АГРОХИМИЯ

UDC: 631.4: 631.8

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IMPACT OF FERTILIZERS ON SOIL FERTILITY IN VEGETABLE CROP ROTATION

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Abstract. The article deals with changes of agro- physical and agro-chemical indicators of fertility of irrigated dark chestnut soils in long term fertilizer application and vegetable crop rotations. As a result of long term use of arable land without fertilizers it has been determined that humus concentration decreased (26-46,9 %) and basic soil fertility parameters deteriorated. Long-term use of fertilizers in vegetable growing in crop rotation results not only in soil fertility reproduction, but also in crop productivity increase in vegetable crop rotations.

Key words: agro-chemical and agro-physical indicators, total humus, fertility indicators.

INTRODUCTION

Sustainable land cultivation development, cost-effective and environmentally safe agricultural production are based on rational use of soil resources and agricultural land. Crops can be provided by nutrients and stable yield can be obtained by soil fertility reserves mobilization. However, as a result of intensive land degradation soil fertility decreased and it is impossible to obtain planned level of agricultural crop yields without using fertilizers. Today the Earth population is at 95 % self-sufficient in food due to soil fertility. In this regard, one of the main issues of modern agriculture is to maintain soil fertility and reproduction.

Extensive and inefficient use of agricultural lands, including irrigated - inevitably resulted in shortage of soil nutrients, deterioration of its quality, agro-physical and water properties, in particular, destruction of soil structure, over compaction of arable and sub-arable horizons, increased erosion, reduction of soil production capacity. Therefore, soil fertility preservation, and increase of crop productivity on this basis is very important.

Mineral fertilizers play an important role in increasing of soil fertility and providing high quality crop production. In this regard, American scientists draw big attention to fertilizers in improving crop yields - 41 %, German scientists note half of the yield, French - from 50 to 70, Russian - up to 50-60, and Kazakhstani - 35 to 50 %.

Analysis of current state of soil fertility of the Republic of Kazakhstan showed that in comparison with period of development of virgin and fallow lands, depending on soil type and environmental conditions, the average weighted humus concentration has decreased from 25 to 33 percent or more from its initial concentration, while on irrigated land from 45 to 60 %. According to agrochemical service, in recent decades the average weighted humus concentration in all soil types is ranging from 1,5 to 20,54 %. This fact to some extent, has impact on country's food safety assurance.

In this regard, it is necessary to develop scientifically justified land cultivation system that ensures soil fertility reproduction. In order to solve this problem, we studied the influence of long term fertilizer application on soil fertility and crop productivity in vegetable crop rotations in conditions of pre-mountain irrigated zone in south-east of Kazakhstan and presented research results in this article.

OBJECTS AND METHODS

Research object - is irrigated dark chestnut soil in pre-mountain zone of the south-east of Kazakhstan and vegetables. Experimental studies were carried out at research station of Kazakh Research Institute of Potato and Vegetable Production (now Kazakh Research Institute of Potato and Vegetable production).

Long term research at station started in 1991 and aimed to study the effect of fertilizers on soil fertility and productivity of intensive vegetable crop rotation.

Previous research data was used in assessing the impact of long term fertilizer application on soil fertility indicators and productivity of vegetable crop rotations [1-5].

Determination of soil chemical and agrochemical parameters was carried out by conventional methods: humus - by Tyurin; total nitrogen - by Kjeldahl; hydrolysable nitrogen - by Tyurin-Kononova; total phosphorus - by Ginzburg and Sheglova with subsequent determination at "Specol"; mobile phosphorus - by Machigin in Grabarov's modification with subsequent determination at FEC- 56 M; gross potassium - by Smith and subsequent determination at "Specol"; mobile potassium - by Machigin in Grabarov's modification with subsequent determination at flame photometer FLARNO 4 (1981); pH - potentiometric (ionomer 160 MI); CO2 - calcimeter by Golubev's method.

RESULTS AND DISCUSSION

Our research shows that pre-mountain dark chestnut soils which are in long-term agricultural use, have undergone significant changes. Soils at research station are used in land cultivation for more than 60 years and during this period the radical changes in fertility parameters have occurred.

Humus concentration in arable horizon is about 3 % and total nitrogen - 0,2-0,3 %, with a fairly wide ratio of organic carbon and nitrogen (C: N = 10-12). With depth, these figures are gradually declining. Absorbing complex is mainly saturated with calcium (75-85 %), partially magnesium (15-20 %), capacity of absorbed bases - 20,3 mEq/100 g soil, pH 7,2-7,3. The volume of soil mass is equal to 1,1-1,2 kg/ cm^3, the lowest moisture content - 26,6 %. Exchangeable sodium in profile is usually absent. Soil structure - friable, weakly expressed. The soil doesn't absorb water under irrigation and heavy rain, forming a thick crust, which breaks its water and air regime [1]. It should be noted that soil agrochemical characteristics in experimental plot complies with its initial indicator.

According to research data it should be noted that soil particle size distribution corresponds to medium loam soils, where concentration of physical clay (clay fraction is <0,01 mm) ranged 43-45 %. Granulometric composition of virgin soil in comparison with arable land is lighter, and silt fraction is less than 0,01 mm, depending on depth of sampling from 36,2 to 39,8 % (Table 1).

As it should be noted, according to Table 1, silt fraction increased in topsoil due to soil erosion and accumulation at lower part of the furrow. On arable land weighting is observed in the upper horizons, reaching a maximum value in deeper layers. Aggregation processes, structure formation occurs due to silt particles, and even increase of silt fraction down the profile is observed. It is known that distribution of humus in soil particle size fractions has certain patterns. More than 70-90 % of total concentration of soil organic matter accounts for colloidal, pre-colloidal and fine silt fractions [5].

The major difference towards increase in carbonates concentration (CO_2) has been observed, in upper layers of irrigated dark chestnut soils it was 1,35-2,46 %, in virgin plot 0,16-1,25 %.

Table 1 - Granulometric composition of pre-mount irrigated dark chestnut soils of the south-east of Kazakhstan

ID	Sampling depth, cm	Absolute dry part, %	Fraction composition in % per absolute dry soil						
			Fraction sizes in mm						
			sand		dust			silt	Physical clay <0,01
			1,0-0,25	0,25-0,05	0,05-0,01	0,01-0,005	0,005-0,001	<0,001	
Virgin									
1	0-10	2,0		5,7	58,1	8,3	19,0	8,9	36,2
2	0-20	2,0		2,1	59,6	12,5	17,7	8,7	38,9
3	20-45	2,0		1,6	58,6	10,5	17,3	12,0	39,8
4	45-57	1,8		3,4	60,2	9,20	17,0	10,2	36,4
Natural background									
6	0-20	2,76	2,1	20,548	30,440	23,859	2,055	20,979	46,8
7	20-40	2,48	0,3	17,206	33,634	16,817	10,255	21,739	48,8
8	40-60	2,3	0,1	13,552	33,163	20,471	12,692	20,061	53,2

In virgin soil profile the greatest amount of carbonates is observed in the lower horizons. Irregular borders of carbonates presence, and large diversity in their accumulation in the profile of virgin soils is caused by linguiform and fracture, that is, processes of leaching by precipitation. On arable land it is not observed. Because annual plowing leads to mixing of the upper and lower soil horizons.

In soils which are used for a long term period, reduction of total and mobile forms of nutrients and absorbed bases occurs, bulk density of subarable horizons increases.

Our monitoring of agrochemical indicators of dark chestnut soil showed that long-term use of soil without fertilizer application results in change of their concentration (Figure 1).

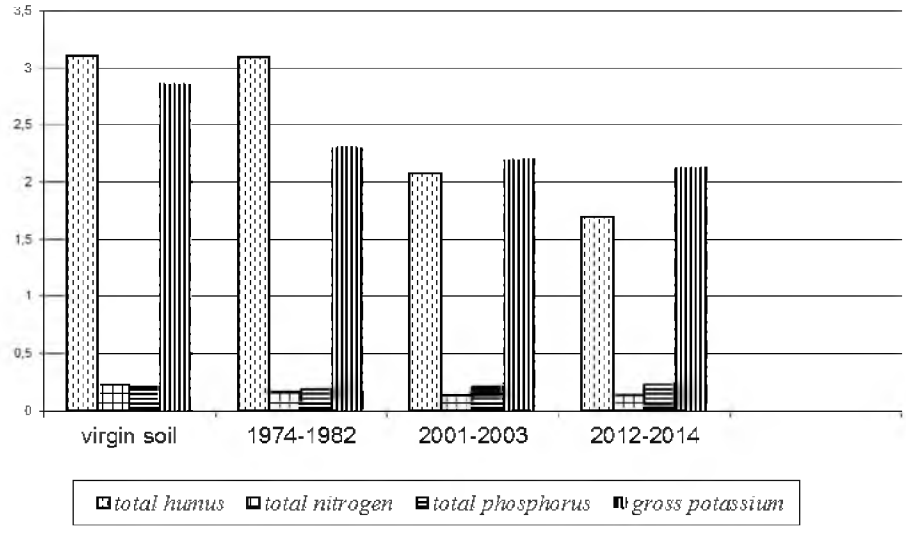

Figure 1 - Monitoring of changes in basic nutrient concentration

It should be noted that according to the results of monitoring, from 1974 to 2014 the significant decrease of humus concentration in arable layer of dark chestnut soil has been observed. Irrigated dark chestnut soils at experimental fields contain almost 1,5 times less humus than virgin land.

Soil fertility is determined, first of all, by concentration of organic matter - humus. Its quality is provided by the pace of accumulation and decomposition of crop residues and applied organic fertilizers into soil, and favorable conditions for decomposition are formed at irrigation. Cultivation of crops - corn, potatoes, sugar beet, vegetables which occupies large areas of irrigated lands, contributes to acceleration of this process. This is due to repeated treatments between rows of crops, which result in intensification of anaerobic microorganisms. As a result, consumption of organic matter proceeds more rapidly on irrigated lands than in rainfed conditions.

Before start of (1991) intensive vegetable crop rotation on the background without fertilizers, humus concentration as 2,35 %, gross forms of nitrogen 0,146 %, phosphorus - 0,195 and total potassium - 2,47 %, i.e., these data is much lower as compared to analysis data of 1981, or humus loss is 8,8 % of its original concentration, nitrogen total forms - 23,2 %, phosphorus - 27,8 nd total potassium - 17,8 %.

Data on agrochemical research of subsequent vegetable crop rotations are shown in Table 2.

Table 2 - Agrochemical characteristics of experimental plot in pre-mountain irrigated dark chestnut soil in the southeast of Kazakhstan [3-4]

Depth, cm	Humus, %	Total forms, %			Mobile forms, mg/kg			CO_2, carbon. %	pH	p
		N	P_2O_5	K_20	N	P_2O_5	K_20			
Data for 2001-2003										
0-20	2,07	0,098	0,225	2,40	58,8	70,0	477,3	2,90	8,35	
20-40	1,64	0,084	0,150	2,50	56,0	42,0	328,8	4,8	8,31	
40-60	0,92	0,056	0,20	2,30	47,6	43,0	276,9	6,24	8,35	
Data for 2012-2014										
0-20	1,61	0,070	0,260	1,92	33,6	44	280	3,65	8,26	
20-40	0,83	0,056	0,212	1,75	30,8	15	130	7,81	8,60	
40-60	0,62	0,028	0,180	1,61	39,2	1	120	9,76	8,65	

Table 2 shows that agrochemical indices of pre-mountain dark chestnut irrigated soil at experimental plot in long-term use have also reduced. In 2001, topsoil humus concentration has decreased to 2,07 %, or 31 % compared to 1981, and by 2014 - to 1,61 %, or 46,9 %, respectively, total nitrogen - up to 0,098 % (2001), or by 48,4 % and in 2014 - up to 0,070 %, or 63,2 %, total phosphorus - up to 0,225 % (2001), or by 16,7 % and in 2014 - to 0,260 %, or 3,7 %, respectively. Total potassium - up to 2,40 % (2001) or 20,0 % (2001) and 2014 - 1,92 %, or 36 %, respectively.

Earlier carbonates in topsoil were detected as traces, while in 20-30 years they increased to 2,90-3,65 %. Also, a decrease in cationic exchange capacity has been observed from 17,9 mgEq/100 g of soil. In addition, in comparison with data of 1981, soil pH has increased from (7,2-7,3) to 8,31-8,35 in 2001 and to 8,20-8,65 in 2014.

Many researchers, both in Russia and abroad, note significant impact of fertilizers on reaction of soil solution, which depends on soil properties as well as forms of applied fertilizers. It was determined that increase of acidity occurs due to the influence of nitrogen fertilizers. D.N. Pryanishnikov [6] and other scientists have pointed out [7-11], that systematic use of fertilizers without considering the impact of salts on soil properties may result in acidification or alkalization and all consequences. This fact is confirmed by our findings, where reaction of soil environment (pH) increased from 7,2 to 8,65, that indicates to it's alkalinization.

We have explored 3 kinds of vegetable crop rotations and analyzed soil samples taken on experimental plots with different vegetable crops, on humus concentration and main nutrients.

In 8-field vegetable-grass crop rotation humus concentration on control (without fertilizer) was 2,07 % at initial level 3,0 %, ie, it has decreased by 0,93 %, or 31 %. On variant with application of single rate of mineral fertilizers, decrease of humus occurred less intensely - 2,22 %. However, humus concentration has reduced by 26 %. Application of double and triple rates of complete fertilizer has stabilized soil fertility. Arable soil layer contained 2,31-2,38 % of humus, which is less than initial concentration by 21-23 %. On fertilized variants humus concentration was higher than on control at 7,25-14,98 %. It should be also noted that in all experiment variants in 8- field rotation the significant increase of nutrient mobile forms concentration has been observed. On control variant mobile phosphorus in soil was 95 mg/kg, exchangeable potassium - 330 mg/kg. Application of fertilizers contributed to the increase of P_2O_5 by 170-258 mg/kg, K_2O - up to 355-430 mg/kg. These data suggest that available phosphorus in soil is high, as for exchangeable potassium it is medium and high. CO_2 concentration in soil varied greatly on experiments variants and soil horizons. On control variant carbon concentration was 3,19-7,71 %, on variants with fertilizer application - 0,86-1,45 %; 1,21-1,62 % and 1,57-3,57 %.

On 4-field intensive vegetable crop rotation on natural background, on control (1,50 %) and on variant with single fertilizer rate (1,51 %) humus concentration has decreased 2 times, and on variant with double (2,04 %) and triple (2,09 %) rates - to 30-32 %. Concentration of hydrolyzable nitrogen in soil samples ranged from 36,4 to 42,0 mg/kg of soil (0-20 cm layer). Concentration of mobile phosphorus in soil arable layer was very high and amounted to 68-122 mg/kg of soil, exchangeable potassium from 255-280 to 315 mg/kg, which corresponds to low and medium availability gradations. Carbon concentration increased from upper layers to lower horizons. Reaction of soil environment has changed from neutral and close to neutral (pH 7,2-7,3) to alkaline (pH 8,01-8,21). On organic background soil fertility parameters were higher in comparison with natural background. Humus concentration in organic control was 2,09 %. In variants with fertilizer application of the same background, humus was at a higher level - 2,21-2,32 %.

Availability of easy available forms of nutrients in irrigated dark chestnut soil varied significantly on variants with fertilizer application. So, on control variant, soil organic background was 39,2 mg of hydrolyzable nitrogen, 69 mg of active phosphorus and 26 mg of potassium exchange per 1 kg of soil. Application of mineral fertilizers in crop rotation in various rates has increased nitrogen concentration in 0-20 cm layer up to 42,0-47,6 mg/kg, phosphorus - up to 78-175 mg/kg, potassium - up to 280-375 mg/kg.

Significant differences in soil humus concentration level and degree of availability of nutrients can be explained by fertilizer application systems in 4-field intensive vegetable crop rotation during many

years rotations (since 1991), as well as diversity of soil fertility in pre-mount dark chestnut soils.

Soil studies, along with 8-field vegetable-grass and 4-field intensive vegetable crop rotations, have been also carried out in conditions of 3-field short grain-vegetable rotation.

The research results showed that soil agrochemical properties indices in 3-field short grain-vegetable rotation significantly exceeded other rotation indicators. Soil humus concentration in 3-field grain-vegetable rotation on control variant was equals to 2,07 %, on variants with organic fertilizers - 2,30-2,79 %. There was a significant excess of mobile nutrient forms concentration. On variants with fertilizer, nitrogen concentration was 30,8-37,8 mg/kg (control - 29,4 mg/kg), potassium - 380-540 mg/kg (control, 305 mg/kg). Humus concentration has significantly decreased compared to initial level, and varies greatly depending on type of vegetable crop rotations and fertilizer application systems for vegetable crops.

Total soil nitrogen concentration under vegetables, depending on type of crop rotation systems and use of fertilizers has fluctuated in a wide range - 0,112-0,168 %, which indicates various amounts of this valuable nutrient in soil. As for phosphorus, quite high level of gross forms was observed. So, 0-30 cm soil layer contained total phosphorus from 0,172 to 0,214 %, mostly - 0,19-0,20 %, which corresponds to the initial level. Gross forms of potassium fluctuated within 2,61-3,34 %. In the majority of soil samples total potassium concentration was 2,5-2,6 %, i.e. it was at initial level.

The yield capacity of vegetable crops, depending on fertilizer system and crop rotation types varied in different ranges. The minimum yield capacity of cabbage on control variant in 8-field vegetable crop rotation was 32,9 t/ha, and application of a single rate of complete fertilizer ($N_{60}P_{30}K_{30}$) has increased productivity of cabbage to 37.8 t/ha, double rate - up to 43 t/ha, triple rate - up to 47,4 t/ha. Yield increase compared to control was 4,9-14,5 t/ha, or 14,9-44,1 %.

On average during research years yield capacity of young cucumbers on control without fertilizers was 16,4 t/ha, which is a very low figure. Application of complete mineral fertilizer provided high yields of cucumber. On variant with application of single rate of mineral fertilizers ($N_{30}P_{30}K_{30}$) in cucumbers, yield rose to 19,6 t/ha, double rates ($N_{60}P_{60}K_{60}$) - 23,9 t/ha, triple rates ($N_{90}P_{90}K_{90}$) - 26,8 t/ha. Yield increase of cucumbers was within 3,2-10,4 t / ha, which is 19,5 - 63,4 % versus control.

High yield of tomatoes was determined on backdrop of fertilizers. Yield capacity on variant without fertilizers (control) was the lowest and amounted to 30,1 t/ha. When applying single rates mineral fertilizers ($N_{90}P_{120}K_{90}$) tomato yield increased to 33,6 t/ha, double rates ($N_{60}P_{60}K_{60}$) - 38,1 t/ha, triple rates ($N_{90}P_{120}K_{90}$) - 42,2 t/ha. Increase of tomatoes yield was within 3,5 - 12,1 t/ha, which is 11,6 - 40,2 % compared to control.

Mineral fertilizers have also showed high agronomic efficiency on sugar beets, increasing productivity of sugar beet by 10,6 - 43,2 % compared to control variant at yield 27,3 t/ha.

In 4-field intensive vegetable crop rotation two fertilizer systems have been compared-- mineral and organic mineral (60 t/ha of manure for crop rotation). On natural background cabbage yield was significantly lower and amounted to 31,1 t/ha. Minimum application of mineral fertilizers ensured yield 35,6 t/ha, moderate - 40,6 t/ha, increased - 44,7 t/ha. Under the influence of complete mineral fertilizer in single, double and triple rates cabbage productivity increased by 14,5 - 43,7 % on control variant.

On organic background with application of 60 t/ha manure cabbage productivity has substantially increased. On control variant cabbage yield was 37,0 t/ha, on variants with fertilizers–about 43-51 t/ha. Compared with natural background cabbage yield on control variants increased by 6 t/ha, while on variants with fertilizers by 6-7 t/ha. That means that due to organic background about 13-20 % yield increase can be obtained. Mineral fertilizers on organic background have increased productivity of cabbage by 15,1-37,0 % to control.

The yield of cucumber on background without fertilizers was 15,7 t/ha. On variants with fertilizers cucumber yield increased within 2,3 - 8,5 t/ha, which is 14,6-54,1 % to control. Mineral system of 4-field vegetable crop rotation does not ensure preservation and improvement of soil fertility, and respectively, levels of vegetable yields, including cucumber. However, organic mineral fertilizer system for cucumbers is more effective. On control variant on organic background, cucumber yield was 20,3 t/ha, on variants with increasing mineral fertilizer rates - 22,8-28,5 t/ha. On equivalent variants on organic background compared to natural background, cucumber yield was higher by 4,3-5,6 t/ha (17,7-29,3 %). That is, formation of organic background by applying 60 t/ha once per rotation on 4-field intensive vegetable rotation provides productivity growth in range of 17-30 %. The yield of tomato on natural background averaged 30,3 t/ha, and on control variant on organic background - 34,5 t/ha. On fertilized variants natural background was 33,7-41,4 t/ha of crops, organic background - 37,6-44,7 t/ha. Different NPK-fertilizers rate will provide additional yield of tomato compared to control variants within 11,2-36,6 % (natural background) and 9,0-29,6 % (organic background).

On control variant without fertilizer application, yields of root crops was minimal in average 18,1 t/ha. Significant yield increase of carrot was observed on variants with fertilizer application- 21,5-29,5 t/ha, which was 18,8-6 %. On organic background yield of carrot was 20,3 t/ha, and on variants with fertilizers - 24,1-30,8 t/ha. The highest increase of carrot yield was observed in application of $N_{150}P_{90}K_{120}$ - up to 63 %.

In conditions of 3-field short grain-vegetable rotation, potato yield on the background without fertilizers was minimal and amounted to 18,7 t/ha. On background of organic fertilizers (chopped straw and half-over-rot manure under plow land) potato yield increased to 21,9-28,3 t/ha. In addition to control 17,1-51,3 % tuber yield was formed. At the same time $N_{180}P_{180}K_{180}$ rate demonstrated the highest efficiency.

Yield capacity of commodity bulbs on control (without fertilizers) was low and averaged 28,5 t/ha, on background of complete mineral fertilizer in rate $N_{50}P_{30}K_{40}$ -34,7 t/ha, $N_{150}P_{90}K_{120}$ rate-40,0 t/ha, $N_{150}P_{90}K_{120}$ rate-44,1 t/ha. The increase of onion- turnip yield in different mineral fertilizers rate was 6,2-15,6 t/ha (21,7-54,7 %).

Sugar beet yield capacity in fertilization with increasing NPK-fertilizers rates increased from 26,5 t/ha (control) to 31,9 - 42,1 t/ha. In addition to control 5,4 and 15,6 t/ha (20,4 to 58,9 %) of root-crop was harvested, respectively, on fertilized variants of experiment.

CONCLUSION

As a result of long term and inefficient use of arable land under pre-mount irrigated dark chestnut soils of the south-east of Kazakhstan humus concentration decreased significantly in arable soil layer compared to initial level, and it varies greatly depending on fertilizer application systems in vegetable crop rotations. On natural background (without fertilizers) not only soil agro-physical properties deteriorated, but also organic matter decreased to 31-46,9 %. Total nitrogen concentration in soil varied widely - 0,112-0,168 %, total phosphorus and exchangea-

ble potassium - at level of initial concentration in the range of 0,172 to 0,214 and 2,61-3,34 %. On mobile forms of nutrients, easily digestible by plants, average and higher levels have been observed.

On granulometric composition premount irrigated dark chestnut soil corresponds to average loam, but in long-term use its composition has worsened and became heavier.

Mineral fertilizer systems in vegetable crop rotation does not ensure soil fertility preservation and increase of crop yields (low yields), while organic-mineral fertilizer systems in vegetable crop rotation are more effective, and ensure not only soil fertility reproduction, but also crop yield increase in vegetable crop rotations. Based on monitoring of dark chestnut soil fertility status in long term fertilizer use, close interaction between soil fertility, productivity and fertilizer application systems in vegetable crop rotations has been determined.

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ТЫҢАЙТҚЫШТАРДЫҢ КӨКӨНІС АУЫСПАЛЫ ЕГІСТІГІНДЕГІ ТОПЫРАҚТЫҢ ҚҰНАРЛЫҒЫНА ӘСЕРІ

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Мақалада көкөніс ауыспалы егістіктердегі тыңайтқыштарды ұзақ пайдаланудағы және дақылдарды өңдеудегі суармалы қара-қоңыр топырақтарының агрофизикалық және агрохимиялық құнарлылық көрсеткіштерінің өзгерістері қарастырылған. Зерттеу нәтижесінде жыртылған жерлерді тыңайтқышсыз ұзақ пайдалану салдарынан қара шіріндінің мөлшері төмендегені (31-46,9 %) байқалған және топырақ құнарлығының негізгі көрсеткіштері нашарлаған. Ауыспалы егісте көкөніс дақылдарын өсіру және тыңайтқыштарды ұзақ қолдану топырақ құнарлығын көтеріп қана коймай көкөніс ауыспалы егістіктеріндегі дақылдардың өнімділігін жоғарлатады.

Түйінді сөздер: агрохимиялық және агрофизикалық көрсеткіштер, өнімділік, құнарлылық көрсеткіштері

РЕЗЮМЕ

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ВЛИЯНИЕ УДОБРЕНИЙ НА ПЛОДОРОДИЕ ПОЧВЫ ОВОЩНЫХ СЕВООБОРОТОВ

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В статье рассмотрены изменения агрофизических и агрохимических показателей плодородия орошаемых темно-каштановых почв при длительном использовании удобрений и возделывании культур овощных севооборотов. Установлено, что в результате длительного использования пашни без внесения удобрений происходит снижение содержание гумуса (на 31-46,9 %)и ухудшение основных параметров плодородия почв. Длительное применение удобрений при возделывании овощных культур в севообороте способствует не только воспроизводству плодородия почвы, но и повышению продуктивности культур овощных севооборотов.

Ключевые слова: агрохимические и агрофизические показатели, урожайность, показатели плодородия.