BIOSCIENCES BIOTECHNOLOGY RESEARCH ASIA, April 2015. Vol. **12**(1), 301-309

Agrochemical Principles of Targetting Winter Wheat Yield on Leached Chernozem of the Stavropol Elevation

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DOI: http://dx.doi.org/10.13005/bbra/1666

(Received: 16 December 2014; accepted: 23 January 2015)

Winter wheat is one of the most common major food crops in the world. Wheat grain value is determined by high content of protein, fat, and carbohydrates. Cultivation of winter wheat is beneficial, as the resulting product has a low cost. Winter wheat is a high-yield crop (second only to rice). The average yield of the winter wheat in the Russian Federation is 30 t/ha, while in the advanced farms it reaches to 50-60 t/ha. The highest yield in the Russian Federation was obtained in the Krasnodar Territory, amounting for 103.6 kg/ha, whereas worldwide, in Canada - 170 kg/ha. Protein content greatly depends on soil and climatic conditions. In wheat and other crops, protein content increases in the regions from north to south and from east to west. Aridity of air, solar radiation, high concentrations of nitrogen in the soil, and the level of agricultural technology affect the quality of the grain. The Department of Agricultural Chemistry and Plant Physiology of the Federal State Budgetary Educational Institution of Higher Professional Education (FSBI HPO) "Stavropol State Agrarian University" carried out studies in the 2010-2014 on leached chernozem of the Stavropol elevation. The conducted studies aimed at targeting of winter wheat (Zustrich cultivar) yield in the zone of moderate humidity based on the optimization of fertilizer application. The article presents the four-year data on the effect of fertilization rates on the dynamics of labile phosphorus and exchangeable potassium in the soil layer of 0-20 cm, as well as on the yield and quality of winter wheat (Zustrich cultivar), cultivated on leached chernozem in the zone of erratic moistening of the Stavropol Territory. According to the results based on three years data, at the expected harvest of 6.0 t/ha, the reliability of the yield targeting on leached chernozem of Stavropol elevation, when applying $N_{126}P_{80}K_{72,}$ was 99% according to the calculation method suggested by V. Ageev (Esaulko & Ustimenko, 2014).

Key words: Weather conditions, Mineral fertilizers, Leached chernozem, Winter wheat, yield targeting.

Winter wheat is the main grain crops in the Stavropol Territory. Every year it is planted on an area of 1.2-1.3 million ha. In 90-ies of the XX century and the beginning of the XXI century, grain yield in the Territory reached to 24-30 t/ha from the entire area, whereas in some years it was even higher, amounting to 32-34 t/ha (Gerasimov *et al.*, 2014).

The total crop acreage of wheat in the Stavropol Territory in 2013 amounted to 1717.5 thousand hectares. In relation to 2012, the acreage decreased by 9%, while compared to 2010, when the area of planted land was maximal, amounting to 1730.7 thousand hectares, crop acreage decreased by 10% (Berezhnoy *et al.*, 2014; Gerasimov *et al.*, 2014).

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Yield of winter wheat in 2013 was 31.5 kg/ha. This is by 29.0% more than in 2012. The average yield of wheat in 2011 was 39.5 kg/ha. This is substantially higher than the yield index in 2012 (43%), though the yield in 2010 is somewhat less than in 2011 by 13% (Gerasimov *et al*., 2014; Trukhachev *et al*., 2014).

In the Stavropol Territory there are sharp fluctuations in the yield of winter wheat, despite the stable crop acreage. Therefore, our task is to optimize the nutrition of winter wheat to improve its yield and quality.

Among the agronomic practices aimed at increasing crop yields and improving the quality of crop production, paramount importance has optimization of mineral nutrition on the basis of rational use of fertilizers, taking into account bioclimatic potential of the area (zone), peculiarities of the plants and market conditions (Esaulko & Gorbatko, 2012; Sadras & Lemaire, 2014). A balanced nutrition of plants by macro-and micronutrients controls many metabolic processes and plays a key role in the formation of the crop and its chemical composition. All nutrients in plants operate vital functions. Their content determines the productivity of crops; lack of nutrients will certainly affect the productivity and product quality (Massoudifar *et al*., 2014; Zhao *et al*., 2014; Kunrath *et al*., 2015; Grahmann *et al*., 2013).

The most important task of domestic agriculture under the contemporary conditions is increasing of its productivity. Currently, the provisions that agricultural chemicals are the material basis of soil fertility, as well as the wealth and power of the state, are increasingly supported by long-term scientific research (‘íp *et al*., 2013). Today’s agronomy is knowledge of the system consisting of soil, plant, and the active layer of the atmosphere. On the other hand, it is a set of agro-technology methods, implemented at different time framesunder specific soil and climatic conditions to insure high yields (Basha *et al*., 2013; Deeks *et al*., 2013). A set of science-based agro-technology methods related to natural and economic parameters contributes to achieving the goal, i.e. obtaining high crop productivity and sustainable crop production with simultaneous reproduction of soil fertility and environmental friendliness of agricultural products (Montemurro&Maiorana, 2013; Yuan *et al*., 2014). The problem of providing the population with foodstuff and feeding is solved mainly through further increase of the arable landproductivity. This is facilitated by the specific field of agricultural science (Wang *et al*., 2014; Pandiaraj *et al*., 2015). Yield targeting meansdevelopment of a set of interrelated activities, whose timely and quality performance provides achievement of the targeted level of crop yields of given quality while improving soil fertility and meeting the requirements of environmental protection (Esaulko & Ustimenko, 2014; Lü *et al*., 2013).

Methodology

Field research was carried out at the agricultural experiment station of the Stavropol State Agrarian University. Studies were conducted in the 2010-2014. The research object was winter wheat (midripening Zustrich cultivar with ripeness period of 273-282 days), medium growth and having high standing ability. This cultivar is of steppe ecotype and has high ecological plasticity, drought hardness and frost tolerance. In terms of quality it belongs to the strong wheat (content of the protein ranges from 12.0 to 13.5%, fibrin from 27 to 28%) (Esaulko & Ustimenko, 2014).

Soil of the test area was represented by low humic, heavy loamy, deep leached chernozem having a pretty solid structure density of 1.15-1.31 g/cm^3. The exchange capacity of the arable layer was 40 mg. eq. per 100 g of soil. The reaction of soil solution averaged to 6.7, which is close to neutral pH. The soil is characterized by medium content of humus (5.1-5.6%), the average contentof labile phosphorus (22 mg/kg of soil), and high content of exchangeable potassium (240-260 mg/kg soil). The total average multiyear precipitation in the area of the conducted experiments is 623 mm, and the average annual temperature is 9.2°C. Based on the main agro-climatic indicators, we can conclude that the weather conditions of the agricultural experiment station are favorable for cultivating and producing sustainable yields of winter wheat.

The ammophos, ammonium nitrate, and potassium chloride were used as mineral fertilizers. The fertilizers were applied before seeding during the basic soil processing. Pea was the preceding crop. Arrangement of plots was carried out using randomized block design replication method with3-fold replications. The plot was 12 m wide and 80 m long, the total test area was 960 m^2, while record plot was 528 m^2.

The formulas for the calculation of mineral fertilizer rates for expected yield of winter wheat

Calculation of mineral fertilizer rates for expected yield of winter wheat equal to 4.0, 5.0 and 6.0 t/ha was carried out by two methods. In accordance with the first approach, developed by V. Ageev, the rates of phosphate and potash fertilizers were calculated as follows:

$$R = \frac{Y - YK_s}{K_f} 100,$$

where:

R–rate of P_2O_5 and K_2O, kg/ha;

Y –P_2O_5 and K_2O removal with the expected grain yield, kg/ha;

K_s–utilization coefficient of phosphorus and potassium from the soil versus removal with the expected grain yield (0.47-0.66 for phosphorus and 0.58-0.70 for potassium with due consideration of labile forms of phosphorus and potassium content in the soils and targeted yield);

K_f –the utilization coefficient of phosphorus and potassium from fertilizer (40 and 70%, respectively).

Rates of nitrogen fertilizers were calculated by the modified formula:

$$R = \frac{Y_{(N)} - Y_{(P2O5)}K_{s(P2O5)}K}{K_f} 100$$

where:

K –the removal (N) ratio of the expected grain yield to the P_2O_5 of the targeted grain yield;

K_f– the utilization coefficient of nitrogen from fertilizers (70%).

According to the second method, developed by the scientists of Stavropol Science Research Institute of Agriculture (SSRIA) and the “Stavropol” Agrochemical Center (SACC), rates of fertilizers were calculated using the formula:

$$R = CYK_c,$$

where:

C –the expected grain yield, hundred weight/ha;

Y–removal of N, P_2O_5 and K_2O per one hundred weight of expected grain yield;

K_c–compensation factor of nutrients removal due to fertilizers (0.49-0.52 for nitrogen, 1.10-1.36 for phosphorus, and 0.30-0.43 for potassium depending on the expected level of productivity). In addition, a control option was included (without fertilizer) and anoption with average recommended fertilizing rates for the given soil-climatic zones. Potassium chloride was applied when plowing, amorphous was applied when sown, while ammonium nitrate was applied during early spring nutrition.

RESULTS

Weather conditions during the research years were characterized by irregular precipitation, inferiorto multiyear rate by 43-89 mm (Table 1).

The most favorable agro-meteorological conditions for the formation of culture crop were in the 2010-2011. The amount of precipitation during the crops growing season (580 mm) was inferior to mean annual precipitation by 7%, though uniform distribution of rainfall contributed to the optimum moisture availability of crops and the highest yield of winter wheat. The average annual temperature of 10.6 °C was by 1.4°C higher than the multiyear values.

Table 1. Distribution of precipitation during the study according to the data of the Stavropol meteorological station, mm

Years	Total precipitation Months												Total annual precipitation
	VIII	IX	X	XI	XII	I	II	III	IV	V	VI	VII	
2010-2011	5	67	83	19	24	19	17	46	52	87	6	54	580
2011-2012	28	39	48	23	16	37	17	37	13	38	96	83	475
2012-2013	75	11	8	34	20	19	6	11	22	63	134	124	527
2013-2014	57	111	45	40	23	55	29	16	61	135	78	55	705
Multiyear average	54	43	46	41	32	27	34	53	70	90	80	53	623

Weather conditions in 2011-2012 were extremely unfavorable for the crop formation. The uneven distribution of precipitation in the spring and summer seasons had an adverse effect on the winter wheatcropformation. The amount of precipitation in 2011-2012 was less than mean multiyear precipitation by 27%. Rainfall in 2012-2013 was worse than the mean multiyear precipitation by 15%. Overall, in 2013-2014 the total amount of precipitations was 705 mm that exceeded the average annual rates by 13%. However, rainfall distribution during the crops growing season was uneven, and a shortage of precipitation was observed against the background of high air temperatures and atmospheric drought (Fuhrer *et al*., 2014). At that, the elevated temperature regime was noted throughout the whole crops growing season. The average annual temperature has exceeded mean multiyear temperature by 0.3°C.

Effect of optimizing the application of mineral fertilizers rates on the dynamics of the labile phosphorus content and exchangeable potassium in the 0-20 cm layer of leached chernozem.

We found that the highest content of labile phosphorus and exchangeable potassium according to V. Ageev calculation method was noted in all the tested options during the bootingstage on labile phosphorus and before seeding stage on the exchangeable potassium; this value was reduces with the increase in vegetative mass till the stage of full ripeness (Tables 2 and 3). Not all tested options exceled control rates in terms of the labile phosphorus content in the soil. Thus, the labile phosphorus content in the soil at the options with the recommended fertilizerrate and $N_{105}P_{60}K_{60}$ was insignificantly lower than controls during all the studied vegetation stages. Other studied fertilizer rates increased during the growing season the content of labile phosphorus in the soil layer of 0-20 cm. At that, the difference with the control was 4.7-6.9mg/kg before seeds; 4.0-5.6mg/kg in the tillering stage; 2.2-4.4mg/kg in the ear stage, and 2.9-5.1mg/kg in a stage of full ripeness. In this case, a significant increase of labile phosphorus relative to control was noted in all the options with the recommended fertilizerrate and $N_{126}P_{80}K_{72}$.

The highest content of labile phosphorus in the soil during all the stages of plant development was noted when applying $N_{126}P_{80}K_{72}$-31.2, 31.0, 26.4, 25.3 mg/kg soil.

Table 2. Effect of the optimized mineral fertilizers applicationon the dynamics of labile phosphorus content (mg/kg) in the 0-20 cm layer of leached chernozem, 2010-2014

Calculation method	Before seeding	Tillering	Earing	Full ripeness
Control	24.3	25.4	22.0	20.2
Recommended$N_{60}P_{60}K_{30}$	29.0	29.4	24.2	23.1
*$N_{60}P_{34}K_{34}$	26.7	27.3	22.9	21.0
*$N_{105}P_{60}K_{60}$	28.0	27.9	24.1	22.7
*$N_{126}P_{80}K_{72}$	31.2	31.0	26.4	25.3

*Calculation method according to V.Ageev

Table 3. Effect of the optimized mineral fertilizers application on the dynamics of the exchangeable potassium content (mg/kg)in the 0-20 cm layer of leached chernozem, 2010-2014

Calculation method	Before seeding	Tillering	Earing	Full ripeness
Control	241	232	218	216
Recommended$N_{60}P_{60}K_{30}$	253	244	228	231
*$N_{60}P_{34}K_{34}$	244	238	221	203
*$N_{105}P_{60}K_{60}$	257	250	232	220
*$N_{126}P_{80}K_{72}$	262	254	240	237

*Calculation method according to V.Ageev

Table 4. Effect of different mineral fertilizers rates on the structure of the winter wheat crop, 2010-2014

Expected yield,t/ha	Calculation method	Fertilizer rates	Quantity,items/m²			Tilling capacity		Spike			Mass of 1000 grains, g	Biological yield, t/ha
			Plants	Footstalls Total	Footstalls with spikelet	Total	Yielding	Length, cm	Number of grains, g	Grain mass, g		
Control	Control	0	207	381	349	1.9	1.7	8.5	23	0.97	34.0	3.39
	Recom-mended	$N_{60}P_{60}K_{30}$	246	479	447	2.0	1.8	9.2	25	0.98	35.2	4.38
4.0	1*	$N_{60}P_{34}K_{34}$	246	467	435	2.0	1.8	9.4	27	0.99	36.4	4.31
	2*	$N_{68}P_{44}K_{24}$	251	484	452	2.1	1.8	9.9	25	1.00	36.1	4.52
5.0	1*	$N_{105}P_{60}K_{60}$	283	558	526	2.2	1.9	9.8	26	1.04	36.7	5.06
	2*	$N_{90}P_{67}K_{40}$	281	527	495	2.1	1.8	9.9	28	1.03	37.1	5.1
6.0	1*	$N_{126}P_{80}K_{72}$	355	620	588	1.9	1.7	11.5	28	1.04	37.2	6.12
	2*	$N_{110}P_{82}K_{51}$	320	581	549	1.9	1.7	10.8	30	1.06	37.5	5.82

* 1-Calculation methodby V. Ageev.
* 2-Calculation method by the scientists of SSRIA and SACC.

During the vegetation not all fertilized options exceeded on average the control in terms of the labile exchangeable potassium content in the soil (Zörb *et al*., 2014). Thus, the content of exchangeable potassium in the soil at the option with $N_{60}P_{34}K_{34}$ was insignificantly lower than controls in all the studied vegetation stages. At that, the substantial increase in exchangeable potassium against the control was mentioned for all the options with $N_{126}P_{80}K_{72}$: 262, 254, 240 and 237mg/kg of soil, and the difference compared with the control amounted to 21 and 22 mg/kg of soil.

Effect of different mineral fertilizers rates on the structure of the winter wheat crop

From the data presented in Table 4 it is obvious that the tested fertilizer rates, as compared to control, reliably increased wheat yield structure parameters (Miao *et al*., 2015), such as the length of the spike (increased by 0.7-3 cm), the number of grains per spike (increased by 2-7 pc.), the weight of thousand grains (increased by 1.2-3.5 g), and the mass per spike (increased by 0.01-0.09 g).

It should be noted th*et al*l studied fertilizer rates had reliable effect on the number of plants per 1 m², as the difference relative to the control was 44-148 pcs. Thus, the numberof plants and the density of productive haulm were priority in the formation of the crop in the option with expected yield of 6.0 t/ha at estimated fertilizer system based on application of$N_{126}P_{80}K_{72}$ and $N_{110}P_{82}K_{51}$; higher values were shown by structural indicators of spike and the mass of thousand grains.

Effect of different mineral fertilizers rates on the yield of winter wheat in the temperate humid zone of the Stavropol Territory

The data presented in Table 5 show th*et al*l studied fertilizers ratesreliably increased the yield of winter wheat (He *et al*., 2013); the difference relative to control was 1.03- 2.9 t/hain 2010-2011, 0.97-2.28 t/ha in 2011-2012, 0.69-3.17 t/hain 2012-2013, and 0.66-2.69 t/hain 2013 - 2014.

When optimizing mineral nutrition for expected yield of winter wheat at the level of 4.0 t/ha, we revealed th*et al*l studied computational methods for determining fertilizers rates showed a fairly high accuracy in targeting of crop yields, while deviations from 3 to 7% were negligible. When applying $N_{68}P_{44}K_{24}$ (4.85 t/ha), the calculations performed by the second method showed culture productivity, which was higher than that calculated by V. Ageev method by 18%.

Similar results were observed when targetingthe yield of 5.0 t/ha. Both calculation methods provided a negligible deviation from the targeted productivity towards decrease by-2.0 and -2.5%.

When applying fertilizers for targeted productivity level of 6.0 t/ha, the rate calculated by V.Ageev method exceeded that calculated by the method, suggested by SSRIA and SACC, by 4.8%. In turn, applying $N_{126}P_{80}K_{72}$ resulted in significant deviation from the targeted productivity level by 11%. In contrast, when applying $N_{110}P_{82}K_{51,}$ calculated by the method of SSRIA and SACC, the deviation was within the experimental error.

Regardless of the calculation method, we were unable to obtain the targeted level of winter wheat yield equal to 6.0 t/ha. Nevertheless, the greatest targeting effect was produced in 2012-2013, when all options provided reliable increase in crop yield (deviation was +4% and +13%, respectively).

Thus, in the course of the research conducted, all studied fertilizer rates significantly increased the yield of winter wheat as compared with the controls. Comparison of the concerned methods of estimated fertilizer rates with regard to targeted yields of 4.0 and 6.0 t/ha showed that there were no significant differences in the yield of winter wheat.

Table 5. Winter wheat yield in temperate humid zone of Stavropol Territory for 2010-2014, based on the optimization of mineral nutrition rates

Fertilizer rates	Calculation methods*	Targeted yield	Yield, t/ha				Average yield
			2010-2011	2011-2012	2012-2013	2013-2014	
0	Control	-	3.12	2.63	3.74	3.25	3.19
$N_{60}P_{60}K_{30}$	Recommended	-	4.3	3.60	4.90	3.91	4.18
$N_{60}P_{34}K_{34}$	1*	4.0	4.15	3.72	4.43	4.15	4.11
$N_{68}P_{44}K_{24}$	2*		4.39	3.93	4.85	4.10	4.32
$N_{105}P_{60}K_{60}$	1*	5.0	4.63	4.34	5.57	4.90	4.86
$N_{90}P_{67}K_{40}$	2*		5.17	4.21	5.42	4.62	4.90
$N_{126}P_{80}K_{72}$	1*	6.0	6.02	4.91	6.91	5.85	5.92
$N_{110}P_{82}K_{51}$	2*		5.8	4.61	6.23	5.94	5.65
HCP_{05}	-	-	0.27	0.32	0.45	0.30	0.25
Sx,%	-	-	3.6	4.6	3.3	4.3	4.6

* 1-Calculation method by V.Ageev.
* 2-Calculation method by the scientists of SSRIA and SACC.

Table 6. Effect of mineral fertilizers rates on grain quality of winter wheat

Expected yield, t/ha	Calculation method	Fertilizer rates	Fibrin content, %	Hardness, %	Fibrin strain	Grain class	Protein
Control	Control	0	17.1	38.0	80	V	9.19
	Recommended	$N_{60}P_{60}K_{30}$	19.5	40.0	73	IV	11.34
4.0	1*	$N_{60}P_{34}K_{34}$	24.7	45.0	75	IV	11.00
	2*	$N_{68}P_{44}K_{24}$	24.9	47.0	72	IV	11.34
5.0	1*	$N_{105}P_{60}K_{60}$	25.8	49.0	72	IV	11.51
	2*	$N_{90}P_{67}K_{40}$	26.5	48.0	73	IV	11.12
6.0	1*	$N_{126}P_{80}K_{72}$	27.0	65.0	75	III	12.48
	2*	$N_{110}P_{82}K_{51}$	26.7	55.0	73	III	12.71

* 1-Calculation method by V.Ageev.
* 2-Calculation method by the scientists of SSRIA and SACC.

On the average, over four years of studies, both calculation methods of fertilizer rates provided targeted wheat yield at the level of 4 t/ha when applying $N_{60}P_{34}K_{34}$ and $N_{68}P_{44}K_{24}$. Targeted yield at thelevels of 5.0 and 6.0 t/ha were not reached, though the greater targeting reliability of 99% was obtained when applying the fertilizer rate of $N_{126}P_{80}K_{72}$ for targeted yield of 6.0 t/ha usingV. Ageev calculation method.

Effect ofvarious mineral fertilizers rates on grain quality of winter wheat in the temperate humid zone of the Stavropol Territory

As is obvious from Table 6, grain hardness index in various options ranged from 38.0 to 65.0%, whereas for the milling industry minimalgrain hardness index of winter wheat should not be below 40% (He *et al*., 2013). Expected yield levels of 4.0 and 5.0 t/ha, as well as the recommended fertilizer rate, provided grain of Class IV, while control parameter corresponded to class V.Nothing but the expected productivity levels of 6.0 t/ha provided grain of class III. On the average, over four years all the studied fertilizer rates increased fibrin content by 2.4-9.9% as compared with the control. At that, in the options with the expected yield of 5.0 and 6.0 t/ha V. Ageev method provided higher fibrin content. The application of all the studied rates of mineral fertilizers also contributed to the production of high quality fibrin: readings of fibrin strain meter showed 72-80 un. All studied fertilizer rates increased protein content as compared to the control. The maximum protein content, regardless of calculation method was observed in the options with the expected yield of 6 t/ha.

DISCUSSION

While conducting research on winter wheat crops, we have found a close relationship between the change in content of labile forms of nitrogen in the soil, as well as mineral fertilizers forms and rates applied depending on the agro-meteorological conditions. Mineral nitrogen content in soil is dependent on the precipitation amount and distribution during the culture's growing season. The higher amount of precipitation, higher the content of mineral nitrogen in soil.

When optimizing mineral nutrition for the expected level of winter wheat yield of 4.0 t/ha, we found th*et al*l studied calculation methods for determining fertilizers rates showed a fairly high accuracy in yield targeting, while deviations from 3 to 7% were negligible. Higher levels of culture productivity was noted when applying $N_{68}P_{44}K_{24}$(4.85 t/ha), calculated by the second method,which was by 18% higher than the rates calculated by V. Ageev method.

Yield targeting at the level of 5.0 t/ha showed similar results. Both calculation methods provided a negligible deviation from the expected productivity towards the decrease by-2.0 and -2.5%.

CONCLUSION

Not all fertilized options on average were superior to control in terms of the labile phosphorus content in the soil during the vegetation. Thus, the content of labile phosphorus in the soil at the recommended system of fertilizers and application of $N_{105}P_{60}K_{60}$was insignificantly lower than controls in all the studied vegetation stages. Other studied fertilizer rates during the growing season increased the content of labile phosphorus in the soil layer of 0-20 cm.The difference with the control was 4.7-6.9mg/kg before seeds; 4.0-5.6mg/kg in the tillering stage; 2.2-4.4 mg/kg in the earstage and 2.9-5.1mg/kg in a stage of full ripeness. At that, a significant increase of labile phosphorus relative to control was noted in all the options with the recommended system of fertilizers and $N_{126}P_{80}K_{72}$.

The highest content of labile phosphorus in the soil in all stages of plant development was noted when applying$N_{126}P_{80}K_{72}$– 31.2, 31.0, 26.4, 25.3 mg/kg soil.

During the vegetation not all fertilized options exceeded on average the control in terms of the content of the labile exchangeable potassium in the soil. Thus, the content of exchangeable potassium in the soil at the option with $N_{60}P_{34}K_{34}$ was insignificantly lower than controls in all the studied vegetation stage. At that, the substantial increase in exchangeable potassium against the control was mentioned for all the optionswith $N_{126}P_{80}K_{72}$:262, 254, 240 and 237mg/kg of soil, and the differencesas compared with the controls were 21 and 22 mg/kg of soil, respectively.

All studied fertilizer rates had reliable effect in terms of the number of plants per 1 m^2, as the difference relative to the control was 44-148 pcs. Thus, the number of plants and the density of productive haulm had priority in the formation of the crop when targeting yield of 6.0 t/ha at estimated fertilizer system with application of $N_{126}P_{80}K_{72}$ and $N_{110}P_{82}K_{51}$; higher values were shown by structural indicators of spike and the mass of thousand grains.

When applying fertilizers for targeted productivity level of 6.0 t/ha, the rate calculated by V.Ageev method exceeded the rate calculated by the method, recommended by SSRIA and SACC, by 4.8%. In turn, when applying $N_{126}P_{80}K_{72}$, we observed a significant deviation by 11% from the targeted level of productivity.In contrast,when applying$N_{110}P_{82}K_{51,}$calculated by the method of SSRIA and SACC, the deviation was within the experimental error.

Regardless of the calculation method we were unable to obtain the targeted level of winter wheat yield of 6.0 t/ha. Nevertheless, the greatest targeting effect was produced in 2012-2013, when all options provided reliable increase in crop yield (deviation was +4% and +13%, respectively).

Grain hardness index in various options ranged from 38.0 to 65.0%, whereas for the milling industry minimalgrain hardness index of winter wheat should not be below 40% (He *et al*., 2013). Expected yield levels of 4.0 and 5.0 t/ha, as well as the recommended fertilizer rate, provided a grain of Class IV, while control parameter corresponded to class V. Nothing but the expected productivity levels of 6.0 t/ha provided the grain of class III. All studied fertilizer rates increased protein content as compared to the control. The maximum protein content, regardless of calculation method was observed in the options with the expected yield of 6 t/ha.

ACKNOWLEDGEMENTS

The authors express their deep gratitude to Professor Vladimir I.Trukhachev,the Chancellor of FSBI HPO"Stavropol State Agrarian University", for the opportunity to conduct research in innovative accredited "Laboratory of Agrochemical Analysis". Field studies were carried out at the experimental station of the Stavropol State Agrarian University.

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