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METHODS OF PHOTOSYNTHETICALLY ACTIVE RADIATION USE INCREASE AND THE PRODUCTION RATE OF POTATO PLANTS IN FOREST STEPPE OF MIDDLE VOLGA REGION

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Abstract

The studies were conducted on gray forest soil of Zakamye in the Republic of Tatarstan on the background - without the use of fertilizers and their introduction in the dose calculated for the planned tuber yield of 30 t/ha. The reaction was studied of the new early maturing variety of RedScarlet potato on the ways of Silk and Albit drug use (soaking of seed tubers before planting, double foliar processing of plants, complex processing (tubers + plants - twice).

It was found that the use of Silk growth regulator for the treatment of tubers before planting, increased the yield of tubers by 2,79-3,11 t/ha, Albit drug - by 1,46-1,89 t/ha depending on a feeding background. The double foliar treatment by Silk during the growing season increased the yield by 3,85-3,94 t/ha, the processing by Albit increased the yield by 2.88-3.00 t/ha. At a complex processing (tubers + tops) the yield increase made 5,47-6,78 and 4,89-5,02 t/ha respectively.

Keywords: potatoes, fluke, calculated doses of fertilizers, growth regulators, leaf area, photosynthetic potential (PP), yield, starch, vitamin C, nitrates.

Introduction

The main means of agricultural production are the plants which serve simultaneously as food and labor items [Zhuchenko, 1990]. Being a primary producer of the whole organic substance they play an important role in the biosphere generally. Using soil minerals, water, air and carbon dioxide they synthesize carbohydrates, proteins and other organic compounds. Photosynthesis is an initial link in the chain of organic matter development [Gulyaev, 1966; Nichiporovich, 1963; Ross, 1975; Gulyaev, 1989].

Among many factors which influence the growth and development of plants, solar radiation is the most difficult regulation factor. Therefore, the most important problem of modern agriculture is the crop productivity increase by the use of solar radiation in the process of photosynthesis.

Many researchers say that in natural phytocenosis an average photosynthetic efficiency makes 0.2-0.3%, in agrocenosis this efficiency makes 0.1-1.0%. Theoretically possible PAR utilization rate may reach 5-10% [Sventitsky, 1985; Tooming, 1984; Shatilov, 1979; Rabson, Bhotia, Mifra, 1978]. Hence, the potential possibilities of productivity increase by increasing the use of photosynthetically active radiation are rather high.

In order to increase the yield of potato plants it is necessary to develop and introduce new methods of this culture productivity improvement. One of these methods is the cultivation of planned crops, which includes the development of interrelated set of elements within cultivation technology, the timely implementation of which will ensure the achievement of the calculated harvest level.

An active part of photosynthetic surface of potato plants is determined mainly by the area of leaves, as leaves act as the main body for photosynthesis (Ross, 1975; Gifford, Jenkins, 1987). They account for 80-90% of all solar radiation absorbed by sowing and 60-90% of organic matter, which is created during the process of photosynthesis (Vavilov, 1981). Many researchers say that an optimum leaf area varies within wide limits (Buttery, 1970; Nodanova 1972; Okubo, Oizumi, NoshIno, 1969).

The objective of our researchers was to clarify the features of potato plants growth and development and the degree of solar energy use by them, depending on the level of mineral nutrition and growth regulator use.

Research conditions, materials and methods. The studies were carried out at the experimental field of Zakamskaya zone in Tatarstan region during 2013-2015. The soil is gray forest one, of clay loam granulometric composition. Agrochemical indicators of soil: The content of humus makes 3,67-3,79%, the content of mobile phosphorus makes 141-155, the content of exchangeable potassium makes 177-185 mg/kg of soil.

The predecessor of this culture is winter wheat. The total area of the plot made 72 m^2, the area of registration plot made 60 m^2. The seed tubers of the first reproduction and middle fraction (60-65 g) were planted. The planting density made 53.2 thousand pcs./ha at the depth of 8-10 cm.

The growth regulators were used in the experiment: Albit, TPS for the treatment of tubers before planting at the amount of 100 g/t, with the working fluid flow rate of 10 l/t. 50 g/ha were used for foliar application with the working fluid flow rate of 400 l/ha. Silk and VE drugs were used at the amount of 100 ml/ton of tubers (10 ml of a.s./t), plant

spraying (double treatment) - 100 ml/ha (10 ml of a.s./ha) during budding phase and 10 days after it. Working solution flow made 300 l/ha. The experiments were laid on two nutrition backgrounds: 1. Without fertilizers. 2. Fertilizers which allow to obtain the yield of tubers at the amount of 30 t/ha.

Organic fertilizers were introduced for the autumn plowing. The ridge tillage was performed during spring by four row ridge forming cutter with the spacing of 75 cm between rows. At the same time the treatment of tubers was performed by the fungicide Prestige KS (1.0 l/t, with the working fluid flow rate of 10 l/m) and fertilizers were introduced. The actual doses of fertilizers in the experience: 2013 - 20 t/ha of manure + $N_{58}R_{45}K_{99}$, in 2014 - 20 t/ha of manure + $N_{78}R_{75}K_{101}$, in 2015 - 20 t/ha of manure + $N_{65}R_{50}K_{94}$.

Experience scheme:

1. Control (water).
2. Processing of tubers prior to planting.
3. Foliar treatment of plants during budding phase and 10 days after.
4. Integrated double processing (tubers + plants).

The herbicide Zenkor Techno VDG was used against weeds with the application rate of 1.2 kg/ha. Ridomil Gold MZ (2.5 kg/ha) and copper-containing drugs were used to combat late blight.

Analysis and discussion of research results

One of the main terms for the productive use of solar radiation is the development of an optimal leaf area in plantings, and then its long stay in an active state by the end of the growing season to perform the maximum transfer of plastic substances by leaves into reproductive and accumulating organs. These substances were accumulated in the structures of leaves.

Most researchers say that the most important role in the development of solar energy belongs to leaves, and depends on its size (Usanova, 1999; Shatilov, Chudnovsky, 1980). The studies performed by M.K. Kayumov (1989) stated, that the planned harvest of tubers at the amount of 24.2 t/ha in potato plantings was developed at the leaf area of 40 thousand m^2/ha and 30.0 t/ha at the area of 54.4 thousand m^2/ha respectively.

The performed studies showed that the value of the leaf formation area by potato plants depended mainly on the doses of introduced fertilizers and on the type of growth regulator application. The area of leaves during all phases of potato plant development was the lowest one in the control variant without the use of growth regulators and fertilizers, and during the phase of its maximum development it made 30.96 thousand m^2/ha (Table. 1).

Table 1 - Potato planting efficiency indicators according to the level of mineral nutrition and the use of growth regulators, 2013-2015.

Nutrition background	Drug application means	Efficiency indicators			
		S. max. thous. m^2/ha	Dry biomass harvest, t/ha	PRL, 1 thous. pcs. FP, kg of tubers	PAR application ratio, %
Without fertilizers	Control (water)	30,96	7,089	8,17	1,50
	Treatment by Silk growth regulator				
	Processing of tubers	33,79	8,368	8,06	1,77
	Processing of leaves	32,32	8,743	9,63	1,85
	Processing of tubers and leaves	35,06	9,522	8,90	2,02
	Treatment by Albit growth regulator				
	Processing of tubers	31,56	7,975	8,61	1,69
	Processing of leaves	31,64	8,219	9,52	1,74
	Processing of tubers and leaves	32,99	8,895	8,91	1,88
Calculation for 30 t/ha	Control (water)	46,08	10,036	8,98	2,12
	Treatment by Silk growth regulator				
	Processing of tubers	52,75	11,143	8,19	2,36
	Processing of leaves	51,54	10,996	8,94	2,33
	Processing of tubers and leaves	54,44	12,295	8,60	2,60
	Treatment by Albit growth regulator				
	Processing of tubers	51,23	10,492	8,45	2,22
	Processing of leaves	49,53	10,847	9,31	2,30
	Processing of tubers and leaves	52,83	11,554	8,94	2,45

The wetting of tubers before planting by the growth regulator Silk increased the leaf area during the blooming stage, during the period of its maximum development on 2.83 thousand m^2/ha. The complex treatment (of tubers before planting and double processing of vegetative mass) by Silk growth regulator increased its value by 4.10 thous. m^2/ha compared to the control one. Maximum leaf area equal to 54,44 thousand. m^2/ha, which is 7.64 thous. m^2/ha more than the control one, was developed in the version with the integrated treatment by Silk growth regulator.

The introduced fertilizers in all experimental variants have greatly increased the intensity of total dry biomass accumulation. The control group without the use of growth regulators: the total dry biomass in making the calculated doses of fertilizers amounted to 10.036 t/ha, which is 2.947 t/ha more than control group on the background without the use of fertilizers.

The estimated doses of fertilizers in the form of seed potato soaking by growth regulators increased the total dry weight of the potato plants by 2,517-2,775 t/ha. In the variant with a double spraying by growth regulator for growing plants fertilizers contributed to the dry biomass harvest growth (by 2,253 and 2,628 t/ha), but to a lesser degree.

The harvest of dry biomass on both nutrition backgrounds was higher at a complex application of growth regulators of and made 8.895 t/ha and 11.554 t/ha at the application of growth regulator Albit and 9.522 and 12.295 t/ha at the application of Silk regulator.

The productivity of 1 thousand of FP units in all variants was higher when growth regulators were introduced for growing plants. The maximum PAR utilization ratio, equal to 2.60%, was obtained against a background of calculated doses of fertilizers introduction at the integrated use of Silk growth regulator.

Productivity

Against the background without fertilizers and growth regulators the tuber yield made 16.44 t/ha. The introduction of estimated doses of fertilizers for a tuber harvest obtaining at the amount of 30 t/ha gave the yield increase of 11.26 t/ha and increased the yield by 68.49% (Table 2).

The processing of tubers by growth regulator Silk before planting on the background without the introduction of fertilizers increased tuber yield by 2.79 t/ha, and double foliar application for growing plants increased the yield by 3.94 t/ha, i.e. it was 1.15 t/ha higher as compared to the variant with the processing of tubers. Albit growth regulator increased the yield on these variants by 1.89 and 2.88 t/ha.

The greatest yield equal to 21.91 t/ha was formed by plants at complex processing (tubers before planting + plants double processing during the growing season) by Silk growth regulator, where the yield increase made 5.47 t/ha as compared to the control variant, and on the background of the calculated doses of fertilizers introduction it reached 6.78 t/ha.

The use of Silk and Albit growth regulators helped to increase the share of commercial potato crop. At different ways of growth regulators and nutrition background it made 77.26% in the control group up to 91.30% at the complex processing by Silk growth regulator.

The correlation analysis showed a close relationship between the yield and the indicators of leaf photosynthetic activity (r = 0,99).

Table 2 - Effect of fertilizers and growth regulators on the yield of potato tubers, 2013-2015.

Nutrition background	Drug application means	Yield, t/ha			
		2013	2014	2015	average
Without fertilizers	Control (water)	15,57	17,30	16,45	16,44
	Treatment by Silk growth regulator, VE				
	Processing of tubers	17,67	19,86	20,18	19,23
	Processing of leaves	18,89	20,60	21,64	20,38
	Complex processing	21,13	22,10	22,51	21,91
	Treatment by Albit growth regulator, TPS				
	Processing of tubers	17,32	18,65	19,01	18,33
	Processing of leaves	18,37	19,10	20,48	19,32
	Complex processing	20,46	21,65	21,87	21,33
Calculation for 30 t/ha	Control (water)	25,60	28,10	29,46	27,70
	Treatment by Silk growth regulator, VE				
	Processing of tubers	28,87	31,46	32,10	30,81
	Processing of leaves	29,70	32,10	32,87	31,55
	Complex processing	33,95	34,06	35,42	34,48
	Treatment by Albit growth regulator, TPS				
	Processing of tubers	27,95	29,14	30,40	29,16
	Processing of leaves	29,05	30,96	32,10	30,70
	Complex processing	31,51	32,60	34,05	32,72

	2013	2014	2015
HCP_{05} lots 1 por.	1,23 t/ha	0,81 t/ha	0,53 t/ha
HCP_{05} lots 2 por.	0,72 t/ha	0,46 t/ha	0,41 t/ha
HCP_{05} A	0,46 t/ha	0,31 t/ha	0,20 t/ha
HCP_{05} B	0,51 t/ha	0,33 t/ha	0,29 t/ha
HCP_{05} AB	1,25 t/ha	0,81 t/ha	1,01 t/ha

An average dry matter content in tubers during the years of study made 20,77-22,73%, depending on the variant of the experiment.

Growth regulators in all studied methods of application contributed to the accumulation of dry matter in tubers. Against the background without the introduction of fertilizers at a complex application of growth regulator Silk dry matter content made 22.73%, and at the background of fertilizer calculated doses introduction on tuber yield of 30

t/ha it made 21.43%. When you use Albit these figures made 22.47 and 21.30% respectively (Table. 3).

Among the application means of growth regulators the difference in dry matter content was low, but with some advantage of tuber treatment before planting. The tubers grown on a fertilized background without the use of growth regulators contained less dry matter (20.77%).

The application of growth regulator Silk increased dry matter content in the tubers by 0.4% on the average during the processing of seed tubers before planting, double foliar treatment of plants during the growing season increased the proportion of dry matter by 0,26-0,33%, and a complex application increased it by 66-0,76%. Similar results were obtained using Albite growth regulator.

The treatment of tubers before planting by Silk growth regulator on the background without the use of fertilizers increased starch content in tubers by 0.70% and the integrated use of it increased it by 0.98%. Against the background of fertilizer application these figures made 0.53 and 0.91%. At the use of growth regulator Albit starch content in the tubers on the background without fertilizers was increased by 0.53 and 0.59%, and with a fertilized background iy increased by 0.43 and 0.69%. Olant processing efficiency during the growing season was lower concerning starch accumulation as compared to the treatment of tubers prior to planting.

Maximum accumulation of vitamin C on the background of fertilizer introduction was noted at an integrated application of growth regulators - 18.87 and 19.69 mg %, against 18.36 and 19.47 mg % on the background without the use of fertilizers. Albit drug also contributed to an increased accumulation of vitamin C in tubers, but it was somewhat inferior to Silk.

The introduction of fertilizers depending on the method of growth regulator Silk application increased the amount of nitrates in potato tubers by 10,39-12,81 mg/kg, at the application of Albit drug the corresponding amount was increased by 11,53-14,77 mg/kg vs. 16.08 mg/kg in the control group.

The treatment by growth regulators reduced the amount of nitrates in potato tubers in all variants of the experiment. The application of growth regulator Silk for the treatment of tubers before planting, depending on the nutrition background reduced the amount of nitrates in tubers by 6,00-10,16 mg/kg, and the use of growth regulator Albin reduced it by 3,2-7,75 mg/kg respectively. A significant reduction of nitrates in tubers was observed at a complex application of growth regulators. The use of Silk at this option reduced the content of nitrate by 12,20-15,47 mg/kg depending on the background of nutrition, and at the application of Albit the corresponding reduction made 10,90-12,21 mg/kg.

We analyzed the relation of yield, dry matter content, starch and protein in potato tubers. Correlation and regression analysis showed the close relationship of these indices (r = 0,96).

Content of heavy metals

Heavy metal content in the tubers during all variants of the experiment was below MPC. The tubers contained: copper - 2,52-3,11, zinc - 3,11-4,11, lead - 0,22-0,23 arsenic - 0,019-0,031, cadmium - 0,010-0,015 mg/kg. The introduced fertilizers led to some increase, and growth regulators on the contrary contributed to the reduction of their amount in tubers. A more significant reduction in the amount of heavy metals was observed at complex application of growth regulators. At a complex application of the growth regulator Silk, the content of copper decreased by 0,35-0,36, zinc - by 0,31-0,34, lead - bt 0,06-0,07, arsenic - by 0,007-0,008, cadmium - by 0,004-0,005 mg/kg. A similar effect qas made by the growth regulator Albit, but this effect was somewhat smaller than the effect of Silk.

Cost-effectiveness of growth regulator use

The cost on potato cultivation without the use of growth regulators on the background without the use of fertilizers made 81.4 thousand rub/ha. The use of growth regulators increased the economic indicators of potato cultivation.

The maximum net income (141.56 thousand rub.) and profitability level (141.8%) was obtained at the complex use of Silk growth regulator.

Summary

The most effective growth regulator turned out to be Silk. The excess of RedScarlet potato yield at the processing of tubers by Albit drug made 4.9 and 5.6%, at the processing of leaves the corresponding increase made 5.5 and 2.8 percent. The most effective method of growth regulator use on potato is a complex processing (of tubers before planting and double processing of plants during the growing season). At that the yield increase as compared to control group made 24.5 and 33.3%. A complex processing by growth regulators provided the best quality of tuber harvest, which contained a smaller amount of heavy metals, nitrates, a larger amount of dry matter, starch, vitamin C.

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References

1. Vavilov P.P. The influence of retardants on the level and structure of the potato harvest / P.P. Vavilov, I.P. Medintsev, A.N. Postnikov. // TSHA news. -1981. - Issue 6. - pp. 31-36.

2. Gulyaev V.I. Photosynthesis and plant productivity: Challenges, achievements, prospects of research / V.I. Gulyaev // Physiology and biochemistry of cultivated plants. - M., 1966.- Issue 28. - №1-2.- pp. 15-35.

3. R.M. Gifford. The use of science in photosynthesis in order to increase the productivity of harvest / R.M. Gifford, L.D. Jenkins // Photosynthesis: in 2 v. Trans. from English. M.: Mir, 1987, V. 72. - pp. 365-410.

4. Zhuchenko A.A. Adaptive plant cultivation. /A.A. Zhuchenko. - Kishinev: Shtiintsa, 1990.- 432 p.

5. M.K. Kayumov. Programming of agricultural harvest / M.K. Kayumov // M.: Agropromizdat, 1989. - 320 p.

6. Nichiporovich A.A. About the ways of plant photosynthesis productivity enhancement in crops / A.A. Nichiporovich // Photosynthesis and plant productivity issues. - M., 1963. - pp. 5-36.

7. Yu.K. Ross. Radiation mode and the architectonics of plant cover / Yu. K. Ross. - L.: Gidrometeoizdat, 1975. - 342 p.

8. Sventitsky I.I. Biophotometry and the analysis of energy flows in plant cultivation / I.I. Sventitsky. - M.: Nauka, 1985. - pp. 87-94.

9. Tooming H.G. Ecological principles of maximum productivity of crops. H.G. Tooming. - L. "Gidrometeoizdat, 1984. - pp. 17-41.

10. Usanova Z.I. Theory and practice of highly productive field crops cultivation / Z.I. Usanova - Tver: TGSKHA, 1999.- 330 p.

11. Photosynthesis, production process and plant productivity: / Edited by B.I. Gulyaev. - Kiev: Nauk Dumka, 1989. - 204.

12. I.S. Shatilov. The photosynthetic capacity and grain harvest / I.S. Shatilov // TSHA news. -1979. - №4. - pp.18-29.

13. I.S. Shatilov. Agrophysical, agrometeorological and agronomic basics of crop programming. Shatilov I.S., A.F. Chudnovsky - L.: Gidrometeoizdat, 1980. -320 p.

14. Buttery B.R. Effects of variation in Ieafareaindexon growth of maize and soy beaпs / B.R. Buttery. – «CropSci», 1970, 10, № 1, p. 9–13.

15. Hodanova D. Structure and development of sugar beet canopy. I. Leaf area – leaf angle relations. – «Photosynthetica, 1972.– 6 (4). – pp. 401-409.

16. Rabson R. Seed protein improvement and nuclear technology / R. Rabson, S.R. Bhotia, R. K. Mifra. – Veinn, 1978. – pp. 3-20.

17. OkuboT., OizumiK., HoshIno M. An observation on solar energy conversion in primary canopies of foragecrops. – In: Photosynthesis and UtiIization of Solar Energy. Leve1 III Experiments. Tokyo, 1969. – pp. 37-39.

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