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The Formation Of Crop Yield And Grain Quality In Winter Wheat In Dependence To Application Of Mineral Fertilizers And Growth Regulators

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ABSTRACT

The positive effect of mineral fertilizers and plant growth regulators on the production processes in winter wheat is established. When using the investigational factors the yield of test crop increases and the quality indicators of wheat improve.

Keywords: Wheat, mineral nutrition, productivity, grain quality.

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INTRODUCTION

The crop yield is the main indicator of crops that is defined by the utilization efficiency of different agricultural methods and is the key measure in impact evaluation of new factors on the crops. To obtain consistent high yields in addition to the crops varietal features it is necessary to provide plants with nutrients throughout the growing season. The yield level is the integrating indicator including the implementation of potential productivity and the state of environmental factors, the modern technological methods inherent in the plant genome using as the means for the full manifestation of the metabolic processes in the cultivated crops. The intensity of the growth and development of agricultural plants and as a result the yield is largely determined by the temperature and moisture conditions during ontogeny. [7] One of the factors reducing this risk is the use of growth regulators and mineral fertilizers in technology of winter wheat growing.

The grain quality is a factor of intensification of the agricultural production, thus the biochemical indicators improvement of grain quality has the key significance in crop production. The wheat grain quality does not often meet the appropriate requirements, however, it should be noted that the natural and climatic conditions in the greater part of the Ulyanovsk region are favorable for cultivation and production of the winter wheat with good biochemical and baking indicators.

The plants consumption of mineral elements is a complex physiological process that depends on the biological properties of the plant and soil-climatic conditions. The different directions in the organic compounds synthesis determine the plants selective ability to a certain extent. From the same soil different crops consume not only different amounts of chemical elements, but their different ratio. The accumulation of mineral nutrition elements in plants is influenced by: concentration of nutrients in soil and their mobility in connection with the moisture provision, degree of acidity, which depends on both the solubility of distinct elements and the absorption process of cations and anions with a plant cell and the presence the air in the soil, etc. The removal of nutrients from the soil increases with the yield increasing.

Moreover, the intensity of biochemical and growth processes occurring in plants, and therefore the nutrients requirement are different in ontogenesis separate phases. Along with the selectivity, the plant is characterized by consumption irregularity of nutrients during the vegetation period. Despite the significant differences of nutrients consumption dynamics in different plant species, they all have common regularity of nutrition [1,2]

The highest demand for nutrients providing is made in the early development. During this period, even the small mineral nutrients deficiency in the soil can limit the growth and development of plants.

The plant nutrition process must be managed by the differentiation of forms, doses, periods, periodicity and application methods of organic and mineral fertilizers, taking into account the biological and physiological plants characteristics, on the one hand, and interaction regularity of environmental factors, on the other hand. [6, 8] Taking into account this possibility and necessity, in recent years, the plant growth regulators become actual as they can improve (control) the mineral nutrition mode of crops.[3, 4,5] In this regard, we have conducted the researches to study the effects of different plant growth regulators in combination with mineral fertilizers on the production processes in the winter wheat plants in its cultivation in the Middle Volga area of the Russian Federation.

METHODS AND RESEARCH CONDITIONS

Field experiments were conducted in 2008-2011 in the agricultural production cooperative "The Volga" of Staraya Maina district, Ulyanovsk region. The test crop is Kazan 560 winter wheat. The predecessor is clean fallow.

The method of carrying out the field experiment is common to the large experiments plots, four times frequency, randomized samples design in the experiment, plot area is 50 sqm. The background crops processing is conducted with the researched growth regulators Crezatsin, Humimax, Albite in recommended by the preparations manufacturer concentrations at the beginning of the tillering period. The application of experimental plant growth regulators is carried out simultaneously with the herbicides application on the basis

of 200 liters of spray material per 1 ha. There are two fertility grounds in the experiment. The 1st ground is the natural fertility, the 2nd ground with the application of mineral fertilizers is based on planned yield of 35 t/ha.

The soil of the test plot is leached Chernozem, thin-humous , medium-deep, medium loamy with the following agrochemical characteristics: humus content is 3,8%, labile phosphorus is 10.0 mg/100 g of soil, exchangeable potassium is 9,2 mg/100 g of soil, PH -6,0 (subacidic), total absorbed bases are 30-55 mg. EQ./100 g of soil. Agrotechnics in all experience variants is traditional, generally accepted in the natural and climatic zone of the Ulyanovsk region.

During the research years meteorological conditions were different in temperature regime and moisture supply of the soil; this enabled comprehensively to study the effect of used factors. In 2008, 2009, 2011 the weather conditions were mainly favorable (enough rainfall, average daily temperatures close to long-time average annual index).

The year 2010 was anomalous torrid and dry, this was the cause of reduction in winter wheat productivity. The harvest record was conducted on every working plot with subsequent weighing and recalculation on 14% of grain moisture.

The dynamics of plants leaf area was determined by the formula: S_l=abK, where “a” is the leaf width, “b” is the leaf length; “K” is the evaluation factor.

The net productivity of photosynthesis was calculated by the formula: $$\mathrm{NPPh} = \frac{B_2 - B_1}{(L_1 + L_2) \cdot n \cdot 0{,}5}$$ g/m^2 per day; where B1, B2 – dry sample weight in the beginning and the end of the record period, L1 and L2 ,
is the leaf area in the beginning and the end of the record period, cm^2; “n” is the number of days in the record period. The protein content as per all-Union State Standard 10846 – 91; the quantity of gluten mass content as per all-Union State Standard 13586.1-74; the quality of gluten on the device IDK - 3;the starch as per all-Union State Standard 10845-98; the nitrogen content (all-Union State Standard 134916.4-93), the phosphorus (all-Union State Standard 26657-97), the potassium (all-Union State Standard 30504-97) were determined in plant samples.

THE RESEARCH RESULTS

The photosynthesis as the primary source of organic matter is the basis of production process. Photosynthetic activity of plantings is mainly connected with the heat, moisture and root nutrition elements supply. The combination of these factors determines not only the total level of biological productivity but also the quantitative composition of biomass and grain.

The high productivity of plant communities is possible only under the forming condition of the optimal photosynthetic apparatus; it is therefore important to introduce the techniques and methods that enhance the plants photosynthetic activity into practice of agricultural production. The preparation effect on the size of the flag leaf area of the winter wheat is studied in our experiment. The wheat breeding is mainly conducted to grow the flag leaf area and increase the photosynthetic potential.

A preferential growth of the photosynthetic potential of upper leaves, supplying maturing grain is determined. (table. 1).

Table 1: The flag leaf area in winter wheat of the variety Kazanskaya 560, sq. cm (2008-2011)

Variant	Years of researches				On the average for the research years
	2008	2009	2010	2011	
Control	16,24	17,15	9,46	20,24	15,77
Humimax	17,12	17,92	11,01	21,06	16,78

Albite	18,66	20,16	12,20	22,46	18,37
Crezatsin	17,25	18,22	11,13	21,18	16,95
Control +NPK	17,14	18,11	9,94	21,12	16,58
Microvit +NPK	19,83	19,54	12,50	22,40	18,57
Humimax +NPK	18,77	19,40	11,74	21,68	17,90
Albite +NPK	20,64	21,18	13,05	23,21	19,52
Crezatsin + NPK	19,23	19,73	12,31	22,00	18,32

The yield formation depends not only on the leaves area, but also on the time of their functioning; in this regard the photosynthetic potential of the crop was calculated (PhP).

This indicator changed depending on the leaves area and the length of their work arranged by the research years. The photosynthetic potential is a generalizing indicator characterizing the efficiency of the whole technological methods.

The maximum photosynthetic potential in winter wheat of the variety Kazanskaya 560 was observed in the grain milk stage at the option of the handling with Albite, it is by 36.8% higher than the control under the natural fertility, and 22.3% under the fertilized background (table. 2).

Table 2: Photosynthetic potential of the leaves in winter wheat of the variety Kazanskaya 560 (million sq. m. *days/ ha), on the average for 2008 – 2011.

Variant	Stages of development			Σ PhP	+/- to control	% to control
	stem elongation	earing	milk stage			
Control	0,302	0,217	0,486	1,005	-	-
Humimax	0,346	0,230	0,552	1,128	0,123	12,2
Albite	0,436	0,292	0,647	1,375	0,370	36,8
Crezatsin	0,359	0,241	0,570	1,170	0,165	16,4
Comtrol +NPK	0,380	0,249	0,564	1,193	-	-
Humimax +NPK	0,411	0,276	0,602	1,289	0,096	8,0
Albite +NPK	0,474	0,295	0,690	1,459	0,266	22,3
Crezatsin + NPK	0,425	0,286	0,600	1,311	0,118	9,9

NPPh is determined and depends not only on the photosynthetic processes, but also on the breath, thus at the same speed of these processes NPPh will be higher in those plants which have more contribution of aerial photosynthetic organs into the phytomass of the whole plant.

Albite has the greatest influence on the net productivity of photosynthesis in the experiments with the winter wheat. The highest indicators of NPPh are observed in the stage of stem elongation – earing, the highest values are also noted in the application of the preparation Albite, both on the fertilized background, and on the areas with natural fertility.The indicator of the net productivity of photosynthesis is determined by the amount of created organic matter in the green surface of agrophytocenosis per day. This indicator is very dynamic and can change even within a few hours, depending on the meteorological conditions, but on the average its parameters for cereal crops are in the limit of 4.5 to 7.0 g/m^2. The amount of net productivity of photosynthesis (NPPh) is widely used to evaluate the performance of the photosynthetic apparatus in the field conditions.

NPPh is the balance reflection between the photosynthesis intensity, the photorespiration and the respiration during day and night.

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The influence of the examined preparations on the net productivity of photosynthesis in winter wheat plants of the variety Kazanskaya 560 is shown in table 3.

Table 3: The influence of the examined preparations on the net productivity of photosynthesis in winter wheat plants of the variety Kazanskaya 560 g/sq. m *day, on the average for 2008 - 2011.

Variant	Tillering- stem elongation	+ /-	stem elongation – earing	+ /-	earing - milk stage	+ /-
Control	7,90	-	24,79	-	12,78	-
Humimax	8,16	0,26	25,33	0,54	13,44	0,66
Albite	8,66	0,76	26,26	1,47	14,22	1,44
Crezatsin	8,29	0,39	25,54	0,75	13,65	0,87
Control +NPK	8,18	-	25,55	-	13,78	-
Humimax +NPK	8,35	0,17	26,17	0,62	14,56	0,78
Albite +NPK	8,76	0,58	27,48	1,93	15,72	1,94
Crezatsin + NPK	8,48	0,30	26,42	0,87	14,86	1,08

The nutrients content in plant body and their ratio in different growth and development periods are an important diagnostic index of the nutrients level that is widely used in practice.

Nitrogen is one of the basic necessary elements for plants. It is a part of proteins, nucleic acids, amino acids, chlorophyll, enzymes, vitamins, lipids and other organic compounds forming in plants. In case of nitrogen deficiency the plants growth checks, the tillering and blossom intensity in grain cereals decreases, the vegetation period shortens, and the protein content in the final yield reduces and the productivity falls.[4]

In winter wheat plants, like all cereals, initiation and differentiation of the reproductive organs begins during the deployment of the first three or four leaves. During this period the nitrogen deficiency leads to the decrease in the formation of number of the spikelets in the ear and to the yield depression. Even subsequent sufficient (normal) nitrogen nutrition cannot reduce the damage caused to the plant during this period.

The results show that the maximum nitrogen content in winter wheat leaves is observed in seedling and tillering stage and is at from 3, 03 to 4, 31%, depending on the type and growth stage, and plants development. This proves the previously marked regularity of nitrogen accumulation dynamics in plants.[5]

In the next stages there is the decrease in the content of nitrogenous compounds in the test crop leaves, reaching the minimum in the milky stage (table.4).

This trend is explained by their intensive outflow in the reproductive organs, this is very important for the formation of high-quality winter wheat products. During the research, the highest nitrogen content in the test crop leaves in all development stages is observed in the samples Albite and Crezatsin, both in natural and fertilized ground. On average during the research years the increase in the use of factors has been from 0.11 to 0.24% on the ground without fertilizer, from 0.06 to 0.29% on the ground with NPK (nitrogen, phosphorus, potassium), depending on a sample. The dynamics of nitrogen content in the winter wheat stalks are similar to the leaves, i.e. there is a gradual reduction of this indicator at the following phenophases (table.4). The minimum nitrogen content in the stems and in the leaves is observed in the milk stage of the test crop. Under the influence of growth regulators and fertilizers the nitrogen content in the reproductive organs increases. The maximum increase is observed in the samples Albite and Crezatsin on both test grounds, these are from 0.16 to 0.54% (tab.4).

The positive correlation relationship of the winter wheat yield with the nitrogen content is established: in the leaves at the tillering stage (D=84,34%, R=0,919); in the stalks in the milky stage (D=88,48%, R=0,941); in the ears - in the earing phase (D=84,20%, R=0,918).

Phosphorus is involved in metabolism, cell division, reproduction, transmission of hereditary properties and other complex processes in winter wheat plants; the key of these processes is photosynthesis.

Phosphorus is especially needed at the beginning of plant growth, as it promotes root system development, increases the intensity of cereal crops tillering. [4]It is determined; increasing the content of soluble carbohydrates in the cellular fluid, phosphorus strengthens the winter crops hardiness. The research has shown that the used growth regulators increase the phosphorus content in the winter wheat plants. Analyzing the dynamics of phosphorus compounds in the growth stages and in some organs, we see the similarity with the nitrogen dynamics in the test crop plants. The maximum phosphorus content in leaves and stalks is observed in seedling and tillering stage, which is 0.77 to 1.13% and 0.68 to 1.05%, respectively. At ripening, the phosphorus amount decreases in the cormophyte biomass with the simultaneous increase of its content in the reproductive organs. The greatest effect at this indicator is noted in the sample of Albite, both in the ground with NPK, and in the ground without NPK. On average during the research years the increase is from 0.11 to 0.36%, depending on the sample and growth and development stage (table.5). The minimum phosphorus content in vegetative biomass is noted in the milky stage and is from 0.19 to 0.40%.

Intensive phosphorus nutrition of winter wheat plants creates conditions for the development of the high yield. On the basis of mathematical data treatment by the multiple correlation and regression analysis technique is found out the positive relationship between winter wheat yield and phosphorus content: in the leaves - in the shooting and earing stage (D=90,98%, R=0,954); in the stalks - in the shooting and earing stage (D=95,40%, R=0,977); in the ears - in the earing and milky stage (D=88,50%, R=0,941).

Potassium is not a part of the composition of plants organic compounds. However, it plays an important physiological role in carbohydrate and protein plants metabolism, activates the nitrogen utilization, affects the physical condition of the cell colloids, increases the water-holding capacity of protoplasm, the plants resistance to wilting and premature dehydration and thereby the plants resistance to short-term droughts increases. Potassium affects the cell membranes formation, increases the strength of culms and their lodging resistance. Potassium deficiency adversely affects the quantity and quality of the yield. [3]

According to the tests results the potassium content in winter wheat leaves and stalks was maximum in the seadling, tillering and shooting stages, this proves the greatest potassium demand in plants in the period of their intensive growth.

The growth regulators and fertilizers which are used in the test increase the potassium content in the winter wheat organs by 0.12 to 0.16%, as compared with the control. The maximum increase is observed in the samples of Albite and Crezatsin. In the ground with NPK this increase is more notable and intensive. (table.6).

The multiple utilization (reusing) is typical for potassium and it moves easily from old plant tissues, which has been already used in young. This is apparently due to the minor variation in the potassium dynamics of winter wheat plant organs under the influence of growth regulators (табл.6). The conducted correlation and regression analysis shows a high relationship between the winter wheat yield with potassium content: in the leaves - in the shooting stage (D=92,37%, R=0,961); in the stalks - in the shooting and milky stage (D=97,87%, R=0,989); in the ears - in the earing phase (D=84,96%, R=0,922).

Table 7: Influence of growth regulators and fertilizers on the winter wheat yield, c/h (2008-2011rr.)

Ground	Samples				TAverage over the 1 factor
	Control	Humimax	Albite	Crezatsin	
2008r.					
Growth regulators	25,2	26,1	28,5	26,5	26,6
Fertilizers	31,6	35,1	36,5	35,3	34,6

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Average over the factors	28,4	30,6	32,5	30,9	30,6
HCP_{05} for particular average = 0,10, HCP_{05} for the second factor= 0,07					HCP_{05}= 0,04
2009r.					
Growth regulators	27,2	28,6	30,1	29,0	28,7
Fertilizers	34,0	36,1	37,3	36,3	35,9
Average over the factors	30,6	32,4	33,7	32,7	32,3
HCP_{05} for particular average = 0,12, HCP_{05} for the second factor = 0,08					HCP_{05} = 0,05
2010r.					
Growth regulators	12,5	13,7	18,2	13,6	14,5
Fertilizers	16,4	18,1	22,8	17,6	18,7
Average over the factors	14,4	15,9	20,5	15,6	16,6
HCP_{05} for particular average = 0,13, HCP_{05} for the second factor = 0,09					HCP_{05} = 0,05
2011r.					
Growth regulators	31,6	32,6	34,6	32,6	32,8
Fertilizers	38,0	40,6	45,0	39,6	40,8
Average over the factors	34,8	36,6	39,8	36,1	36,8
HCP_{05} for particular average = 2,04, HCP_{05} for the second factor = 1,00					HCP_{05} = 1,42
Average 2008-2010rr.					
Growth regulators	24,1	25,3	27,9	25,4	25,7
Fertilizers	30,0	32,5	35,4	32,2	32,5

The improvement demand of wheat plants in mineral nutrients at their single growth and development phases is of great practical importance using growth regulators and fertilizers. This helped to the increase of test crop productivity (tab.7). On average during the research years the winter wheat yield has been increased by 1.2 - 5.4 c/ha, depending on the sample. More effective was the application of growth regulators Albite, especially in the NPK ground (table.7).

The most important part of wheat is the nitrogenous matter, consisting mainly of proteins. The nutritional value of the final product depends on their number and quality. Among the cultivated crops the wheat exceeds all other cereals in protein content. The synthesis and accumulation of proteins in the bruchid of cereals happens basically due to the outflow of nitrogen substances (mainly amino acids) from vegetative organs. The greatest amount of nitrogenous substances enters the forming bruchid from the leaves, especially the upper layer.

Table 8: Influence of growth regulators and mineral fertilizers on the protein content in winter wheat grain of the variety Kazanskaya 560, %

Variant	2008 r.	2009 r.	2010 r	2011r.	Average
Control	10,94	11,06	10,89	14,02	11,73
Humimax	11,34	12,08	11,34	14,25	12,26
Albite	13,11	13,00	12,14	14,93	13,28
Crezatsin	11,86	12,20	11,63	14,71	12,60
Control +NPK	12,20	12,60	11,91	15,05	12,94
Humimax +NPK	13,40	13,62	13,05	15,28	13,85
Albite +NPK	15,11	14,48	13,68	16,07	14,82
Crezatsin + NPK	13,00	13,80	13,22	14,88	13,68
HCP_{05} 1 factor	0,43 0,61	0,51 0,72	0,42	0,46 0,66	

2 factor			0,59		

1 Factor – plant growth regulators
2 Factor - mineral fertilizers

The researches show that the applied growth and development plants regulators and also mineral fertilizers increase the protein content in winter wheat grain of the variety Kazanskaya 560 by 0.53 to 1.55% on the natural background and by 1.21 to 3.09% on the fertilized background (table. 8). During all the research years the highest protein content in wheat grain was observed in the variants of Albite and Krezatsin, and in both nutrient status.

Analyzing the dynamics of protein deposition in grain according to the research years, it should be noted that the relatively favourable weather conditions in 2008, 2009 and 2011 encouraged the maximal synthesis of proteins. In the vegetative period of 2010 abnormal, high-drought conditions led not only to a significant reduction in the winter wheat yield, but also to the minimal indicators of the protein content in grain. The observed trend confirms that the formation of grain quality is more often the interaction result of three external factors: light, heat and moisture.

On the basis of mathematical data processing with the method of correlation and regression analysis a positive relationship is found between the winter wheat yield of the variety Kazanskaya 560 and the protein content in grain: the total ratio of multivariable correlation (R=0,955); the determination coefficient (D=91,22%). The regression equation is : Y= 6,457+0,23 x.

One of the most important indicators determining the technological advantages of baking wheat is the mass fraction of gluten. In wheat the formation of grain gluten complex occurs with the reserve protein accumulation; in the process of maturing the gluten content increases and its quality improves.

Under the quality of gluten it is usually meant the combination of its physical properties such as extensibility, elasticity, viscosity, and also the ability to save the original physical properties.

According to the test results the gluten content in winter wheat grain of the variety Kazanskaya 560 has ranged on the average for the research years from 21.8% to 25.3%, depending on the variant. The highest gluten content was observed in the variant of Albite, both in natural and fertilized backgrounds.
The increase was 2.7 to 3.5%, depending on the nutrient status (table. 9).

Table 9: Mass fraction of gluten in winter wheat grain of variety Kazanskaya 560, depending on the application of growth regulators and mineral fertilizers, %

Variants	2008 г.	2009 г.	2010 г	2011г.	Average gluten content %	Icrease	
						In absolute terms %	в % to control
Control	21,2	22,0	22,4	21,7	21,8	-	-
Humimax	21,8	22,8	24,0	22,8	22,9	1,1	5,0
Albite	24,6	24,6	25,0	23,6	24,5	2,7	12,4
Crezatsin	22,0	22,8	23,2	23,1	22,8	1,0	4,6
Control +NPK	22,4	22.6	23,0	22,3	22,6	-	-
Humimax +NPK	23,0	23,4	23,6	23,6	23,4	0,8	3,5
Albite +NPK	25,2	25,6	25,3	25,0	25,3	2,7	11,9
Crezatsin + NPK	23,2	23,6	24,0	23,2	23,5	0,9	4,0
$НСР_{05}$ 1 factor 2 factor	0,15 0,21	0,22 0,31	0,33 0,47	0,36 0,52			

1 Factor – plant growth regulators
2 Factor - mineral fertilizers

Researchers have shown that the quality of gluten in grain of test crop changes under the influence of the applied plant growth regulators and mineral fertilizers (table.10). The best results in terms of this indicator are observed in the variants of Albite and, Crezatsin in both nutrient status of this crop. IDG indications vary from 46 to 74 standard units, depending on the variant and they correspond to the I quality group.

Table 10: Influence of growth regulators and mineral fertilizers on the quality of gluten in winter wheat grain of the variety Kazanskaya 560

Variants	2008r.		2009r.		2010r.		2011r.	
	IDG s.u.	Quality Group	IDG s.u	Quality Group	IDG s.u.	Quality Group	IDG s.u	Quality Group
Control	46	I	46	I	47	I	46	I
Humimax	52	I	50	I	53	I	54	I
Albite	60	I	57	I	62	I	61	I
Crezatsin	58	I	54	I	57	I	58	I
Control +NPK	59	I	56	I	57	I	57	I
Humimax +NPK	64	I	62	I	65	I	66	I
Albite +NPK	70	I	72	I	74	I	71	I
Crezatsin + NPK	66	I	65	I	68	I	67	I

CONCLUSIONS

Thus, the weather and climatic conditions influence on the production processes of winter wheat during organogenesis, as well as the study factors under theses influence increase the size of the activity and duration of leaf apparatus life and the net productivity of photosynthesis. The studied factors influence on the intensity of the nutrient metabolism in plants, resulting in the mobilization of total nitrogen, phosphorus and potassium in the growth and development initial stages and their outflow in the ripening time. The improving the supply of mineral elements in the plant body with the application of growth regulators and mineral fertilizers is one of the important factors in increasing the yield and quality of winter wheat grain.

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