Received: 07.06.2024. Revised: 24.11.2024. Accepted: 04.02.2025.

EKONOMIKA APK

https://doi.org/10.32317/ekon.apk/1.2025.20

Ekonomika APK, 32(1), 20-32

UDC 330.322:658.152

Investment and innovation development of seed production in Ukraine in the context of accession to the European Union

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▸ **Abstract.** The study aimed to assess the investment and innovation support of seed production, to develop measures to improve efficiency and to propose proposals for protecting the rights of breeders to receive royalty and breeding payments. Monographic, economic statistical, tabular and graphical, empirical, comparative analysis, forecasting, and abstract and logical methods were used in the study. The study analysed the organisation and functioning of the seed industry in Ukraine. The main indicators of the development of seed production of cereals, legumes and oilseeds were investigated, and the outstripping rates of development of imports over exports and, accordingly, Ukraine's import overdependence, which leads to vulnerability in the global seed market, were revealed. The dynamics of costs to produce seeds of cereals, oilseeds and legumes is summarised, and the standard cost of wheat seeds is calculated. Proposals were developed to protect the rights of breeders in terms of protecting intellectual property rights to plant varieties, accounting for the best practices of European countries. The actual and proposed value-added chains to produce conditioned seeds in Ukraine were built. The most important indicators of seed production growth in Ukraine are the volume of sowing (2,300-2,500 thousand tonnes), exports (77 million USD), and imports (350 million USD). The largest share in the cost structure of all producers is the production of seeds, which are then delivered to the company for processing (40-80%, depending on the category of producers). The amount of royalties paid annually averages 90 million UAH, with a potential of 900 million UAH. Breeding payments are not paid in Ukraine at all, although they could amount to 725.7 million UAH

▸ **Keywords:** conditioned seeds; cost; commercialisation; breeding institutions; added value; optimisation

▸ **Suggested Citation**: Zakharchuk, O., Vyshnevetska, O., Navrotskyi, Ya., & Kondratyuk, V. (2025). Investment and innovation development of seed production in Ukraine in the context of accession to the European Union. *Ekonomika APK*, 32(1), 20-32. doi: 10.32317/ekon.apk/1.2025.20.

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▸ Introduction

The development of agricultural production is based on modern breeding, variety renewal and timely variety replacement, and an effective national seed system that ensures optimal use of the genetic potential of Ukrainian varieties and meets the needs of agricultural producers for conditioned seeds. This will increase crop yields, reduce costs and increase the economic efficiency of agricultural production, as well as strengthen the competitive position of the Ukrainian seed industry and the agricultural sector in general.

The genesis of breeding and seed production in Ukraine, strengthening the position of Ukrainian seed producers in the international market, foreign investment (Sergeyeva *et al.*, 2020) to build a world-class seed infrastructure (Borras *et al.*, 2020; Qian, 2021) are not possible in the future without the implementation of European standards, without Ukraine's membership in the International Organisation for Economic Cooperation and Development (OECD) and accession to variety certification schemes. The use of conditioned seeds in agriculture is a key factor in its genesis and the basis for increasing the economic efficiency of the crop production industry. This is evidenced by global trends related to food security, bio- and genetic engineering, conversion to biofuels, adaptation to meteorological changes, etc. The constant demand in the global food market requires increasing agricultural potential, including through seed production. The role of innovative factors in agriculture and the economy has increased and will continue to grow in the future (Bass *et al.*, 2020). This can be achieved through a well-organised and efficiently operating Ukrainian seed industry.

The development of the seed industry and related problems of providing agriculture with highly productive seeds and planting material, the issues of increasing the efficiency of seed production and forming strategic directions for its development have been discussed and clarified in the research of many Ukrainian and foreign scientists. The development of Ukrainian agriculture is largely dependent on the supply of high-quality seeds for high yields. All other production factors also depend on the quality of seed material. For instance, J. Singh *et al.* (2019) estimated that the contribution of quality seeds alone to total crop-dependent production is estimated to be 15-20% and that this figure can be increased to 45% if other inputs are managed effectively.

K. Deconinck (2019) and P. Singh (2021) argue for the need to build a seed production system that will be the basis for food security. A seed system includes technological, organisational, market and non-market institutions that provide access to quality seed. D. Nabuuma *et al.* (2022) analysed the importance of seed system interventions in the food supply of low- and middle-income countries. The researchers recognise that food producers and consumers are often uninformed about the availability of seeds and other agricultural inputs. Therefore, the extent to which seeds, and seed systems directly or indirectly contribute to improved nutrition has not been proven or determined.

To meet the needs of agricultural producers with updated crop varieties, the seed system should take measures including plant breeding and variety development programmes to provide agricultural producers with quality seeds. S. Gairhe *et al.* (2021), in an analysis of the cultivation and marketing of maize seeds, concluded that it is necessary to provide state support to farmers in the innovation of their technologies for commercial seed production. The limited availability of investment resources for small farmers and other value chain actors is a major constraint in the seed industry.

D.A. Vermunt *et al.* (2022) study the place of seed systems in the provision of seeds. This group of scientists considers seed systems to be market and non-market institutions for providing farmers with conditioned seeds, technologies, organisational structures, etc. The seed system is regulated through plant breeding and propagation methodologies, official regulation, certification, and laws and regulations. Due to the high price, small agricultural producers usually do not use high-quality conditioned seeds. On the contrary, large and medium-sized enterprises are users of conditioned seeds as natural capital (Mattana *et al.*, 2022).

The importance of seed production in the development of agricultural science was also studied by Ukrainian scientists O. Zakharchuk *et al.* (2019). The study included a retrospective analysis of the formation of seed production in Ukraine and an analysis of the current state and prospective ways of its development; organisation of market infrastructure and determination of the patterns of its effective functioning; highlighting problems and developing measures to improve the commercial circulation of seed material based on foreign experience, as well as the introduction of fees for the use of seeds as an object of intellectual property.

The current development of the seed industry is hampered by the following problems: the prevalence of foreign varieties in the seed market, the low level of state support for seed production and its further reduction, the lack of certified seeds from agricultural producers, etc. Their solution will have a positive impact on the level of supply of seeds of Ukrainian varieties to agricultural enterprises, the development of the export potential of the seed industry, primarily oilseeds and grains, and the inflow of investments that will ensure high and stable development of Ukrainian seed breeding and seed production. All these problems require a comprehensive study and analysis and the development of effective ways to solve them. The study aimed to comprehensively analyse the level of investment and innovation support for seed production, to develop ways to improve the efficiency of the industry and to make practical proposals aimed at protecting the intellectual rights of breeders and variety owners concerning royalties and breeding payments.

▸Materials and methods

The main methods used in the study of the production cost of Ukrainian-conditioned seeds were the dialectical method and the systematic approach. Monographic (to present the opinions of scientists on the issue, to study the current state of seed production of cereals, legumes and oilseeds); economic and statistical (Yang, 2022) (to analyse the structure of costs to produce crop production), tabular and graphical (to visualise the results of the study) were also used. At the same time, empirical

(McEwan, 2010) (to consider the experience of other countries in protecting intellectual property rights to plant varieties, collecting royalties and breeding payments and implementing their experience in their practice); comparative analysis (to identify the most significant problems of Ukrainian seed production); analytical forecasting method (Masayuki, 2022) (to determine the potential amount of royalties and breeding payments from the use of certified seeds by Ukrainian farmers); abstract and logical (to summarise the results of the study and formulate conclusions).

Seed production is a logical extension of breeding. The use of breeding techniques is necessary in some seed production technologies, for example, for cereals. Therefore, varietal resources were assessed and analysed. The improvement in the qualitative and quantitative composition of plant varieties of Ukrainian breeding, which are recognised as suitable for cultivation, has been recognised by experts of the World Intellectual Property Organisation. Indicators calculated according to the Ukrainian Institute of Plant Variety Expertise (n.d.) indicate the quality of national varietal resources.

The production of varietal seeds is the basis for the development of the agricultural sector. The study firstly analysed the structure of the cost of seed production, which includes seeds for sowing for further reproduction, seed insurance fund, wages, salaries, payroll, fuel, fertilisers, plant protection products, routine maintenance, depreciation, and seed processing costs. Production costs and value-added cannot be considered separately. These two values are interrelated and determine the selling price of conditioned seeds. To assess the intensity of changes in production losses over time, time series indicators were used.

The analysis of the seed production of conditioned seeds, in addition to studying the structure of production costs and added value, is complemented by the study of such indicators as the sown area, production volumes of certified seeds of the most common crops of Ukrainian and foreign selection, calculation of potential royalty and breeding payments. The system of indicators is built based on an attribute assessment using descriptive statistics and statistical analysis methods. The study analysed the production of additional basic and certified seeds by different categories of producers and built a scheme to produce seeds of different categories by the institutions of the National Academy of Agrarian Sciences of Ukraine (NAAS) network.

The mechanism for managing the market for conditioned seeds involves the development and implementation of mandatory breeding payments and royalties. Given the lack of experience in protecting intellectual property rights, the experience of other countries was used and adapted to Ukrainian realities. Based on this, the potential number of payments that can be further directed to the development of breeding science was calculated.

To deepen the study, the research analysed the conditions of seed production and bringing it to consumer conditions by different categories of processors in Ukraine and the world, from its sale after harvesting the seed material to its sale on the market. For this purpose, the chain analysis method was used (Depro & Rouse, 2022). The analysis used data from Euroseeds (n.d.), the National Academy of Agrarian Sciences of Ukraine (n.d.) and private producers and provided a new vision of the formation of the final standard price of conditioned seeds, incorporating the costs of all links in the value chain and the profit received.

Therefore, the stages of the study are: generalisation of research on seed production, assessment of seed production in the dynamics of national and foreign enterprises, determination of the share of seeds of Ukrainian selection in the total volume, calculation of their cost and recommendations for improving the state of Ukrainian seed production by spreading the practice of introducing royalty and selection payments to strengthen the innovation and investment potential of the industry and strengthening export potential. Calculations are based on data from the State Statistics Service of Ukraine (2023; 2024), the Ministry of Agrarian Policy and Food of Ukraine (2024a), and the Ukrainian Institute of Plant Variety Expertise (n.d.).

▸ Results and discussion

The production of conditioned seeds is a key prerequisite not only for the renewal of crop production but also for increasing crop yields. The efficiency of agricultural production is significantly affected by the quality of the varieties and hybrids sown. Therefore, it is necessary to create innovative high-quality varietal resources and use the most effective ones. The main objectives of the seed industry are to increase the number of crop varieties and hybrids to meet the maximum social needs; increase their yields; improve the quality characteristics of agricultural products; and use simplified growing and harvesting technologies. In the breeding process, the above-mentioned areas of crop improvement are addressed systematically, and optimisation of the value chain of seed production in Ukraine, including proposals for the main areas of investment in the development of breeding seed production, will allow for more efficient operations.

In the period 1990-2024, plant breeding and seed commercialisation gained significance at the global level. Crop breeding has become a priority activity of global multinational corporations focused on the production of conditioned seeds, which has led to conflicts, disputes and lobbying for the protection of intellectual property rights in seeds. The high complexity of assessing the advantages and disadvantages of different regimes for the protection of intellectual property rights in the seed sector has led to a decrease in attention to them. A proper and balanced approach to assessing this important issue involves removing political obstacles, ranging from comparing the appropriateness of patents and special forms of intellectual property protection as a factor in stimulating innovation to ethical and moral aspects (Campi & Nuvolari, 2015).

During the same period, the seed industry also grew steadily. Several changes occurred: improved market organisation, increased contract trading, increased mechanisation of agriculture, easier access to credit, increased exports, use of plant protection products, mineral fertilisers and high-yielding seeds, and the growing importance of private business in processing, branding, marketing and other activities. The government has taken many progressive and reformist steps to increase the importance of the seed sector in the country's economy.

The Ukrainian seed system operates in a highly competitive market environment and is aimed at increasing agricultural production and ensuring food security (Novikov *et al.*, 2021). The main activities of the system are the breeding and multiplication of Ukrainian varieties, import and multiplication of foreign varieties, variety testing and registration, issuance of certificates for seed products, etc. (Table 1). The first subsystem is aimed at ensuring the innovative development of seed production and the creation of new plant varieties; the second subsystem provides state qualification expertise; the third subsystem ensures the production and propagation of certified seeds; and the fourth subsystem is responsible for variety certification and monitoring compliance with seed production standards. All system entities are directly subordinated to the Ministry of Agrarian Policy of Ukraine.

Table 1. Structure and functions of the system of conditioned seed production of grains, oilseeds and pulses in Ukraine

Seed production subsystem	Subjects	Functions and objectives
Innovative development of seed production and breeding	Research institutes and breeding research stations, breeders – authors of varieties, patent holders	Development of new varieties based on innovative technologies and their primary propagation
State qualification examination of plant varieties	Ukrainian Institute for Plant Variety Examination (UIPVE) and its branches	Testing, expert evaluation and registration of varieties
Production and propagation of agricultural plant varieties	Research institutes, experimental stations and farms of educational institutions, private enterprises registered in the State Register as producers of seeds and planting material	Production of supplementary, basic and certified seeds
Varietal certification and control over seed production	Authorised state and private enterprises	Direct field inspections, seed quality checks, certification of farms and monitoring of compliance with production standards

Source: developed by the authors

The need to create sustainable high-yielding hybrids adapted to the soil, terrain and climate conditions of a particular area is driven by modern demands. However, not all farmers are ready to experiment and prefer to buy old, time-tested hybrids. Solving the problems associated with low variety adoption and slow turnover requires new knowledge about the impact of individual demand factors in the seed value chain to determine the conditions for farmers to make the best decision when purchasing seeds, as well as to identify marketing risks inherent in new products by seed producers and sellers. P. Rutsaert *et al.* (2024) emphasise that the source of information on the effectiveness of a new hybrid or variety is the results of farmers' experiments with them, and that closer interaction between agricultural enterprises on the one hand and seed producers and sellers on the other is needed to intensify these experiments.

To prevent financial losses due to insufficient or excessive seed production, producers must respond quickly to changes in demand and constantly monitor their state. The production planning process is based on information about the timing of sowing, the area under crops, the demand for seeds, the dynamics and future trends, and the government support programmes that producers can participate in. Sources of information can include offices of agricultural producers, trade organisations, internet searches, seed centres, etc. (Qadir *et al.*, 2024).

Seed producers need to be aware of the state of demand for seed products. Over- or under-production can have serious financial consequences for seed producers. Information on seed demand is crucial for producers when planning seed production. To plant seed production, they need to obtain information on the area under cultivation, the sowing season, seed demand (variety, quantity, location and time) in previous and subsequent years and government programmes. They can obtain this information from a variety of sources, including private search, agricultural offices, agricultural shops, SCAs (e.g. Badan Pengawasan dan Sertifikasi Benih [Seed Control and Certification Bureau]) and seed centres (Qadir *et al.*, 2024).

Indicators characterising the state of seed production of major crops (cereals, oilseeds) in Ukraine are shown in Table 2. These include: the equivalent value of seeds – about 70.0 billion UAH; seed turnover – 55.0 billion UAH; seed production – 2.3-2.5 million tonnes; about 50 seed plants and 500 seed producers; the number of varieties and hybrids – approximately 5.0 thousand; the number of varieties for which primary seed production is carried out – only 3.2 thousand varieties Ministry of Agrarian Policy and Food of Ukraine (2024a).

Table 2. Indicators of functioning and development of Ukrainian seed production of grains, pulses and oilseeds in Ukraine as of 01.01.2024

Metric	Value
Seed value, billion UAH	69.5
Seed turnover in Ukraine, billion UAH	55.0
Annual investments, billion UAH	up to 10.0
Production volume, thousand tonnes	~ 2,400
Seed production entities, units	~ 500
Seed plants, units	~50

Table 2, Continued

Metric	Value
Varieties and hybrids, units	5,000
Primary seed production (management), units	3,200
Export, million USD (seeds exported)	77.0
Import, million USD (seeds imported)	350.0
Royalties paid annually, million UAH	80-100
Potential royalty value of nationally bred varieties, million UAH	900.0
The potential value of breeding payments, million UAH	700-750

Source: calculated by the authors

Seeds of grains, pulses and oilseeds account for a significant share of about 10-12% in the structure of costs to produce grains, pulses and oilseeds (Table 3). In 2015-2023, agricultural producers' expenditures on seeds in value terms increased more than tenfold compared to 2010. In 2023, the cost of seeds increased to 55.0 billion UAH, which corresponds to the growth rate of total costs per hectare of arable land over these years. Total expenditures also increased by more than 10.6 times. In the analysed period, several factors contributed to the growth of seed costs. Firstly, the seed industry was undergoing intensification, which resulted in a simultaneous increase in the costs of producing seed and its quality. Secondly, prices for inputs included in the cost of seeds increased, and thirdly, the share of purchased seeds in the total volume of seeds increased. Agricultural producers value their seeds at cost, while purchased seeds are valued at the purchase price. At a time when the seed industry is becoming more specialised, the share of seed used by agricultural enterprises is increasing, it is taking on a commodity form, and the calculation of seed costs at average cost does not meet the requirements of seed production development. In such circumstances, the reporting materials of agricultural enterprises cannot be an objective basis for comparing production efficiency when using owned and purchased seeds.

Table 3. Dynamics of costs of production of grains, pulses and oilseeds and the place of seeds in 2010-2023

Expenditure	Year							
	2010		2015		2020		2023	
	billion UAH	%	billion UAH	%	billion UAH	%	billion UAH	%
Salary	4.3	8.6	7.9	5.1	18.1	6.5	38.0	7.1
Contributions to social activities	1.5	3.0	2.8	1.8	4.0	1.4	8.4	1.6
Seeds	**6.1**	**12.2**	**18.4**	**11.8**	**27.4**	**9.8**	**55.0**	**10.3**
Mineral fertilisers	8.1	16.1	29.1	18.6	45.9	16.5	142.3	26.8
Petroleum products	6.7	13.3	18.3	11.7	22.2	8.0	64.8	12.2
Current repairs	3.0	6.0	10.8	6.9	14.7	5.3	17.7	3.3
Amortisation	3.0	6.0	7.5	4.8	24.6	8.8	53.3	10.0
Payment for services and works	8.1	16.1	30.0	19.2	24.0	8.6	12.6	2.3
Other expenses	9.4	18.7	31.5	20.1	98.1	35.1	140.9	26.4
Total	**50.2**	**100.0**	**156.3**	**100.0**	**279.0**	**100.0**	**533.0**	**100.0**

Source: calculated by the authors and data of the State Statistics Service of Ukraine (2021)

The economic efficiency of seed production directly depends on the costs incurred for breeding activities. Objectively speaking, the production of additional seeds for all crops is quite costly. At the same time, additional seeds have the best yield potential, as they contain all the valuable genetic properties of the variety. Therefore, the price of additional seeds of cereals, pulses and oilseeds is formed considering the valuation of intellectual property rights. The costs of producing additional seeds in scientific breeding institutions include all material costs to ensure the necessary organisational and technological conditions for breeding activities. Using the example of the Sinelnykivska breeding and research station, the formation of the standard cost of seeds of spiked cereals can be analysed by stages of production of additional categories in 2023 (Table 4).

Table 4. Calculation of the standard cost of conditioned grain seeds*, 2023

Metric	Measurement unit	Nursery for the selection of elite plants	Nursery for testing offspring 1	Nursery for testing offspring 2	Propagation nursery 1	Propagation nursery 2
Area	hectare	-	0.1	0.2	1.2	8
Gross yield	kg	3,000 elite plants	200	800	4,800	32,000
Seed yield	kg		80	400	3,000	20,000
Used: for the insurance fund	kg	1,000 elite plants	40	200	1,500	-

Table 4, Continued

Metric	Measurement unit	Nursery for the selection of elite plants	Nursery for testing offspring 1	Nursery for testing offspring 2	Propagation nursery 1	Propagation nursery 2
for sowing (further reproduction)	kg	1,000 elite plants	400 families, 40 kg	200	1,500	-
Seeds	UAH	0	11,864	17,185	18,960	32,010
Remuneration and social contributions	UAH	11,864	20,740	16,758	22,399	34,014
Fuels and lubricants	UAH	0	747	1,494	3,984	26,560
Fertiliser application	UAH	0	1,200	2,400	14,400	96,000
Plant protection products	UAH	0	0	620	3,720	24,800
Current repairs	UAH	0	200	400	2,400	16,000
Depreciation and amortisation expense	UAH	0	120	260	1,560	9,800
Refinement of seeds	UAH	0	0	0	7,680	38,600
Total expenses	**UAH**	**11,864**	**34,870**	**39,117**	**75,103**	**239,184**
including seeds	UAH	11,864	34,371	37,917	69,703	203,184
Production cost of seeds, kg	UAH	×	429.64	94.80	23.23	10.16
Costs for certification of 1 kg of seeds	UAH	×	×	×	×	0.41
Production cost of 1 kg of additional seeds, total	**UAH**	×	×	×	×	**10.57**

Notes: * – in the units of the National Academy of Agrarian Sciences of Ukraine; × – data is not calculated
Source: data from the National Academy of Agrarian Sciences of Ukraine (n.d.)

State-owned research and breeding institutions that produce pre-basic seeds require significant amounts of funding. However, even the state budget funds cover no more than half of the costs of state breeding institutions. For instance, in 2023, the cost of producing 1 kg of seeds of the first generation of cereal crops at the Synelnykivska Selection and Research Station was 429.64 UAH. The structure of material costs changes according to the technological processes at different stages of production. At the same time, the output increases each year, so the cost per unit of production decreases significantly as gross costs increases. For instance, according to experts, the cost of producing 1 kg of seeds in the second year of propagation was 10.16 UAH. Additional costs are also incurred for seed certification, which involves seed control, including field inspection, sowing quality control, and soil (varietal) control. Per 1 kg of additional seed, these costs amounted to another 41 kopecks, or almost 4.0% of total seed production costs (Table 3). The primary task for the future is to increase solvency at the key links (initial and final) of the seed distribution chain from breeders to agricultural producers. This is a short-term task. Further, an increase in the supply of seeds without an increase in demand will increase carry-over stocks and lower prices on the domestic market. Only after the gradual resolution of the issue of increasing demand for seeds will it be possible to reorient the market management mechanism to increase the supply of seeds, reduce their cost, improve their quality and range, and control price declines. To do this, it is necessary to create a full-fledged infrastructure of the plant variety market, the elements of which would harmoniously and efficiently cooperate in the production and sale of seeds.

A. Qadir *et al.* (2024) identified a correlation between seed producers, their production and production capacity, and institutional categories. The authors view the solution to production problems as promoting interagency coordination and network research related to testing and breeding new varieties and hybrids and developing seed production infrastructure to meet the ever-increasing demand. The sustainable agriculture system has four components: breeding of new varieties and technologies; production of new varieties of seeds and their distribution; certification of new varieties of seeds and quality control; and supporting components of the system such as legal regulation, financing, human resources, etc.

The institutional framework for the protection of intellectual property rights in the seed industry was studied by B. Charnley & G. Radick (2013). The authors insist on the settlement of disputes over the use of new varieties and their ownership between breeders and unscrupulous seed users. The scientists believed that it was unfair to consumers who threatened the profitability of new varieties. This issue has not lost its relevance for more than a century. Since 1900, scientists have been studying institutional mechanisms to protect the rights of breeders. In this regard, global legislation and/or patent practice is being revised due to challenges from agriculture, science and business. Protection of plant-related objects can be carried out by patenting a plant variety, patenting a utility model or patenting a plant (USA). Since utility model patenting does not provide the same protection as plant variety patenting, it is much more complicated. Such patenting is used in countries where patents are granted for higher forms of life and experimental support for it should be at a much higher level. At the same time, the scope of protection is gradually narrowing (Sechley & Schroeder, 2002).

Proposals for improving the Ukrainian seed industry by 2030:

Proposal 1. The efficiency of the seed industry will be enhanced by the creation of regional (oblast) seed production systems that will be focused on meeting the existing needs of agricultural producers, considering expected changes in the future. In this regard, it is necessary to create three organisational elements of the seed production system – a seed breeding centre, a seed enterprise and a regional association of seed producers.

As of 1 January 2024, there were 126 seed plants and seed facilities in Ukraine, including 46 seed plants (Ministry of Agrarian Policy and Food of Ukraine, 2024a). Therefore, each region can operate under the above scheme. At the same time, seed producers will be able to receive varietal seeds that have been cleaned, calibrated, treated and packaged following international requirements. This will allow Ukraine to create new opportunities to enter the international market, namely the European market, which is the most attractive and expensive.

The stability of the supply of seeds to agricultural enterprises is a key to national food security. Seed producers and seed distributors play a crucial role in developing the seed production system, ensuring demand and increasing the supply of seeds, by introducing many varieties and hybrids into circulation and delivering seeds to consumers. The total volume of the seed market is measured by the number of seed available, its accessibility to consumers, and its price. Access to quality seeds is determined by the ability of agricultural enterprises to obtain them from official and unofficial sources. The availability of quality seeds is limited by low supply, high price and insufficient buyer's ability to pay. The criteria for accessibility of seeds for agricultural enterprises are the following indicators: the volume of production demand for seeds, ease of purchase and price adequate to the enterprise's capabilities.

To form the price of grain seeds and ensure the full functioning of the market environment, it is possible to calculate the standard cost, purchase price for the plant and selling price of 1 tonne of winter wheat seeds with the involvement of farmers in the region (Fig. 1). The calculation methodology is universal for cereals, legumes and oilseeds.

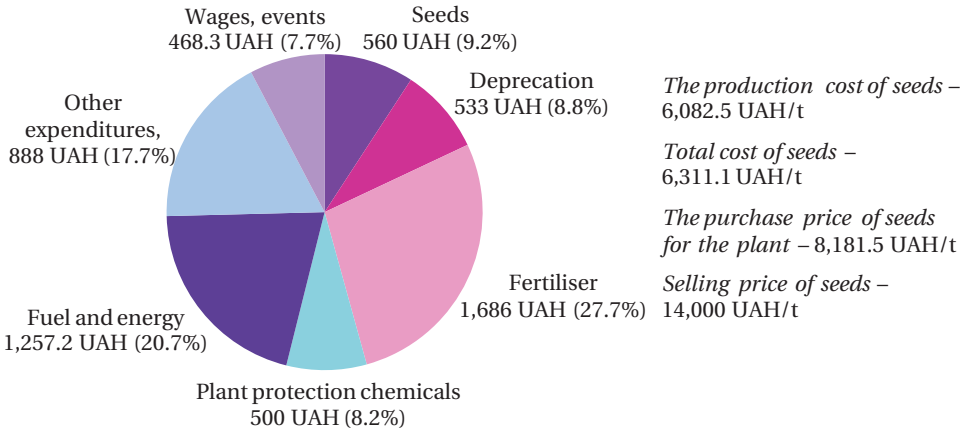

Figure 1. The structure of the standard cost and price of 1 tonne of winter wheat seeds for farmers, the purchase price for the plant and the selling price for agricultural producers as of 01.10.2023
Source: calculated by the authors

Strategic areas of development aimed at meeting the needs of agricultural production should include: the development of regional variety selection for specific natural conditions; ensuring the growth of the human resources of research institutions; balancing supply and demand using economic levers; and ensuring commercialisation and profitability of seed production. In developing countries, the share of seed products in the commercial seed market is quite small and often meets no more than 10% of the needs of agricultural enterprises (Qadir *et al.*, 2024).

At the current stage of seed production development, several issues of agronomic, technical and technological, socio-economic origin, etc., significantly addressed the volume of seed production and sales. In the process of creating and distributing seed value, the main ones are the lack of a well-developed national policy for the development of the industry and the formation of seed producers' income; low productivity of seed production and limited business access; limited horizontal links between actors and access to foreign markets.

A. Fugeray-Scarbel & S. Lemarié (2024) analysed the drivers of new variety development and marketing. The authors analysed all links in the value chain from breeding a new variety to the production of finished crops and their further processing. A comparison is made between the most common and minor crops – wheat and peas. Comparison of crops with different market sizes was used to track each link of value creation in the production and sales process through the impact of this parameter on each of the actors (breeding institutions, seed traders, agricultural enterprises, elevators and the processing industry). The influence of market size on the strategy of each of the actors involved in value creation is determined, which necessitates the inclusion of a mechanism of self-reinforcement through interaction between them.

Seed producers should retain a certain portion of the profit from the sale of seeds after harvesting, and send the seeds to processing companies that process, treat and package them. Royalties that will be paid in the future to the owner of the variety in the total costs of the seed plant were also included. The proposed scheme is shown in Figure 2.

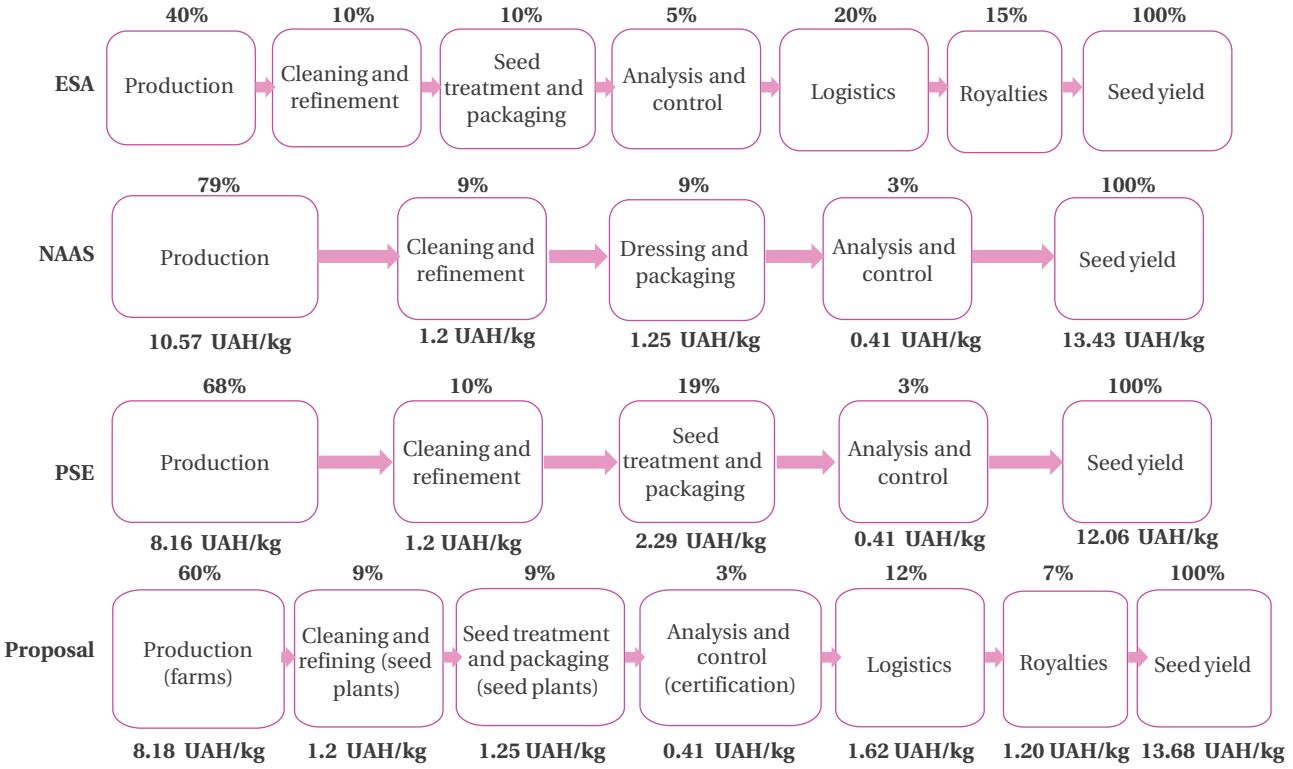

Figure 2. Actual and proposed value chains of conditioned seed production in Ukraine and the world
Notes: NAAS – National Academy of Agrarian Sciences of Ukraine; ESA – European Seed Association; PSE – private seed enterprise
Source: calculated by the authors

This will ensure the transition of seed production in Ukraine from artisanal to a more professional level. The use of the successful experience of European countries (Lazarieva, 2022) in supporting seed production will increase the solvency of producers and consumers of conditioned seeds at all stages of their marketing; develop a mechanism for managing the seed market to increase the supply of conditioned seeds, reduce their price, improve their quality and range; attract a significant number of farms to produce nationally selected seeds in different climatic zones of Ukraine; create regional (oblast) seed production systems, which should include a seed breeding centre, seed plant, and regional union of seed producers.

Proposal 2. Given the limited budgetary funding and protection of the interests of Ukrainian breeding centres and breeders, it should be mandatory to make royalty and breeding payments as the main investment component of further development of seed production of cereals, legumes and oilseeds. Based on its research, the European Seed Association (Euroseeds, n.d.) identifies royalties as a component of the main costs of selling conditioned seeds in the amount of 15% of total costs (Fig. 3). The other components are seed production costs – 40%, cleaning, processing, treatment and packaging – 20%, logistics – 20% and analysis and control – 5%.

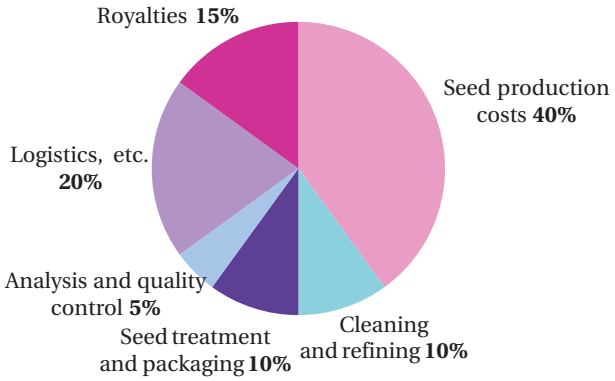

Figure 3. Cost components in the cost of conditioned seeds
Source: created by the authors based on The voice of the European Seed Sector (n.d.)

Analysing the main components of the cost of creating conditioned seeds, it is possible to note that the cost of seed production is only 40% of the total cost, the rest is added value. N. Kalaitzandonakes & A. Magnier (2013), E. Gimon *et al.* (2013), and Y.A. Yigezu *et al.* (2018) argue that the genesis of national seed systems is hampered by global challenges. Multinational companies have contributed to the monopolisation of the seed market by imposing excessive licence fees and controlling food resources at the global level. The result is overcharging farmers and having devastated environmental impacts on agriculture. The private seed companies that dominate the seed market are changing the goals of breeding programmes and setting new market trends. Their research in breeding activities is innovatively aimed at creating seed traits that would maximise their profits. This is primarily the creation of hybrids of profitable crops, such as vegetables.

Seed production is a highly profitable industry. Therefore, significant amounts of private investment are channelled into the seed business every year. According to the Ministry of Agrarian Policy and Food of Ukraine (2024b), it is projected that the value of seeds will increase from 2.7 to 4.2 billion USD in 10 years. The average cost of seed in Ukraine will increase to 110 USD per hectare over this period, or 35% from the level of 2023 (80 USD per hectare). The construction of new seed plants alone is expected to attract 84.0 million USD of investment resources annually.

According to the authors of the study, investment support for seed production of cereals, legumes and oilseeds is up to 10.0 billion UAH, or approximately 300.0 million USD annually (Table 1). Potential royalty and breeding payments are presented in Tables 5 and 6. Annual payments for varieties of Ukrainian breeding amount to 80-100 million UAH, with a potential royalty of 5.2 billion UAH, of which about 800 million UAH from the use of seeds of Ukrainian breeding, which could be used for the development of breeding and the use of new varieties and hybrids. Therefore, annually, Ukrainian crop producers pay about 5.0 billion UAH to support and invest in foreign science that produces varieties of domestic selection.

Table 5. The cost of conditioned seeds and royalty calculation in Ukraine in 2013

Cultures	Seeds produced, thousand tonnes	Cost of seeds, million UAH	Area planted, thousand ha	Royalties, million UAH		Royalties per 1 ha of crops, UAH
				total	including those from Ukrainian breeding	
winter wheat	78.8	1182	394	118.2	56.9	300
spring barley	10.7	149.8	59.4	14.98	5.3	252.1
winter barley	12.2	170.8	67.8	17.08	3.5	252.1
corn	103	22,660	4,923.6	3,399	611.8	690.3
winter rye	5.9	82.6	32.8	8.26	1.0	252.1
buckwheat	0.7	28	8.8	2.8	2.8	320.0
millet	0.6	21	12	2.1	2.1	175.0
oats	0.9	12.6	5.0	1.26	1.3	250.7
triticale	0.4	5.6	2.2	0.56	0.6	252.5
spring wheat	5.3	74.2	26.5	7.42	1.7	280.0
peas	6.1	122	20.3	12.2	2.0	600.0
Total cereals	**224.6**	**24,508.6**	**5,552.4**	**3,583.9**	**688.9**	×
soy	22.6	678	188.4	67.8	4.5	359.9
winter rape	5.1	1,530	1,020	229.5	22.5	225.0
sunflower	35.7	8,925	5,100.0	1,338.75	89.7	262.5
Total oilseeds	**63.4**	**11,133**	**6,308.3**	**1,636.1**	**116.7**	×
Total	**288**	**35,641.6**	**11,860.7**	**5,219.9**	**805.5**	×

Notes: × – data is not calculated
Source: calculated by the authors based on data from the Ministry of Agrarian Policy and Food of Ukraine (2024a)

Table 6. Amounts of royalties and breeding payments for grains, oilseeds and pulses (based on the example of 2023 sowing) in Ukraine

Cultures	Royalties per 1 ha of crops, UAH	Breeding payments per 1 ha of crops, UAH (50% of royalties)	The area where selection payments can be made, thousand hectares	The potential annual amount of selection payments, million UAH
winter wheat	300.0	150.0	2,971.1	445.7
spring barley	252.1	126.1	198.7	25.0
winter barley	252.1	126.1	366.6	46.2
winter rye	252.1	126.1	5.9	0.7
buckwheat	320.0	160.0	106.9	17.1
millet	175.0	87.5	66.9	5.9
oats	250.7	125.4	47.4	5.9
triticale	252.5	126.3	3.2	0.4

Table 6, Continued

Cultures	Royalties per 1 ha of crops, UAH	Breeding payments per 1 ha of crops, UAH (50% of royalties)	The area where selection payments can be made, thousand hectares	The potential annual amount of selection payments, million UAH
spring wheat	280.0	140.0	112.7	15.8
peas	600.0	300.0	117.9	35.4
soy	359.9	180.0	1,475.2	265.5
Total	×	×	**5,472.5**	**863.6**

Notes: × – data is not calculated
Source: calculated by the authors according to the Ministry of Agrarian Policy and Food of Ukraine (2024), State Statistics Service of Ukraine (2024)

In addition, the transition to breeding payments could additionally provide Ukrainian breeders with over 700 million UAH, even if breeding payments are no more than 50% of the royalty value. Comparing France, Germany and Ukraine – countries with similar crop areas – the amount of royalties paid is very different. Annually, 125 million euros are paid in royalties and breeding fees in France, 65 million euros in Germany, and only 2.5-3 million euros in Ukraine (Zakharchuk *et al.*, 2024). Compared to European countries, royalty and breeding payments in Ukraine are virtually non-existent and payments for intellectual property protection are several times lower.

There are no state programmes to support the development of Ukrainian breeding and seed production of cereals, pulses and oilseeds. State programmes to finance plant breeding were in place only until 2011. In 2018-2019, the Programme "Partial compensation (80%) of the cost of seeds of agricultural plants of Ukrainian breeding purchased from seed producers of the basic, certified category (excluding VAT, but not more than 80 thousand UAH per farm)" was in effect but was cancelled by Resolution of the Cabinet of Ministers of Ukraine No. 106 (2018). This may lead to a reduction in the share of Ukrainian varieties on the seed market. Nevertheless, there is a need to improve the process of collecting licence fees, depending on the actual consumption of seeds under licence and sublicence agreements and breeding fees for Farm Saved Seed – seeds for in-house use.

Using the Canadian (French) mode of collecting breeding fees (per tonne of marketable grain sold), the Polish or German scheme (per 1 ha of marketable crops) as a basis, in any case, revenues to breeders and breeding institutions could amount to between 0.7 and 1.0 billion UAH. At the same time, each owner of a variety should be guaranteed protection of its intellectual property. For this purpose, agricultural producers need to declare varietal production crops, register licensing agreements and collect royalties, and control, form and maintain a database of seed and commercial crops by varieties and hybrids. This will help to increase the flow of investment resources to produce new high-yielding varieties of Ukrainian breeding.

For the restoration of Ukrainian breeding and the future, including proposals for optimising the value chain of seed production in Ukraine and the main areas of investment in the development of breeding seed cultivation/production, it is necessary to improve the technical and technological support of breeders and scientific breeding institutions, develop recommendations on modern technologies for growing seeds in different natural and climatic zones of the country; improve the legal and organisational aspects of the activities of NAAS research institutions based on public-private partnership; gradually adapt Ukrainian seed production to global requirements for seed production and certification, join all OECD seed modes; strengthen the export potential of Ukrainian seeds of national selection, increase their competitiveness and eliminate bureaucratic and logistical barriers to the supply of seeds to the global market.

Conclusions

The study substantiated that the creation of a sustainable investment and innovation seed system is necessary to create new varieties of crops to meet the needs of agricultural enterprises. The study determined that 496 seed production entities operate in the Ukrainian seed system, including 46 seed plants. In 2023, the register contained 5,000 seed varieties and hybrids, and only 3,200 of them were used for primary seed production. The volume of seed imports in terms of value is 4.5 times higher than exports and in 2023 amounted to 350 million USD.

The calculations confirmed that in the structure of the standard cost of seeds of additional categories, the largest share is accounted for by mineral fertilisers (22.8%), fuels and lubricants (20.1%), rent for the use of land plots (10.8%), seed material (9.2%) and depreciation of fixed production assets (8.8%). It is proved that in the structure of the value added of conditioned seeds, the largest share is made up of seeds that come from the enterprises that grow them for processing. For enterprises that are members of the European Seed Association (EU countries), this share is 40%, institutions of the National Academy of Agrarian Sciences – 79%, and private enterprises – is 68%, according to the authors' calculations, this share should be optimally 60% for Ukraine. Other components of value added are less significant in the final price and account for 5-10% of the total value added. At present, neither the institutions of the National Academy of Agrarian Sciences nor private enterprises of Ukraine include royalties and breeding payments in the total cost of conditioned seeds.

According to the calculations, the potential royalties from the use of conditioned seeds of cereals, pulses and oilseeds could amount to 5.8 billion UAH, including approximately 900 million UAH for Ukrainian varieties. The estimated potential amount of breeding payments could be over 700 million UAH. This is a substantial investment that could become innovative in supporting Ukrainian breeders. Ukraine could become one of the most

innovative countries in the genetic, breeding and seed sector with significant achievements in the protection of plant variety rights in terms of intellectual property, but a more detailed review of these issues will require further research in the future.

Acknowledgements
None.

Conflict of interest
None.

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► **Анотація.** Метою статті була оцінка інвестиційно-інноваційного забезпечення насінництва, розробка заходів з підвищення ефективності й пропозицій захисту прав селекціонерів щодо отримання роялтних та селекційних платежів. У дослідженні використано монографічний, економіко-статистичний, табличний та графічний, емпіричний, порівняльний аналіз, прогнозування, абстрактно-логічний методи. У результатах статті розглянуто організацію і функціонування насіннєвої галузі в Україні. Досліджено основні показники розвитку насінництва зернових, бобових та олійних культур, виявлено випереджальні темпи розвитку імпорту над експортом і, відповідно, імпортна надзалежність України, що призводить до вразливості на світовому насіннєвому ринку. Узагальнено динаміку витрат на виробництво насіння зернових, олійних та бобових культур, розраховано нормативну собівартість насіння пшениці. Розроблено пропозиції щодо захисту прав селекціонерів в частині захисту прав інтелектуальної власності на сорти рослин, враховуючи передовий досвід європейських країн. Побудовано фактичні та запропоновано власні ланцюги доданої вартості виробництва кондиційного насіння в Україні. Найвагомішими показниками зростання насінництва в Україні є обсяг посіву (2300-2500 тис т.), експорт (77 млн дол. США), імпорт (350 млн дол. США). В структурі собівартості всіх виробників найбільшу частку становить виробництво насіння, яке надходить на підприємство на доробку (40-80 %, залежно від категорії виробників). Обсяг сплаченого роялті щорічно становить в середньому 90 млн грн. при потенційно можливому 900 млн грн. Селекційні платежі в Україні не сплачуються взагалі, хоча могли б становити 725,7 млн грн

► **Ключові слова:** кондиційне насіння; собівартість; комерціалізація; селекційні установи; додана вартість; оптимізація