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The Impact of New and Improved Elements of Agricultural Technologies on Potato Productivity in the South-east of Kazakhstan

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There are results of research on the effectiveness of new and improved elements of potato cultivation technology applied to the soil and climatic conditions of a foothill zone in the south-east of Kazakhstan. It has been established the influence of various precursors in crop rotations, irrigation technologies, new varieties of potatoes and fertilizer systems on yield, quality and keeping capacity of tubers. It was found that the productivity of a potato has increased by 33,7-39,8% when placing at the best predecessors in crop rotations, by 9,02-12,89% when using water-saving technologies, in the selection of highly productive varieties by 12,5-19, 6%, and while improving the conditions of mineral nutrition - from 18,6 up to 47,3%.

Key words: Potato, variety, crop rotation, finely dispersed irrigation, fertilizer, yield, quality, keeping capacity.

Potato is one of the most important crops. In the global crop production potato ranks fourth place after wheat, rice and corn. Given the importance of the potato as a valuable food crop 2008 was declared as "International Year of the Potato" by the United Nations (UN).

In the Republic of Kazakhstan in 2015, potatoes were cultivated on the area of 190 hectares. The gross yield of tubers was 3,54 million tons. In our country potato is in great demand among the population as an important staple food, in processing enterprises as a valuable raw material. According to the Kazakh Academy of Nutrition, potato consumption rate per 1 inhabitant of the republic is 100 kg per year.

Potato tubers contain an average 23-27% of dry matter, 14-22% of starch, 1,4-3,0% of protein, about 1% of cellulose, 0,2-0,3% of fats and 0,8-1,0 % of ash content. Potatoes are rich enough in vitamins C, B1, B2, B6, PP, and minerals. Especially a lot of vitamins contain in young tubers[1-3].

Gross yield of potatoes in Kazakhstan increases from year by year. This is mainly due to the expansion of cultivated areas of the culture. However, the productivity of potato plantations for many decades grows slowly and still remains low. Average yields of tubers are in the range of 15-18 t/ha, whereas biological potential of new varieties is 45-50 t/ha[2, 4].

To increase the potato yield it is necessary to create and implement in the farms highly productive varieties, as well as to develop new and improve existing technologies of cultivation. The conservation and improvement of soil fertility, irrigation regime, mineral nutrition system and the protection of plants against harmful organisms under strict crop rotation are also of great importance. All these factors play a great role in the formation of high yields of potatoes[2, 3, 5-12].

The foregoing shows the relevance of

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research on the development of elements of agricultural technologies to increase the productivity of the potato culture.

MATERIALS AND METHODS

Fields details

Research was carried out in 2013-2015 years on experimental plots of three departments (the cultivation technology of vegetable crops and potatoes, potato breeding, potatoes seed production) of the Kazakh Scientific Research Institute of Potato and Vegetable Growing (KazSRIPVG), located in Karasai district, Almaty region of Kazakhstan. Research area's description: South East Kazakhstan, foothill zone, 1000-1050 meters above sea level, the slope of the experimental plots - from 2 to 7 ° C.

The climate of the region is sharply continental. The warm period lasts 240-275 days, frost-free period - 140-170 days. Sum of active temperatures equals to 3100-3400 ° C. The hydrothermal coefficient is 0,7-1,0. The annual precipitation constitutes 350-600 mm; 250-320 mm drops out during the growing season.

Soil of experimental plot is dark brown, medium loamy. The humus content in the soil is 3%, total nitrogen – 0,18-0,20%, total phosphorus - 0,19-0,20%, total potassium – 2,4-2,7%, mobile phosphorus ($Ð_2Î_5$) - 33 -35 mg/kg, exchangeable potassium ($Ê_2Î$) - 340-360 mg/kg. The reaction of soil environment is slightly alkaline (pH 7,2-7,3). The bulk density of soil is 1,1-1,2 g/ cm^3.

Sample preparation and analytical methods

Research has been carried out by conventional methods[13-15]. In the experimental fields and laboratory studies methods of field experience (Dospehov, 1985); methods of agrochemical research (Yudin, 1980); the methodology of experimental work in the vegetable and melon growing (ed. V.F.Belik, 1992) were used.

Phenological observations were conducted by the method of A.I. Rudenko (1950) in order to establish the timing and completion of the of certain phase development of plants. During growing season of potato plants following phenological phases have been noted: sprouting, budding, blooming, tuber formation, foliage dying.

Biometric studies have been conducted to determine the effect of studied factors on the potato biomass. At the same time, indicators such as height and the total mass of the plant, the number of stems, the number and weight of the leaves, the number and weight of tubers were taken into account. On experimental plots 3-5 certain places with 10-15 plants in a row with the same plant alimentation area were allocated to carry out the biometric studies.

Accounting for the potato yield was carried out by a continuous method with the determination of its structure in each plot on 4 replications.

Biochemical analyzes of tubers were conducted using the following methods: dry matter - gravimetrically, starch - by Evers, total sugars - by Bertrand, vitamin C - by Murry, nitrates - potentiometrically.

Keeping ability of potato was studied in experimental storages of KazSRIPVG according to the "Guidelines to conduct research on potato storage" (Moscow, 1998). Tubers were stored in perforated plastic bags of 20 kg at a temperature of +2-4° C, air humidity - 88-92%. Experiment was replicated 4-fold. Storage bookmark started in III decade of September; the recess will be realized in III decade of April. Storage period lasts for 7 months.

Potato cultivation in the experiments was carried out in accordance with the recommendations of KazSRIPVG for foothill area in south-east of Kazakhstan. Potatoes planting scheme - 75×25 cm. Density of potato plants standing - 53 thousand units per 1 ha. Potato crop rotations: 3-pole, 5-pole and 7-pole. Types of fertilizer: ammonium nitrate (34% N), double superphosphate (46% P_2O_5) and potassium sulphate (56% K_2O). In experiments 4 varieties of KazSRIPVG selection were cultivated: Berkut, Jualy, Tien Shanski, Ushkonyr.

Experimental data were processed using a statistical method (Dospehov, 1985).

RESULTS AND DISCUSSION

This paper presents the main results of our research on important elements of potato cultivation technology, as crop rotation, variety, irrigation and fertilizer.

Crop rotation is one of the main elements of potato cultivation technology. Potato crop

rotation is the easiest, most affordable, no cost associated, suitable for all manufacturers element of agricultural technology. Science-based and strictly complied rotation ensures good results in terms of soil conservation, improved fields contamination, creating optimal conditions for growing of potato plants and formation of high yields with the best quality indicators and keeping capacity.

Given the importance of crop rotation, we have studied 3 types of crop rotations: 3-pole (cereals, potatoes, eating root vegetables), 5-pole (soya beans, potatoes, cabbage, cucumber, eating root vegetables) and 7-pole (corn with sowing of perennial grasses, perennial herbs, perennial herbs, potatoes, cabbage, onions, potatoes). In process of crop rotation productivity of potatoes was determined. It was found that the precursors have a significant impact on crop yield. For example, during the cultivation of potatoes in the 3-pole short rotational crop rotation, where the precursor was barley, tuber yield made up 24,4-27,6 t/ha. Under the conditions of 5-pole intensive vegetable crop rotation, where the potato was placed after the legume (soybeans) enriching the soil with nitrogen 28,0-31,7 t/ha tubers were formed. In the 7-pole vegetables-potato-herbs crop rotation on a layer of alfalfa 34,1-36,9 t/ha of potatoes were received. The highest potato yields were achieved by placing a potato on perennial grasses. For 3 years of growing alfalfa soil is enriched with nitrogen, organic matter, its agrochemical, agro physical and biological properties are improved. This contributes to increase of powerful plant biomass and the formation of high yields of potatoes.

One of the important elements of potato cultivation technology is irrigation. In Kazakhstan with the exception of mountainous areas (1500-2000 m above sea level), where precipitation amount is quite a lot, mostly potatoes are cultivated on irrigated land. High yields of tubers can be obtained only when the irrigation of potato is used. However, the development of irrigation erosion on the slope of the land and limited water resources pose some problems in potato irrigation. In this regard, we have identified the role of water-saving technologies in the chain of agro-technical methods of potatoes cultivation. On the experimental plots the efficacy of a finely dispersed irrigation technology via using sprinklers was assessed.

Table 1. Influence of finely dispersed irrigation on potato yield (t/ha)

Irrigation technology	Potato varieties				
	Tamasha	Berkut	Jualy	Tien Shanski	Ushkonyr
Furrow irrigation	25,5	29,9	29,4	28,7	30,5
Finely dispersed irrigation	27,8	32,7	32,8	32,4	33,6
Harvest difference t/ha	2,3	2,8	3,4	3,7	3,1
%	9,02	9,36	11,56	12,89	10,16

Note - on mineral background $N_{200}P_{120}K_{160}$

Our research has shown that sprinkler irrigation has a definite advantage over furrow irrigation. So, depending on potato varieties the value of the additional tuber yield per 1 ha area was as follows: Tamasha – 9,02%, Berkut – 9,36%, Jualy – 11,56%, Tien Shanski – 12,89%, Ushkonyr – 10,16% (Table 1). Probably, the data on yield increase of potato tubers by using sprinkler irrigation is relatively low, however, a significant excess compared with traditional furrow irrigation was observed. There are also important other aspects - prevention of irrigation erosion and conservation of irrigation water.

There are some differences between the varieties of potato. So, in relation to a variety, Tamasha (approved for use in 1996), new crop varieties have provided a significant increase in tuber yield. When cultivating varieties Berkut (2014) growth of the potato yield was 17,25%, Jualy (2012) – 15,29%, Tien Shanski (2014) – 12,55%, Ushkonyr (2012) – 19,61%.

The use of mineral fertilizers is considered an important factor increasing the tuber yield. Therefore, in the experimental plots we have studied

the effectiveness of various rates of fertilizer used during the planting of potatoes new varieties of Kazakhstan breeding. The results obtained are shown in table 2.

Table 2. The productivity of potato varieties depending on the rates of mineral fertilizers (2013-2015)

Fertilizer rates	Potatoes new varieties of Kazakhstan breeding							
	Tien Shanski		Jualy		Berkut		Ushkonyr	
	Yield, t/ha	Increment from NPK,%	Yield, t/ha	Increment from NPK,%	Yield, t/ha	Increment from NPK,%	Yield, t/ha	Increment from NPK,%
$N_0P_0K_0$	20,0	-	20,2	-	21,1	-	20,7	-
$N_{50}P_{30}K_{40}$	21,2	6,0	22,1	9,4	23,3	10,4	22,9	10,6
$N_{100}P_{60}K_{80}$	23,7	18,5	24,3	20,3	25,6	21,3	24,9	20,3
$N_{150}P_{90}K_{120}$	26,8	34,0	26,1	29,2	27,5	30,3	26,7	28,9
$N_{200}P_{120}K_{160}$	28,7	43,5	29,4	45,5	29,9	41,7	30,5	47,3

m, %: 1,22-1,48; LSD_{05}, t/ha: 0,98-1,19

All studied new varieties of potatoes have produced the minimum tuber crops without the use of fertilizer in the experiments: Tien Shanski – 20,0 t/ha; Jualy – 20,2 t/ha; Berkut – 21,1 t/ha; Ushkonyr – 20,7 t/ha. On fertilized variants of the experiment a significant increase in potato crops was observed: Tien Shanski - 6,0-43,5%; Jualy - 9,4-45,5%; Berkut - 10,4-41,7%; Ushkonyr - 10,6-47,3%. Relatively high values of potato productivity were obtained when for the mineral nutrition of plants elevated and high standards of NPK-fertilizers were used.

Since potato is a product consumed almost every day its quality indicators are of a big importance. The quality of the potato crop has a close relationship with a number of factors. Among them, mineral fertilizers have the greatest impact on the biochemical composition of tubers, because they determine the conditions of plant nutrition. Considering this, biochemical analyzes of potato varieties harvested from various fertilized variants of field experiments were conducted.

Table 3 summarizes the laboratory data to assess the impact of fertilizer norms on the quality indicators of new potato varieties of Kazakhstan breeding. Improved quality indicators of tubers were marked for all varieties studied under the influence of the fertilizers. The dry matter content in the tubers for a variety Tien Shanski was on control 25%, on fertilized variants - 26,4-27,4%; for a variety Jualy – 26,4% and 26,8-28,0%; for Berkut – 25,0% and 26,0-27,3%; for a variety Ushkonyr – 24,7% and 24,8-26,7%, respectively. There was also a slight increase in the content of vitamin C, which fluctuated within an average of 10-12 mg%. Results obtained on total sugar content differed by varieties and fertilization rates. In experiments with a new variety Tien Shanski on control variant tubers contained 3,5% of total sugar, and on the fertilized variants – 2,9-3,5%. In experiments with a variety Jualy there was a slight decrease in the total sugar content: on control – 3,8%, on fertilized variants – 3,2-3,6% (except for the variant with the moderate NPK standards – 4,5%). Positive effect of fertilizers on the total sugar content in the tubers of new varieties Ushkonyr and Berkut was noted. Moreover, the starch content in the tubers, which is the primary indicator of potato, was quite high in all varieties, mostly at the level of 18-20%. In some variants a slight reduction in starch content was observed when big norms of NPK-fertilizers were applied. This can be explained by the growth of the tubers and the dilution of the starch throughout the large volume of the tuber.

The nitrate content in tubers was significantly lower than the maximum allowable norms for potatoes (250 mg/kg wet weight) indicating the environmental safety of farmed product.

Keeping capacity is an important indicator of the potato during storage. We studied

Table 3. The quality and keeping capacity of potato varieties depending on the rates of fertilizers (2013-2015)

S. No.	Fertilizer rates	Dry matter, %	Vitamin C, mg/%	Total sugars, %	Starch content, %	Nitrates, mg/kg	Keeping capacity, %
Variety Tien Shanski							
1	$N_0P_0K_0$	25,8	9,9	3,5	19,4	19	88,5
2	$N_{50}P_{30}K_{40}$	27,1	10,2	3,5	19,6	31	89,6
3	$N_{100}P_{60}K_{80}$	26,4	10,9	2,9	17,9	40	91,4
4	$N_{150}P_{90}K_{120}$	26,4	12,3	3,0	18,1	62	90,5
5	$N_{200}P_{120}K_{160}$	27,4	11,8	3,1	18,9	83	87,2
Variety Jualy							
1	$N_0P_0K_0$	26,4	9,5	3,8	19,6	17	87,9
2	$N_{50}P_{30}K_{40}$	28,0	10,8	4,5	19,8	31	88,4
3	$N_{100}P_{60}K_{80}$	27,9	12,2	3,4	19,5	40	89,3
4	$N_{150}P_{90}K_{120}$	26,8	12,1	3,6	19,9	56	87,0
5	$N_{200}P_{120}K_{160}$	27,8	10,3	3,2	18,8	78	86,8
Variety Berkut							
1	$N_0P_0K_0$	25,0	10,6	2,6	18,2	14	89,1
2	$N_{50}P_{30}K_{40}$	26,0	11,3	3,3	18,4	31	89,3
3	$N_{100}P_{60}K_{80}$	26,4	12,1	3,1	17,5	44	90,7
4	$N_{150}P_{90}K_{120}$	27,3	10,9	3,2	17,6	56	91,0
5	$N_{200}P_{120}K_{160}$	26,0	10,8	2,6	15,5	80	88,5
Variety Ushkonyr							
1	$N_0P_0K_0$	24,7	10,9	2,4	17,8	15	90,2
2	$N_{50}P_{30}K_{40}$	24,8	11,8	3,0	19,0	30	91,0
3	$N_{100}P_{60}K_{80}$	26,0	12,5	2,9	19,0	45	90,4
4	$N_{150}P_{90}K_{120}$	26,7	11,5	3,1	19,4	57	89,8
5	$N_{200}P_{120}K_{160}$	25,8	11,0	2,3	18,5	82	89,0

keeping quality of new crop varieties, depending on the varietal characteristics and conditions of mineral nutrition. According to data received, all new varieties of potato have high storage ability - at the level of 89-91%. Total losses of potatoes during long-term storage (7 months) were in average 9-11%. If we consider that from the total losses in the share of natural loss of mass account for about 7-8%, these figures can be considered as a minimum. Moderate and average, and in some varieties the increased rate of fertilizers had positive effect on potato storage ability.

CONCLUSION

Thus, potatoes placing at the best predecessors in crop rotation promotes increase of culture productivity by 33,7-39,8%. The use of water-saving irrigation technology provides growth of potato tubers at harvest by 9,02-12,89%. The cultivation of high-yield varieties of potato increases crop yield by 12,5-19,6%. It was found that the improvement of the conditions of mineral nutrition of potato plants increases their productivity by 18,6-47,3%. Under the influence of optimal fertilization rates the improvement in biochemical parameters was observed: in tubers dry matter content, starch, total sugar and vitamin C have increased, significantly. The optimal mineral nutrition has provided high keeping capacity of tubers during long-term (7 months) storage in the average by 90-91%.

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