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РЕСУРСОСБЕРЕГАЮЩИЕ ПРИЕМЫ ВОЗДЕЛЫВАНИЯ КОРМОВЫХ КУЛЬТУР В ЗАБАЙКАЛЬСКОМ КРАЕ

Пилипенко Н.Г., (✉) Андреева О.Т., Сидорова Л.П., Харченко Н.Ю.
Научно-исследовательский институт ветеринарии Восточной Сибири – филиал Сибирского федерального научного центра агробиотехнологий Российской академии наук
Забайкальский край, г. Чита, Россия
(✉) e-mail: frau.Olgaa2015@yandex.ru

Представлены результаты исследований по сравнительной оценке различных приемов обработки почвы в полевом севообороте с разным уровнем минерального питания ($N_{30}P_{30}$ и $N_{60}P_{30}$ кг д.в./га). Эксперимент проведен на малогумусном малокарбонатном черноземе лесостепной зоны Восточного Забайкалья в 2012–2014 гг. Для посева использованы районированный сорт яровой пшеницы Бурятская-79, сорт овса Метис. Изучены малозатратные приемы обработки почвы, предусматривающие сохранение и повышение плодородия почвы, повышение продуктивности зернофуражных и кормовых культур, снижение материальных и энергетических затрат. Замена основной обработки плугом ПН-4-35 с кольчатым катком в третьем и четвертом полях севооборота поверхностной обработкой культиватором Степняк-7,4 и прямым посевом по стерне сеялкой ППМ Обь-4-ЗТ при внесении минеральных удобрений в норме $N_{60}P_{30}$ кг д.в./га оказывала положительное влияние на состояние почвы. Достигнуты следующие показатели плодородия почвы: коэффициент структурности 1,28–1,38, содержание органического вещества 3,15–3,33%, содержание продуктивной влаги в слое 0–50 см 29,2–31,8 мм, выделение углекислоты 1,810–1,969 кг за 1 ч, содержание P_2O_5 в слое 0–20 см 71–96 мг/кг почвы, K_2O – 57–82 мг/кг почвы. Обеспечена прибавка урожайности зерна овса 0,16–0,21 т/га, зеленой массы однолетних трав – 3,4–4,0 т/га, сбор кормовых единиц – 0,32–0,34 т/га, снижение затрат горюче-смазочных материалов на 31,2–36,4%, повышение рентабельности на 25,0–40,3%.

Ключевые слова: севооборот, отвальная вспашка, поверхностная обработка, прямой посев, плодородие почвы, минеральные удобрения, продуктивность, экономическая эффективность

RESOURCE-SAVING METHODS OF FODDER CROP CULTIVATION IN THE TRANS-BAIKAL TERRITORY

Pilipenko N.G., (✉) Andreeva O.T., Sidorova L.P., Kharchenko N.Yu.
Scientific Research Institute of Veterinary Medicine of Eastern Siberia – Branch of the Siberian Federal Scientific Centre of Agro-BioTechnologies of the Russian Academy of Sciences
Chita, Trans-Baikal Territory, Russia
(✉) e-mail: frau.Olgaa2015@yandex.ru

The results of the study on the comparative assessment of different tillage methods in the field crop rotation with different levels of mineral nutrition ($N_{30}P_{30}$ and $N_{60}P_{30}$ kg of active ingredient/ha) are presented. The experiment was carried out on low-humus low-carbonate chernozem of the forest-steppe zone of Eastern Trans-Baikal Territory in 2012–2014. The zoned variety of Buryatskaya-79 spring wheat, and Metis oat variety were used for sowing. Low-cost methods of soil tillage were studied, providing for the preservation and improvement of soil fertility, an increase in the productivity of grain and fodder crops, and a decrease in material and energy costs. Replacement of the basic tillage with a PN-4-35 plow with a ring roller in the third and fourth crop rotation fields by surface tillage with a Stepnyak-7.4 cultivator and direct sowing on the stubble with a PPM Ob-4-ZT seeder when applying mineral fertilizers at a rate of $N_{60}P_{30}$ kg of active ingredient/ha had a positive effect on the condition of the soil. The following indicators of soil fertility were achieved: structural coefficient 1.28–1.38, organic matter content 3.15–3.33%, productive moisture content in the 0–50 cm layer 29.2–31.8 mm, the release of carbon dioxide 1.810–1.969 kg per 1 hour, the content of P_2O_5 in the 0–20 cm layer 71–96 mg/kg of soil, the content of K_2O – 57–82 mg/kg of soil. An increase in the yield of oat grain of 0.16–0.21 t/ha, the green mass of annual grasses of 3.4–4.0 t/ha, the collection of feed units of 0.32–0.34 t/ha, a reduction in the cost of fuel and lubricants by 31.2-36.4%, and an increase in profitability by 25.0–40.3% were achieved.

Keywords: crop rotation, moldboard plowing, surface tillage, direct sowing, soil fertility, mineral fertilizers, productivity, economic efficiency

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INTRODUCTION

Different intensity of land use in combination with complex natural and economic factors in the conditions of the Trans-Baikal Territory (violation of the technology of cultivation of agricultural crops, non-observance or absence of scientifically grounded crop rotations, poor quality fallow preparation and tillage) is gradually leading to degradation of the soil and vegetation cover [1-3].

One of the most important tasks of agriculture is to ensure the sustainable development of the production of grain, grain fodder and fodder crops based on the optimization of the structure of sown areas using a biologized and resource-saving farming system.

Tillage in a farming system is an energy-intensive process. In the conditions of Transbaikalia, plowing remains the predominant method of mechanical processing, but its high energy intensity is a limiting technological factor in resource-saving agriculture. Currently, the range of soil cultivation equipment is being replenished by the production of high-performance multi-operational implements, which makes it possible to switch from traditional tillage to minimum.

Usually, to perform pre-sowing soil cultivation, 4-6 passes through the field with tillage and sowing equipment are required. The use of such new units as the PN-4 mounted ripper, the Stepnyak-7,4 cultivator, the Ob-4-ZT tillage and sowing machine allows to reduce the number of passes to a minimum [3, 4].

In recent years, enough experimental material has been accumulated on the development of scientifically grounded biologized crop rotations and resource-saving soil cultivation systems that allow preserving soil fertility, increasing crop yields and product quality, and reducing costs for their cultivation [1, 5-7].

The purpose of the research is to evaluate in comparison energy-saving methods of soil cultivation at different levels of mineral nutrition in field crop rotation on grain fodder and forage crops, to determine the influence of technologies on the main indicators of fertility of low-humus low-carbonate chernozems, crop productivity and their economic efficiency.

MATERIALS AND METHODS

Field agrotechnical experiments were carried out in a stationary four-field field crop rotation of pairs - wheat - oats - annual grasses (oats) in the fields located in the southwestern part of the Ingodinsko-Chita forest-steppe.

The climate of the zone is sharply continental with little snow, cold winters, hot summers and a lack of precipitation. The frost-free period lasts for 90-110 days. The average annual precipitation is 330-380 mm, the main amount (85-90%) falls in the warm period, the maximum -

in July - August, the minimum - in May - June. In general, the regime is characterized by variability of moisture. Years with good moisture supply give way to satisfactory, and more often dry periods. The sum of temperatures above 10 ° C for the summer months is 1500–1800 ° with a high average monthly temperature in July - 19.1 ° C. Hydrothermal coefficients (HC) of the growing seasons during the years of research were 2.7; 2.1; 0.6. According to the State Customs Committee, 2012 and 2013 characterized as sufficiently humid, 2014 - severely arid.

The soil of the experimental plot is chernozem, low-humus, low-carbonate, low-power, light loam. The humus content in the arable layer is 2.78%. The soil supply with mobile forms of phosphorus and exchangeable potassium is average. Lumpiness of the soil is below the threshold of resistance to wind erosion.

The experiment was repeated three times. The sown area of the plot is 1000 m^2. The placement of variants in the first repetition is sequential, in the second and third - randomized. The fields in the crop rotation were located both in space and in time. To cultivate the soil a PN-4-35 mounted plow with rolling ZKKSh-6A, a mounted PN-4 cultivator, KPE-3.8 and Stepnyak-7.4 cultivators, and a PPM Ob-4-ZT seeder for direct sowing were used. The experiment scheme is presented in table 1.

Agrotechnology of cultivation of field crops in crop rotation was carried out according to the scheme of the experiment. Mineral fertilizers were applied simultaneously with sowing at the rate of $N_{30}P_{30}$ kg a.i. / ha in the form of ammonium nitrate and superphosphate for each crop rotation and N_{30} kg a.i. / ha for pre-sowing cultivation in oats and annual grasses in options without basic tillage. In the fight against smut fungi and root rot, the seeds were treated with the fungicide "Bunker" before sowing at a rate of 0.5 l / t of seeds. For sowing, we used the zoned spring wheat variety Buryatskaya-79, the Metis oat variety. Sowing dates: spring wheat in the 1st decade of May, oats in the 3rd decade of May, annual grasses in the 3rd decade of June. For sowing, a PPM Ob-4-ZT seeder was used. The method of sowing is striped with a seeding depth of 6–8 cm. Crop care of agricultural crops was carried out in accordance with the recommendations [1]. In the tillering phase against weeds, wheat and oats were treated with a tank mixture of herbicides Dialen super (0.2 l) + Magnum (0.007 kg) per 1 ha. The harvesting and accounting of the harvest of grain crops was carried out by direct combining with a Yenisei combine (the yield led to 14% moisture and 100% purity), annual grasses for green mass - with a KS-2.1 mower.

The observations and counts were carried out according to the generally accepted methods in agriculture and crop production[1–6].

RESULTS AND DISCUSSION

The research results showed that replacing the traditional moldboard plowing in the third and fourth fields of crop rotation with resource-saving processing systems (cultivation, direct seeding) did not worsen the structural-aggregate state of the arable horizon of 0-30 cm. Against the background of low-cost tillage, the coefficient of structure was 1.28-1 , 37, on the control with moldboard plowing - 1.0-1.1. In the compared variants, the higher indices of the volumetric mass in the arable soil layer in the summer period (1.30 and 1.34 g / cm^3) were obtained without main treatment, lower (1.26 and 1.29 g / cm^3) - in the variants with moldboard plowing. In terms of productive moisture reserves in a half-meter soil layer before harvesting, the traditional technology of cultivation of agricultural crops was inferior to energy-saving

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Табл. 1. Схема опыта в севообороте

Table 1. Scheme of the experiment in crop rotation

Crop rotation fields			
Fallow	Wheat	Oats	Annual grasses (herbage oats)
Tillage type			
Basic tillage PN-4-35 (20–22 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS-1 for 8–10, 10–12 cm	Pre- sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH-6A	Basic tillage PN -4-35 (20–22 cm), pre-sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Basic tillage PN -4-35 (20–22 cm), pre- sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A
Tillage PN-4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre- sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Tillage LDT -4 (25–27 cm), pre-sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Tillage LDT -4 (25–27 cm), pre- sowing cultivation KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Cultivation Stepnyak-7,4 for 16–18 cm, seeding (fertilizers $N_{30}P_{30}$)	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{30}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{60}P_{30}$)	Cultivation Stepnyak-7,4 for 16–18 cm, sowing (fertilizers $N_{60}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE-3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Sowing on untreated stubble (fertilizers $N_{30}P_{30}$)	Sowing on untreated stubble (fertilizers $N_{30}P_{30}$)
Tillage PN -4 (25–27 cm), during the fallow period 2–3 cultivation KPE -3,8 with BZSS -1 for 8–10, 10–12 cm	Pre-sowing cultivation, KPE -3,8 for 6–8 cm, compacting ZKKSH -6A, sowing (fertilizers $N_{30}P_{30}$), compacting ZKKSH -6A	Sowing on untreated stubble (fertilizers $N_{60}P_{30}$)	Sowing on untreated stubble (fertilizers $N_{60}P_{30}$)

ones in oats by 2.6–3.1 mm, annual grasses by 6.1–7.7 mm (see Table 2).

The accumulation of plant residues in the upper layer with deep flat-cut loosening, minimal surface treatments and direct sowing on the stubble led to an intensive reproduction of bacteria that enhance the processes of mineralization of organic matter in the soil. In these variants with an increased level of mineral nutrition ($N_{60}P_{30}$), the highest rates of carbon dioxide emission were obtained during the growing season - 1.810–1.969 kg/ha per 1 hour. During moldboard tillage, due to the low input of organic matter and low moisture content, the emission of CO_2 was minimal. - 1.154 kg/ha per 1 hour. Low rates of carbon dioxide emission corresponded to a looser composition of the arable soil layer - 1.26 g/cm^3 (on variants with surface treatments - 1.29-1.30 g/cm^3). The supply of plants with assimilable forms of phosphorus and potassium was higher in crops without basic tillage. The excess to the control in terms of the content of mobile forms of phosphorus and exchangeable potassium in oat crops was 21–46 and 24–40 mg/kg of soil, in crops of annual grasses, respectively - 3–19 and 7–22 mg / kg of soil. The content of organic matter in the variant with deep moldboard plowing was 2.78%, in the variants with low-cost tillage systems - 3.15–3.33% [8–10].

Cultivation of grain fodder crops without basic tillage with the introduction of mineral fertilizers at the rate of $N_{30}P_{30}$ kg a.i./ha provided an equivalent grain yield with the option where the traditional technology was used 1.49-1.60 t / ha (control - 1.59 t/ha). A significant increase in yield to the control variant (0.16–0.21 t/ha) was obtained with surface tillage methods with an increased level of mineral nutrition $N_{60}P_{30}$ kg ai/ha (see Table 3).

The grain yield of oats, depending on the tillage, was formed mainly due to the density of the standing of the plants and the productive stalk. On variants with traditional technology, the plant density before harvesting was 293 plants / m^2, the number of productive stems was 370 plants / m^2, on variants with surface treatments, respectively, 307–327 and 383–454 plants / m^2.

Табл. 2. Влияние предпосевной обработки почвы на ее агрофизические и агрохимические свойства в посевах овса и однолетних трав
Table 2. Effect of pre-sowing tillage on soil agrophysical and agrochemical properties in oat and annual grass crops

Tillage type	Crop rotation culture	Soil criterion					
		Structure coefficient (0–30 cm)	Weight by volume (0–20 cm), gr/cm^3	Productive moisture reserves before harvesting (0–50 cm), mm	Productive moisture reserves before harvesting (0–50 cm), mm	Productive moisture reserves before harvesting (0–50 cm), mm	Organic matter content at the end of the crop rotation (0–20 cm), %
Basic tillage PN -4-35 with star-wheeled roller ZKKSH -6A for 20–22 cm, pre-sowing cultivation for 16–18 cm, compacting ZKKSH -6A, sowing for 6–8 cm, compacting ZKKSH -6A (control)	Oats	1,1	1,26	28,7	1,154	50–42	2,78
	Annual grasses	1,0	1,29	23,1		68–50	
Pre-sowing cultivation for 16–18 cm, sowing for 6–8 cm	Oats	1,37	1,29	31,3	1,714	71–66	3,15
	Annual grasses	1,28	1,32	29,2	1,969	71–72	
Sowing on untreated stubble for 6–8 cm	Oats	1,31	1,30	31,8	1,610	96–82	3,33
	Annual grasses	1,28	1,34	30,8	1,810	87–57	

The same dependence on the methods of soil cultivation and the level of mineral nutrition has developed in the crops of annual grasses.

Variants with traditional technology and the use of low-cost resource-saving methods with the level of mineral nutrition $N_{30}P_{30}$ provided almost equal yield of green mass of annual grasses of 13.2-13.5 t / ha (control - 13.1 t / ha), dry matter collection - 3, 80–4.02 t / ha (control - 3.95 t / ha). The excess to the control for green mass 3.4–4.0 and collection of dry matter 1.0–1.18 t / ha was obtained on variants with surface tillage and direct sowing with an increased level of mineral nutrition ($N_{60}P_{30}$).

Resource-saving technologies for the cultivation of agricultural crops provided savings in material and labor costs. This was achieved through the use of low-cost tillage and the combination of agrotechnical operations using multi-operational tillage and sowing machines. The economic assessment of crops of oats and annual grasses revealed a higher efficiency of the resource-saving soil cultivation system in comparison with the traditional one based on continuous plowing. Depending on the level of mineral nutrition, direct costs decreased by 5.6–15.5%, the cost of fuel - by 31.2–36.4%, the profitability of production increased by 25.0–40.3% (see Table 4).

Resource-saving tillage methods in field crop rotation on low-humus low-carbonate chernozem ensured the highest crop productivity and return on energy costs per hectare of crop rotation area in comparison with traditional technology (see Table 5).

Low-cost tillage compared to moldboard plowing with the same level of mineral nutrition ($N_{30}P_{30}$) increased the collection of fodder units by 0.05–0.05 tons, with an increased level of mineral nutrition ($N_{60}P_{30}$) - by 0.32–0.34 tons. The system data ensured the greatest return on energy costs, where the energy efficiency coefficient, corresponding to the levels, increased by 0.4–0.6 and 1.0–1.2 units. The data obtained agree with the results of other authors [11–16].

CONCLUSIONS

1. Replacement of the main tillage with pre-sowing cultivation and direct sowing on stubble provided the following indicators of soil condition: structural coefficient 1.28-1.38 (in the control with moldboard plowing 1.0-1.1), max-

Табл. 3. Урожайность и элементы структуры урожая овса в зависимости от приемов обработки почвы при разных уровнях минерального питания

Table 3. Yield and structure elements of the oat output depending on the methods of tillage with different levels of mineral nutrition

Experiment option	Crop yield, t/ha	Number of plants, pcs / m2		Number of productive stems, pcs / m²	Head length, cm	Number of grains in one head, pcs.	Grain weight from one head, g	Weight of 1000 seeds, g
		by seedlings	before harvesting					
Plowing, pre-sowing cultivation, compacting ZKKSH -6A, sowing, fertilizers $N_{30}P_{30}$, compacting ZKKSH -6A (control)	1,59	309	293	370	13,6	48	1,53	32,2
Pre-sowing cultivation, sowing, fertilizers $N_{30}P_{30}$	1,60	317	314	386	13,3	45	1,34	32,7
Pre-sowing cultivation, sowing, fertilizers $N_{60}P_{30}$	1,80	313	307	445	14,1	46	1,42	32,3
Sowing on untreated stubble, fertilizers $N_{30}P_{30}$	1,49	326	319	383	13,4	45	1,33	32,8
Sowing on untreated stubble, fertilizers $N_{60}P_{30}$	1,79	327	327	454	14,2	46	1,42	32,6
$LSD_{0,5}$	0,15	7	15		$F_ф < F_{0,5}$	$F_ф < F_{0,5}$	$F_ф < F_{0,5}$	

imum content of productive moisture before harvesting in layer 0 –50 cm 29.2–31.8 mm (control 23.1–28.7), release of carbon dioxide 1.810–1.969 kg per hour (control 1.154 kg per hour), content of mobile forms of phosphorus P_2O_5 71– 96 mg / kg soil, exchangeable potassium K_2O 57–82 mg / kg soil (control - P_2O_5 50–68 mg / kg soil, K_2O 42–50 mg / kg soil), organic matter content 3.15–3 , 33% (control 2.78%).

2. Energy-saving methods of soil cultivation in combination with mineral fertilizers ($N_{60}P_{30}$ kg a.i./ ha) provided an increase in the yield of oat grain 0.16-0.21 t / ha (in the control 1.59 t / ha), green mass of annual grasses - 3.4–4.0 t /

Табл. 4. Экономическая эффективность ресурсосберегающих приемов обработки почвы с разными уровнями минерального питания при возделывании овса и однолетних трав в севообороте

Table 4. Economic efficiency of resource-saving methods of tillage with different levels of mineral nutrition in the cultivation of oats and annual grasses in the crop rotation

Element	Traditional technology with a level of mineral nutrition $N_{30}P_{30}$, р.	Resource-saving technology without core tillage with the level of mineral nutrition			
		$N_{30}P_{30}$		$N_{60}P_{30}$	
		р.	% to traditional technology	р.	% to traditional technology
Production cost	7500	7400	–	9000	–
Direct costs – total	5048	4265	84,5	4765	94,4
Including:					
payroll with accruals	800	587	73,4	637	79,6
POL	1156	736	63,6	796	68,8
seeds, fertilizers, pesticides	1896	1996	105,3	2350	123,9
depreciation	530	430	81,1	450	84,9
regular maintenance	666	516	77,5	532	79,8
cost efficiency	48,5	73,5	25,0	88,8	40,3

Табл. 5. Продуктивность и энергетическая эффективность ресурсосберегающих приемов обработки почвы при разных уровнях минерального питания в полевом севообороте

Table 5. Productivity and energy efficiency of resource-saving tillage techniques with different levels of mineral nutrition in the field crop rotation

Process scheme	Output of fodder units from 1 hectare of crop rotation area, t	Energy consumption, MJ, ha	Energy efficiency ratio
Plowing, cultivation, compacting, sowing (fertilizers $N_{30}P_{30}$, herbicides), compacting	1,84	11273	4,5
Cultivation, sowing (fertilizers $N_{30}P_{30}$, herbicides)	1,89	10557	4,9
Cultivation, sowing (fertilizers $N_{60}P_{30}$, herbicides)	2,16	11859	5,5
Direct sowing on stubble (fertilizers $N_{30}P_{30}$, herbicides)	1,89	10295	5,1
Direct sowing on stubble (fertilizers $N_{60}P_{30}$, herbicides)	2,18	11597	5,7

ha (control 13.1 t / ha), collection of feed units - 0.32–0.34 t / ha (control 1.84 t / ha).

3. Resource-saving tillage techniques in field crop rotation provided the greatest return on energy costs per hectare of crop rotation area in comparison with traditional technology. With the level of mineral nutrition $N_{30}P_{30}$, the energy efficiency coefficient increased by 0.4–0.6 units, with $N_{60}P_{30}$ - by 1.0–1.2 units. (on control 4.5 units).

4. Direct costs of growing crops decreased by 5.6–15.5% of fuel and lubricants - by 31.2–36.4%, profitability increased by 25.0–40.3%.

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Информация об авторах

Пилипенко Н.Г., кандидат сельскохозяйственных наук, старший научный сотрудник

(✉) **Андреева О.Т.,** кандидат сельскохозяйственных наук, ведущий научный сотрудник; **адрес для переписки:** Россия, 672010, Забайкальский край, г. Чита-10, ул. Кирова, 49, а/я 470; e-mail: frau.Olgaa2015@yandex.ru

Сидорова Л.П., старший научный сотрудник

Харченко Н.Ю., научный сотрудник

Author information

Natalya G. Pilipenko, Candidate of Science in Agriculture, Senior Researcher

(✉) **Olga T. Andreeva,** Candidate of Science in Agriculture, Lead Researcher; **address:** P.O. Box 470, 49 Kirov St., Chita-10, Trans-Baikal Territory, 672010, Russia; e-mail: frau.Olgaa2015@yandex.ru

Lyudmila P. Sidorova, Senior Researcher

Nadezhda Yu. Kharchenko, Researcher

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