DOI: 10.32636/01308521.2022-(72)-2-3
UDC 631.13:633.1:633.367

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FORMATION OF PRODUCTIVITY OF BINARY AND SINGLE-SPECIES CENOSIS IN THE CONDITIONS OF THE WESTERN FOREST-STEPPE

The effectiveness of certain elements of the technology for growing binary cenosis of grain crops (oat, triticale) and grain-legume (vetch, lupine) crops in the soil and climatic conditions of the Western Forest-Steppe was evaluated. It was established that mineral fertilization and the rate of seeding of the grain component in mixtures significantly impacted the formation of the crop structure. With the introduction of mineral fertilizer in a dose of $N_{32}P_{32}K_{32}$, an increase in the number of productive stems, the weight of 1000 grains, and the nature of grain both in monospecies and in mixed crops were noted.

Binary cenosis of grain and grain-legume crops were characterized by higher indicators of dry matter. On the background of mineral nutrition ($N_{32}P_{32}K_{32}$) in the XI stage of organogenesis, the maximum values of the dry matter of 100 plants were noted: for lupine-oat mixtures – 1065–1085 g, triticale-lupin mixtures – 1011-1069 g, vetch-oat mixtures – 848–949 g, vetch-triticale mixtures – 811–886 g.

Mineral fertilizer $N_{32}P_{32}K_{32}$ ensured the formation of a greater number of beans, the mass and number of grains in the ear, and plant productivity, but had a negative effect on the process of root nodule formation: in mixtures with vetch, their mass decreased by 0.82–0.84 g/plant (to 0.52–0.66 g), in mixtures with lupine – by 0.07–0.17 g/plant (to 2.29–2.36 g). The same pattern was observed in single-species crops.

Reduction of the seeding rate of the grain component by 1 million germinated seeds/ha in mixtures with legumes contributed to the increase in the number of grains in the ear (panicle) and seeds in the bean pod.

The introduction of mineral fertilizer $N_{32}P_{32}K_{32}$ contributed to the growth of the mass of 1000 grains of grain and grain-legume crops both in monospecies and in mixed crops. In single-species crops, the mass of 1000 grains on fertilized plots increased in oat and triticale by 1.3 and 2.5 g, respectively, in spring vetch – by 5.4, and lupine – by 10.4 g. The growth of this indicator was also noted in mixed crops.

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Sowing a mixture of oat and spring vetch (4.0 + 0.8 million of germinated seeds/ha) on the background of mineral fertilizer $N_{32}P_{32}K_{32}$ provided the highest yield – 5.3 t/ha. Reduction of the seeding rate of the grain component by 1 million of germinated seeds/ha caused a decrease in yield by 0.25 t/ha. The yield increase compared to unfertilized crops was 1.07 and 1.15 t/ha, respectively.

Keywords: oat, triticale, spring vetch, narrow-leaved lupine, sowing rates, fertilizer, productivity.

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Формування продуктивності бінарних і одновидових ценозів в умовах Лісостепу Західного

Проведено оцінку ефективності окремих елементів технології вирощування бінарних ценозів зернових (овес, тритикале) і зернобобових (вика, люпин) культур у ґрунтово-кліматичних умовах Лісостепу Західного. Встановлено, що мінеральне удобрення та норма висіву зернового компонента у сумішах мали значний вплив на формування структури врожаю. За внесення мінеральних добрив у дозі $N_{32}P_{32}K_{32}$ відзначили зростання кількості продуктивних стебел, маси 1000 зерен, натури зерна як в одновидових, так і в сумісних посівах.

Бінарні ценози зернових і зернобобових культур характеризувалися вищими показниками повітряно-сухої маси. На фоні мінерального живлення ($N_{32}P_{32}K_{32}$) у XI етапі органогенезу відзначено максимальні значення повітряно-сухої маси 100 рослин: для люпино-вівсяних сумішок – 1065–1085 г, тритикале-люпинових – 1011–1069 г, вико-вівсяних – 848–949 г, вико-тритикалевих – 811–886 г.

Мінеральне удобрення $N_{32}P_{32}K_{32}$ забезпечувало формування більшої кількості бобів, маси і кількості зерен у колосі, продуктивності рослин, але негативно позначилося на утворенні кореневих бульбочок: у сумішках з викою їх маса зменшилася на 0,82–0,84 г/рослину (до 0,52–0,66 г), з люпином – на 0,07–0,17 г/рослину (до 2,29–2,36 г). В одновидових посівах вики і люпину спостерігали таку ж закономірність.

Зменшення норми висіву зернового компонента на 1 млн сх. нас./га у сумішках з зернобобовими зумовило збільшення кількості зерен у колосі (волоті) та насінин у бобі.

Внесення мінеральних добрив $N_{32}P_{32}K_{32}$ сприяло зростанню маси 1000 зерен зернових і зернобобових культур як в одновидових, так і в змішаних посівах. В одновидових посівах маса 1000 зерен на удобрених ділянках збільшилася у вівса і тритикале відповідно на 1,3 і 2,5 г, у вики ярої – на 5,4, люпину – на 10,4 г. Зростання цього показника відзначено й у змішаних посівах.

Висів суміші вівса та вики ярої (4,0 + 0,8 млн сх. нас./га) на фоні мінерального удобрення $N_{32}P_{32}K_{32}$ забезпечив найвищу врожайність – 5,3 т/га. Зменшення норми висіву зернового компонента на 1 млн сх. нас./га зумовило зниження врожайності на 0,25 т/га. Приріст урожайності порівняно з неудобреними посівами становив відповідно 1,07 та 1,15 т/га.

Ключові слова: овес, тритикале, вика яра, люпин вузьколистий, норми висіву, удобрення, продуктивність.

Introduction. For the development of agricultural production in modern socio-economic conditions, it is essential to expand the area of grain-legume crops and increase the production of high-protein fodder by increasing their yield. The growth of the share of grain-legume crops to 20% should optimize the structure of the sown areas of agricultural crops in the agriculture of Ukraine, and preserve and increase the level of fertility of the soils.

In the complex of numerous measures aimed at solving this important problem, there is an effective use of the bioclimatic potential of justified climatic zones. Optimal, taking into account climatic conditions, localisation of the production of grain legumes in the regions, because they, as a result of differences in biological properties and morphological traits, are characterized by different requirements for certain soil and climatic conditions [10, 21, 22, 24]. Among the crops suitable for growing in the zone of the Western Forest-Steppe are spring vetch and narrow-leaved lupine.

Narrow-leaved lupine deserves special attention, as it can grow normally, develop and produce high yields on weakly acidic and acidic soils. In addition, it is able to assimilate phosphorus from poorly soluble forms of fertilizers and soil reserves and leaves behind in the soil up to 200 kg/ha of biological nitrogen. Lupine, in particular, is irreplaceable in increasing soil fertility, especially in organic farming. This culture has a fairly short growing season and is a good precursor for winter crops. Contributes to supporting a positive balance of humus in the soil, loosening the arable and sub-arable horizons, returning potassium and other macro- and microelements to the root layer, converting difficult-to-dissolve compounds of phosphorus and potassium into available forms, leaves for the next crop 80–220 kg of nitrogen, 30 kg of phosphorus and 50 kg of potassium [6, 7, 8, 9].

Nitrogen-fixing plants remain a powerful and irreplaceable factor in maintaining the ecological balance in agricultural systems [24, 29, 30]. One of the important indicators for grain-legume crops is the mass of root nodules at different stages of their growth and development, because the issue of soil fertility, increasing the yield of agricultural crops is primarily associated with an increase in the amount of nitrogen in the soil, and the process of nitrogen assimilation is somewhat dependent on nodule bacteria activity [19].

According to a number of researchers [4, 5, 11, 12, 13, 14, 16, 22, 25, 26], in order to obtain fodder, balanced by the content of proteins and carbohydrates, improve nitrogen nutrition of crops and preserve soil fertility, it is advisable to grow mixed agrocenoses of legume-grain crops. When growing binary legume-grain crops, a dense cenosis is formed, the productivity of which is stable over the years and can exceed the yield of components in monoculture.

The fodder value of spring vetch is determined by its high protein content. The green mass contains 18–22%, and the seeds – from 22 to 37%. When grown for grain, vetch plants are prone to lying down. When collecting them for seeds, there are certain difficulties, that is, this culture needs a supporting culture, which will increase ecological plasticity and resistance to stress in agrophytocenoses [1, 24]. The advantage of growing spring vetch in binary crops is especially evident in conditions of rainfall deficit at elevated temperatures. At the same time, single-species crops of vetch sharply reduce the yield, and positive allelopathy is manifested in mixed crops [1], therefore, it is important to determine the best components of the mixtures, and their optimal ratio [4, 24].

Researchers indicate the effectiveness of applying mineral fertilizers in agrocenoses of spring grain and legume-grain crops [2, 3, 15, 17, 18, 19, 27, 30].

Materials and methods. The object of the study was single-species and binary cenoses of grain (oat, triticale) and legume-grain (vetch, lupine) crops. Oat (*Avena sativa L.*) variety Arkan, spring triticale (Triticosecale) variety Khlibodar Kharkivskyi, spring vetch (*Vicia sativa L.*) variety Bilotserkivska, narrow-leaved lupine (*Lupinus angustifolius L.*) variety Flamingo was sown. The ratio of components in the mixtures was 0.8 million of germinated seeds of lupine or vetch and 3.0 and 4.0 million of germinated seeds/ha of oat or triticale. In single-species crops, oat and spring triticale were sown at the rate of 5.5 million of germinated seeds/ha, vetch and lupine – 1.2 million of germinated seeds/ha Mineral fertilizers ($N_{32}P_{32}K_{32}$) were applied according to the research scheme in the form of nitrophoska (N:P:K 16:16:16).

The repetition of the study is sixfold. The total area of the site is 19.3 m^2, and the accounting area – 12 m^2.

Harvest accounting was carried out by threshing the grain in sections with a "Sampo-130" combine, followed by weighing and conversion to 14% moisture content.

The experimental work was carried out in the fields of IA of the Carpathian region of the National Academy of Sciences on gray forestal surface-glayed soil with the following agrochemical parameters (in the 0–20 cm layer): humus (according to Tyurin) – 1.5–1.6, alkaline-hydrolyzed nitrogen (according to Kornfield) – 105 –110 mg, mobile phosphorus (according to Kirsanov) – 111–114 mg, exchangeable potassium (according to Kirsanov) – 101–107 mg per 1 kg of soil. According to the current gradation, such soil has a very low provision of nitrogen, medium – phosphorus and low – potassium. The reaction of the soil solution (pH_{salt} – 5.75) is weakly acidic.

In general, the years of research significantly differed in terms of the main indicators (heat, moisture) from the multi-year average values. The growing seasons of 2016, 2017, 2019, and 2020 were characterized by increased (by 1.4–2.64 °C) air temperature and lower than-normal precipitation (61.0–91.5% of normal). In 2018, an elevated temperature regime was also observed (by 2.5 ºC), but more precipitation fell than normal (104.4%), which contributed to the active growth and development of the grain-legume component.

There are many methods for agronomic assessment of moisture conditions, in which it is noted that the supply of moisture to plants is directly dependent on the amount of productive soil moisture and inversely to evaporation, which depends on temperature, that is, on HTI (hydrothermal index). As a result of HTI calculations, it can be seen that the period of starting, formation and ripening of grain took place mainly under the optimal level of moisture in 2016 and 2017 (HTI – 1.21–1.34) and excessive in 2018–2020 (HTI – 1 .66–2.01).

The research aims to develop effective technology elements for growing binary cenosis of grain (oat, triticale) and grain-legume (vetch, lupine) crops and to establish the peculiarities of their productivity in the soil and climatic conditions of the Western Forest-Steppe. Research methods: in the field (to observe the growth and development of plants during the growing season); laboratory-field (determination of the influence of the studied factors on the dynamics of biometric indicators of plants); laboratory-chemical (determination of seed quality indicators, the content of nutrients in the soil), measuring and weighing (determination of yield and crop structure); mathematical and statistical (determining the reliability of the obtained results); calculation and comparison (determination of economic efficiency).

Results and discussion. During the period of research (2016–2020), the peculiarities of the growth and development of grain and grain-legume crops were established depending on the composition of mixtures, the rate of sowing components and mineral fertilizer.

It was determined that the combined grain and grain-legume crops were characterized by higher indicators of air-dry mass. On the background of mineral nutrition ($N_{32}P_{32}K_{32}$) in the XI stage of organogenesis, the maximum values of the dry matter of 100 plants were noted: for lupine-oat mixtures – 1065–1085 g, triticale-lupine mixtures – 1011–1069 g, vetch-oat mixtures – 848–949 g, vetch-triticale mixtures – 811–886 g.

On unfertilized plots, the air-dry weight of 100 plants was lower – 737–771 g for triticale-vetch mixtures, 754–815 g for vetch-oat mixtures, 819–859 g for triticale-lupine mixtures and 974–978 g for oat-lupine mixtures.

On the background of mineral fertilizer, the air-dry mass of plants increased. In the areas where vetch-oat mixtures were sown, this indicator in the XI stage of organogenesis increased by 94.0–134 g, when sowing oat-lupine mixtures – by 91.0–107 g, triticale-vetch – by 74.0–115, 0 g, triticale-lupines – by 192.0–210.0 g. In single-species oat crops – by 119.0 g, triticale – 118.0 g, vetch – 13.0 g, lupine – 79.0 g. Overall an increase in the total raw and air-dry mass of the mixtures was observed under the condition of reducing the seeding rate of the grain component from 4.0 to 3.0 million of germinated seeds/ha due to the increase in the mass of the grain-legume component (both lupine and vetch).

The soils of the Western region lack nitrogen compounds available for plants. One of the ways to replenish its reserves is the use of biological nitrogen, which accumulates in the process of the symbiosis of grain-legume plants with nodule bacteria (Table 1). The intensity of the formation of root nodules depends on many factors, including the genetic characteristics of the culture, temperature regime, precipitation, soil moisture, etc.

In the ontogenesis of spring vetch and lupine, regardless of the studied version of the growing technology, the mass of nodules increased until the flowering phase. On unfertilized crops at the beginning of intensive growth of grain legumes, their weight was 0.2–0.25 g/plant in spring vetch and 0.28–0.33 g/plant in lupine. Application of mineral fertilizers $N_{32}P_{32}K_{32}$ somewhat slowed down the processes of formation of root nodules and their weight was lower: in spring vetch by 0.1–0.17, in lupine – by 0.12–0.15 g/plant compared to unfertilized areas.

A significant increase in the mass of root nodules was noted in the simultaneous sowings of grain with spring vetch, while the inverse relationship was observed in lupine. In the flowering phase, the mass of root nodules of spring vetch plants in binary cenoses increased to 1.36–1.49 g/plant in unfertilized variants and by 0.04–0.18 g/plant with the application of $N_{32}P_{32}K_{32}$ (in single-species crops, respectively, 0.94 and 0.48 g/plant).

1. Mass of root nodules, g/plant (average data for 2016–2020)

Options	Start of intensive growth		End of intensive growth		Flowering	
	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$
Oat (5.0 million of germinating seeds/ha)	0.25	0.08	0.46	0.41	0.94	0.48
Spring triticale (5.0 million of germinating seeds/ha)	0.33	0.18	0.71	0.70	2.84	2.50
Spring vetch + Lupine (1,2+1.2 million of germinating seeds/ha)	-	-	-	-	-	-
	0.20	0.08	0.39	0.39	1.48	0.66
Oat + spring vetch (4.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.20	0.10	0.40	0.41	1.37	0.52
Oat + spring vetch (3.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.29	0.14	0.62	0.63	2.40	2.31
Oat + lupine (4.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.30	0.17	0.64	0.66	2.36	2.29
Oat + lupine (3.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.20	0.10	0.37	0.38	1.49	0.58
Triticale + vetch (4.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.22	0.10	0.38	0.39	1.36	0.53
Triticale + vetch (3.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.28	0.16	0.60	0.62	2.53	2.36
Triticale + lupine (4.0 + 0.8 million of germinating seeds/ha)	-	-	-	-	-	-
	0.30	0.17	0.63	0.66	2.49	2.29

In the cenosis of lupine with grains, a decrease in the mass of root nodules was observed compared to single-species crops. In variants without mineral fertilizers, it was 2.36–2.53 g/plant (in the control 2.84 g/plant).

With the introduction of mineral fertilizer – 2.29–2.36 g/plant (in the control 2.5 g/plant).

The yield of crops depended on the composition of the mixtures, the sowing rate of the grain and grain-legume component and fertilizer. On variants of single-species crops without fertilization, the actual yield was: 3.23 (oat), 2.84 (triticale), 1.29 (vetch) and 1.42 t/ha (lupine). With the introduction of mineral fertilizer at the rate of $N_{32}P_{32}K_{32}$, there was an increase in the yield of oat by 0.66 t/ha, spring triticale by 0.87 t/ha, spring vetch by 0.58 t/ha and lupine by 0.44 t/ha.

By the cultivation of grain and grain-legume crops in binary cenosis the yield increased. It was the highest by sowing a mixture of oat and spring vetch (4.0 + 0.8 million of germinating seeds/ha) and application of mineral fertilizers in a dose of $N_{32}P_{32}K_{32}$ – 5.3 t/ha. Reduction of the seeding rate of the grain component by 1.0 million of germinating seeds/ha caused a decrease in yield by 0.25 t/ha. The yield increase compared to unfertilized crops in these options was 1.07 and 1.15 t/ha, respectively.

The given productivity indicators were formed on the basis of the relevant indicators of the crop structure. As the data in Table 2 shows, the number of productive stems and plants before harvesting both grain and grain-legume crops directly depended on the rate of sowing. On single-species crop options with sowing grains of 5.0 million of germinating seeds/ha, legumes 1.2 million of germinating seeds/ha were 354 pcs/m^2 (oat), 321 (spring triticale), 83 (spring vetch), 78 (lupine). In binary cenosis, the norm of 4.0 and 3.0 million of germinating seeds/ha was used for grains, and for legumes – 0.8 million of germinating seeds/ha. The number of productive stems and plants was proportional to the sowing rate and on unfertilized plots was within 267–330 pcs/m^2 (grains) and 45–57 pcs/m^2 (legumes) (Table 2).

The number of beans on a plant depended significantly on the application of mineral fertilizers, and if in the control plants of spring vetch it was formed in the range of 6.7–7.7 pcs, then with the application of $N_{32}P_{32}K_{32}$ – 7.5–9.4 pcs, in lupine respectively – 7.5–9.4 pcs and 7.3–8.8 pcs.

In spring vetch in mixed crops, a tendency to increase the number of beans from one plant was observed compared to single-species on the background of mineral nutrition – up to 8.5–9.4 pcs, in lupine on the contrary – in single-species crops their number is greater (8.8 pcs), and in mixed crops it is less (7.5–7.9 g).

2. Formation of the elements of the mixture structure depending on the studied factors (average data for 2016–2020)

Options	Number of productive stems/plants, pcs/m^2		Number of beans per 1 plant, pcs		The number of grains in 1 ear (panicle)/seeds in 1 bean, pcs		Weight of grain from 1 ear/from 1 plant, g	
	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$
1	354	364	-	-	37.6	40.9	1.10	1.24
2	321	343	-	-	32.1	37.6	1.07	1.31
3	83	85	6.7	7.5	5.7	6.3	1.86	2.53
4	78	82	8.1	8.8	3.4	3.5	3.62	4.09
5*)	330	354	-	-	39.5	42.4	1.18	1.28
	57	57	7.3	8.5	6.3	6.5	2.29	3.13
6*)	267	292	-	-	38.4	43.3	1.20	1.34
	57	59	7.7	9.0	6.4	6.7	2.56	3.50
7*)	327	345	-	-	40.2	42.8	1.19	1.32
	45	48	6.8	7.5	2.9	3.1	2.31	2.90
8*)	269	286	-	-	40.8	43.7	1.25	1.38
	48	48	7.1	7.7	3.1	3.3	2.67	3.28
9*)	286	300	-	-	34.6	39.3	1.16	1.38
	55	55	7.5	8.9	6.3	6.6	2.40	3.29
10 *)	222	238	-	-	36.0	39.7	1.21	1.43
	57	58	7.7	9.4	6.6	6.8	2.66	3.64
11 *)	278	301	-	-	35.0	40.2	1.23	1.45
	47	48	6.6	7.3	3.1	3.2	2.49	3.22
12 *)	221	240	-	-	34.1	41.1	1.27	1.50
	49	49	7.2	7.9	3.2	3.5	2.97	3.58

*) in the numerator – grains, in the denominator – legumes

The number of grains in an ear (panicle) and seeds in a bean pod varied depending on the fertilizer and the rates of mixtures' sowing. If in single-species crops, their number (pieces per plant) in the control (without fertilizers) was: 37.6 (oat); 32.1 (spring triticale); 5.7 (spring vetch); 3.4 pcs (lupine), then with the introduction of $N_{32}P_{32}K_{32}$, it increased by 3.3, 5.5, 0.6, 0.1 pcs, respectively. The same regularity was noted in mixed crops of grain and grain-legume crops. However, it is worth noting that the number of grains in the ear of spring triticale and the panicle of oat and the number of seeds in the bean pod of spring vetch was greater in mixed crops compared to pure crops, and on the contrary, it decreased in lupine.

Obviously, slight shading of lupine by grain crop, especially by oat, led to such a result.

Research results indicate that a decrease in the seeding rate of the grain component by 1 million of germinating seeds/ha in mixtures with legumes led to an increase in the number of grains in the ear (panicle) and seeds in the bean pod.

The weight of grain from one ear and from one plant depended on the fertilizer and the rate of sowing mixtures. The introduction of mineral fertilizers at the rate of $N_{32}P_{32}K_{32}$ contributed to the growth of this indicator in all agrocenoses.

In the control (without fertilizers), the weight of grain from an ear was within 1.1–1.25 g (oat); 1.07–1.27 g (spring triticale); from one plant – 1.86–2.67 g (spring vetch); 3.62–2.97 g (lupine), and with the introduction of $N_{32}P_{32}K_{32}$ their weight increased to 1.24–1.38, 1.31–1.5; 2.53–3.64 and 4.09–3.58 g, respectively. If we analyze this indicator, we can see that it increases in oat, triticale and vetch in mixed crops.

Mineral fertilizer ($N_{32}P_{32}K_{32}$) contributed to the growth of the mass of 1000 grains of grain and grain-legume crops both in monospecies and in mixed crops. In single-species crops, the weight of 1000 grains on fertilized plots increased by 1.3 and 2.5 g in oat and triticale, by 5.4 g in spring vetch, and by 10.4 g in lupine (Table 3). The growth of this indicator was also noted in mixed crops.

In spring vetch, sown in mixtures with grains, an increase in the mass of 1000 grains was noted by 3.0–5.1 g on unfertilized crops and by 4.1–5.2 g on the $N_{32}P_{32}K_{32}$ background, while in lupine this indicator decreased, respectively, by 1.5–7.9 and 1.5–9.4 g. Moreover, when sowing lupine with oat, a greater decrease in the weight of 1000 grains was observed – by 6.2–9.4 g, while in mixtures with triticale this indicator decreased by 1.5–5.2 g, depending on the fertilizer option.

The nature of the grain was higher on the background of mineral fertilization in all agrocenoses and in single-species crops it was 402 g/l in oat, 707 g/l in spring triticale, 817 g/l in spring vetch, and 793 g/l in lupine, which exceeds the control options without fertilizer by 10.0, 17.0, 9.0 and 10.0 g/l, respectively. In mixed crops, the nature of the grain increased with a decrease in the seeding rate of the grain component. Reduction of the sowing rate by 1 million of germinating seeds/ha in mixtures of oat with spring vetch caused an increase in nature by 47 g/l, with lupine – by 7–23 g/l, triticale with vetch – by 7.0–8.0 g/l, with lupine – by 11 .0 g/l.

3. Individual physical indicators of grain depending on the studied factors (average data for 2016–2020)

Options	Weight of 1000 grains, g		Nature of grain, g/l[2]	
	control (without fertilizers)	$N_{32}P_{32}K_{32}$	control (without fertilizers)	$N_{32}P_{32}K_{32}$
Oat (5.0 million of germinating seeds/ha)	29.6	30.9	392	402
Spring triticale (5.0 million of germinating seeds/ha)	32.9	35.4	690	707
Spring vetch + Lupine (1,2+1.2 million of germinating seeds/ha)	48.8	54.2	808	817
Lupine (1.2 million of germinating seeds/ha)	125.6	136.0	783	793
Oat + spring vetch (4.0 + 0.8 million of germinating seeds/ha)	30.7 52.0	32.0 58.3	461	470
Oat + spring vetch (3.0 + 0.8 million of germinating seeds/ha)	31.3 53.5	31.9 59.2	508	517
Oat + lupine (4.0 + 0.8 million of germinating seeds/ha)	31.1 117.7	31.9 126.6	472	478
Oat + lupine (3.0 + 0.8 million of germinating seeds/ha)	31.5 119.4	32.3 128.2	479	501
Triticale + vetch (4.0 + 0.8 million of germinating seeds/ha)	34.9 51.8	36.3 58.4	750	761
Triticale + vetch (3.0 + 0.8 million of germinating seeds/ha)	35.5 53.9	36.5 59.4	758	767
Triticale + lupine (4.0 + 0.8 million of germinating seeds/ha)	33.4 120.4	37.1 131.5	739	749
Oat (5.0 million of germinating seeds/ha)	36.5 124.1	37.4 134.5	750	760

Over the years of research, the maximum area of the leaf surface was noted in the VIII stage of organogenesis in all variants of the experiment. On the XI stage of orthogenesis, a decrease in the leaf surface of crops due to the attenuation of assimilation processes was recorded. According to the research data, the area of the leaf surface of the crops in the control plots in the V stage of organogenesis averaged 13.3 thousand m^2/ha, in the VIII stage it increased by 15.5 thousand m^2/ha (up to 28.8 thousand m^2/ha), in the XI stage – decreased by 5.6 thousand m^2/ha (to 23.2 thousand m^2/ha). On the variants with the introduction of mineral fertilizer, an increase in the area of leaves was observed in the V stage of organogenesis by an average of 6.0 thousand m^2/ha (19.3 thousand m^2/ha), in the VIII stage by 5.3 thousand m^2/ha (34.2 thousand m^2/ha), in the XI stage – by 4.8 thousand m^2/ha (up to 28.1 thousand m^2/ha) compared to the control without fertilizers.

The maximum values of the leaf surface area at all stages of organogenesis were recorded by the sowing of the oat-vetch mixture (4.0 million of germinating seeds/ha of oat and 0.8 million of germinated seeds/ha of vetch) and the application of mineral fertilizers, respectively 21.1, 34.02, 29.69 thousand m^2/ha. The highest rates of net photosynthesis productivity were also noted on these crops – 23.85 and 17.45 g/m^2 of dry matter per day in the V–VIII and VIII–XI stages of organogenesis, respectively. In the control plots (without fertilizers), the net productivity of photosynthesis was on average 18.84 g/m^2 of dry matter in the V–VIII stages of orthogenesis and 16.38 g/m^2 of dry matter per day in the VIII–XI stages. Fertilization contributed to the growth of PPF, respectively by 4.81 and 1.07 g/m^2 of dry matter per day.

Reduction of the seeding rate of the grain component by 1 million of germinated seeds/ha led to a decrease in this indicator by 1.19–0.89 g/m^2 of dry matter per day (in the control) and by 0.42–0.29 g/m^2 of dry matter per day (after application of $N_{32}P_{32}K_{32}$). For mixtures of grains with lupine situation was similar with slightly lower indicators.

Fertilization of crops contributed to the growth of the net productivity of photosynthesis compared to the unfertilized control in all variants of the experiment. On average, during the years of the study, the PPF on fertilized crops increased compared to the control by 44.76 g/m^2 of dry matter per day in the V–VIII stages of organogenesis and by 13.12 g/m^2 of dry matter per day in the VIII–XI stages.

Conclusions

Reduction of the seeding rate of the grain component in binary cenosis by 1 million of germinated seeds/ha influenced the growth of the number of beans on vetch and lupine plants, the number of grains in the ear (panicle) and seeds in the bean pod.

Sowing a mixture of spring vetch with oat (4.0 million of germinating seeds/ha of oat and 0.8 million of germinating seeds/ha of vetch) and application of mineral fertilizers $N_{32}P_{32}K_{32}$ contributed to the formation of the largest leaf surface area (34.02 thousand m^2/ ha) and net productivity of photosynthesis (23.85 g/m^2 of dry matter per day). Reduction of the oat sowing rate by 1.0 million of germinating seeds/ha led to a decrease in these indicators by 1.19 thousand m^2/ha and 0.62 g/m^2 of dry matter per day.

Sowing a mixture of oat and spring vetch (4.0 + 0.8 million of germinating seeds/ha) on the background of $N_{32}P_{32}K_{32}$ provided the highest yield – 5.3 t/ha. Reduction of the seeding rate of the grain component by 1 million of germinating seeds/ha caused a decrease in yield by 0.25 t/ha. The yield increase compared to unfertilized crops was 1.07 and 1.15 t/ha.

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Received: September 1, 2022
Accepted: November 4, 2022