

INFLUENCE OF FERTILIZATION ON THE PRODUCTIVITY OF WINTER RAPE IN THE WESTERN FOREST-STEPPE

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The optimal systems of mineral fertilizers for winter rape cultivation on typical low-humus loamy chernozem in the conditions of the Western Forest-Steppe were substantiated by the research results. It was found that the best degree of overwintering (95.2–95.5 %) and plant survivability (97.8–98.1 %) during the spring-summer period was observed under the calculated fertilization systems.

It was established that in the case of three foliar fertilization of winter rape with Avanhard R bor + Avanhard R ripak at the different stages of growth and development: in the 4–6 leaf stage BBCH₁₅ (0.5 + 0.1 l/ha), in the rosette stage BBCH₃₂ (1.0 + 2.0 l/ha), in the stage of the beginning of budding BBCH₅₃ (1.0 + 2.0 l/ha) on the background of the recommended rate N₃₀P₉₀K₁₈₀ + N₁₀₈ + N₄₂S₄₈, by the normative method N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈, on removal N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈ the yield increased by 0.52 t/ha, 0.53 t/ha, 0.89 t/ha, respectively.

The highest number of pods per plant (294.5–315.5 pcs), the number of seeds in a pod (23.8–24.5 pcs), and the 1000 seed weight (4.24–4.27 g) were determined at the recommended rate N₃₀P₉₀K₁₈₀ + N₄₂S₄₈, by the normative method N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈, by removal N₃₀P₁₃₂K₁₉₂ + N₁₉₈ + N₄₂S₄₈ in combination with foliar fertilization Avanhard R bor + Avanhard R ripak – at BBCH₁₅ (0.5 + 0.1 l/ha), BBCH₃₂ (1.0 + 2.0 l/ha), BBCH₅₃ (1.0 + 2.0 l/ha).

The highest yield of winter rape (4.05–4.59 t/ha) was provided by fertilizer systems of N₃₀P₉₀K₁₈₀ + N₁₀₈ + N₄₂S₄₈, N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈, N₃₀P₁₃₂K₁₉₂ + N₁₉₈ + N₄₂S₄₈ with three-time foliar fertilization of Avanhard R bor + Avanhard R ripak.

Key words: winter rape, fertilization system, rates of fertilizers, microfertilizers, foliar feeding.

Winter rape (*Brassica napus* L. ssp. *oleifera* Metzg) is a crop with significant potential. Among the oil crops of the cabbage family, this crop ranks first according to the oil content. It significantly improves soil structure due to this is a good predecessor for cereals.

Rape is a cold-resistant crop, and its winter hardiness depends on varietal characteristics. It is highly demanding on moisture that is extremely important to consider when sowing. Adherence to sowing technology and general rules of rapeseed cultivation is the basis for a high and quality seed yield [1, 2].

Many scientists have shown that about 70 % of the future winter rape yield depends on weather conditions before the beginning of the winter. In the autumn, plant root system actively forms to ensure reliable resistance to sudden changes in temperature. There is an accumulation of nutrient and sugar reserves for the spring growth resumption. It is important that the rape flower buds initiation begin in the autumn. In the future, the number of side shoots will depend on the number of leaves on the plant – one

leaf corresponds to one shoot. Therefore, the proper provision of rape plants with readily available compounds of macro-micronutrients in the autumn plays a special role both strengthening the root system growth and development and in overwintering plants, and also in the initiation of generative organs [3, 4].

An important element of intensive technology for growing winter rape is a scientifically-based fertilizer system, which depends on the winter hardiness of plants, resistance to diseases and pests, and ultimately – seed yield [5].

Winter rape is highly demanding on nutrients. The nutrient utilization begins from the sprout emergence. Lack of nutrients during this period negatively affects the growth and development of plants and reduces seed yield [6, 7].

During the growth and development of winter rape plants, the nutrient utilization increases, but it decreases in the ripening stage, and then stops altogether. During this period, plants utilize nitrogen, phosphorus, potassium and other nutrients accumulated in stems, leaves and roots to form seeds [8, 9].

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It was determined that the winter rape absorbs 2 times more nitrogen, phosphorus, potassium, magnesium, boron and sulfur, and 5 times more calcium than winter wheat. During the growing season, winter rape plants differently respond to the amount of nutrients in the soil in different development stages. In autumn, plants absorb nitrogen about 20 % of annual nutrient requirements, potassium – 20 %, phosphorus and sulfur – 10 %. The largest amount of nutrients is absorbed during the spring growing season, reaching a maximum from the beginning of the side-shoot formation to the end of flowering stage. During this period, plants absorb 67 % of nitrogen, phosphorus – 70 %, potassium – 80 %, sulfur – 65 %. The most potassium is consumed at the beginning of the flowering, and phosphorus, calcium, magnesium – before flowering stage [10–12].

Aim. To prove of the mineral fertilizer system for winter rape cultivation on a typical low-humus light loam chernozem in the Western Forest-Steppe for the maximum realization of biological potential.

Materials and Methods. The research was conducted during 2018–2020 at the Institute of Agriculture of Western Polissia a on typical low-humus light loam chernozem with the following agrochemical parameters of 0–30 cm soil layer: humus content according to Tiurin was 1.96 %, alkaline hydrolyzable nitrogen content by Cornfield's method – 79.2 mg/kg of soil, mobile phosphorus (P_2O_5) and potassium (K_2O) according to Kirsanov – 251 and 109 mg/kg of soil, respectively, and pH (salt) – 6.2, hydrolytic acidity by Kappen – 1.14 mg-eq./100 g of soil.

Predecessor was winter wheat, replication was three times. The experiment scheme is systematic. The accounting area of plot was 25 m²; the sown area was 50 m².

The research was based on fertilizer systems (factor A): $N_{30} + N_{108} + N_{42}S_{48}$; $N_{30}P_{50}K_{90} + N_{108} + N_{42}S_{48}$; $N_{30}P_{70}K_{135} + N_{108} + N_{42}S_{48}$; $N_{30}P_{90}K_{180} + N_{108} + N_{42}S_{48}$; $N_{30}P_{110}K_{160} + N_{126} + N_{42}S_{48}$; $N_{30}P_{132}K_{192} + N_{198} + N_{42}S_{48}$ factor B - foliar feeding: without fertilizers (control); Avanhard R bor – BBCH₁₅ (0.5 l/ha), BBCH₃₂ (1.0 l/ha), BBCH₅₃ (1.0 l/ha); Avanhard R bor + Avanhard R ripak – BBCH₁₅ (0.5 + 1.0 l/ha), BBCH₃₂ (1.0 + 2.0 l/ha), BBCH₅₃ (1.0 + 2.0 l/ha); Avanhard R ripak – BBCH₁₅ (1.0 l/ha), BBCH₃₂ (2.0 l/ha), BBCH₅₃ (2.0 l/ha).

Dressing was carried out: in autumn in the following stages: 4–6 leaves (BBCH₁₅), spring rosette (BBCH₃₂), the beginning of budding (BBCH₅₃).

Avanhard R bor is a concentrated liquid boron fertilizer based on organic polyborates with the active ingredients: boron (150 g/l), nitrogen (65 g/l) and amino acids.

Avanhard R ripak is a complex concentrated fertilizer with a balanced ratio of macro-, meso- and microelements (Mo – 0,1 g/l, MgO – 50 g/l, Zn – 7 g/l, Mn – 10 g/l, Fe – 4 g/l, B – 6 g/l, SO₃ – 121 g/l, K₂O – 10 g/l, N – 60 g/l, Cu – 3 g/l, Co – 0,1 g/l).

The weather conditions in 2018–2020 were satisfactory for the growth and development of winter rape and close to the long-term average, despite fluctuations in air temperature and moisture level. Thus, the state of winter rape areas did not deteriorate during the growing season and winter.

We performed statistical processing the obtained research results by the Dospikhov's method of variance analysis with Microsoft Office Excel, Statistica 5.0.

Results. We proposed for region conditions the improved elements of intensive technology of winter rape cultivation based on different fertilizer systems, foliar feeding, which allow to obtain the yield and seed quality close to the potential of this crop in production conditions.

The fertilizer systems were a main factor which influenced the plant density. Among the studied variants, the best variant was the recommended fertilizer system $N_{30}P_{90}K_{180} + N_{108} + N_{42}S_{48}$, and calculated according to the normative method $N_{30}P_{110}K_{160} + N_{126} + N_{42}S_{48}$ with nutrient depletion of $N_{30}P_{132}K_{192} + N_{198} + N_{42}S_{48}$, and foliar feeding with *Avanhard R bor* + *Avanhard R ripak* – BBCH₁₅ (0.5 + 0.1 l/ha), BBCH₃₂ (1.0 + 2.0 l/ha), BBCH₅₃ (1.0 + 2.0 l/ha). In this case, the overwintering plants were 95.2–95.5 %, and plant survivability during the growing season was 97.8–98.1 %.

When these fertilizer systems were applied, the plant density after the growth resumption ranged from 38.8 to 39.2, and before harvest – from 37.9 to 38.7 pcs/m²; when the fertilizer system of $N_{30} + N_{108} + N_{42}S_{48}$ was used, these indicators were 34.8 and 33.7 pcs/m², respectively (Table 1).

1. Influence of fertilizer system on plant density, degree of overwintering and plant survivability, (average for 2018–2020)

Fertilizer system (factor A)	Foliar feeding (factor B)*	Plant density after growth resumption, pcs/m ²	Number of overwintering plants, %	Plant density before harvest, pcs/m ²	Plant survivability, %
N ₃₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	30.8	89.2	29.2	94.6
	2	36.0	90.8	34.3	95.5
	3	34.8	91.1	33.7	95.9
	4	33.7	90.8	32.4	95.3
N ₃₀ P ₅₀ K ₉₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	36.0	91.9	34.6	96.2
	2	37.9	93.7	36.7	97.1
	3	38.0	94.0	36.9	97.3
	4	37.7	83.8	36.4	96.8
N ₃₀ P ₇₀ K ₁₃₅ + N ₁₀₈ + N ₄₂ S ₄₈	1	36.3	92.1	34.9	96.3
	2	38.0	94.0	36.9	97.1
	3	38.3	94.4	37.3	97.4
	4	37.8	93.9	36.6	97.0
N ₃₀ P ₉₀ K ₁₈₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	37.3	92.3	35.9	96.4
	2	38.5	94.3	37.4	97.3
	3	38.8	95.2	37.9	97.8
	4	38.3	94.2	37.2	97.1
N ₃₀ P ₁₁₀ K ₁₆₀ + N ₁₂₆ + N ₄₂ S ₄₈	1	37.6	92.5	36.2	96.7
	2	38.8	94.5	37.7	97.4
	3	39.0	95.5	38.1	97.9
	4	38.6	94.5	37.5	97.3
N ₃₀ P ₁₃₂ K ₁₉₂ + N ₁₉₈ + N ₄₂ S ₄₈	1	37.8	92.6	36.5	96.7
	2	38.9	94.9	38.0	97.7
	3	39.2	95.4	38.7	98.1
	4	38.8	94.8	37.8	97.7

* Foliar feeding with microfertilizers in variants 1-4 was carried out according to the experiment scheme.

Thus, the main elements of the winter rape yield structure are the total number of pods and seeds per a plant, the average number of seeds per pod, the 1000 seed weight and the seed weight per plant. The analysis of the yield structure indicated that the fertilizer system of N₃₀ + N₁₀₈ + N₄₂S₄₈ characterized by the smallest number of pods per plant – 214.5–235.5 pcs, the seeds per a pod – 18.7–20.2 pcs, the lowest 1000 seed weight – 3.96–4.03 g, while the application of system with phosphorus-potassium fertilizers, these indicators increased by 19.6–34.0; 6.4–21.2; 1.3–6.0 %, respectively (Table 2).

Improvement of mineral nutrition according to the recommended fertilizer system (N₃₀P₉₀K₁₈₀ + N₁₀₈ + N₄₂S₄₈) and calculated according to the normative method (N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈) with nutrient depletion of

(N₃₀P₁₃₂K₁₉₂ + N₁₉₈ + N₄₂S₄₈) positively affected on the yield structure. The introduction of the studied fertilizer systems with foliar feeding led to the number of pods per a plant was 269–315.5 pieces, the number of seeds per a pod – 21.9–24.5 pieces, the 1000 seed weight – 4.11–4.27 g compared to the fertilizer system of N₃₀ + N₁₀₈ + N₄₂S₄₈.

Improvement of the yield structure increased the seed productivity of winter rape. Thus, on average over the years of research under different fertilizer systems, the winter rape yield ranged from 3.06 to 3.29 t/ha (N₃₀ + N₁₀₈ + N₄₂S₄₈), 3.24–3.62 (N₃₀P₅₀K₉₀ + N₁₀₈ + N₄₂S₄₈), 3.36–3.77 (N₃₀P₇₀K₁₃₅ + N₁₀₈ + N₄₂S₄₈), 3.53–4.05 (N₃₀P₉₀K₁₈₀ + N₁₀₈ + N₄₂S₄₈), 3.55–4.08 (N₃₀P₁₁₀K₁₆₀ + N₁₂₆ + N₄₂S₄₈), 3.70–4.59 t/ha (N₃₀P₁₃₂K₁₉₂ + N₁₉₈ + N₄₂S₄₈) (Table 3).

2. Influence of fertilizer systems on the parameters of the yield structure of winter rape, (average for 2018–2020)

Fertilizer system (factor A)	Foliar feeding (factor B)*	Number of pods per 1 plant, pcs	Number of seed per a pod, pcs	1000 seed weight, g
N ₃₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	214.5	18.7	3.96
	2	220.0	19.3	3.99
	3	235.5	20.2	4.03
	4	216.0	18.9	3.99
N ₃₀ P ₅₀ K ₉₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	256.5	19.9	4.01
	2	261.0	20.4	4.05
	3	266.5	20.8	4.18
	4	257.0	20.3	4.06
N ₃₀ P ₇₀ K ₁₃₅ + N ₁₀₈ + N ₄₂ S ₄₈	1	260.0	21.2	4.08
	2	269.0	21.6	4.14
	3	286.5	22.7	4.23
	4	267.0	21.4	4.17
N ₃₀ P ₉₀ K ₁₈₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	269.0	21.9	4.11
	2	277.0	22.7	4.20
	3	294.5	23.8	4.24
	4	275.0	22.5	4.20
N ₃₀ P ₁₁₀ K ₁₆₀ + N ₁₂₆ + N ₄₂ S ₄₈	1	276.0	22.3	4.11
	2	284.0	23.1	4.21
	3	315.5	24.0	4.26
	4	281.0	22.9	4.21
N ₃₀ P ₁₃₂ K ₁₉₂ + N ₁₉₈ + N ₄₂ S ₄₈	1	240.5	23.1	4.12
	2	296.0	23.6	4.22
	3	302.0	24.5	4.27
	4	292.0	23.4	4.22

* Foliar feeding with microfertilizers in variants 1-4 was carried out according to the experiment scheme.

3. Yield seed of winter rape depending on the fertilizer system, t/ha (average for 2018–2020)

Fertilizer system (factor A)	Foliar feeding (factor B)*	Average	Increase in the yield due to foliar feeding
N ₃₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	3.06	-
	2	3.22	0.16
	3	3.29	0.23
	4	3.18	0.12
N ₃₀ P ₅₀ K ₉₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	3.24	-
	2	3.42	0.18
	3	3.62	0.38
	4	3.40	0.16
N ₃₀ P ₇₀ K ₁₃₅ + N ₁₀₈ + N ₄₂ S ₄₈	1	3.36	-
	2	3.56	0.20
	3	3.77	0.41
	4	3.52	0.16
N ₃₀ P ₉₀ K ₁₈₀ + N ₁₀₈ + N ₄₂ S ₄₈	1	3.53	-
	2	3.82	0.29
	3	4.05	0.52
	4	3.79	0.26
N ₃₀ P ₁₁₀ K ₁₆₀ + N ₁₂₆ + N ₄₂ S ₄₈	1	3.55	-
	2	3.88	0.33
	3	4.08	0.53
	4	3.83	0.28
N ₃₀ P ₁₃₂ K ₁₉₂ + N ₁₉₈ + N ₄₂ S ₄₈	1	3.70	-
	2	4.10	0.40
	3	4.59	0.89
	4	4.04	0.34

LSD₀₅, t/ha A – 0.25 B – 0.12 AB – 0.37

* Foliar feeding with microfertilizers in variants 1-4 was carried out according to the experiment scheme

The largest yield was 4.05; 4.08; 4.59 t/ha when applying $N_{30}P_{90}K_{180} + N_{108} + N_{42}S_{48}$, $N_{30}P_{110}K_{160} + N_{126} + N_{42}S_{48}$, $N_{30}P_{132}K_{192} + N_{198} + N_{42}S_{48}$ and foliar feeding with Avanhard R bor + Avanhard R ripak – BBCH₁₅ (0.5 + 1.0 l/ha), BBCH₃₂ (1.0 + 2.0 l/ha), BBCH₅₃ (1.0 + 2.0 l/ha). The increase in grain yield due to foliar feeding with microfertilizers and the introduction of these fertilizer systems was 4.7; 4.9; 4.1 %, for variants without foliar feeding – 3.53; 3.55; 3.70 t/ha, respectively.

Conclusions.

According to the research results aimed to ground the optimal fertilizer systems for cultivation of winter rape in the Western Forest-Steppe, it was found that the introduction of calculated fertilizer systems provided the high rates of overwintering plants – 95.2–95.5 % and plant survivability – 97.8–98.1 % for the spring-summer period.

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The largest number of pods per a plant (294.5–315.5 pcs.) and seeds per a pod (23.8–24.5 pcs.), a significant 1000 seed weight (4.24–4.27 g) were observed under application of the recommended rates of mineral fertilizers $N_{30}P_{90}K_{180} + N_{42}S_{48}$, according to normative method of $N_{30}P_{110}K_{160} + N_{126} + N_{42}S_{48}$ with nutrient depletion of $N_{30}P_{132}K_{192} + N_{198} + N_{42}S_{48}$ in combination with foliar feeding of plants with a mixture of Avanhard R bor + Avanhard R ripak – BBCH₁₅ (0.5 + 1.0 l/ha), BBCH₃₂ (1.0 + 2.0 l/ha), BBCH₅₃ (1.0 + 2.0 l/ha).

Introduction of fertilizer systems such as $N_{30}P_{90}K_{180} + N_{108} + N_{42}S_{48}$, $N_{30}P_{110}K_{160} + N_{126} + N_{42}S_{48}$, $N_{30}P_{132}K_{192} + N_{198} + N_{42}S_{48}$ at foliar feeding with a mixture of Avanhard R bor + Avanhard R ripak in 4–6 leaves stage, spring rosette stage and the beginning of budding increased the winter rape yield to 4.05; 4.08; 4.59 t/ha.