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Improving the Use of Green Manure Crops in Potato Production in Western Siberia

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Abstract*: *The paper presents the results of three years of studying the effects of green manure fallow on the yield and the quality of potato varieties of various ripeness groups (2016 through 2018) on leached heavy-loamy black soils of the forest-steppe of the Ob region (West Siberia, Russia). The efficiency of cultivated crops (vetch-and-oats mixture, creeping trefoil, medick, white melilot, spring rape, brown mustard, oil radish), as well as the use of manure and pure fallow, has been shown. It has been shown that the highest yields of green manure crop for potatoes were obtained in the variant with the use of oil radish (50 t/ha), white melilot (40 t/ha), and medick (36 t/ha). In cultivating potatoes on green manure fallow, the leaf area with the photosynthetic capacity of 2,400 m2d/ha is formed. The highest yield of the early-ripening variety Lyubava is 32.8 t/ha on the background of medick, and of the mid-ripening variety Sapho after oil radish – 32.6 t/ha. Green manure crops allow forming the high quality of the products: marketability of tubers – 93 %, dry matter content – 24.9 %, and starch – 17.4 %, with the concentration of nitrates in the tubers by 5.5 – 7 times lower than the maximum permissible concentrations for potatoes.

Index Terms*: *potato, varieties, manure, green manure crops, green manure, leaf area, yield, starch content of tubers.

I. INTRODUCTION

One of the reserves of increasing and improving the quality of potatoes is developing the scientific bases for optimizing the growing conditions, improvement of the production techniques applied to various natural zones of Western Siberia [1-3]. For the conditions of the region, potato is a widely spread crop [4, 5]. In the aspect of the potato industry, it is important to consider the high productivity of the crop, its exceptional nutritional value, and ecological plasticity [6-10]. In order to increase potato yield and improve its quality, fertilizing with organic and mineral fertilizers plays a crucial role along with other agrotechnical practices [11, 12]. Introduction of organic fertilizers also improves physical properties of the soil and makes it more structured, optimizes its water, air, and thermal conditions [13, 14]. Light, and even more, sandy soils become more buffer, and hold nutrients and moisture better in the topsoil [15, 16]. Organic fertilizers are the source of energy for most microorganisms in the soil; they stimulate the growth of saprophytic microorganisms and reduce the number of pathogenic microorganisms [17-19]. In the case of manure deficiency, the nutrients balance in the soil may be maintained by growing green manure plants.

Researchers have found that potatoes used 60 % of nitrogen from the green mass plowed into the soil and only 34 % from manure [20]. After green manure crops, potato yield increases significantly (up to 40 %), and its quality improves [21]. Growing and using green manure crops reduces the weeds, inhibits the spread of pests and diseases, and reduces leaching of nutrients from the topsoil to deeper soil horizons.

In this respect, the research was aimed at improving the elements of the green manure crops cultivation technology for potato production in the forest-steppe of the Ob region (West Siberia, Russia).

II. PROPOSED METHODOLOGY

The study was performed in 2016 – 2018, on the leached black soil of LLC KFH Quant in the Novosibirsk district of the Novosibirsk region. The soil of experimental plots contained 5.67 – 7.21 % of humus (medium-humic black soil), total nitrogen – 0.36 %, phosphorus – 0.21 %, and potassium – 0.91 %. The content of easily hydrolyzable nitrogen ranged between 8.10 and 12.6 mg/100 g of soil, mobile phosphorus – between 11.2 and 14.8 %, and exchange potassium – between 8.4 and 14.8 mg/100 g of soil, pH of the saline extracts was 5.67. In the years of the study, various weather conditions were observed. The hydrothermal coefficient ranged between 0.68 and 1.47. On average over the years of the study, the annual rainfall amounted to 449 mm, including the vegetation period: 2016 – 252 mm, 2017 – 329 mm, and 2018 – 319 mm with the long-time average annual data equal to 288 mm.

Algorithm. The field experiments were performed in four replications with the plot accounting area of 25 m2 with the randomized layout. The phenological phases of potato were determined according to the method of Gossortispytania (State variety testing), the leaf area – according to the method of N. F. Konyaev, and the photosynthetic potential (PSP) – by A. A. Nichiporovich.

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Potato infestation was accounted for quantitatively – by the gravimetric method after processing by the method of the All-Russian Potato Breeding Research Institute (VNIIKH). Plant infestation with diseases was determined by the method of RAAS, plants preservation rate – by the method of VNIIKH. The report data were processed by the variation statistics by B. A. Dospekhov based on the SNEDECOR computer application [22].

III. RESULT ANALYSIS

The studies in 2016 – 2018 that were performed on leached black soil of the forest-steppe in the Ob region on the fields of LLC KFH Quant show that the use of green manure fallow for potatoes has a positive effect on the growth and development of the target crop. Green manure crops had a significant amount of green mass, and its introduction into the soil had a positive effect on the main crop – the potato. It has been found that the amount of the green mass in the variant with oil radish was 49.6 t/ha, followed by white melilot – 39.4 t/ha. The minimum accumulation of the green mass is typical for the variant with the vetch-and-oats mixture (Table 1). In terms of the dry matter, variants with oil radish and white melilot also prevail. In terms of nutrients accumulation, pure fallow with the introduction of 20 t of manure per hectare should be noted. From the variants with green manure fallow, nutrients are mostly accumulated after oil radish: 96 kg of nitrogen per hectare, 23 kg of phosphorus, and 143 kg of potassium per hectare.

In both studied potato varieties from various ripeness groups, the greatest average leaf area was observed after green manure fallow with oil radish: variety Lyubava (early-ripening) – 17.6 thousand m^2/ha, and Sapho – 18.4 thousand m^2/ha, and in the variant with white melilot, 16.9 and 17.5 thousand m^2, respectively. In these variants, PSP reaches 2,360 m^2/ha vs 1,980 thousand m^2/ha in the variant with pure fallow and the use of 20 t of manure per hectare.

Table 1. Yield of green manure crops as precursors for potatoes. Average for 2016 – 2018

Variant	Green mass, t/ha	Dry matter, %	Accumulation of nutrients, kg/ha		
			N	P_2O	K_2O
Pure fallow (reference)	-	-	-	-	-
Pure fallow + manure 20 t/ha	-	-	187	69	172
Vetch-and-oats mixture	29.5	6.12	41	15	105
Creeping trefoil	32.6	6.17	52	20	118
Medick	35.8	6.18	56	22	125
White melilot	39.4	6.23	47	20	117
Spring rapeseed	36.5	6.16	38	19	123
Brown mustard	32.4	6.07	83	17	116
Oil radish	49.6	6.24	96	23	143
LSD_{05}	1.76	0.41	-	-	-

It has been found that green manure fallow crops significantly influence the yield and the quality of potato. For variety Lyubava (early-ripening), the use of 20 t of manure per hectare over pure fallow ensured the increase of yield, compared to the pure fallow in the reference, by 18 %, compared to medick – by 34 %, and compared to white melilot – by 29 %. For mid-ripening variety Sapho, the increase in the yield, compared to the reference, was higher with the use of oil radish – 44 %, spring rape – 41 %, and white melilot – 36 % (Table 2).

Table 2. The effect of green manure fallow crops on the yield and quality of potato. Average data for 2016 – 2018

Variant	Variety	Tubers yield			Tubers marketability	Content in the tubers			
		t/ha	increase to reference			dry matter, %	starch, %	vitamin C, mg/100 g	nitrates, mg/kg
			t/ha	%					
Pure fallow (Reference)	Lyubava	24.5	-	-	84	24.4	16.8	12.3	48
	Sapho	22.6	-	-	86	24.3	17.0	13.0	36
Pure fallow + manure 20 t/ha	Lyubava	28.8	4.3	18	88	24.7	16.6	13.2	65
	Sapho	26.3	3.7	17	89	24.6	17.3	13.4	30
Vetch-and-oats mixture	Lyubava	29.7	5.2	21	89	24.7	16.5	14.0	48
	Sapho	28.2	5.7	25	90	24.6	17.2	13.5	28
Creeping trefoil	Lyubava	30.4	5.9	24	87	24.7	17.0	13.6	50
	Sapho	28.1	5.5	25	91	24.8	17.2	12.8	35
Medick	Lyubava	32.8	8.3	34	90	24.8	17.4	12.3	39
	Sapho	30.5	7.9	35	93	24.9	17.4	12.6	38
White melilot	Lyubava	31.6	7.1	29	90	24.6	17.1	12.0	44
	Sapho	30.8	8.2	36	92	24.7	17.3	12.7	32
Spring	Lyubava	30.4	5.9	24	89	24.6	17.2	11.8	53

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rapeseed	Sapho	31.8	9.2	41	90	24.7	17.3	12.5	35
Brown mustard	Lyubava	29.5	5.0	20	87	24.3	16.8	13.4	39
	Sapho	27.4	4.8	21	91	24.6	17.0	12.0	48
Oil radish	Lyubava	29.9	5.4	22	86	24.4	17.0	12.8	44
	Sapho	32.6	10.0	44	89	24.8	17.3	13.0	40
LSD_{05}		1.82	-	-	0.86	0.15	0.23	0.44	5.65

*Note. The results of variance analysis of the three-factor experiment (2*9*3): LSD_{05} for particular differences – 1.82, LSD_{05} A – 2.15, LSD_{05} for B and AB – 1.96; the main effects of the factors and their interaction – A (genotype) – 28, (the green manure fallow crops) – 38, year – 23 %; AB – 2.65; BC – 4.25; AC – 2.12; and ABC – 0.89 %.*

For variety Lyubava, the tubers marketability was the best in the variant with white melilot (7 % increase to the reference), and for variety Sapho – in the variant with medick – 93 % (7 % increase to the reference), and white melilot – 6 %.

In terms of dry matter and starch content, variants with medick and creeping trefoil (for variety Lyubava), and variants with medick and radish oil (for variety Sapho) were the best. In terms of vitamin C, no significant difference was noted among the variants of the experiment. In the tubers of all variants, the content of nitrates was on average 5.5 – 7 times lower than the maximum permissible concentration for potato.

It has been statistically shown that potato yield depended on the genotype by 28 %, the crop of green manure fallow – by 38 %, and the conditions during the year – by 23 %. Among the interactions of the factors, relations between the genotype and the green manure fallow crop, as well as between the genotype and the conditions during the year stood out.

IV. ANALYSIS

An important element of improving fertility is the use of green manure crops and plowing the green mass for subsequent potato. The results of the studies performed on leached black soils were in conformity with the data of the experiments made by A. G. Kushnarev [3] that had been performed in Russia (dark brown and gray forest soils (Transbaikalia)), and the results obtained by the Russian scientists V. N. Mihailov [17] and I. Sh. Fatykhov [20] (gray forest and sod-podzolic soils). However, they contradict the results obtained by M. N. Pannikov [5] in the non-chernozem belt, where the effect of green manure crops on potato was less visible.

It has been shown that in the conditions of Western Siberia, the maximum accumulation of green mass was observed in the variant with oil radish (almost 50 t/ha) and white melilot (40 t/ha). It should be noted that the minimum formation of green mass was observed on the background of the vetch-and-oats mixture.

The results of the research performed by the authors are consistent with the literature data of B. A. Pisarev [6] and D. Shpaar [7] stating that the effect of manure with pure fallow ensures the significant accumulation of nutrients in the soil. The studies of the authors show that radish oil ensures the significant accumulation of nutrients in the soil: about 100 kg/ha of nitrogen, 25 kg of phosphorus, and almost 150 kg/ha of potassium. The high fertility potential of the soil after manure crops such as oil radish and white melilot affected the development of the leaf apparatus. In the varieties from various ripening groups (early and medium early), the maximum average leaf area was observed with the following green manure predecessor crops: oil radish and white melilot. It has been found that green manure fallow crops significantly influence the yield of the studied potato varieties bred in Siberia – Lyubava and Sapho. The yield increase compared to the reference (pure fallow) was achieved on the background of oil radish for variety Lyubava – 22 %, and Sapho – 44 %, with high marketability of tubers (up to 91 %) and good chemical composition of the tubers. The nitrate content in the variants of the experiment was 6 – 8 times lower than the maximum permissible concentration for this crop (250 mg/kg). Variance analysis of the three-factor experiment has shown that the yield of potato largely depended on the green manure fallow crops – by 38 %, on the genotype – by 28 %, and on the year – by 23 %.

V. DISCUSSION

Modern farming is characterized by switching to energy-saving technologies in cultivating agricultural crops. In these technologies, the use of green manure fallow as a precursor for potato is crucial. This technology not only ensures the reduction of labor, energy, material, and financial costs, but also the rational use of local soil and climatic conditions and resources, especially soil fertility. Taking into account that the soil in the Western Siberian region varies by the granulometric texture, the thickness of humic layer, depth to the groundwater, the water-holding and absorption capacity, one should be especially careful in using various precursors and giving preference to green manure fallow as the source of organic matter accumulation in the soil. This problem is also of particular importance in the environmental context. The role of green manure is also important in improving the phytosanitary situation in potato cultivation.

The studies performed on the soils that are typical for the West Siberian region – leached heavy loamy black soils in various temperature and humidity conditions – allow making a conclusion that green manure crops provide an accumulation of sufficient amounts of green mass for its introduction into the soil with the aim of improving fertility. The yield rate of green mass reaches 50 t/ha with an accumulation of the active substance of nutrients: nitrogen – 100 kg, phosphorous – over 20 kg, and potassium – over 140 kg per 1 ha. It has been shown that green manure ensures obtaining 40 % of the potato crop, which is almost two times greater than the dependence on the harsh weather conditions of Western Siberia (Russia).

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VI. CONCLUSION

On leached black soil of the forest-steppe in the Ob region (West Siberia, Russia) in the years with various meteorological conditions (2016 – 2018), the use of green manure crops for green manure had a positive effect on potato growth and development.

The maximum yield of green manure crops before the potato was obtained with the use of oil radish – 50 t/ha, white melilot – 40t/ha, and medick – 36 t/ha.

The use of pure fallow with the introduction of 20 t of manure/ha allows accumulating 190 kg of nitrogen, 70 kg of phosphorus, and 170 kg of potassium per hectare. The use of oil radish as a precursor ensures the accumulation of 100 kg of nitrogen, 20 kg of phosphorus, and 140 kg of potassium per 1 hectare.

Potato cultivation after green manure fallow allows forming the well-developed foliage apparatus with the average area of leaves of 17.6 thousand m2/ha in the early-ripening variety Lyubava, and 18.4 thousand m2/ha in the mid-early variety Sapho, with the level of PSP of up to 2,360 thousand m2.

The use of green manure ensures the increase in the yield rates of tubers of the Russian varieties of various ripeness groups: Lyubava (early-ripening) and Sapho (mid-early). The maximum yield of Siberian variety Lyubava was achieved with green manure crop medick – 32.8 t/ha, and of the mid-early Siberian variety Sapho – with oil radish – 32.6 t/ha.

Green manure crops allow forming high marketability of tubers – up to 93 %. Dry matter content was the highest and reached 24.9 % in variety Sapho (medick). Both varieties had the maximum amount of starch after medick – 17.4 %.

Nitrates concentration in the product was 5.5 – 7 times lower than the maximum permissible concentration for potato.

The analysis of variance of the three-factor experiment has shown that potato yield mostly depended on green manure crops (38 %), the genotype (28 %), and the weather conditions (23 %).

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