly, foothill and desert plains. Accordingly, the humus content of the Zarafshan Valley soils is affected by their cultural development, soil formation conditions, etc., while the height of the oases above sea level and the drainage of surface waters have an impact on the pH.

In the research, to study the effect of the humus content, pH, nutrient content, and granulometric composition of the Zarafshan Valley soils on the quantitative and qualitative changes in microelements, 3-7 replicate samples were taken from the plow layer of the main soil types and subtypes distributed along the Zarafshan River (from Jomboy district to Olot district, a total of 17 soil pit (profile) and analyzed (Table 1). Fieldwork was carried out on an expedition route along the base plots characterizing the irrigated soil type. Soil samples were taken by tillage, subsoil, and parent rock. Humus, pH, mobile phosphorus, exchangeable potassium, and manganese (Mn) were determined for agrochemical characterization of the soils.

In the studies, total manganese was determined according to E.K.Kruglova [39; p. 440]. The total manganese (Mn) content in the topsoil of the studied soils was compared with the content of the standard sample SP-1 (590 mg/kg) in Kursk black soils, which was taken as a standard. Available manganese was determined

using a Shimadzu AA-7000 atomic absorption spectrophotometer.

In the experiment, agrochemical and agrophysical analyses were performed using the following methodological manuals: "Methods of agrochemical, agrophysical and microbiological studies in cotton fields [39; p. 440]", "Methods of agrochemical studies [37; p. 336]", "Methods for determining macro and micro-elements in plants, soil and water [38; p. 91]". In the experiment, the granulometric composition of the soil was determined according to N.A.Kachinsky [39; p. 440].

Agrochemical analyses included humus (%) according to I.V.Tyurin; total nitrogen, phosphorus, and potassium (%) according to I.M.Malsyev, L.P.Gritsenko; mobile phosphorus (mg/kg) according to B.P.Machygin, exchangeable potassium (mg/kg) according to P.V.Protasov, and soil pH determined using an Anion-7010 ionomer.

Table 1

Some agrochemical parameters of the soils of the Zarafshan Valley (arable)

Soil pit (profile)	Repetition	Humus, %	pH	P_2O_5, mg/kg	K_2O, mg/kg	Granulometric composition
1//31	4	1,25	7,4	26,3	228	Light-loam
2//32	3	1,07	7,3	26,4	218	Light-loam
3//29	3	1,25	7,3	27,2	235	Light-loam
4//32	7	1,16	7,2	22,3	223	Light-loam
5//31	3	0,98	7,2	20,8	220	Light-loam
6//34	4	1,31	7,4	27,8	194	Light-loam
7//16	5	1,28	7,4	25,7	224	Light-loam
8//16	3	1,18	7,3	26,7	240	Light-loam
9//33	3	1,26	7,5	28,1	218	Medium loam
10//38	5	1,09	7,4	23,8	214	Light-loam
11//15	3	1,19	7,5	26,5	220	Heavy loam
12//26	4	0,64	7,2	8,3	169	Light-loam
13//23	4	0,86	7,4	20,8	208	Medium loam
14//24	4	1,27	7,7	26,2	176	Heavy loam
15//30	5	1,21	7,5	25,6	213	Heavy loam
16//32	3	1,23	7,6	23,6	206	Heavy loam
17//33	3	1,21	7,7	24,5	168	Heavy loam

The soil pit (profile) is the same in tables and diagrams: 1/31- Jomboy district, meadow-serozem soil with stratum corneum; 2/32- Jomboy district, right bank of the Zarafshan River, 2 terrace, irrigated meadow alluvial; 3/29- Oqdarya district, meadow-serozem soil with matrix horizons; 4/32-Ishtikhan district, right bank of the Zarafshan River, 2 terrace, irrigated meadow alluvial; 5/31-Ishtikhan area irrigated meadow; 6/34-Payariksky area, meadow marsh, irrigated; 7/16-Payariksky district, right bank of the river Zarafshan, 3 terrace, irrigated typical serozem soil; 8/16-Pastdargom district, left bank of the river Zarafshan, 3 terrace, irrigated typical serozem soil; 9/33-Kattakurgan District, 2 terrace, irrigated meadow alluvial; 10/38-Narpay district, left bank of the river Zarafshan, 3 terrace, light serozem soil; 11/15-Navoiy district, irrigated meadow alluvial; 12/26-Kiziltepa district, newly irrigated brown-grassland; 13/23-Vobkent district, Bukhara upper delta, irrigated meadow takir; 14/24-Romitan district in the central part of the Bukhara delta, alluvial meadow; 15/30-Dzhandar area, the lower reaches of the Bukhara delta, alluvial meadow; 16/32-Karakul district, the upper part of the region Karakul delta, alluvial meadow; 17/33-Alat district, in the central part of the region, the meadow-alluvial soils

Statistical analysis of the experimental results was carried out according to B.A.Ushkarenko et al. [60; p. 33].

RESULTS AND DISCUSSION

In the arable layer of meadow-gray soils with a humus layer (Jomboy

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district, 1/31; Okdaryo district, 3/29- pit (profile)), the average content of total and available manganese was found to be slightly higher than the reference value. Its distribution along the profile varied, with the lowest content being in the humus layer (286.1 and 297.1; 43.33 and 41.67 mg/kg, respectively). There is no need to apply manganese fertilizers in these soils (Table 2).

Table 2

Distribution of Mn trace elements in soils of the Zarafshan Valley

Soil pit (profile)	Repetition	Profile	Mn, mg/kg									Km	
			totalw				available					total	available
			lim	x̄	$tS_{\bar{x}}$	$V,\%$	lim	x̄	$tS_{\bar{x}}$	$V,\%$	% of total		
1/31	4	*	622,3-812,5	710,3	82,98	11,68	56,3-169,5	112,28	50,12	44,64	15,81	1,37	1,36
		**	445,0-812,3	651,9	163,64	25,10	46,7-158,7	95,75	47,62	49,73	14,69		
		//	116,4-401,3	286,1	123,64	43,22	6,1-80,4	43,33	32,06	73,99	15,15		
		***	313,4-779,2	519,9	197,52	37,99	10,5-148,2	82,45	56,78	68,87	15,86		
2/32	3	*	565,2-648,8	606,5	41,81	6,89	97,3-122,8	110,17	12,75	11,57	18,16	0,95	0,74
		**	465,6-687,1	555,0	116,76	21,04	68,7-164,6	114,53	48,09	41,99	20,64		
		***	463,3-873,1	640,2	210,56	32,89	94,4-206,5	149,20	56,09	37,59	23,30		
3/29	3	*	612,5-801,2	708,5	94,39	13,32	53,6-146,8	102,10	46,72	45,76	14,41	1,40	1,46
		**	434,5-800,3	639,0	186,68	29,21	44,5-145,8	88,30	52,02	58,91	13,82		
		//	123,6-420,4	297,1	154,62	52,04	8,6-78,3	41,67	34,99	83,97	14,03		
		***	303,3-767,8	505,1	238,16	47,15	13,7-154,8	89,13	71,06	79,73	17,65		
4/32	7	*	564,3-648,6	605,3	32,81	5,42	96,5-123,4	110,47	10,22	9,25	18,25	0,98	0,69
		**	465,5-686,3	563,3	79,92	14,19	68,1-165,3	109,01	37,92	34,79	19,35		
		***	464,4-874,1	615,7	147,34	23,93	93,9-208,1	159,06	42,22	26,54	25,83		
5/31	3	*	490,8-547,7	522,2	28,92	5,54	72,2-109,6	89,70	18,82	20,98	17,18	1,04	1,00
		**	490,5-593,8	543,2	51,68	9,51	52,1-110,2	78,90	29,31	37,15	14,53		
		***	473,1-526,6	500,6	26,78	5,35	44,3-138,2	90,10	46,99	52,15	18,00		
6/34	4	*	623,7-815,6	725,6	86,38	11,90	63,2-195,4	125,15	59,40	47,46	17,25	1,32	0,99
		**	450,4-823,3	666,4	171,50	25,74	67,8-187,0	104,58	55,42	52,99	15,69		
		***	330,1-794,5	549,5	192,68	35,06	15,3-182,4	94,63	68,84	72,75	17,22		
7/16	5	*	498,1-656,3	576,6	69,13	11,99	75,9-90,7	82,92	5,81	7,01	14,38	1,02	0,86
		**	456,5-671,4	547,9	91,42	16,69	77,8-90,8	83,84	5,12	6,11	15,30		
		***	478,8-673,5	563,0	83,29	14,79	78,6-117,1	96,38	16,63	17,25	17,12		
8/16	3	*	497,7-655,6	566,5	80,88	14,28	76,2-90,8	84,17	7,39	8,78	14,86	1,02	0,88
		**	467,2-673,8	565,6	103,65	18,33	78,2-90,7	85,07	6,34	7,45	15,04		
		***	478,8-674,4	554,5	105,02	18,94	79,6-116,8	95,93	19,01	19,82	17,30		
9/33	3	*	604,9-684,8	644,4	39,96	6,20	101,7-132,1	113,43	16,34	14,41	17,60	1,03	0,67
		**	579,8-692,7	628,4	58,08	9,24	110,3-149,8	126,60	20,63	16,30	20,15		
		***	603,7-642,6	623,3	19,45	3,12	112,6-166,2	133,50	28,68	21,48	21,42		
10/38	5	*	550,6-666,8	606,0	45,84	7,56	82,2-97,4	90,76	6,54	7,21	14,98	0,94	1,04
		**	579,7-676,6	621,7	38,60	6,21	85,2-91,6	89,50	2,61	2,92	14,40		
		***	508,2-792,3	642,2	116,89	18,20	78,1-95,7	86,90	7,06	8,12	13,53		
11/15	3	*	881,7-922,4	902,1	20,35	2,26	134,3-173,2	154,38	19,48	12,62	17,11	1,22	0,73
		**	776,2-1077,3	945,1	153,86	16,28	168,2-191,6	178,83	11,84	6,62	18,92		
		***	632,7-882,4	737,7	129,51	17,56	187,8-246,3	212,77	30,18	14,18	28,84		
12/26	4	*	857,2-893,0	877,0	15,03	1,71	62,3-80,5	70,40	8,30	11,79	8,03	1,31	0,93
		**	744,5-782,4	764,8	15,65	2,05	60,8-78,4	68,30	8,14	11,92	8,93		
		***	655,6-686,7	669,9	15,28	2,28	67,2-86,4	75,93	7,97	10,50	11,33		
13/23	4	*	525,4-765,6	645,8	109,38	16,94	102,2-125,3	110,43	10,62	9,62	17,10	1,05	0,52
		**	486,7-632,4	556,7	71,97	12,93	135,1-182,3	157,23	22,92	14,58	28,24		
		***	527,8-697,8	613,9	80,72	13,15	194,2-233,1	211,35	16,11	7,62	34,43		

Soil pit (profile)	Repetition	Profile	Mn, mg/kg									Km	
			totalw				available					total	available
			lim	x̄	$tS_{\bar{x}}$	*V*,%	*lim*	x̄	$tS_{\bar{x}}$	*V*,%	% of total		
14/24	4	*	355,2-408,9	378,4	24,52	6,48	105,2-138,9	123,80	13,94	11,26	32,72	0,44	0,74
		**	584,5-701,3	643,9	58,13	9,03	96,4-123,3	109,28	12,36	11,31	16,97		
		***	765,3-905,6	859,1	63,66	7,41	157,3-186,7	168,05	13,19	7,85	19,56		
15/30	5	*	736,2-912,4	853,9	74,81	8,76	140,1-173,4	156,96	13,35	8,51	18,38	1,18	0,79
		**	673,3-1088,9	900,8	184,22	20,45	76,2-184,4	158,40	46,10	29,10	17,58		
		***	457,8-884,3	725,8	166,22	22,90	95,3-264,5	199,18	65,91	33,10	27,44		
16/32	3	*	577,8-768,9	657,4	99,48	15,13	190,3-212,3	200,13	11,18	5,59	30,44	1,08	2,06
		**	502,3-603,4	564,1	54,20	9,61	131,8-165,0	150,33	16,93	11,26	26,65		
		***	564,4-674,5	607,2	59,02	9,72	85,6-108,2	96,93	11,30	11,66	15,96		
17/33	3	*	344,2-390,1	370,3	23,60	6,37	178,9-220,8	194,63	22,82	11,72	52,56	0,36	2,59
		**	321,8-365,2	343,3	21,70	6,32	126,2-153,3	138,20	13,81	9,99	40,26		
		***	965,2-1114,7	1034,0	75,46	7,30	64,4-86,7	75,27	11,16	14,83	7,28		

It was found that the total manganese content in the arable layer of the 2nd terrace of the Zarafshon River (Jomboy district, 2/32; Ishtikhon district, pit (profile) 4/32) was at the reference level (606.5 and 605.3 mg/kg, respectively). Often, the parent rock here was characterized by a high level of total manganese. It was found that the manganese available to plants in the arable layer was slightly higher than the accepted standard (110.17 and 110.47 mg/kg, respectively), while it belonged to the highly supplied gradation. Irrigated swamp-meadow soils (Payariq district, pit (profile) 6/34) were found to be rich in available manganese, especially in the upper layer (125.15 mg/kg). The use of manganese microfertilizers in these soils is unnecessary.

Bioaccumulation of total manganese in the humus layer was not recorded. The only exceptions were the marshy-meadow soils of Payariq district (pit (profile) 6/34) and meadow-gray soils with a humus layer (Jomboy district, sections 1/31 and Akdaryo district, pit (profile) 3/29), where the migration coefficient Km=1.32-1.40.

The total manganese content in the plow layer of the typical gray soils of the left and right banks of the 3rd terrace of the Zarafshon River (Pastdargom district, section 7/16 and Payariq district, pit (profile) 8/16) with old irrigation, where the study was conducted, varies from 497.7 to 656.3 mg/kg. Its content was found to be 576.6 and 566.5 mg/kg, i.e. less than the reference value. This indicates that it depends on the granulometric composition of the soil, pH and other factors. In addition, in the soils of the automorphic soil region (pit (profile) 7/16; 8/16 and 10/38), the total manganese content fluctuates widely along the profile (456.5-729.3 mg/kg), which is characterized by its redox potential and drainage of leachate. It was noted that the available manganese in these soils is within the permissible level (82.92 and 84.17 mg/kg). It is advisable to conduct field experiments in this area in various directions to study the effectiveness of manganese fertilizers.

In the tilled layer of the old irrigated light gray soils of the 3rd terrace of the left bank of the Zarafshan River (Narpay district, pit (profile) 10/38), total manganese was found to be 550.6-666.8 mg/kg (average 606.0 mg/kg), which is at the level of the reference value (598 mg/kg) (Figure 1).

The content of available manganese in the arable layer was within the permissible limits and amounted to 14.98% of the total amount, the variation coefficient V=7.21%, i.e. the variability was insignificant. Therefore, it is not necessary

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to introduce manganese microfertilizers into the soil on these soils, they can be used for soaking seeds or foliar feeding.

The content of gross manganese in the arable horizon of old-irrigated meadow-alluvial soils (Karmana district, pit (profile) 11/15) and newly irrigated harsh-brown-meadow soils (Kyzyltepa district, pit (profile) 12/26) of the Navoi-Konimeks oasis was 881.7-922.4 (average 902.1 mg/kg) and 857.2-893.0 (average 877.0 mg/kg), respectively, which is higher than the standard value.

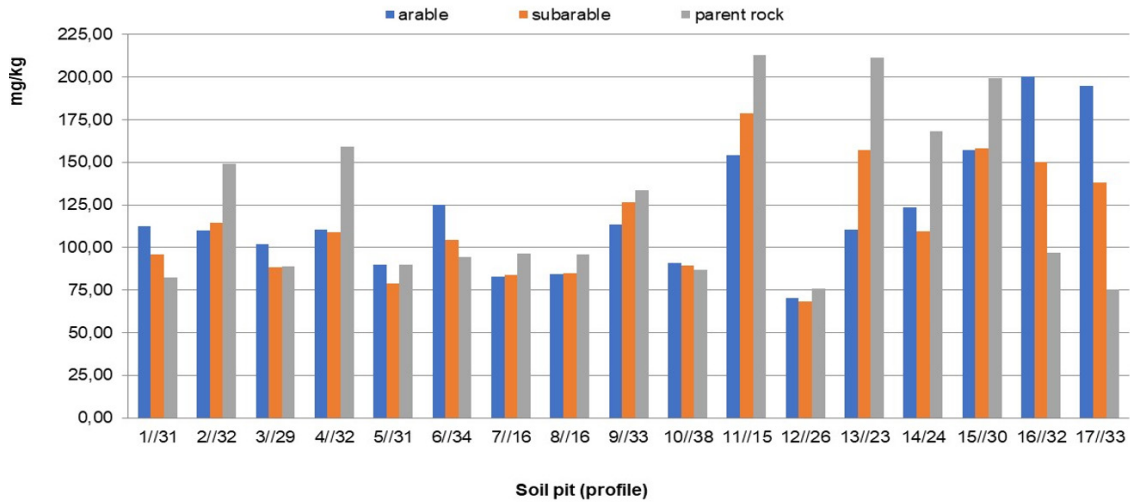


Figure 2. Amount of manganese in absorbable form in Zarafshan Valley soils

It was found that the available manganese in the arable layer of the old irrigated meadow alluvial soils of the Karmana district (pit (profile) 11/15) was 154.38 mg/kg, which is a very high supply group, and its content increased especially in the arable subsoil and parent rock, accounting for 28.84% of the total amount (Figure 2 and Table 2).

In the profile of the newly irrigated sur brown-meadow soils of the Kyzyltepa district (pit (profile) 12/26), it was found that the amount of available manganese is lower than in the studied soil types, subtypes and the permissible amount in the Zarafshan valley, its amount in the till layer is 70.40 mg/kg or only 8.03% of the total amount. This is probably due to the low content of humus (0.64%) and boron (0.39 mg/kg), the presence of gypsum in the soil composition, and the fact that the soil is newly irrigated

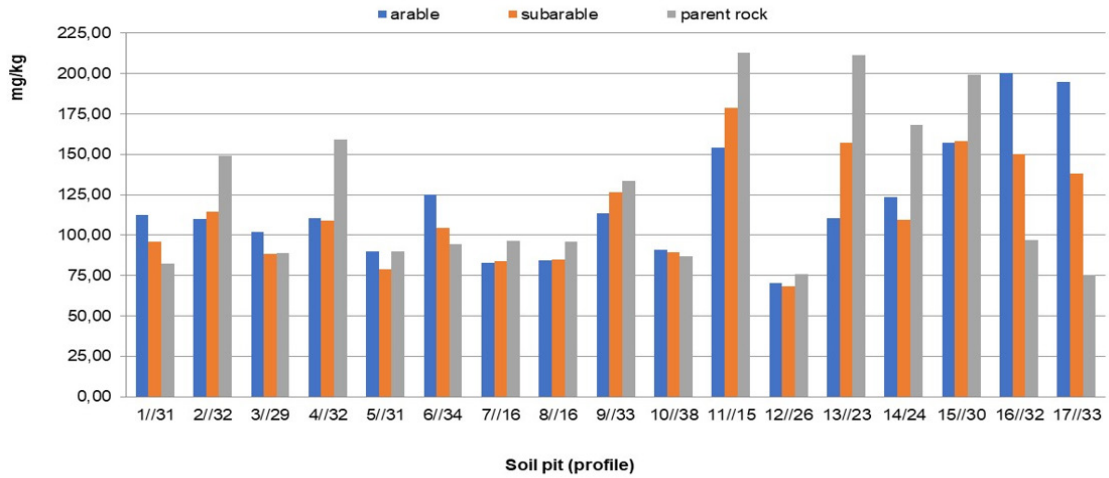


Figure 2. Amount of manganese in absorbable form in Zarafshan Valley soils

In the upper part of the Bukhara Delta, irrigated meadow-barren soils (pit (profile) 13/23), it was found that the total manganese content in the top layer was almost equal to the reference value (645.8 mg/kg), and was distributed evenly along the profile. The migration coefficient of total manganese in these soils was recorded as Km=1.05. The manganese absorbed in this soil type was at the permissible level in the top layer (110.43 mg/kg), and its content in the parent rock was almost 2 times higher than the permissible level, and accordingly, the migration coefficient was Km=0.52. This is due to the high content of sodium cations in the absorption complex of these soils [64; p. 572].

In the absorption complex, an exchange occurs depending on the ionic radii, and instead of a calcium ion with a radius of 0.104 nm, two sodium cations with a radius of 0.098 nm enter [65; p. 352]. The released Ca^{2+} cation quickly combines with the SO_4^{2-} ion with a small ionic radius (0.0129 nm), forming small gypsum particles of a light gray color. Under these conditions, the migration of manganese to the upper layer is limited. This is also confirmed by the fact that the coefficient of variation in the subsurface layer (V=14.58%) is higher than in the arable layer and parent rock. In these soil conditions, it is advisable to use various organic fertilizers containing microelements.

The alluvial meadow soils formed in the alluvial deposits of the Bukhara delta of the Zarafshan River (Romitan district, pit (profile) 14/24; and Jondor district, pit (profile) 15/30) are characterized by the heavy granulometric composition of the arable layer, which is also confirmed by the total manganese content in them.

In the alluvial soils of the meadow of the Romitan district (pit (profile) 14/24), total manganese was found to be 355-408.9 mg/kg (average 378.4 mg/kg), i.e. less than the reference value, while in the alluvial soils of the meadow of the Jondor district (pit (profile) 15/30) it was found to be 736.2-912.4 mg/kg (average 853.9 mg/kg), i.e. almost 1.5 times higher than the reference value. However, both studied soils were characterized by the fact that the parent rock had almost the same level of total manganese content. Accordingly, the migration coefficient of total manganese was equal to Km=0.44 and Km=1.18, respectively, for the pit (profile) (Table 2). This is probably due to the high content of total boron (189.6 mg/kg), cobalt (13.1 mg/kg) and molybdenum (5.18 mg/kg) in the 14/24-section subsoil and parent rock, since it is stated in the literature [6; p. 272] that there is an antagonistic relationship between manganese - molybdenum and manganese - cobalt.

The amount of mobile manganese in the profile of alluvial soils of the meadows of the Bukhara oasis (Romitan district, pit (profile) 14/24 and Zhondor district, pit (profile) 15/30) exceeds the permissible norms and is 123.80 and 156.96 mg/kg in the arable layer, respectively. Based on this, it can be assumed that there is no need to use manganese fertilizers in the oasis.

The total manganese content of meadow alluvial soils formed in the alluvial deposits of the Karakul delta of the Zarafshan River (pit (profile) 16/32; Karakul district; and 17/33 in the Olot district) was sharply different. In the meadow alluvial soils of the Karakul district (pit (profile) 16/32), the total manganese content was almost evenly distributed along the profile, and its content in the arable layer was 657.4 mg/kg and the migration coefficient Km=1.08, while in the meadow alluvial soils of the Olot district (pit (profile) 17/33), the total manganese content in the arable layer was 370.3 mg/kg, or less than the reference value, and its content in the parent rock was 1034.0 mg/kg.

It was noted that the available manganese content in the arable layer of these soils was higher than the

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permissible level (200.13 and 194.63 mg/kg, respectively), decreasing towards the parent rock.

It was found that the migration coefficient of available manganese in the alluvial soils of the Karakul oasis meadow was higher than in the soils studied in the valley (Km=2.06; and Km=2.59). Thus, there is no need to apply manganese fertilizers in the soils of the Bukhara and Karakul oases.

Based on the analysis of data collected on the studied soil types and sub-types of the Zarafshan Valley, it was determined that there is a varying degree of correlation between certain soil properties and available manganese (Table 3).

Table 3

The response of available manganese to soil properties

№	Indicators	unit of measurement	Regression equation	Correlation coefficient	Impact
1	Granulometric composition		y=57,95+6,84x	r = 0,93	strong, positive
2	pH		y=69,28+5,58x	r = 0,76	
3	B	mg/kg	y = 69,21+5,59x	r = 0,76	
4	Zn	mg/kg	y = 83,3+4,02x	r = 0,54	average, positive
5	Co	mg/kg	y = 95,84+2,63x	r = 0,36	
6	Humus	%	y=101,8+1,96x	r = 0,26	weak, positive
7	In the parent rock	mg/kg	y=106,7+1,42x	r = 0,19	
8	K_2O	mg/kg	y =147,8-3,15x	r=-0,43	average, negative
9	Mo	mg/kg	$y=122,9-9,59x+0,79x^2$	r = 0,78	average, positive
10	Total	mg/kg	$y=141,2-7,86x+0,47x^2$	r = 0,28	weak, positive
11	P_2O_5	mg/kg	$y=81,05+11,74x-0,64x^2$	r=-0,38	average, negative
12	Cu	mg/kg	No connection		

For most indicators, a linear relationship (y=a+bx) was observed according to the change in direction, and according to the analytical expression, a linear relationship (y=a+bx), and the strongest relationship (r>0.7) was observed in the interaction with granulometric composition, pH, and water-soluble boron. An inverse relationship (y=a-bx) was found in the interaction with exchangeable potassium. The strength of the relationship was moderate (r=-0.43). Data analysis shows that the relationship between available molybdenum and the total amount of manganese is parabolic ($y=a-bx+cx^2$), with molybdenum levels greater than 0.20 mg/kg having a moderate positive effect on the increase in manganese, while levels greater than 600 mg/kg having a weak positive effect. The relationship with mobile phosphorus is in the form of a hyperbola ($y=a+bx-cx^2$), and it has been statistically proven that phosphorus levels up to 25-26 mg/kg have a positive effect on manganese levels, and higher levels have a negative effect.

Conclusion

In conclusion, heavy granulometric composition, alkalinity of pH and high water-soluble boron have a positive effect on available manganese, while mobile phosphorus content exceeding 25-26 mg/kg has a negative effect. Accordingly, hydromorphic soils of the Samarkand oasis, meadow alluvial soils of the Bukhara and Karakul oases are rich in available manganese. Manganese microfertilizers can be effective only on the 3rd terrace of the right and left banks of the Zarafshan River, typical gray soil, which has been irrigated for a long time, and meadow-gray soils of the Ishtikhan district. The newly irrigated brown-grassland soils of the Navoi-Konimex oasis are deficient in available manganese. Under these conditions, it is appropriate to conduct field experiments on the application of manganese fertilizers in various ways.

References

1. Akhmedov, A.U., & Myrzambetov, A.B. (2018). Soil and meliorative conditions of the Zarafshan River basin. Scientific review, 3, 5-11.
2. Alejandro, S., Höller, S., Meier, B., and Peiter, E. (2020). Manganese in Plants: from acquisition to subcellular allocation. Frontiers in Plant Science 11:300. https://doi.org/10.3389/fpls.2020.00300.
3. Allard, S.; Gutierrez, L.; Fontaine, C.; Croué, J.-P.; Gallard, H. (2017). Organic matter interactions with natural manganese oxide and synthetic birnessite. Sci. Total Environ, 583, 487–495.
4. Alloway, B. J. (2008). Micronutrients and crop production: an introduction; pp. 1–40 in B. J. Alloway (ed.), Micronutrient deficiencies in global crop production. Springer. Dordrecht. https://doi.org/10.1007/978-1-4020-6860-7_1.
5. Annalisa Pinsino, Valeria Matranga, Maria Carmela Roccheri. (2012). Manganese: A New Emerging Contaminant in the Environment. Environmental Contamination. DOI:10.5772/31438.
6. Anspok P.I. (1990). Microfertilizers: reference book. - 2nd ed. Revised and supplemented. - Leningrad «Agropromizdat», -272.
7. Baginskas B.P. (1971). Microelements in the soils of Latvia and their influence on plants [PhD thesis] Kaunas, 1971. -34.
8. Batrachenko E.A., Dolgopolova N.V., Dudkina T.A. (2021). Investigation of the soil cover ecological state under the different geomorphological elements conditions. IOP Conference Series Earth and Environmental Science 677 (4):042081. DOI: 10.1088/1755-1315/677/4/042081.
9. Behera, S. K., Shukla, A. K. (2014). Total and extractable manganese and iron in some cultivated acid soils of India: status, distribution and relationship with some soil properties. Pedosphere 24(2):196–208. https://doi.org/10.1016/S1002-0160(14)60006-0.
10. Blamey, F. P. C., & Lombi, E., (2015). Synchrotron-based techniques shed light on mechanisms of plant sensitivity and tolerance to high manganese in the root environment. Plant Physiol. 169, 2006–2020. https://doi.org/10.1104/pp.15.00726.
11. Burnell, J.N., (1988). The biochemistry of manganese in plants. In: R.D. Graham, R.J. Hannam, N.C. Uren, eds. Manganese in soils and plants: dordrecht: Kluwer Academic Publishers, pp: 125-136.
12. Cailliatte, R., Schikora, A., Briat, J.-F., Mari, S., and Curie, C. (2010). Highaffinity manganese uptake by the metal transporter NRAMP1 is essential for Arabidopsis growth in low manganese conditions. Plant Cell 22, 904–917. https://doi.org/10.1105/tpc.109.073023.
13. Emilene Andrade, Miyazawa M., Pavan Marcos A., Oliveira Edson L. de. (2002). Effect of Organic Matter on Manganese Solubility. Brazilian Archives of Biology and Technology. 45(1). -pp. 17-20. https://doi.org/10.1590/S1516-89132002000100003.
14. Ergashev O. (2014). The importance of macro and microelements in increasing soil fertility and crop resistance to various diseases. Agro-Science – Agriculture of Uzbekistan. 2(30). 72-73.
15. Gilkes R.J., McKenzie R.M. (1988). Geochemistry and Mineralogy of Manganese in Soils. Manganese in Soils and Plants. -pp 23-35. DOI: 10.1007/978-94-009-2817-6_3.
16. Hernandez-Soriano MC, Degryse F, Lombi E, Smolders E (2012). Manganese toxicity in barley is controlled by solution manganese and soil manganese speciation. Soil Science Society of America Journal 76, 399–407.
17. Huang, Y. L., Yang, S., Long, G. X., Zhao, Z. K., Li, X. F., and Gu, M. H. (2016). Manganese toxicity in sugarcane plantlets grown on acidic soils of southern China. PLoS One 11. http://dx.doi.org/10.1371/journal.pone.0148956
18. Isreal Zewide and Abde Sherefu. (2021). Review Paper on Effect of Micronutrients for Crop Production. Nutrition and Food Processing, 4(7); http://dx.doi.org/10.31579/2637-8914/063.
19. Ivanov G.M., Kashin V.K. (1998). Manganese and copper in the soils of Zabaikalya Soil Science. 4. 423-426.
20. Joshua Sherman, Richard Heerema, Dawn VanLeeuwen, Rolston St. Hilaire. (2017). Optimal Manganese Nutrition Increases Photosynthesis of Immature Pecan Trees. HortScience 52(4):634-640. DOI: 10.21273/HORTSCI11252-16.
21. Kabata-Pendias A. (2005). Problems of modern biogeochemistry of microelements. Rus. chemical journal. 3. 15-19.
22. Karimberdieva A.A. (2000). Provision of irrigated soils of the Samarkand region with microelements. Reports and abstracts of the III Congress of Soil Scientists and Agrochemists. December 5, 123-124.

ISSN 2181-0826 3/2025 y.

23. Kashin V.K., Ivanov G.M. (2003). Manganese and growth in Zabaikalya. Agrochemistry. 1. 38-44.

24. Khairiyeva N., Eshmurodov D.E. (2002). The content of boron (B), copper (Cu) and manganese (Mn) elements in tricolor gray soils. Chemist. A collection of articles dedicated to the 75th anniversary of Samarkand State University named after A. Navoi. № 4. – Samarkand, 2002. 101-102.

25. Khashimov, F.Kh., Ortikov, T.K., Toshkenboev, O. (1997). Agrochemical characterization of soils of the middle part of the Zarafshan valley. Factors of increasing the efficiency of agricultural production during the transition to a market economy. Contents of reports of the 55th scientific reporting conference of professors, teachers and postgraduates. – Samarkand, 9.

26. Khashimov, F.Kh., Sanakulov, A.L. (2017). Microelement composition of Zarafshan valley soils and increasing the efficiency of microfertilizers in cotton cultivation (monograph). – Tashkent: "Turon-iqbol", 288.

27. Kruglova, E.K., Aliyeva, M.M., Kobzeva, G.I., Popova, T.P. (1984). Microelements in irrigated soils of the Uzbek SSR and the use of microfertilizers. T.: "Science", 252.

28. Kudashkin M.I. (2005). Prospects for the use of microelements (Cu, Mo, Mn) in field agrophytocenoses. Achievements of Science and Technology of the Agro-Industrial Complex. 5. 4-6.

29. Kuziyev R.K., Sektimenko, V.E. (2009). Soils of Uzbekistan. – Tashkent: Extremum Press, 351.

30. Kuziyev, R.K., Sektimenko, V.E., Ismonov A.J. (2010). Atlas of soil covers of the Republic of Uzbekistan. T.: State Committee "Ergeodezcadastre", 45.

31. Kuznetsova M.R. (1985). Manganese in the soils of the Udmurt Autonomous Soviet Socialist Republic. Soil Science. 8. 45.

32. Leonid Perelomov, Alexey Chulin. (2014). Molecular Mechanisms of Interaction of Microelements with Microorganisms in the Environment. Direct Biological Transformation of Microelement Compounds. Biology Bulletin Reviews 4(4):285-299. DOI: 10.1134/S2079086414040070 .

33. Litvinovich, A., & Saljnikov, E. (2023). Changes in Mn availability and soil acidity in Albic Retisol limed with dolomite screenings of various sizes and doses: A long-term microfield experiment in the north-western Russia. Bio. Comm. 68(3): 135–144. https://doi.org/10.21638/spbu03.2023.301

34. Lukin S.V., Avramenko P.M., Melentsova S.V. (2006). Dynamics of the content of mobile forms of zinc and manganese in arable soils of the Belgorod region. Agrochemistry. 7. 5-8.

35. Luther G.W. (2005). Manganese (II) oxidation and Mn (IV) reduction in the environment – two one-electron transfer steps versus a single two-electron step. Geomicrobiology Journal. 22, 195–203.

36. Marija Knez, Robin D. Graham. (2013). The Impact of Micronutrient Deficiencies in Agricultural Soils and Crops on the Nutritional Health of Humans. Essentials of Medical Geology. DOI: 10.1007/978-94-007-4375-5_22

37. Methodology of agrochemical research. Edited by F.A. Yudin. M.: "Spike", 1980, 336.

38. Methods for determination of macro and microelements in plants, soil and water. Taraz, 2002, 91.

39. Methods of agrochemical, agrophysical and microbiological research in irrigated cotton regions. T.: UzSRIC, 1963, 440.

40. Michael, W.S., Becks, S.C., (2001). Manganese deficiency in pecan. Horticulture Science. 36,1075-1076

41. Millaleo, R., & Alberdi, M., (2010). Manganese as essential and toxic element for plants transport, accumulation and resistance mechanisms. Journal of Soil Science and Plant Nutrition. 10, 470-481.

42. Mineev V.G. (2004). Agrochemistry. Textbook. – 2nd ed., revised. and additional –M.: «Kolos», 720.

43. Mirzajonov, Q.M., Nurmatov Sh.N. and others. (2009). Recommendations on the use of mineral and local fertilizers in crop nutrition. T.: UzSRIC, 29.

44. Murashkina M.A., Koptsik G.N., Savzgard R.D., Chizhikov N.P. (2004). Compounds of iron, aluminum, silicon and manganese in soils of forest ecosystems of the taiga zone. Soil Science. 1. 40-49.

45. Nazarov, M., Mirzajonov, K., Ibragimov, O., Isayev, S. (2014). Use of micronutrient fertilizers in

cotton farming. Cost-effective technologies of farming. –T.: 179.

46. Nebolsin, A. N. and Nebolsina, Z. P. (2010). Liming of soils. 254 pp. St. Petersburg University Press. St. Petersburg. (In Russian)

47. Panin M.S. (1986). Forms of manganese in soils of the middle zone of Eastern Kazakhstan. Soil Science. 8. 120.

48. Pereverzeva A.K. (1961). Application of microfertilizers for cotton. –T.: 100.

49. Pronko, V. V., & Tošić, S. (2022). Poorly soluble and mobile forms of heavy metals in the soils of the Volga steppes. In E. Saljnikov, L. Mueller, A. Lavrishchev, F. Eulenstein (eds), Advances in Understanding Soil Degradation. Innovations in Landscape Research. Springer, Cham. https://doi.org/10.1007/978-3-030-85682-3_24

50. Radjabov A.I. (2002). The content of microelements in granulometric fractions of soils of the Urgut region. Chemist. A collection of articles dedicated to the 75th anniversary of Samarkand State University named after A. Navoi.4. – Samarkand, 2002. 105-106.

51. Rasulov S.K. (2002). Some biogeochemical features of the content of microelements in the soils of the Zarafshan Valley. Improving the productivity of irrigated gray soils and its environmental challenges: Proceedings of a conference. Part 2. – Samarkand, 2002. 125-128.

52. Recep Vatansever, Ibrahim Ilker Ozyigit, Ertugrul Filiz. (2017). Essential and Beneficial Trace Elements in Plants, and Their Transport in Roots: a Review. Applied Biochemistry and Biotechnology 181(1). 464-482. DOI: 10.1007/s12010-016-2224-3

53. Rengel, Z. (2015). Availability of Mn, Zn and Fe in the rhizospheres. Journal of Soil Science and Plant Nutrition 15(2):397–409. https://doi.org/10.4067/S0718-95162015005000036

54. Samanta Thomas-Valdés, & Helena Maria Pinheiro-Sant'Ana. (2016). Association between Vitamin Deficiency and Metabolic Disorders Related to Obesity. Critical Reviews In Food Science and Nutrition. 57 (15). DOI: 10.1080/10408398.2015.1117413

55. Sattarov J.S. et al. (2011). Agrochemistry «Cho'lpon», – 552.

56. Shcatula Y. (2021) Evaluation of efficiency of application of growth stimulators and microfertilizers in maize crops. Norwegian Journal of development of the International Science 57. 8-14.

57. Sims J.T. (1986). Soil pH Effects an the Distribution and Plant Availability of Manganese, Copper and Zinc . Soil Sci. Soc. Am. J. 50,(2) 367-373.

58. Sparrow L.A., Nick Uren. (2014). Manganese oxidation and reduction in soils: Effects of temperature, water potential, pH and their interactions. Soil Research 52 (5): 483–494. DOI: 10.1071/SR13159

59. Tebo BM, Geszvain K, Lee S-W (2010). The molecular geomicrobiology of bacterial manganese (II) oxidation. In 'Geomicrobiology: molecular and environmental perspective'. pp. 285–308. (Springer Science+Business Media: Dordrecht, The Netherlands)

60. Ushkarenko, V.A., Lazarev, N.N., Goloborodko, S.P., Kokovikhin, S.V. (2011). Dispersion and correlation analysis in plant growing and grassland farming. RGAU – Moscow Agricultural Academy named after K.A. Timiryazev, 336.

61. Vasilievskaya V.D. (1973). Manganese Microelements in the soils of the Soviet Union. M.: Publishing house of Moscow University, 199-206.

62. Vodyanitsky Y.N. (2009). Mineralogy and geochemistry of manganese: A review of publications. Eurasian. Soil Sci. 42, 1170–1178.

63. Vodyanitsky Yu.N., Vasiliev A.A., Lesovskaya S.N. and others. (2004). Formation of manganese oxides in soils Journal of Soil Science 6. 663-675.

64. Xoliqulov Sh., Uzoqov P., Boboxo'jayev I. (2011). Soil science. – Tashkent, 572.

65. Yuldashev G'.Yu., Isag'aliyev M.T. (2014). Soil biogeochemistry. – Tashkent, 352.

66. Yunusov, R., Makhmudov, M., Usmonov, T. (2013). Ways to improve the melioration condition of the soils of the Bukhara oasis. Problems and prospects of cultivation, storage and primary processing of agricultural products in southern Uzbekistan. Collection of articles of the Republican scientific and technical conference. – Karshi, 237-238.

67. Zafar Iqbal Khan, Kafeel Ahmad, Hareem Safdar, Yunus Dogan. (2018). Manganese bioaccumulation and translocation of in forages grown in soil irrigated with city effluent: An evaluation on health risk. Research Journal of Pharmaceutical Biological and Chemical Sciences. 9 (5):759-770