Impact of Water-Saving Irrigation Technology on Yield and Quality of White Cabbage Varieties in the South-East Kazakhstan

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Abstract----**Cabbage is valued as high vitamin vegetable. In regard with the distribution and areas of cultivation, production and consumer demand cabbage is a leader in Kazakhstan. According to statistics, the plantation of white cabbage in the republic is 20 thousand hectares, the gross yield of products is 500,0 thousand tons. The average yield of heads is low (25.0 t / ha) at high biological potential of new varieties (55-70 t / ha). One of the main limiting factors of productivity is irrigation, since cabbage is very demanding on the soil moisture. Cabbage is irrigated approximately 12-15 times in the south-east of Kazakhstan. Factors such as limited water resources at low rainfall and high temperature prevents the creation of optimal conditions for water consumption of cabbage plants. In this respect, advanced water-saving technologies are considered to be relevant and effective. Due to the lack of irrigation water and the strong development of irrigation erosion in the foothills of the south-east of Kazakhstan a lot of farmers are switching to water-saving irrigation technologies year by year.**

Finely dispersed irrigation using sprinklers is a new method of irrigation in irrigated vegetable production in Kazakhstan. For a broad introduction of this technology it is necessary to assess its effectiveness and to adapt to conditions of the region.

In the Kazakh Research Institute of Potato and Vegetable growing studies to assess the technology of sprinkler irrigation on vegetable crops, including the cabbage were conducted. The influence of sprinkler irrigation on water consumption of cabbage, water and physical properties of the soil, phytosanitary condition of fields, productivity, biochemical composition of heads and their keeping quality during storage were studied.

It has been established that in comparison with furrow irrigation finely dispersed irrigation (sprinkler irrigation) saves irrigation water (24,12%), decreases the contamination of fields (46,03%), contributes to higher yields of cabbage varieties (7 t / h or more) and improves the quality (dry matter - 9,68-11,96%, vitamin C - 29.7 mg%).

Therefore, the finely dispersed irrigation is a promising technology for the south-east of Kazakhstan.

***Keywords*: sprinkler irrigation, yield, cabbage biochemical content, south-east Kazakhstan, and water-saving technology.**

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I. The Current State Of Irrigated Lands

Vegetables as the main sources of biologically active compounds, antioxidants, flavonoids, vitamins, dietary fiber, minerals essential to the human body have an important place in the modern concept of the balanced nutrition of the population. According to the minimum norms of food consumption per capita in Kazakhstan every resident of the Republic must get in average 175 kg of different vegetables annually, including 25 kg of cabbage [1].

Cabbage is valued as high vitamin vegetable and contains a wide variety of vitamins (P, K, E, U, B group), but mainly it contains vitamin C [2], the level of which is not reduced even during prolonged storage and/or pickling. Moreover, cabbage comprises macro- and microelements, some of them quite rare such as sulfur, calcium, magnesium, potassium, phosphorus, chlorine, iodine, cobalt, iron, zinc, copper, and manganese [3]. Among the amino acid lysine, carotene and pectin that helps to bind and to dissolve the proteins of foreign origin are allocated in the cabbage. Cabbage fiber has a beneficial effect on the activity of the gastrointestinal tract, reduces cholesterol and the amount of adipose tissue, and kills bacteria in the intestines putrid [4]. As it was reported by some researchers *Brassica* vegetables have protective role in colorectal cancer. Essential compounds of *Brassica* vegetables such as phytochemical compounds, micronutrients and dietary fiber may contribute to the capacity of these vegetables to decrease the cancer risk [5], [6].

Cabbage is widely cultivated in all regions of Kazakhstan. In accordance with Statistics Committee of RK annual growth of the gross harvest of vegetables and potatoes in the 2010-2014 periods was reported. The increase in production of cabbage was due to growth in the cultivated area from 16,9 to 19,9 thousand hectares in 2010 and 2014, respectively. Gross yield of the cabbage was amounted up to 498,0 thousand tons in 2014 [7]. These values can be increased due to the introduction of the water-saving irrigation technologies on irrigated lands.

Irrigation is needed to maintain vegetable crop production during the periods of insufficient rainfall. Sprinkler irrigation and drip irrigation are considered as leading water-saving technologies in irrigated agriculture of Kazakhstan [8]. Nowadays, a very limited number of farms use water-saving technologies. One of the main reasons is the lack scientific recommendations [9].

Deficit of irrigation water, the development of irrigation erosion [10], deterioration of soil agrochemical properties [11] and phytosanitary condition of the fields that are observed by

using traditional furrow irrigation method, force landholders to improve the irrigation technology in order to obtain the guaranteed vegetable crop yield in conditions of Kazakhstan.

At the present time irrigated land was characterized by increasing degradation processes in the soil root zone, so crop yield has decreased by 1,5-2 times [12],[13]. It should be noted that the reason for the decline of fertility of irrigated soils were salinity and alkalization of soils, which in turn was one of the main reasons for the decrease of productivity and ecological processes in irrigated ecosystems [13].

Using of the perspective varieties of vegetables is another way to improve the productivity.

In the research varieties of cabbage used in RK such as Nezhenka, Belosnezhka, Kharkovskaya zimnyaya, and Slava 1305 were cultivated. They have been used to assess the effectiveness of sprinkler irrigation technology, and its impact on the productivity of different crop varieties.

Eventually, this paper shows the preliminarily results of the study conducted to find out the impacts of sprinkler irrigation on yield and biochemical content of white cabbage.

II. Objects And Methods Of Research

Objects of research are advanced water-saving technologies (finely dispersed irrigation), 4 varieties of cabbage (Nezhenka, Belosnezhka, Kharkovskaya zimnyaya, and Slava 1305).

Studies on the effect of sprinkler irrigation on the main indicators of the productivity of vegetable crops, including the cabbage were conducted on the experimental plots of Kazakh Research Institute of Potato and Vegetable Growing in accordance with the classical methods, guidelines, recommendations and instructions [14]- [18].

The effect of a finely dispersed irrigation on saving of irrigation water, contamination of the fields, productivity and quality of the cabbage heads was studied. Accounting of irrigation water was produced by a flood-free weir "Chipoletti" with a threshold of 50 cm, set in the beginning and the end of the experimental plot to account waste water.

To assess the influence of the conditions of mineral nutrition on the quality indicators of products the edible parts of vegetable were analyzed, in which dry matter was determined by the drying method, total sugars by the Bertrand method, vitamin C by Murry, and nitrates potentiometrically with Ion Selective Electrode.

Accounting of cabbage harvest was conducted through continuous method by plots on each replication of experience field. The structure of the crop was determined. The mathematical processing of the received data on the harvest of vegetable crops was carried out by analysis of variance [16].

Agricultural technologies in the experiences were carried out in accordance with the generally accepted recommendations of Kazakh Research Institute of Potato and Vegetable farming in the piedmont area of south-east Kazakhstan [19].

On the experimental plots varieties of cabbage allowed to use (zoned) such as Nezhenka, Belosnezhka, Kharkovskaya zimnyaya, and Slava 1305 were cultivated

Studies to evaluate the effect of irrigation technology on shelf life of the products were held in the storage of research institute according to "Methodology for research on the storage of vegetables" [20]. Cabbage heads were kept in wooden boxes of 25 kg in 4-fold replications at 0-10^{0}C and relative humidity of 95-97%. Products were laid down for storage in the III decade of October; the recess is in the III decade of March. Period of storage is 5 months.

III. Results Of Research

A. Weather conditions in 2014-2015

Research work was carried out on experimental plots of Kazakh scientific research institute of potato and vegetable growing located in the foothills of the south-east of Kazakhstan, on the northern slope of the Trans-Ili Alatau at an altitude of 950-1050 m above sea level.

Weather conditions in 2014 differ from the average long-term data insignificantly. So, in the spring an increase in temperature was noticed. The variation was from (+1^{0}C) to (+3^{0}C). During the summer period an increase in the temperature had also been seen. Deviation from the long-term average data was from (+ 2^{0}C) up to (+4^{0}C). On the contrary, in the autumn there was a decrease in temperature. The deviation from the average long-term data was (-2,4^{0}C). (Fig.1a).

The long rainy and warm spring period was replaced by summer period with high air temperatures; prolonged absence and a minimum amount of rainfall.

There was an uneven distribution of precipitation during the growing season (April - September) in 2014 which was a feature of the meteorological parameters of that year.

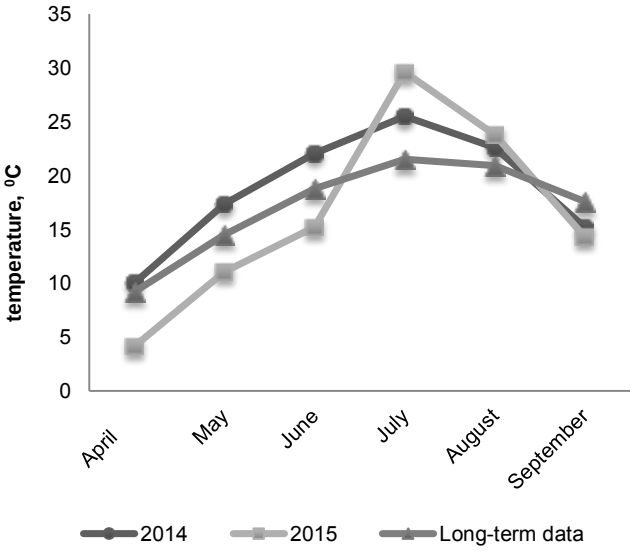

Fig. 1a. Data of the average monthly air temperature in 2014-2015

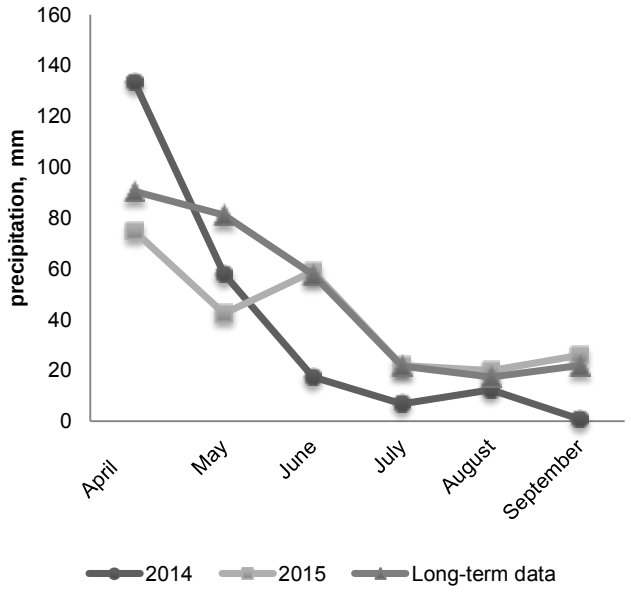

Fig. 1b. Data of the average monthly precipitation in 2014-2015

Weather conditions during the vegetation period in 2015 also differed from the average long-term data. These strong fluctuations of weather conditions were observed for individual months (Fig. 1b).

The average monthly air temperature in April was $4,5^0$C, which was 2 times lower than the average long-term data ($9,2^0$C). In May, June and September the decrease in temperature at 3,3-3,6^0C also has been marked in comparison to the long-term data, and on the contrary, in July there was a significant (at $8,1^0$C) excess of the temperature at $29,6^0$C and $21,5^0$C, respectively.

Precipitation in 2015 was considerably smaller than in the previous years and in comparison with long-term data. Just 239 mm of rainfall for 6 month has been dropped, which was less than the average long-term data (288 mm) by 17%. Especially, there was little precipitation in the spring. So, in April 74,8 mm and in May 42,5 mm of precipitation dropped, which was less than the average long-term data by the 17,4 and 47,7%, respectively. Inadequate rainfall was regulated by vegetation irrigation of vegetables, including cabbage.

B. Effect of sprinkler irrigation on the amount of irrigation water and contamination of crops

Experimental plots were laid down on 4 varieties of cabbage (Nezhenka, Belosnezhka, Kharkovskaya zimnyaya, and Slava 1305). At the same time, the influence of sprinkler irrigation on *saving of irrigation water* and *phytosanitary condition* of the fields was studied.

The preliminary results of our research show that finely dispersed irrigation technology with spraying device (sprinkler) demonstrates high efficiency and has great prospects in the soil and climatic conditions of a foothill zone in the south-east of Kazakhstan. Accounting for the consumption of irrigation water showed that the sprinkler irrigation has decreased the cost of irrigation water, markedly.

In 2014 during the growing season of the crops at the furrow irrigation 6200 m^3 and at the sprinkler irrigation 4850 m^3 of irrigation water per 1 hectare of cabbage crops was used. It is less by 1230 m^3, or by 19,83%.

Similar results were obtained in 2015. At conventional method of cabbage irrigation 6550 m^3/ha of water was applied and, while sprinkler irrigation it was 4970 m^3/ha. Saving of irrigation water for growing season comprised 1580 m^3/ha, or 24,12% to control (Fig. 2).

Phytosanitary monitoring of cabbage crops showed that while sprinkler irrigation a contamination of field was significantly reduced. So, in 2014 in the growing season on the variants with finely dispersed irrigation compared with furrow irrigation the number of weeds decreased to 34 units/m^2 or 46,03%. When accounting the field debris in 2015, a reduction of the number of weeds was 34,65%, or up to 33 units/m^2 (Fig. 3).

C. Impact of sprinkler irrigation on quality and yield of cabbage varieties

Qualitative indicators of white cabbage are important as directly linked to the health of the population. Cabbage is a source of vitamins and other nutrients that make up a valuable part of the daily human diet. In this regard, the quality factor of environmental safety is required a special approach.

Mineral nutrition and biochemical composition has a close connection. Optimal mineral nutrition improves the quality of cultivated products significantly, and on the contrary, the excess rate of fertilizer makes it worst.

In this regard, given the importance of the quality of vegetables for fresh food and for processing biochemical analyzes of the crop were performed. Determination of vegetables quality was carried out in the laboratory of mass analysis (Kazakh scientific research institute of potato and vegetable growing).

It has been established that the conditions created by finely dispersed irrigation and fertilizer have a definite effect on the biochemical composition of vegetable products. In the experiments with determination the quality of the products the dry matter content in cabbage heads was 8,32-8,4% during furrow irrigation, and at the variants with sprinkler irrigation it was 9,68-11,96%. Total sugar content also varied depending on the varieties and kinds of experiments. On variant with furrow irrigation depending on the cabbage varieties total sugar content was 4,06-4,7%, on studied variants the same indicator was 4,29-6,06.

Ascorbic acid (vitamin C) in the cabbage is the most valuable and its number increased in the results obtained while using sprinkler irrigation. At the variant with the traditional method of irrigation the vitamin C content in cabbage head was 24,7-28,6, while, on the variants under studied watering it was 24,2-29,70 mg%.

Thus, the greatest amount of ascorbic acid (vitamin C) was recorded on the variants with varieties Belosnezhka and Kharkovskaya zimnyaya

It should be noted that the levels of nitrate in cabbage heads was low on all variants of the experiment. The content of NO_3 in the production were significantly lower of the accepted limit (MPC for cabbage is 500 mg/kg of wet weight). Therefore, products are environmentally friendly.

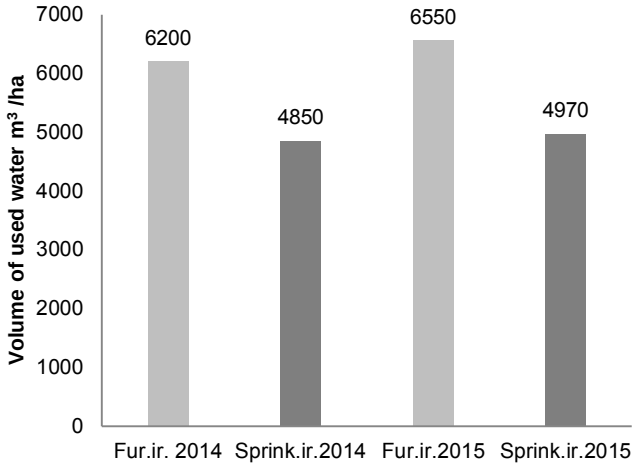

Fig. 2 Influence of sprinkler irrigation on the savings of irrigation water

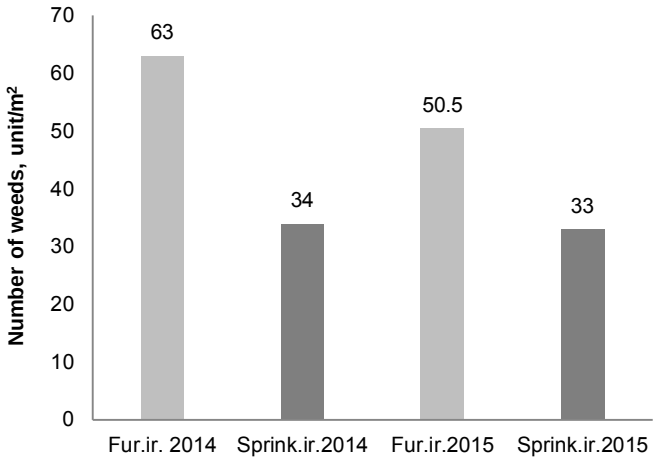

Fig. 3 Influence of sprinkler irrigation on the phytosanitary condition of the fields

TABLE I: MATHEMATICAL PROCESSING OF YIELD DATA OF CABBAGE VARIETIES (2014)

IRRIGATION TECHNOLOGIES	CABBAGE VARIETIES	CABBAGE HEADS YIELD BY REPLICATIONS (t/ha)				AVERAGE YIELD, t/ha
		I	II	III	IV	
FURROW IRRIGATION	BELOSNEZHKA	44,7	41,6	45,1	42,7	43,5
	NEZHENKA	41,9	43,8	40,4	42,2	42,8
	KHARKOVSKAYA ZIMNYAYA	43,0	38,5	41,6	39,4	40,6
	SLAVA 1305	34,2	37,0	33,9	36,3	35,4
SPRINKLER IRRIGATION	BELOSNEZHKA	51,3	50,1	47,5	49,8	49,7
	NEZHENKA	46,6	45,2	50,2	48,5	47,6
	KHARKOVSKAYA ZIMNYAYA	47,6	42,9	48,0	46,8	46,3
	SLAVA 1305	40,4	41,7	37,5	39,5	39,8

TABLE II: MATHEMATICAL PROCESSING OF YIELD DATA OF CABBAGE VARIETIES (2015)

IRRIGATION TECHNOLOGIES	CABBAGE VARIETIES	CABBAGE HEADS YIELD BY REPLICATIONS (t/ha)				AVERAGE YIELD, t/ha
		I	II	III	IV	
FURROW IRRIGATION	BELOSNEZHKA	46,3	43,5	45,1	47,4	45,6
	NEZHENKA	42,8	40,1	39,4	41,2	40,9
	KHARKOVSKAYA ZIMNYAYA	40,7	39,8	41,3	44,0	41,5
	SLAVA 1305	37,5	36,2	38,7	35,5	37,0
SPRINKLER IRRIGATION	BELOSNEZHKA	50,4	53,6	49,0	51,7	51,2
	NEZHENKA	51,0	47,5	47,3	46,3	48,0
	KHARKOVSKAYA ZIMNYAYA	44,9	47,3	43,6	46,8	45,7
	SLAVA 1305	41,6	40,4	44,0	42,5	42,1

The results obtained show that during the use of finely dispersed irrigation compared to conventional way of irrigation the cabbage produced a higher yield (Table I).

As noted in table I, in 2014 during the furrow irrigation in the experimental field the cabbage yield depending on the variety varies from 35,4 to 39,8 tons per 1 ha. Use of a new method of irrigation for watering contributed to adding cabbage productivity. Crop yields ranged from 39,8 to 49,7 t/ha. Accuracy of the experience in 2014 was 3,61%; and the least significant difference was 3,16 t/ha.

Similar results were obtained in data of 2015 (Table II). It easily can be seen that increase in productivity depending on varieties of cabbage ranged between 37,0-45,6 t/ha at the traditional method of watering, whereas in the sprinkler irrigation figures were 42,1-51,2 t/ha. Accuracy of the experience in 2015 was 2,00%; least significant difference was 2,91 t/ha.

This means that due to water saving technology 6,2 and 7,1 tons of additional yield was obtained from 1 hectare in 2014 and 2015, respectively. This is a rather high indicator.

Studies have been conducted to evaluate the effect of irrigation technology on shelf life of cabbage heads. Losses during long storage can reach large sizes (25-30%) due to the biological characteristics of the culture. Factors such as varietal characteristics and conditions of cabbage cultivation affect the shelf life, significantly.

Therefore, the experiments in the storage of Kazakh scientific research institute of potato and vegetable growing have been laid. Currently, the storage mode (temperature, relative humidity, the prevalence of disease) is controlled. The results will be obtained in the spring after the recess of products from storage.

IV. CONCLUSION

Nowadays, under the global climate changes monitoring and management of water resources in irrigation systems take a critical economic importance due to the acute shortage of surface water, which in the future will only increase. Authors have reported that in Central Asia the climate change was

characterized as decreased precipitations. Furthermore, human activities mainly as water consumption for irrigation and reservoirs construction result in shrinkage of inland lakes. Consequently, under climate change scenarios water saving by reducing losses in irrigation systems was estimated at 2,9 km^3 and by applying more efficient farming methods, and the use of new irrigation technologies will be 2,3 km^3 [21]. Therefore, the introduction of the water-saving irrigation technologies is relevant.

In our research it has been established that in comparison with furrow irrigation sprinkler irrigation saves irrigation water, reduces the contamination of fields, considerably. It also contributes to higher yields of cabbage varieties (7 t / h or more) and improves the quality products. Thus, implementation of relatively new method of irrigation in farms of Kazakhstan is very important. That is why scientifically approved recommendations are needed.

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REFERENCES

[1] http://www.economy.gov.kz/economyabout/9251/59665/ On approval of physiological norms of food consumption

[2] USDA U.S. Dept. of Agriculture Agricultural Research Service. 2005. USDA national nutrient database for standard reference release 18. Available from: http://www.nal.usda.gov/fnic/foodcomp/Data/. Accessed May 8, 2007

[3] Jahangir, M., Kim, H. K., Choi, Y. H. and Verpoorte, R. (2009), Health-Affecting Compounds in *Brassicaceae*. Comprehensive Reviews in Food Science and Food Safety, 8: 31–43. doi: 10.1111/j.1541-4337.2008.00065.x

[4] Hounsome, N., Hounsome, B., Tomos, D. and Edwards-Jones, G. (2008), Plant Metabolites and Nutritional Quality of Vegetables. Journal of Food Science, 73: R48–R65. doi: 10.1111/j.1750-3841.2008.00716.x

[5] Verkerk, R., Schreiner, M., Krumbein, A., Ciska, E., Holst, B., Rowland, I., De Schrijver, R., Hansen, M., Gerhäuser, C., Mithen, R. and Dekker, M. (2009), Glucosinolates in *Brassica* vegetables: The influence of the food supply chain on intake, bioavailability and human health. Mol. Nutr. Food Res., 53: S219. doi: 10.1002/mnfr.200800065

[6] Hall, M. K. D., Jobling, J. J. and Rogers, G. S. (2015), Variations in the most abundant types of glucosinolates found in the leaves of baby leaf rocket under typical commercial conditions. J. Sci. Food Agric., 95: 552–559. doi: 10.1002/jsfa.6774

[7] Statistics Committee of RK. Policy brief of vegetable market for 2014.

[8] Mirzakeev E.K., Saparov A.S., Sharypova T.M., Aitbayev T.E. Erosion of piedmont dark chestnut soils of the Trans-Ili Alatau. Proceedings of the international scientific-practical conference "State and prospects of research on potato, vegetables and melons". Kaynar, Kazakh research institute of potato and vegetable growing, July 7-8, 2011, pp. 412-415

[9] Aitbaev T.E., Aitbaeva A.T. Water-saving technologies- a promising way of irrigated vegetable growing // Proceedings of the international scientific-practical conference "Achievements and prospects of agriculture, biology and breeding of crops." Almalybak, 24-25 June, 2010 - p.p. 337-339.

[10] Tattibaev J.A., Kaldarova S.M. Ways to improve the technical level of irrigation. Journal of Agricultural Science of Kazakhstan №9, 2014, pp. 84-90.

[11] Kenenbayev S.B, Manankov M.E. Ways to improve the fertility of the soil in the vegetable growing sector. Thematic collection of scientific papers for potato, melon and vegetable growing. Almaty, 2004, p. 198-201.

[12] Zhaparkulova E.D. Effective ways of water use in irrigated agriculture. Zharshy №11 - 2014, pp. 22-28.

[13] Bekbaev R.K., Zhaparkulova E.D. Ecological processes in the root zone of irrigated soils of southern Kazakhstan. Journal of Agricultural Science of Kazakhstan №12, 2014, pp. 55-58.

[14] Sokolov A.V. Agrochemical research methods of soil. M .: Nauka, 1975 – p.656).

[15] Yudin F.A. Agrochemical Research Methods. Moscow. Kolos 1980, - p. 366).

[16] Dospehov B.I. Methods of field experience. M .: "Kolos", 1985 – p.420)

[17] The methodology of experimental work in the vegetable and melon growing. Ed. V.F.Belik.Moscow: Agropromizdat, 1992 - p.320.

[18] Guidelines for determination of nitrate in crop production. Moscow: Agropromizdat,1986- p.45.

[19] Recommendations. Kaynar, KazNIIKO, 2011.

[20] Methodology for research on storage of vegetables. M., 1982.

[21] State program of water resource management of Kazakhstan for the years 2014-2040 (the project). The Ministry of Environment and Water Resources of Kazakhstan. Astana, 2013, p. 72