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ANALYSIS OF WINTER RYE PRODUCTION TRENDS AND YIELD DEPENDENCE ON FORECROPS AND SOWING RATES

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The article presents results of analyzing winter rye production variations, volume dynamics and influencing factors as well as correlation data on yield dependence on forecrops and sowing rates, which were experimentally obtained in the field of the State Biotechnology University in 2016-2022. The soil was typical heavy loam chernozem on loess. Predecessors of winter rye and sowing rates were chosen as technological factors. Yield data depending on the specified factors in a six-year experiment are summarized. Winter rye was found to give the greatest yields when sown after sunflower at the rate of 5 million seeds/ha. Recommendations for winter rye production regarding the use of sunflower as a forecrop and mandatory adherence to the sowing rate of 5 million germinable seeds/ha have been rationalized and formulated.

Key words: *winter rye, yield, area, gross harvest, forecrops, sowing rate, dynamics, correlation analysis*

Introduction. Winter rye is considered one of the most promising crops grown in most agro-climatic zones of Europe, in particular in the Left-Bank Forest-Steppe of Ukraine. The potential of this crop cultivation is manifested in its ability to yield a lot even on poor soils and due to winter rye allelopathy [1, 2]. Rye saturates the soil with organic substances, nitrogen and potassium. Among green-manure crops, it is the least picky about soil fertility and has a strong root system that reaches a depth of more than 1 m, providing the plant with nutrients and water. Rye is also considered a good phytosanitary plant. Due to its strong tillering and rapid growth, it fights well with annual and perennial weeds, suppresses pathogenic fungi, and, by absorbing nitrates, reduces their content in the soil, thereby improving the ecological condition of the soil [3]. It is known that allelopathy of many domestic plants, which is determined not by one species-specific compound, but by a set of substances of different nature, is quite high. During growth and development, plants secrete biological inhibitors (cholines) through the root system into the soil, which can significantly inhibit the growth and development of subsequent crops in crop rotations [4]. All these indicate a high potential of winter rye cultivation, because of both good yields and biological factors.

Although the specified provisions indicate the significant role and advantages of winter rye compared to other cereals, it should be noted that winter rye areas on Ukrainian farms have been significantly reduced. Between 2000 and 2020, winter rye fields in the country decreased from 667,700 hectares to 138,500 hectares (almost 5-fold reduction). A similar situation is observed at agricultural enterprises in the Kharkiv Region, where the rye percentage in the cereal assortment decreased from 0.9% in 2020 to 0.2% in 2021. According to the 2021data of the Main Department of Statistics, all farms of the Kharkiv Region harvested 74,587 tons of winter rye grain from 2,064 hectares. The yield was 36.1 cwt/ha.

The specified provisions determine the relevance of winter rye growing issues and cereal growing issues in general, namely rationalize studies of yielding properties of seeds depending on sowing rates and forecrops.

Literature Review and Problem Articulation. Boiko P.I. [5] found that crop rotation was a measure that, almost without additional financial costs, helped to boost yields of field crops grown in accordance with their biological requirements by 20–25%. The crop rotation importance is a complex and includes effects on the soil moisture, circulation and availability of nutrients, soil temperature, development of beneficial microorganisms, formation of growth-stimulating substances contained in plant residues, and physical structure of the soil. Predecessors influence the seed bed quality for a subsequent crop, pests, weeds and pathogens. It is important to plant winter rye after crops that are harvested early and allow timely cultivation. It is less demanding on its forecrops than other winter cereals. Such forecrops in the forest-steppe include single-mowed perennial grasses, green fodder winter crops, green fodder corn, rye-oat green fodder and hay mixtures, grain pea, and winter wheat.

Bronnikova L.F. believes that corn, sunflower, potato, and legumes are good forecrops for winter rye. Beneficial results were obtained when winter rye was sown after seeded fallow, especially in locations with sufficient water supply. When growing rye, one should take into account a lodging possibility for tall varieties when they are planted after fertilized seeded fallow or after and perennial grasses on fertile soils. In this case, it is more expedient to plant these forecrops before winter wheat, and to sow winter rye after other recommended forecrops [6].

For example, the suitability of sunflower as a forecrop for other crops is determined by the climatic conditions during its cultivation. In regions with large precipitation amounts, it is considered a fairly good forecrop for winter wheat and for other winter cereals. Sunflower's powerful roots penetrate the soil, creating favorable conditions for a subsequent crop, as its roots can use soil "tunnels" left after sunflower. In the field, sunflower leaves about 7 t/ha of dry organic mass of plant residues; they must be crushed and put into the soil so that the subsequent crop would use nutrients. Sunflower residues contain significant amounts of magnesium and potassium, which is why subsequent crops, in most cases, do without potash fertilizers, but nutrient (especially nitrogen) and moisture reserves are almost exhausted after sunflower.

As for safflower, it belongs to the same family as sunflower. It is positioned as an alternative to sunflower when grown on rainfed lands in the southern Steppe of Ukraine as well as on poor (saline and eroded) soils of little utility [7]. Biological features of the crop and its adaptive potential correspond to the arid conditions of the southern Steppe of Ukraine. Under extremely dry conditions, where winter cabbage crops are often killed by frost, it is safflower that can stabilize oilseed production and guarantee the profitability of crop production. Safflower is a good forecrop for spring cereals. Its influence on winter crops has been studied very little.

As for sowing rates, which determine further plant density, it is important to remember that they are not constant for cereals: they depend on soil and climatic conditions, predecessors, fertilization, variety or hybrid, and other factors. The most accurate determination of a sowing rate of cereal seeds, with due account for various factors, will ensure harvesting high yields, considerable reducing capital investments and increasing the profitability of farms [8].

To harvest a high yield of winter rye, it is necessary to ensure the optimal numbers of plants and productive stems per unit area, which is achieved by setting appropriate sowing rates.

Purpose and Objectives. The study purpose was to investigate trends in the winter rye production volumes and factors on farms in the Kharkiv Region and to analyze effects of some technological factors (namely, forecrops and sowing rates) on winter rye yield. To achieve this purpose, we set the following objectives:

1) To analyze fluctuations of the gross harvest of winter rye grain and the first-order factors that cause its change;

2) To establish trends in the winter rye grain production volumes on the farms in the Kharkiv Region using mean annual indicators values for 1990-2021;

3) By analytical equalization of a dynamic series, to investigate the direction of changes in the winter rye yield as the main indicator of the technological efficiency of grain production;

4) To analyze dependence of the winter rye yield on forecrops and sowing rates.

Materials and Methods. In part 1 of our study, viz. analysis of volumes and the first-order factors affecting the gross harvest of winter rye on the farms in the Kharkiv Region over the period of 1990-2021 (sown area, yield), we used data of the statistical collection “Silske Hospodarstvo Kharkivskoi Oblasti (Agriculture of the Kharkivska Oblast)" and the statistical bulletin "Osnovni Ekonomichni Pokaznyky Vyrobnytstva Produktsii Silskoho Hospodarstva v Silskohospodarskykh Pidpryiemstvakh (Major Economic Indicators of Agricultural Production at Agricultural Enterprises)" as a starting basis. The main methods of analysis were summarizing statistical data, absolute and relative values, mean values, variations, dynamics series, tabular and graphic methods.

Part 2 of our study was devoted to evaluation of the factor influence on the winter rye yield. The research was conducted in a stationary experiment at the Department of Agriculture and Herbology named after O.M. Mozheiko of Kharkiv National Agrarian University named after V.V. Dokuchayev (now the State Biotechnological University) in 2016-2022. In the experiment, the Khamarka variety was sown (the originator is the Plant Production Institute named after V.Ya. Yuriev; the variety has been in the State Register of Plant Varieties of Ukraine since 2007 (Table 1).

The following methods were used to analyze the influence of forecrops and sowing rates on the yield: field surveys, determination the winter rye yield structure, measurements of plant growth and development, determination of yield, phenological observations; mathematical and statistical methods to test significance of results (variance analysis, correlation analysis).

Table 1

Effects of forecrops and sowing rates on the winter rye yield in 2016 – 2022

Forecrop	Sowing rate, mil. seeds/ha	Yield, t/ha						Mean yield, t/ha
		2017	2018	2019	2020	2021	2022	
Sunflower	4.0	2.11	1.82	1.75	1.95	1.99	1.68	1.88
	5.0	2.14	2.03	2.16	2.20	2.28	2.13	2.16
	6.0	1.67	1.78	1.61	1.88	1.71	1.83	1.75
Safflower	4.0	2.06	1.82	1.88	1.95	1.77	1.60	1.85
	5.0	2.20	2.13	2.07	1.98	2.17	2.00	2.10
	6.0	1.71	1.55	1.75	1.64	1.87	1.77	1.72
$LSD_{0.05}$					0.17			

Results and Discussion. In part 1, we collected data on the absolute area sown with winter rye and the volumes of winter rye grain production and calculated the yields at enterprises of the region for 32 years. Using variation analysis, we obtained assessed variations of all three parameters for 1990-2021 and summarized them in Table. 2.

Table 2

Variations of the winter rye grain production on the farms in the Kharkiv Region, 1990 – 2021

Variation parameters	Indicators		
	area	production	yield
Mean for 1990 – 2021	7.102	188.154	27.6
Maximum	17.218	568.200	38.3
Minimum	1.900	46.170	15.4
Variation range	15.318	522.030	22.9
Variance	21.724	17472.631	45.744
Standard deviation	4.660	132.184	6.763
Coefficient of variation, %	65.6	70.3	24.5

Analyzing the data in Table 2, we can draw the following conclusions: from 1990 to 2021, the largest areas on the farms in the Kharkiv Region were sown with winter rye in 1990 (17,218 hectares), and the smallest (1,900 hectares) – in 2018. The economic theory says that area is an extensive factor in grain production development. Its mean value over the studied period was 7,102 hectares. The fluctuation degree of the winter rye-sown area in absolute units was very high, as evidenced by the coefficient of variation of 65.6%.

The gross harvest of winter rye grain varied even greater. Thus, in 1990, agricultural enterprises of the region harvested the largest amount of rye grain over the 32-year period: 568,000 cwt compared to 46,000 cwt in 2018. With the mean gross harvest for the studied period of 188,000 cwt, the coefficient of variation was 70.3%.

The winter rye yield experienced the smallest fluctuation (coefficient of variation 24.5%), ranging 15.4 cwt/ha in 2010 to 38.3 cwt/ha in 2020. We believe that this is not a very good sign, because within 32 years reserves for increasing yields of this crop (indicator of intensive development, i.e. production growth solely at the expense of increasing the productivity of a unit of land area) could have been invented.

In the real economy, as a rule, signs of extensive and intensive development are combined. Figure 1 illustrates the dynamics of the winter rye grain production volumes and winter rye-sown areas on the farms in the Kharkiv Region in 1990-2021.

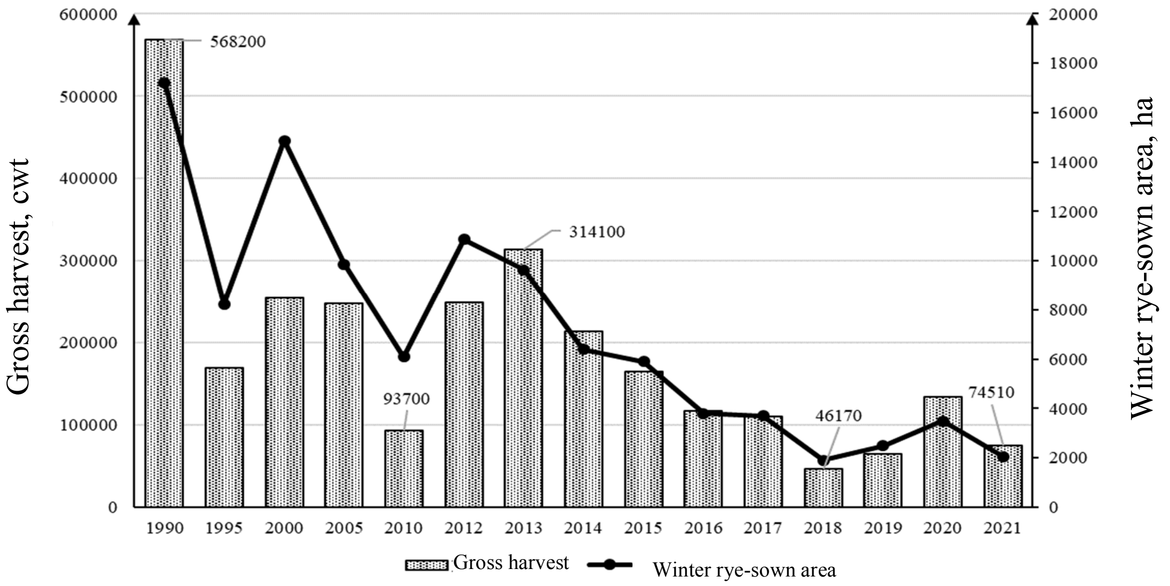

Fig. 1. Dynamics of the winter-rye sown areas and winter rye grain production volumes on farms of any categories in the Kharkiv Region, 1990-2021

The data in Fig. 1 clearly confirm the negative trends in the winter rye grain production that have developed on the farms in the region. Despite high qualities of rye as a food and fodder crop, its high adaptability to any zone of Ukraine, low transpiration coefficient (15-20% lower than that of wheat), unpretentiousness and ability to give good yields on poor soils, the rye area was annually reduced. In 1990, 17218 hectares were sown with winter rye in the Kharkiv Region, which was by 8.3 times larger that the winter rye-sown area in 2021. During the investigated 32-year period, the winter-rye sown area decreased annually by approximately 610 hectares or 9%.

To analyze the winter rye grain production growth rate on the farms in the Kharkiv Region, we used the mean annual values of the dynamic series for aggregated multi-year periods, namely absolute growth, growth rate (geometric mean), gain rate. These indicators were chosen due to the fact that it is possible to analyze the direction of changes in gross grain harvests simultaneously in absolute and relative units. Combination of the indicators in multi-year periods makes it possible to abstract from changes in production caused by random factors and to reveal systematic variations. For calculations, we adopted the following designations: y_o – initial volume of the winter rye grain production in each period cwt; y_n – production volume in the last year of the period, cwt; n - number of years in the period (Table 3).

Table 3

Dynamics of the winter rye grain production on the farms of any categories in the Kharkiv Region, 1990 – 2021

Years	Production volumes, cwt	Multi-year periods	Mean annual values of the gross harvest dynamics		
			Absolute gain (+,-), cwt	Growth rate, %	Gain rate (+,-), %
1990	568.200	-	-	-	-
1995	169.600	1990-1995	-79.720	78.5	-21.5
2000	254.200	1995-2000	16.920	108.4	8.4
2005	247.600	2000-2005	-1.320	99.5	-0.5
2010	93.700	2005-2010	-30.780	82.3	-17.7
2015	165.200	2010-2015	14.300	112.0	12.0
2020	134.050	2015-2020	-6.230	95.9	-4.1
2021	74.510	2016-2021	-8506	91.4	-8.6
Mean for 1990 – 2021			-15.925	93.7	-6.3
Mean for 2000 – 2021			-8.557	94.3	-5.7

As a result of the calculations, we established that the winter rye grain production volume on the farms of the Kharkiv Region decreased at the greatest rate in 1990-1995 (every year on average by 79,720 cwt or by 21.5%). The decrease rate was also high in 2005-2010 (every year on average by 30,780 cwt or by 17.7%). If we take the entire 32-year studied period, we see that the gross harvest of winter rye grain decreased on average by 15,925 cwt per year or by 6.3%.

Currently, production intensification is one of the most important challenges of the economic development. Intensification means that the growth rates of indicators characterizing production results outpace the growth rates of costs for ensuring the indicator growth. It is known that grain production intensification involves using intensive rather than extensive methods. From this point of view, analysis of trends in changes in the winter rye yields on the farms of the Kharkiv Region for the period of 1990 - 2021 as an indicator of the technological efficiency of the crop production, becomes important.

Using analytic quantization of dynamic series by linear equation, we found that with a probability of 0.95 we could assume that the annual absolute gain in the rye yields on the farms of the Kharkiv Region in 1990 - 2021 was 0.7979 cwt/ha per year. The 4^{th} degree polynomial describes this trend more adequately and in detail, since the significance criterion of approximation here is much higher than that for the linear equation: 0.6808 and 0.2703, respectively. According to the curvilinear function, we have a pairwise alternation of yield decline and yield growth periods.

We evaluated the influence of forecrops and sowing rates on the winter rye yield. Thus, sunflower as a forecrop and the sowing rate of 4 million seeds/ha provided the mean yield of 1.88 t/ha; 5 million seeds/ha – 2.16 t/ha, and 6 million seeds/ha – 1.75 t/ha.

Safflower as a forecrop resulted in somewhat lower yields of winter rye compared to sunflower: 1.85, 2.10, and 1.72 t/ha with the sowing rate of 4, 5 and 6 million seeds/ha, respectively.

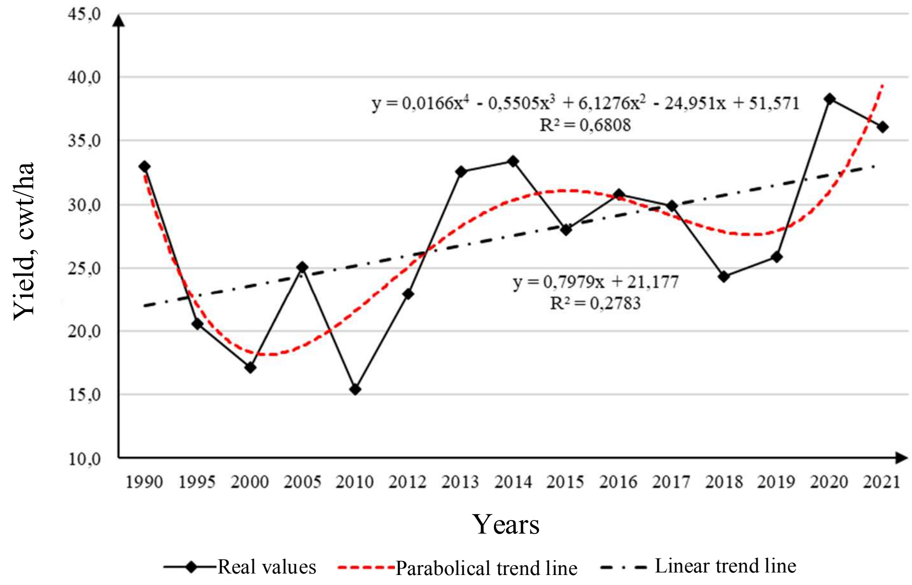

Fig. 2. Trend in the winter rye yield changes on the farms of any categories in the Kharkivska Oblast, 1990 - 2021

To confirm the drawn conclusions, we applied correlation-regression analysis. We investigated the post-sunflower sown winter rye yield dependence (y_x, cwt/ha) on sowing rates (x, mil. seeds/ha). Two correlation models were constructed using linear pairwise correlation: in the first one, the post-sunflower sown winter rye yield variations were simulated for sowing rates of 4-5 million seeds/ha. In the second model of the post-sunflower sown rye yield, the sowing rates ranged from 5 to 6 million seeds/ha (Table 4).

Table 4

Correlation-regression analysis of the winter rye yield dependence on sowing rates (forecrop - sunflower)

Indicators	Sowing rate, mil. seeds/ha	
	Model I 4 – 5 mil. seeds/ha	Model II 5 – 6 mil. seeds/ha
Countdown start, a_0	7.9000	42.0667
Coefficient of regression, cwt/ha, a_1	+2.7333	-4.1000
Coefficient of linear pairwise correlation, R	+0.7595	-0.9244
Coefficient of determination, R^2	0.5768	0.8545
Actual value of Fisher's (F) exact test	13.628	58.731
Tabular value of Fisher's (F) exact test	10.56	10.56
Direction of relationship	Direct	Inverse
Strength of relationship	Strong	Strong

The correlation-regression analysis results summarized in Table 4 give grounds for the following conclusions:

The linear regression model of the post-sunflower sown winter rye yield dependence demonstrates that with an increase in the sowing rate from 4 to 5 million seeds /ha, we get a gain in the yield of 2.7333 cwt/ha. The coefficient of pairwise correlation is 0.7595 and gives grounds for two conclusions:

1) There is a significant, strong stochastic relationship between the post-sunflower sown winter rye yield and sowing rate (0.7595 > 0.7);

2) The relationship between these parameters is direct, that is, the higher sowing rate is, the greater winter rye yield is.

The coefficient of pairwise determination (R^2) of 0.5768 means that 57.68% of variability in the post-sunflower sown winter rye yield is explained by sowing rate. 42.32% account for uninvestigated factors.

A different result was obtained for the post-sunflower sown winter rye yield dependence on sowing rates with rates of 5 - 6 million seeds/ha. It turned out that with an increase in the sowing rate to 6 million seeds/ha, the yield decreases by 4.1 cwt/ha. Significance and reverse direction of the relationship is confirmed by coefficient of linear pair correlation (-0.9244). The coefficient of determination (R^2) of 0.8545 confirms the significant relationship, because 85.45% of variability in the post-sunflower sown winter rye yield is explained by the studied factor (other, not included in the model, factors explain the remaining 14.55%).

Adequacy of the constructed models was verified and confirmed using Fisher's exact test, the actual values of which exceed the tabular values.

Conclusions. The results on the winter rye production trends and winter rye yield dependence on forecrops and sowing rates allowed us to draw the following conclusions:

1. We found that on the farms of the Kharkiv Region in 1990 – 2021, the gross harvest of winter rye grain and winter rye-sown areas had varies greatly (the coefficient of variation amounted to 70.3% and 65.6%, respectively). The winter rye fields were reduced by 8.3 times during the studied period; the grain production volume - by 7.6 times.

2. The 1990 – 2021 dynamics indicators showed that the winter rye grain production decreased at the highest rates in 1990 – 1995 and 2005 – 2010: by 79,720 cwt (or by 21.5 %) and 30,780 cwt (17.7%), respectively, at the investigated enterprises of the region.

3. The winter rye grain production intensification should be associated with outpacing rates of yield growth compared to the growth of costs for ensuring this yield growth. Analytic quantization of the dynamic series of winter rye yields by 4th degree polynomial showed that with a probability of 0.95 we could note periods of decline in theoretically expected yields from 1990 to 2005 (from 32.2 cwt/ha to 18.3 cwt/ha) and from 2016 to 2019 (from 31 cwt/ha to 27.44 cwt/ha). We also have periods of rising yields in 2010 – 2015 (from 21.6 cwt/ha to 31 cwt/ha) and in the last two years (2020 – 2021) (from 30.4 cwt/ha to 38.5 cwt/ha).

4. We revealed that sunflower as a forecrop and the sowing rate of 5 million seeds/ha ensured the highest yield of winter rye. The yields with the sowing rates of 4 million seeds/ha and 6 million seeds/ha are within the permissible error of the experiment.

5. Correlation-regression analysis demonstrated that, with a probability of 0.95, it could be assumed that with a sowing rate of 4-5 million seed/ha, the post-sunflower sown winter rye yield would increase by 2.7333 cwt/ha. The relationship between these parameters is direct, significant and strong. The coefficient of paired determination is 0.5768, indicating that 57.68% of the winter rye yield variability is attributed to changes in sowing rates. Factors, which were not included in the model, account for 42.32%. Judging by F-test, the paired linear model is adequate and can be used for to predict winter rye yields and to estimate the needs for seeds.

6. Analysis of the yield data made it possible to recommend sunflower as a forecrop in winter rye production, with mandatory adherence to the sowing rate of 5 million germinable seeds/ha.

7. We do not recommend safflower as a forecrop in winter rye production, since it decreases yields because of lower moisture content in the soil is caused by a higher density of safflower plants and later harvest times compared to sunflower. Safflower is the most appropriate forecrop in spring cereal cultivation.

Список використаних джерел

1. Adhikari L., Mohseni-Moghadam M., Missaoui A. Allelopathic Effects of Cereal Rye on Weed Suppression and Forage Yield in Alfalfa. American Journal of Plant Sciences. 2018. № 9. С. 685–700. DOI: https://doi.org/10.4236/ajps.2018.94054.
2. Кучерявий О.В. Проблематика сільськогосподарської алелопатії: історична ретроспектива. Virtus. Scientifical Journal. Монреаль, Канада: CPM «ASF». 2019. Вип. 34, травень. С. 194–199.
3. Будьонний В., Башкатова Г. Потенційна забур΄яненість ґрунту під час вирощування жита озимого. Вісник Харківського національного аграрного університету. Серія «Рослинництво, селекція і насінництво, плодоовочівництво і зберігання». 2019. Вип.2. С. 123–132. DOI: https://repo.btu.kharkov.ua//handle/123456789/15284.
4. Гродзинский А.М. Аллелопатия в жизни растений и их сообществ. Киев: Наук. думка, 1965. 198 с.
5. Бойко П.І., Бородань В.О., Коваленко Н.П. Екологічно збалансовані сівозміни – основа біологічного землеробства. Вісн. аграр. науки. 2005. № 2. С. 9–13.
6. Броннікова Л.Ф. Формування ботанічного складу посівів озимого жита залежно від впливу різних попередників. Сільське господарство та лісівництво. 2022. № 4(27). С. 228–241. DOI: https://doi.org/10.37128/2707-5826-2022-4-16.
7. Барашовець О.В., Попова Н.В., Бондаренко Н.Ю.,. Блажеєвський М.Є. Флавоноїди та антиоксидантна активність сафлору красильного. Український біофармацевтичний журнал. 2018. № 3 (56). С.60–65. DOI: https://doi.org/10.24959/ubphj.18.181.
8. Цюк Ю.В. Урожайність озимого жита залежно від елементів технології вирощування. Матеріали наукової конференції, присвяченої 100-річчю від дня народження академіка П.А. Власюка і 150-річчю від дня народження професора Л.П. Симиренка. Умань: УДАУ. 2016. 316 с.

References

1. Adhikari L., Mohseni-Moghadam M., Missaoui A. Allelopathic Effects of Cereal Rye on Weed Suppression and Forage Yield in Alfalfa. American Journal of Plant Sciences. 2018; 9: 685–700. DOI: https://doi.org/10.4236/ajps.2018.94054.
2. Kucheriavyi O.V. Problems of agricultural allelopathy: a historical retrospective. Virtus. Scientific Journal. Montreal, Canada: CPM "ASF". 2019; 34: 194–199.
3. Budionnyi V. Potential weediness of soil contamination in winter rye cultivation / V. Budionnyi, H. Bashkatova // Visnyk Kharkivskoho Natsionalnoho Ahrarnoho Universytetu Series "Roslynytstvo, Selektsiia a Nasinnytstvo, Plodoovochivnytstvo i Zberihannia". 2019; 2: 123–132. DOI: https://repo.btu.kharkov.ua//handle/123456789/15284.
4. Grodzinsky A.M. Allelopathy in the life of plants and their communities Kyiv: Naukova Dumka, 1965. 198 p.
5. Boiko P.I., Borodan V.O., Kovalenko N.P. Ecologically balanced crop rotations - a basis of biological agriculture. Visnyk Ahrarnoi Nauky 2005; 2: 9–13.
6. Bronnikova L.F. Formation of the botanical composition of winter rye fields depending on different predecessors. Silske Hospodarstvo ta Lisivnytstvo. 2022; 4 (27): 228–241. DOI: https://doi.org/10.37128/2707-5826-2022-4-16.
7. Barashovets O.V., Popova N.V., Bondarenko N.Yu. Blazheevsky M.E. Flavonoids and antioxidant activity of safflower. Ukrainskyi Biofarmatsevtychnyi Zhurnal. 2018; 3(56): P.60–65. DOI: https://doi.org/10.24959/ubphj.18.181.
8. Tsiuk Yu.V. Winter rye yield depending on growing technology components. Abstracts of the Scientific Conference Dedicated to the 100th Anniversary of the Birth of Academician P.A. Vlasiuk and the 150th Anniversary of the Birth of Professor L.P. Symyrenko. Uman: UDAU. 2016. 316 p.

АНАЛІЗ ТЕНДЕНЦІЙ ВИРОБНИЦТВА І ЗАЛЕЖНОСТІ УРОЖАЙНОСТІ ЖИТА ОЗИМОГО ВІД ПОПЕРЕДНИКІВ ТА НОРМИ ВИСІВУ

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Мета і задачі дослідження. Дослідити тенденції обсягів і факторів виробництва озимого жита в господарствах Харківської області, проаналізувати вплив окремих технологічних чинників (а саме, попередників та норми висіву насіння) на урожайність цієї зернової культури.

Матеріали і методи дослідження. У якості вихідної бази нами використано дані статистичних збірників «Сільське господарство Харківської області», статистичних бюлетенів «Основні економічні показники виробництва продукції сільського господарства в сільськогосподарських підприємствах». Основними методами при виконанні аналізу були методи зведення статистичних даних, абсолютних і відносних величин, середніх величин і показників варіації, рядів динаміки, табличний і графічний методи. Для аналізу впливу попередників і норм висіву на урожайність використані такі методи: польові – для проведення оперативного обстеження посівів, проведення основного обстеження, визначення структури урожаю жита озимого, визначення росту й розвитку рослин, визначення врожайності, ведення фенологічних спостережень; математично-статистичні методи для оцінки достовірності отриманих результатів досліджень - (дисперсійний аналіз, кореляційний аналіз).

Обговорення результатів. За 1990 – 2021 рр. найбільші площі посіву жита озимого у господарствах Харківської області були відведені у 1990 р. – 17218 га, найменші – 1900 га у 2018 р. Згідно економічної теорії, розмір посівної площі жита є екстенсивним фактором розвитку зерновиробництва, середнє значення якого за досліджуваний період становило 7102 га. Ступінь коливання абсолютного розміру посівних площ цієї сільськогосподарської культури дуже високий, про що свідчить коефіцієнт варіації 65,6%. Найменшого ступеня коливання зазнає урожайність жита озимого (коефіцієнт варіації 24,5%), розмір якої коливається від 15,4 ц/га у 2010 р. до 38,3 ц/га у 2020 р. Вважаємо, що це є не дуже добрим знаком, оскільки за 32 роки можна було винайти резерви збільшення урожайності цієї культури як показника інтенсивного зростання – тобто зростання виробництва виключно за рахунок підвищення продуктивності одиниці земельної площі. У 1990 р. під посіви жита озимого у Харківській області відводилося 17218 га землі, що у 8,3 рази більше за показники 2021 р. Протягом досліджуваного 32-річного періоду посівна площа скорочувалася щорічно приблизно на 610 га або 9%. Лінійна регресійна модель залежності урожайності жита озимого (по соняшнику) показує, що при збільшенні норми висіву насіння з 4 до 5 млн шт/га отримуємо приріст урожайності у розмірі 2,7333 ц/га. При зростанні норми висіву насіння да 6 млн. шт/га урожайність зменшується на 4,1 ц/га.

Висновки. Інтенсифікація виробництва зерна жита озимого треба пов'язувати із випереджаючими темпами зростання урожайності порівняно із ростом витрат на забезпечення цього росту. Вирівнювання динамічного ряду урожайності жита озимого за рівнянням параболи четвертого порядку показало, що з імовірністю 0,95 можна зазначити періоди спаду теоретично очікуваної урожайності з 1990 р. по 2005 р. (з 32,2 по 18,3 ц/га) і з 2016 р. по 2019 р. (з 31 ц/га до 27,44 ц/га). Також маємо періоди росту урожайності у 2010 - 2015 рр. (з 21,6 ц/га по 31 ц/га) та в останні два роки у 2020 – 2021 рр. (з 30,4 ц/га до 38,5 ц/га). Не рекомендуємо використання в якості попередника жита озимого сафлору красильного, який сприяє зниженню врожайності за рахунок меншого вмісту вологи в ґрунті, що спричиняють більша густота посіву сафлору красильного та більш пізні строки його збирання в порівняні з соняшником.

Ключові слова: *жито озиме, урожайність, площа, валовий збір, попередники, норма висіву, динаміка, кореляційний аналіз.*

ANALYSIS OF WINTER RYE PRODUCTION TRENDS AND YIELD DEPENDENCE ON FORECROPS AND SOWING RATES

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The purpose and objectives of the study. The study purpose was to investigate trends in the winter rye production volumes and factors on farms in the Kharkiv Region and to analyze effects of some technological factors (namely, forecrops and sowing rates) on winter rye yield.

Materials and research methods. We used data of the statistical collection “Silske Hospodarstvo Kharkivskoi Oblasti (Agriculture of the Kharkivska Oblast)" and the statistical bulletin "Osnovni Ekonomichni Pokaznyky Vyrobnytstva Produktsii Silskoho Hospodarstva v Silskohospodarskykh Pidpryiemstvakh (Major Economic Indicators of Agricultural Production at Agricultural Enterprises)" as a starting basis. The main methods of analysis were summarizing statistical data, absolute and relative values, mean values, variations, dynamics series, tabular and graphic methods. The following methods were used to analyze the influence of forecrops and sowing rates on the yield: field surveys, determination the winter rye yield structure, measurements of plant growth and development, determination of yield, phenological observations; mathematical and statistical methods to test significance of results (variance analysis, correlation analysis).

The discussion of the results. From 1990 to 2021, the largest areas on the farms in the Kharkiv Region were sown with winter rye in 1990 (17,218 hectares), and the smallest (1,900 hectares) – in 2018. The economic theory says that area is an extensive factor in grain production development. Its mean value over the studied period was 7,102 hectares. The fluctuation degree of the winter rye-sown area in absolute units was very high, as evidenced by the coefficient of variation of 65.6%. The winter rye yield experienced the smallest fluctuation (coefficient of variation 24.5%), ranging 15.4 cwt/ha in 2010 to 38.3 cwt/ha in 2020. We believe that this is not a very good sign, because within 32 years reserves for increasing yields of this crop (indicator of intensive development, i.e. production growth solely at the expense of increasing the productivity of a unit of land area) could have been invented. In 1990, 17,218 hectares were sown with winter rye in the Kharkiv Region, which was by 8.3 times larger that the winter rye-sown area in 2021. During the investigated 32-year period, the winter-rye sown area decreased annually by approximately 610 hectares or 9%. The linear regression model of the post-sunflower sown winter rye yield dependence demonstrates that with an increase in the sowing rate from 4 to 5 million seeds /ha, we get a gain in the yield of 2.7333 cwt/ha. It turned out that with an increase in the sowing rate to 6 million seeds/ha, the yield decreases by 4.1 cwt/ha.

Conclusions. The winter rye grain production intensification should be associated with outpacing rates of yield growth compared to the growth of costs for ensuring this yield growth. Analytic quantization of the dynamic series of winter rye yields by 4th degree polynomial showed that with a probability of 0.95 we could note periods of decline in theoretically expected yields from 1990 to 2005 (from 32.2 cwt/ha to 18.3 cwt/ha) and from 2016 to 2019 (from 31 cwt/ha to 27.44 cwt/ha). We also have periods of rising yields in 2010-2015 (from 21.6 cwt/ha to 31 cwt/ha) and in the last two years (2020-2021) (from 30.4 cwt/ha to 38.5 cwt/ha). We do not recommend safflower as a forecrop in winter rye production, since it decreases yields because of lower moisture content in the soil is caused by a higher density of safflower plants and later harvest times compared to sunflower. Safflower is the most appropriate forecrop in spring cereal cultivation.

Key words: *winter rye, yield, area, gross harvest, predecessors, sowing rate, dynamics, correlation analysis.*