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Indicators of the Relationship Between the Chemical Composition of Plant and Harvest Potatoes

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Abstract

The authors carried out long-term research on the effect of mineral fertilizers on the "Gala" potato variety in the Pavlodar region. The relationship was established between the nitrogen, phosphorus and potassium chemical composition of the potato plant in certain phases of growth and development. Various chemical and biochemical processes occur in soil and plants every second. The productivity of plants (y) depends on how the processes take place and proceed, since it is a function of the chemical composition (x) of the leaves: y = f x. The theoretical foundations of plant diagnostics are based on the role of nutrients in the formation of the crop, starting from the early stages of development. According to Yu. I. Ermokhin, the theory of this research provides information on the needs of plants, and in practice these needs must be satisfied. The authors carried out field experiments with fertilizers to obtain the sought-for connections from the low to the optimal content between the ratio of nutrients in the potato plant, which is confirmed by high correlation coefficients (r = 0.79-0.97). If the nitrogen content is higher than the optimal 4.64% in the 7-leaf phase and 4.16% in the flowering phase, then the nature of the ovary takes on a different meaning and the equation is described in a quadratic parabola form.

Keywords: potato, harvest, nutrition, fertilizers, plant growth.

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1. Introduction

Lately, experts in Russia and abroad have begun to recognize the need to diagnose plant nutrition conditions by the plant chemical composition. The development of fast, simple and accurate methods for diagnosing the mineral nutrition is one of the main methods for increasing the efficiency of fertilizers [1].

The potato is one of the main vegetable crops in North and North-East Kazakhstan. Numerous studies show that the balanced plant nutrition using fertilizers is a key factor of

high and stable yields. Significant differences in soil and climatic conditions of different regions, including Northern Kazakhstan, in the framework of potato growing require constant study of potato nutrition, depending on the growing region.

The plant diagnostics is a promising method that clarifies the actual need of vegetable crops for fertilizers and makes it possible to take measures to improve the plant nutrition during the growing season [2].

In Kazakhstan, special attention is paid to the agricultural sector. The level and quality of life of the country's population change constantly [3]. The population in the Pavlodar region is provided with potatoes only by 70-75% thanks to local producers. Every year the need for potatoes grows and there is a need for an import of the missing volume of potatoes. Safeguarding the national food security of the republic is a priority of the Russia's policy. In connection with this, the creation of a balanced nutrition of agricultural crops in order to obtain ecologically high-quality crop products is one of the decisive factors in ensuring the country's food security.

Currently, to increase the cultivation of potatoes in the region, it is necessary to use varieties of the local selection of potatoes with higher economic characteristics. This will make it possible to create competition for varieties of foreign producers that have filled the local market.

The correct establishment of the doses of the optimal ratio of nutrients in plants, the timing and methods of application for a particular agricultural crop, the determination of the latter's need for fertilizers in case of their sharp relative deficiency or excess and imbalance in the soil are now more and more important. The potatoes' need in nutritional elements varies depending on the cultivation methods of potatoes, varieties, supply of nutrients with the help of various dosages of fertilizers used in the crop rotation.

The ability of the potato plant to accumulate a significant number of mineral elements is a biological feature of potatoes, which needs increased availability of nutrients.

One of the tasks was to establish the relationship between the chemical composition of plants and the doses of fertilizers used, as well as to establish optimal levels for the potato content and a ratio of nutrients, contained in the plants.

At present, the characteristics of improving the mineral nutrition of potatoes sown in chestnut soils of the Pavlodar region are insufficiently studied. The reality of the prospect of increasing the productivity of the culture can be determined using the science-based fertilization system that provides the high-quality cultivation of potatoes and allows regulating the change in soil fertility without disturbing the ecological stoppage of agrobiogeocenosis.

2. Methods and Equipment

Field experiments were carried out on the basis of the *Ushterek & K* LLP in the Pavlodar region of the Republic of Kazakhstan in 2016-2017. The objects were the *Gala* potatoes variety, soil, mineral fertilizers, combined in a single complex with agrotechnical measures and meteorological conditions.

The experiments were laid in the field, based on the potato research work program of 2016-2017. The potatoes were planted in blackfallow. The factor determining the size of the yield in the experiment is various doses and combinations of mineral fertilizers with paired and triple combinations of N, P and K elements.

The experience was laid in a 4-fold repetition with the allocation of plots in four tiers. The individual plot area was 48 m^2.

The forms of fertilizers were ammonium nitrate (N - 34.5%), ammophos (N - 12%, P_2O_5 - 52%), potassium chloride (K_2O - 62%).

3. Results

It is known that soil analysis does not always reflect the true availability of nutrients to a plant. Since the soil environment even within the same variety is far from being homogeneous, microrelief, texture and microstructure of the soil, the content of trace elements, the biological activity of the soil contribute to the different efficiency of the use of basic nutrients by plants due to the heterogeneity of the conditions of growth and development. J. B. Bussengo, having carried out physiological studies in 1837 - 1838, noted the impossibility of assessing the availability of nutrients by soil analysis and believed that to check the opinions of scientists, one should ‘ask for the opinion’ of the plant itself [1, 2].

The method of plant diagnostics, in contrast to soil analysis, reflects the direct intake and accumulation of the main nutrients in the plant at each critical period of the formation of the future crop and adjusts the need for agricultural crops in nutrients by development phases. The ability to determine and identify the relationship between the value of nutrient intake in plants with their growth and development, and, ultimately, with the yield and quality, has always been one of the main tasks of agricultural chemists, both in our country and abroad [4, 5].

The results of the method of plant diagnostics make it possible to obtain the ‘response’ of a plant to its supply with nutrients [6–8] and use these data to refine

the analysis of soils, composition and doses of fertilizers in order to increase their efficiency [9, 10].

The use of various doses and combinations of mineral fertilizers for potatoes made it possible to observe their effect on the process of the entry of basic nutrients into plants during the vegetation period [11-15].

For example, in the phase of 7 leaves, the applied combinations of nitrogen fertilizers from 45 to 135 kg a. s./ha against the background of $P_{45}K_{45}$ increased the total nitrogen content in potato plants: from 4.27% to 4.69%, i.e. by 9.8% (table 1).

Table 1 presents data obtained from the study of field experiments with fertilizers, showing the relationship (x) between the potato harvest and the level of total nitrogen in plants during ontogenesis from low (4.27% N – phase of 7 leaves, 3.86% - flowering phase) to the optimum content. Respectively, 4.64; 4.16% of N are meaningful because they are characterized by high correlation coefficients (Table 2).

Table 1: The dependence of the yield of potato tubers on the nitrogen content (% on the dry matter) in plants

Potato yield, t / ha	Phase of 7 leaves		Flowering phase	
	% N	Increase, %	% N	Increase, %
30.3	4.27	-	3.86	-
32.7	4.52	5.9	3.93	1.8
33.9	4.64	8.7	4.16	7.8
33.1	4.69	9.8	4.42	14.5

Table 2: Mathematical models of the relationship between the yield of potato tubers (Y, t / ha) and the total nitrogen content in plants (X, %)

Development phase	Regression equation	r
7 leaves	Y = 9.71x - 11.17 (1)	0.99
flowering	Y = 10.31x - 8.77 (2)	0.78

When the total nitrogen content in plants is higher than 4.64% (Table 1 - phase of 7 leaves, % N - 4.69) and above 4.16% (flowering phase, % N - 4.42), the nature of the relationship between the nitrogen content and the yield of potato tubers is described by the quadratic parabola equation (equations 3-4):

$$\text{Y t/ha} = -18.326 \cdot {}^{2} + 171.7 \cdot - 368.75; \quad \eta = 0.94 \tag{3}$$

$$\text{Y t/ha} = -28.559 \cdot {}^{2} + 240.52 \cdot - 472.13; \quad \eta = 0.89. \tag{4}$$

The relationships established by the authors between the chemical composition of plants (in terms of nitrogen) make it possible to construct in the early phase of potato

development practical calculations for the diagnosis of nitrogen nutrition of the culture and forecasting the yield of the studied one.

The introduction of accounting for correlations and their quantitative assessment (equation 1) allow predicting the yield in the range from low to optimal levels of mineral nutrition, to predict the process of plant development at an early stage from the quantitative aspect of plant nutrition [1, 3].

In this there is the deep theoretical meaning and applied value of the link indicators - 'chemical composition of plants – harvest'.

According to equations 1-2, data were obtained on the level of nitrogen nutrition during the formation of the potato yield.

Thus, in the development phase of 7 potato leaves (critical nutritional level) with an increase in nitrogen content by 0.1%, the yield increased by 0.97 t / ha; in the flowering phase this quantitative characteristic was 1.0 t / ha.

Therefore, the specific yields of potato tubers of this culture should have an optimal chemical composition of nitrogen in crucial phases of growth and development.

Thus, according to equation 2, the forecast nitrogen content in the flowering stage is to yield:

$$30 \text{ t tubers/ha} : \%N = \frac{30\,t + 8.77\,t}{10.31} = 3.76\%,$$

$$33 \text{ t tubers/ha} : \%N = \frac{33\,t + 8.77\,t}{10.31} = 4.05\%,$$

$$34 \text{ t tubers/ha} : \%N = \frac{34\,t + 8.77\,t}{10.31} = 4.15\%.$$

This principle of predicting the chemical composition of plants can be applied to other phases of culture growth and development. To do this, it is enough to reveal the real mathematical relationships between two significant factors (for example: the chemical composition of plants - % N or % P with yield).

It is necessary to consider the interpretation of relationships and the effect of phosphorus fertilizers in doses from 45 to 90 kg a. s. / ha on the background of $N_{45}K_{45}$ on the yield of potato tubers (Table 3).

By exerting a positive effect of phosphorus fertilizers on the yield, a close relationship is manifested between the chemical composition of plants and the yield when applying increasing doses of fertilizers.

Equations 5-6 characterize the real and practical meaning of the indicators of the relationship between the total phosphorus content of plants in the period of 7 leaves and in the flowering phase and the yield (Table 4).

TABLE 3: The dependence of the yield of potato tubers on the phosphorus content (% on the dry matter) in plants

Potato yield, t / ha	Phase of 7 leaves		Flowering phase	
	% P_2O_5	Increase, %	% P_2O_5	Increase, %
30.1	0.40	-	0.34	-
32.7	0.43	7.5	0.38	11.8
34.5	0.44	10.0	0.39	14.7

TABLE 4: Mathematical models of the relationship between the yield of potato tubers (Y, t / ha) and the total nitrogen content in plants (X, %)

Development phase	Regression equation	r
7 leaves	Y = 104.62x - 11.85 (5)	0.97
flowering	Y = 81.43x + 2.31 (6)	0.95

In the phase of 7 leaves of potato nutrition, an augmentation in the phosphorus content in the plant by 0.1% increases the yield of this culture by 10.4 t / ha (equation 5), in the subsequent phase of development (flowering), the characteristic corresponds to 8.1 t / ha.

4. Discussion

The phosphorus bond index in this system makes practical sense in developing a phosphorus fertilizer application system. From this characteristic it follows that for certain yields of the studied culture, an optimal phosphorus composition is required, taking into account the phases of potato development.

According to equation 6, such forecast of the optimal phosphorus content in the flowering phase is used for the productivity:

$$30\ \text{t tubers/ha}: \% = \frac{30t + 2.31t}{81.43} = 0.40\%,$$

$$33\ \text{t tubers/ha}: \% = \frac{33t + 2.31t}{81.43} = 0.43\%,$$

$$34\ \text{t tubers/ha}: \% = \frac{34t + 2.31t}{81.43} = 0.45\%.$$

5. Conclusion

Data processing by means of statistical processing over the years of research made it possible to establish and then mathematically simulate the dependence of the nitrogen

and phosphorus content (X,%) in a plant with a yield (Y, t / ha) of potato tubers through the regression equations.

Thus, the chemical composition of plants (nitrogen and phosphorus) for specific phases of culture development is suitable for monitoring the level of supply with these nutrients, as well as predicting yield during the process of growth and development of potatoes.

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Conflict of Interest

The authors have no conflicts of interest.

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