The effectiveness of the use of mineral fertilizers in the technology of potato seed production in the conditions of the mountainous zone of Kabardino-Balkaria

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Abstract. The realization of the maximum productive capabilities of agricultural crops provides for mandatory compliance with a number of technological situations. Mountainous areas with a temperate climate of the North Caucasus have the best soils for potato cultivation. Optimization of technological parameters of the use of mineral fertilizers for the production of potato seed material in the conditions of the mountainous zone of Kabardino-Balkaria is an important urgent task of modern seed culture. The correct system of mineral nutrition is the key to reducing the impact of the negative consequences of adverse climatic conditions on the plant nutrition and, in general, on the growth and development of potato plants. The introduction of combinations of nitrogen-phosphorus and nitrogen-potassium against the background of increased nitrogen content in the soil does not provide high rates of photosynthetic potential of potato plantings. Optimized application of NPK mineral fertilizers and combination with non-root spraying with a trace element in the budding-flowering phase of potatoes contributes to the production of more seed material and higher quality.

1 Introduction

The mountainous areas of potato origin have affected its biological and ecological status. The realization of the maximum productive capabilities of agricultural crops provides for mandatory compliance with a number of technological situations. Compared with other agricultural plants, potatoes have a relatively poorly developed root system, the depth of penetration of the root system is small and does not exceed a depth of 60-70 cm [2, 3].

This determines the high demands of potato plants on the soil moisture regime and the level of mineral availability of the fertile soil layer.

Optimal soil and climatic conditions for potatoes are regions with moderately warm summers and with light granulometric soil parameters. The highlands of Kabardino-Balkaria with a cool climate, with a relatively light granulometry composition, low-weathered, light, sod humus accumulative, never subjected to waterlogging of the soil determined the preference of the area for scientific research.

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The temperate climate of the mountainous regions of the North Caucasus region has at its disposal the best soil and climatic conditions for potato cultivation. Chernozem (black earth) and forest light soils are concentrated in Karachay-Cherkessia, Kabardino-Balkaria, North Ossetia, Alania and Krasnodar region, where high yields of excellent quality potatoes are obtained on high-altitude and mountainous chernozems, the height of the location above sea level is from 600 to 1000 m .

Currently, perceptions regarding the consumer and table qualities of food potatoes and the structure of the intended use of the crop are changing [1, 6].

The combination of the optimal humidity regime and growth regulators in addition to the use of NPK contributed to an increase in the number of tubers of the seed fraction of this size per bush and per hectare of plantings. In 2013, the increase in the yield of the seed fraction in these variants was expressed in 12-13 percent, in 2014 — 12-16 percent compared to 229-254 thousand tubers per hectare with the use of NPK [8].

Leaf fertilizing by spraying of vegetative potato plants with micro-fertilizers in chelated form stimulate the productive work of leaves, providing a high yield of tubers (14.79-15.53 kg per 1000 units of photosynthetic potential) and an increase in potato yield (by 16.2-18.0 t/ha of tubers [9].

An important role in increasing potato yields belongs to seed production. The organization of the production of high-quality seed tubers is a complex and energy-intensive work. Optimization of technological parameters for specific conditions of seed production of higher reproductions is an important urgent task of modern agriculture. Potatoes have an increased ability to mineralize the organic matter of the soil and a large amount of its assimilation. Therefore, the relevance of developing a mineral nutrition regime for all cultivation conditions remains always relevant.

Determining the issue for solving the problem of increasing productivity and product quality concerning soil fertility is especially significant. When solving this issue, you need to clearly know the indicators of soil fertility, the improvement of which will potentially raise the level of plant productivity. At the moment, in the world of agricultural production, an increase in yield by 50% is achieved due to optimizing the fertilizer system of the crop in the crop rotation [7].

In cultivation technology, potatoes are one of the most fertilized plants, the calculated doses of fertilizers per hectare are the highest. The structure of mineral fertilizers according to active substances is quite stable: nitrogen accounts for 61%, phosphorus - 24% and potassium - 15%.

The soil and climatic factors of the place of cultivation play a decisive role in the effectiveness of mineral fertilizers. Dependence on the weather conditions of the cultivation that develops during the year limits the effectiveness of the use of mineral fertilizers in technology, and therefore there is a need for a thorough study of the issues of mineral nutrition of potatoes in the agroecological conditions of the mountainous zone.

Creating optimal conditions for obtaining seed material of higher reproductions of domestic varieties is an urgent issue for each seed farm. This mainly affects not only the yield and quality of products, but also the food security of the country, in terms of the importance of culture for the population.

The purpose of this work is to optimize the technological parameters of the use of mineral fertilizers for the production of potato seed material in the conditions of the mountainous zone of Kabardino-Balkaria.

The scientific novelty lies in the identification of the possibility of increasing the yield of seed material and its quality in the fertilizer system of crop rotation in a mountainous zone.

The practical significance of the work is to optimize the fertilizer system of crop rotation in the technology of potato planting material production by using various combinations of mineral fertilizers.

2 Materials and Methods

Research work to identify the effectiveness of plant growth regulators is carried out within the framework of the plan of a comprehensive scientific and technical project in the fields of LLC “Zolsky Potato [4,5].

Agrotechnics of growing seed potatoes in the nursery is designed to use advanced technology with the use of high-class tools and machines. In the research, elite seed tubers of domestic varieties with an average weight of 65g were used for planting. The predecessor in the crop rotation was winter barley. The planting scheme provided for the distribution of 60 thousand tubers per hectare, the planting depth was 10-15cm, when creating a ridge, its height was 18-20cm. The working area of the plot is 72 m2, the accounting area is 60m2[4,5].

Field experiments, observations, and laboratory analyses were carried out according to generally accepted methods. Mathematical processing of yields was carried out using computer programs for statistical data processing.

During the growing season of potatoes, observations, analyses, and records were carried out in accordance with generally accepted methods. Phenological observations were carried out in accordance with the "Potato Culture Research Methodology". Cleaning is done manually. Mandatory accounting procedures are carried out for diseases: phttophthora , ring rot, blackleg, scab, rhizoctoniosis and viral diseases. The level of starch content in potato tubers is determined for all varieties of the same ripening period [4, 5].

The area of the assimilation surface was determined using a modified method of accelerated calculation of the area of the leaf surface of agricultural crops using a scanner.

Analysis of the structure of the potato crop; plant resistance to diseases and pests was evaluated before harvesting according to the "Reference scale for accounting the damage to the surface of tubers by diseases" [1, 5].

The qualitative indicators of the harvest were determined by the content of dry matter in it – starch, nitrogen, ash content, vitamin content. The yield of dry matter in tubers was determined by drying at a temperature of 105 ° C, starch – by washing and further drying the crushed mass of tubers, nitrate nitrogen – using a pH meter by an electrode method, protein – according to State Standard 134964-84. ash content – was found by tubers burned in a muffle furnace, previously well washed, dried and weighed (according to State Standard 26226-84). The yield data of the varieties underwent a computer analysis of variance [4, 5].

The object of research were domestic varieties: early ripening- Goryanka, Zhukovsky the early, Udacha.

The effectiveness of fertilizers in the field experiment was studied against a background of very high humus content in the soil, but at the same time the phosphorus content was very low, and the potassium content was increased. The scheme of the experiment covered the options allowing to determine the effect of each element of mineral nutrition against the background of the other two elements. The doses of mineral fertilizers in the experiment were calculated by the balance method, taking into account the nutrient content in the soil for an increase in the yield of tubers by 70%. The scheme was supplemented with a variant with the use of « Microvit» along with a full dose of mineral fertilizer N90P90K90. Spraying of the tops was carried out in the budding phase at a dose of 2 liters / ha with a working fluid in the volume of 300 liters. The composition of Microvit includes: boron - 9

g / l, iron – 30, manganese – 20, copper – 8, zinc – 8, molybdenum – 5, cobalt– 1, sulfur– 40, nitrogen– 30, phosphorus - 2.5, potassium - 20, magnesium – 14 g / l.

3 Results and Discussion

The results obtained to establish the effectiveness of the use of mineral fertilizers in crop rotation on potatoes confirm that a properly composed system of mineral nutrition of the crop was the main method of agricultural technology, contributing to an increase in the dynamics of the process of assimilation area formation, the duration of its active work during the growing season of potatoes. The use of mineral fertilizers, especially in the variants of the experiment with a more significant background, a significant increase in this indicator compared to the control variant is observed at all times of taking into account the area of the assimilation surface.

The analysis of the obtained data on the dynamics of the assimilation surface growth showed that the maximum leaf surface was registered in the potato flowering phase. On average, in three years, the area of leaves under control in this phase reached by varieties: Goryanka-24.51, Zhukovsky early - 27.44 and Udacha - 33.24 thousand m2/ha. The introduction of NP combinations increased the leaf area by 8.0, 11.68 and 9.624 thousand m2/ha times, respectively, against the background of NK – by 11.11, 5.2 and 8.7 thousand m2/ha times, PK – 11.7, 14.86 and 11.6 thousand m2/ha times, and against the background of N90P90K90+ Microvit, the leaf area was 1.69, 1.59 and 1.36 times higher compared to the control version. It should be noted that in the Zhukovsky early variety, the difference in increase in the third variant is 2 times lower than in the variants with the use of nitrogen fertilizers. On the other two varieties, we did not observe a significant decrease from lack of nitrogen.

By the time of mowing the tops, the leaf area on average decreased by 2 times. They gradually died off, and their assimilation activity significantly decreased.

The photosynthetic potential of potato plantings of the fourth variant was of the greatest importance for all varieties (Table 1), the average excess with the control variant was 1124, 1249 and 927 thousand m2 × days/ha. On average, for four years, the photosynthetic potential varied against the background of N60P120 and N60 K180 – the same for all varieties and this indicator exceeded the control variant by 1.39, 1.09 and 1.37 thousand m2 × days/ha times. Against the background of P120K180, this indicator is 1.42, 1.57 and 1.36 thousand m2 × days /ha, which suggests that these varieties need phosphorus-potassium fertilizers first of all to increase the photosynthetic potential index. The introduction of combinations of nitrogen-phosphorus and nitrogen-potassium against the background of increased nitrogen content in the soil does not provide high rates of photosynthetic potential of potato plantings. It should also be noted that in the third variant, the efficiency of potassium absorption from fertilizers by plants is lower than in the second variant, due to its positional inaccessibility. The reason is the transition of potassium in the soil to a state of inaccessibility to plants due to the high percentage of silty fraction in the granulometric composition of the soil. This, in turn, leads to the predominance of the physiological excretory process of potassium by the root system of plants over its consumer. In contrast to the use of potash fertilizers, the effectiveness of phosphorus fertilizers in all phases of potato vegetation is noted.

Table 1. Photosynthetic potential of potato plantings under various systems of mineral fertilizers in crop rotation, thousand m2 × days/ha, 2018-2021.

Experience variant	Development phase				amount for vegetation
	Shoots-budding	Budding-flowering	Flowering-the beginning of tops wilting	the beginning of tops- wilting harvesting	
Goryanka					
Control variant without fertilisers	299	274	1186	310	2069
$N_{60}P_{120}$	423	385	1988	456	3252
$N_{60}K_{180}$	411	394	1844	408	3057
$P_{120}K_{180}$	408	348	1804	388	2948
$N_{90}P_{90}K_{90}$ +Microvit	442	340	1985	426	3193
Zhukovskiy early					
Control-variant without fertilisers	317	235	1265	383	2200
$N_{60}P_{120}$	473	368	2052	459	3352
$N_{60}K_{180}$	445	326	1638	421	2830
$P_{120}K_{180}$	359	297	1490	396	2542
$N_{90}P_{90}K_{90}$ +Microvit	481	382	2179	407	3449
Udacha					
Control variant without fertilisers	356	310	1466	398	2539
$N_{60}P_{120}$	488	424	2189	432	3533
$N_{60}K_{180}$	474	409	2124	422	3429
$P_{120}K_{180}$	476	400	2108	409	3393
$N_{90}P_{90}K_{90}$ +Microvit	498	422	2204	438	3466

The conducted studies have shown that the calculated doses of mineral fertilizers for the programmed increase in the productivity of potato plants were fully justified (Table 2). The value of potato productivity and the effectiveness of the use of mineral fertilizers over the years were primarily due to the interaction of two main growth factors: annual moisture supply and elements of mineral nutrition during the growing season.

In conditions of favorable humidification in 2019 and 2021, the efficiency of soil fertility reserves and background application of mineral fertilizers increases sharply, which contributes to the creation of conditions for obtaining higher productivity of potato plants on all tested varieties. It can also be indicated that the maximum amount of precipitation fell in these years during the phase of the greatest need for moisture in the budding and flowering phase.

The control variant without fertilization in 2020, when the plants were subjected to the greatest moisture deficiency, productivity was of the minimum value and averaged 8.74 t/ha, which is significantly lower than the yield in the moisture-friendly 2021, when the productivity in the control averaged 21.36 t/ha, this indicator is 244.4% more. It follows from this that the provision of crops with moisture is the main condition for increasing the efficiency of mineral fertilizers.

With the improvement of the water regime in the experience of 2019 and 2021, the responsiveness of potatoes to a significant level of potato nutrition also increases sharply. The increased consistency of high-altitude soils with the main mineral nutrients, to what extent the effectiveness of the use of fertilizers has been reduced. In our experiments, there is an increase in the trend of positive action, the effectiveness of the combination of nitrogen and phosphorus fertilizers in the second variant. A fairly significant efficiency of the use of nitrogen fertilizers was achieved in the experience of the relatively wet years of the study in 2019 and 2021.. In these years, there is a high efficiency of nitrogen action in the first half of the growing season of potatoes, both in the dynamics of growth and the number of stems.

The low initial level of availability of phosphorus content in the soil for plants and the low degree of its use by potato plants is shown in the control variant. The use of phosphorus fertilizers on the variants provided an increase in the productivity of the crop. And the combination of phosphorus and potassium gives an even higher increase than their separate use in the second and third variants. The increase in productivity of early-ripening potato varieties was 138% for the Goryanka variety, 170% for Zhukovsky early and 193.5% for Udacha. These results prove once again that a high increase in productivity is achieved with a low content of mobile phosphorus in the soil, under these conditions, the effectiveness of readily available mineral phosphorus fertilizers is most significant. The effectiveness of phosphorus fertilizers for potatoes naturally and non-linearly decreases as its content in the soil increases in an accessible form.

Table 2. Productivity of early-ripening potato varieties depending on the fertilizer system in crop rotation, t/ha, (2018-2021).

Experience option	2018	2019	2020	2021	Average	Increase t/ha
Giryanka						
control variant without fertilization	13,24	18,04	8,56	20,42	15,07	-
$N_{60}P_{120}$	21,48	28,56	13,42	28,22	22,65	7,58
$N_{60}K_{180}$	20,20	27,24	13,08	27,46	22,0	6,93
$P_{120}K_{180}$	22,08	31,20	13,96	31,24	26,01	10,94
$N_{90}P_{90}K_{90}$ +Microvit	24,32	35,44	16,38	34,36	27,63	12,56
HCP $_{0,5}$	0,56	0,62	0,30	0,41	0,50	
Zhukovskiy the early						
control variant without fertilization	16,36	19,57	9,42	21,1	16,61	-
$N_{60}P_{120}$	25,42	36,71	15,58	35,89	28,4	11,79
$N_{60}K_{180}$	23,28	32,90	13,39	32,97	25,64	9,03
$P_{120}K_{180}$	25,59	37,27	15,44	37,11	28,85	12,24
$N_{90}P_{90}K_{90}$ +Microvit	31,77	43,86	18,15	42,01	33,95	17,34
HCP $_{0,5}$	0,56	0,62	0,30	0,41	0,50	

Udacha						
control variant without fertilization	19,64	23,8	8,24	22,56	18,56	-
$N_{60}P_{120}$	28,55	42,36	16,64	34,08	30,41	11,85
$N_{60}K_{180}$	26,96	41,89	16,40	32,95	30,08	11,52
$P_{120}K_{180}$	29,64	43,32	16,04	35,42	31,11	12,55
$N_{90}P_{90}K_{90}$ +Microvit	34,14	45,56	19,12	43,64	35,62	17,06
$HCP_{0,5}$	0,56	0,62	0,30	0,41		

When using the natural content of soil minerals, the average yield of potato tubers for four years was on average 16.75t/ha, the highest productivity in the control variant was shown by the Luck variety 18.56 t/ha. The application of the NP NK fertilizer combination showed a higher reliable increase in all varieties according to the option with the use of phosphorus fertilizers. If this difference was insignificant for the Goryanka and Udacha varieties, then for the Zhukovsky early variety the difference was more than 16.6 t/ha.

The PK combination for all grades gives a higher increase compared to the second and third options. If for the Goryanka variety this indicator exceeds the increase by more than 3 t / ha, then for other varieties the difference is no more than 1t / ha. These data prove once again that the equivalence of phosphoric and potash fertilizers, their introduction into the soil, regardless of the presence of their amount in the soil, is a necessary technological technique.

A full range of macro fertilizers enhanced with Microfit for all varieties gives the greatest increase. On the Goryanka variety 83.3% and Luck 91.9%, but the Zhukovsky early variety showed higher responsiveness, where the increase was more than 100%.

4 Conclusion

Conclusions based on the results of research on the optimization of mineral nutrition in the technology of growing potato seed material.

The value of potato productivity on the mountain meadow chernozem soil of the mountain zone mainly depends on the availability of moisture during the growing season. This is the dominant factor determining the effectiveness of mineral nutrition. Optimization of mineral nutrition by applying fertilizers amortizes to some extent the deterioration of moisture supply for the growth and development of potatoes. To increase the FP index, phosphorus-potassium fertilizers are needed first of all.

The introduction of combinations of nitrogen-phosphorus and nitrogen-potassium against the background of increased nitrogen content in the soil does not provide high rates of AF of potato plantings. In contrast to the use of potash fertilizers, the effectiveness of phosphorus fertilizers in all phases of potato vegetation is noted.

The potato yield and the efficiency of mineral fertilizers application over the years were primarily determined by the interaction of two main factors of growth and development - moisture availability and mineral nutrition regime.

The PK combination for all grades gives a higher increase compared to the second and third options. If for the Goryanka variety this indicator exceeds the increase by more than 3t / ha, then for other varieties the difference is no more than 1t / ha. These data prove once again that the equivalence of phosphoric and potash fertilizers, their introduction into the soil, regardless to their amount in the soil, is a necessary technological technique.

Optimized application of NPK mineral fertilizers and combination with non-root sprayings with a trace element in the budding-flowering phase of potatoes contributes to obtaining the highest seed material and higher quality.

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