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**THE FORMATION OF THE PRODUCTIVITY OF WINTER WHEAT
DEPENDING ON THE LEVEL OF THE CONTAMINATION OF CROPS
UNDER THE CONDITIONS OF THE APPLICATION OF
RESOURCE-SAVING TECHNOLOGY IN THE CONDITIONS OF
SOUTHERN UKRAINE**

S u m m a r y

Background. The aim of the study was to determine the effect of different levels of weed infestation on the morphological and physiological characteristics and structural elements of the yield of the winter wheat Duma Odeska variety in the conditions of the Southern Steppe of Ukraine.

Results and Conclusions. A data analysis showed that the winter wheat Duma Odeska variety formed seedlings even with a lack of soil moisture (moisture at a depth of 10 cm – 13.5 %) and demonstrated intensive development of leaf mass up to $33 \div 35 \text{ g/m}^2$ in the shoot phase. In the tillering phase, the average number of productive stems was $3 \div 5 \text{ pcs./plant}$, and the tillering coefficient was 3.2, which contributed to early row closure and partial weed suppression. At a medium level of contamination ($150 \div 200 \text{ plants/m}^2$), the main productivity indicators decreased moderately: the number of productive stems was 518 pcs./m^2 , the number of grains per year was 32.2, the mass of 1,000 grains was 41.1 g, and yield was 4.75 t/ha. With high contamination (more than 250 plants/m^2), the number of productive stems decreased to 446 pcs./m^2 , the number of grains per ear to 29.4, the mass of 1,000 grains to 38.7 g, and yield to 3.92 t/ha. The following types of weeds caused the greatest damage: common millet, wild oats, creeping mustard, common poppy, nettle and fescue. These species dominated the three waves of weed germination during the growing season. The variety showed relative drought and heat tolerance, including the preservation of the assimilation surface under temperature stress up to $+35 \div +36 \text{ }^\circ\text{C}$ in the earing phase and root penetration to $120 \div 140 \text{ cm}$. However, the positive characteristics of the variety did not fully compensate for weed pressure above 200 plants/m^2 , especially under the conditions of a moisture deficit. The practical importance of the study lies in identifying weed-density thresholds that can guide control measures in the Southern Steppe of Ukraine.

Key words: ontogenesis of culture, plant protection, crop structure, technological approaches, agroecological conditions, Duma Odeska

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Introduction

The relevance of the subject is due to the instability of climatic conditions in the Steppe zone of Ukraine, which is becoming the main limiting factor in the cultivation of winter wheat. The increasing frequency of dry periods, uneven precipitation distribution and rising average annual temperatures negatively affect plant growth and development. In the conditions of water scarcity, the ability of varieties to maintain yields at a stable level is important. This determines the need for systematic research of drought-resistant genotypes and actualizes the approach to selection for adaptability. The issue is caused by insufficient theoretical consistency in approaches to exploring the adaptive potential of winter wheat varieties in the conditions of climate instability. The difficulty lies in the limited interdisciplinary models that combine biological characteristics with agroclimatic factors, and in the fragmentary criteria for assessing drought resistance, which makes it difficult to develop effective breeding and agronomic strategies for risky farming regions.

Based on an analytical review, the results of Tsyliuryk et al. [58] were presented, which highlight the current directions of development of tillage systems. The paper substantiates the expediency of minimizing mechanical impact to stabilize agricultural landscapes. In the course of field research, Pochkolina et al. [43] revealed the dependence of wheat yield on the type of cultivation under the conditions of short-rotation crop rotation. The highest indicators were obtained against the background of combined loosening with moisture retention in the arable layer. Considering phytosanitary risks, Babych et al. [2] analyzed the ways to control nematodes in grain agrocenoses. A positive effect was provided by the use of crop rotations with the inclusion of pathogen-resistant crops. Within the framework of the technological approach of Kumar et al. [25], agricultural practices before and after harvesting management were analyzed. Integrated solutions showed the highest efficiency in the conditions of increased drought. Based on a system analysis, Das et al. [7] summarized the impact of conservation farming on yield and resource saving. It was determined that reducing cultivation contributes to preserving the soil structure and reducing CO₂ emissions. As a result of a multidimensional assessment of Leharwan et al. [28], the effect of crop residue management in the rice–wheat system was established. The largest yield increases were recorded in a combination with zero cultivation and mulching. In the context of the review developments by Navi et al. [35], the effectiveness of approaches to weed control in conservation farming systems was assessed. Various combinations of mechanical and biological methods showed a noticeable reduction in the phytotoxic load on the crop.

International studies have also confirmed that weed infestation and wheat productivity are influenced by predecessors, tillage systems, cover crops, herbicide intensity and integrated depletion of the weed seed bank [3, 9, 61, 48, 27, 30, 31, 66]. According

to the conservation system, a decrease in weed density was recorded while maintaining crop productivity. Based on experimental data provided by Woźniak [62], the dependence of contamination and quality characteristics of wheat grain on the previous crop are described. After legumes, there were fewer weeds in the crops and stable yield indicators. Gandía et al. [13] demonstrated the influence of a combination of hydro-thermal conditions and agrotechnical background on the structure of weed groups. Crop rotation and moderate cultivation systems contributed to the regulation of unwanted vegetation biomass. Within the framework of an applied research by Yanev et al. [63], the effectiveness of several herbicide combinations in mixed contamination was compared. The combined application of the action on cereals and dicotyledonous species allowed controlling the number of the main dominants. According to Zhang et al. [66], the depletion of the weed seed bank in the soil proved to be an effective means of reducing contamination in wheat crops. The introduction of integrated methods made it possible to reduce the pressure of sprouting competitors without significantly affecting the main crop.

The species composition of weeds at all stages of wheat vegetation remains insufficiently examined – most of the available work focuses only on the initial stages of crop development (germination – tillering), while further stages, including tubing, earing and the pre-harvest phase, are often disregarded. This complicates the formation of a complete picture of the seasonal dynamics of contamination, the interaction between cultivated and weed species, and the effective planning of integrated protection systems throughout the growing season. The study aimed to establish the dependence of the level of contamination of winter wheat crops on the morpho-physiological characteristics of the variety and to assess its influence on the elements of the crop structure in the conditions of the Steppe of Ukraine.

Materials and methods

The study was analytical and summarizing in nature, and was based on materials collected and published within the Mykolaiv region, in particular, at the Educational, Scientific and Practical Center of Mykolaiv National Agrarian University, which ensured that the regional agro-ecological conditions of the Steppe zone of Ukraine were considered. The choice of the Duma Odeska variety was due to its stable yield and relative adaptability to agroclimatic risks, which makes it an illustrative example for analyzing the possibilities of improving the efficiency of growing winter wheat in the zone of risky farming. In the course of the work, methods of systematization and comparative analysis were used, which provided for comparing the morpho-biological characteristics of the variety according to the Register of Plant Varieties Suitable for Distribution in Ukraine [52]. Such characteristics as the duration of the growing season, plant height, ear length, a mass of 1,000 grains, grain nature, raw gluten content

and average yield under various technological conditions were evaluated. The method of generalizing literary data was used in the analysis of long-term materials from the Odesa State Agricultural Research Station of the National Academy of Agrarian Sciences (NAAS) [36], herbological reference books by Kachanova [19] and the NAAS catalogue of innovative developments for 2020 [7]. A classification analysis method based on the provisions of the European Weed Research Society (EWRS) was applied to classify weeds according to their morphological-ecological groups and phases of their threatening impact [11].

In this article, the resource-saving technology is understood as a combined cultivation system based on reduced mechanical tillage, the preservation of mulch or crop residues on the soil surface, local fertilization, partial mechanical weed control and reduced chemical load. Herbicide treatment was not treated as a separate experimental factor in the resource-saving system; reduced chemical load refers to limited, need-based use of registered plant protection products rather than continuous full-dose herbicide protection. Exact application rates were not recalculated because the study is analytical and summarizes published and registered materials rather than reporting a new field trial.

The method of generalized interpretation of physiological and biological indicators based on the specialized work of Hutianskyi et al. [17] was used to characterize the morpho-physiological characteristics of wheat, including the assimilation surface area, photosynthetic potential, transpiration coefficient and chlorophyll content. No direct SPAD measurements were conducted within this study; therefore, the SPAD values presented in the Results should be interpreted as generalized literature-derived ranges rather than field measurements obtained by a SPAD meter. The methodological support of the study accounted for international recommendations, particularly the IPGRI protocols (International Plant Genetic Resources Institute) of Reed et al. [47], who describe standards for assessing the impact of biotic factors on cultivated plants in the field. Materials of the NSC "Institute of grain crops of the National Academy of Sciences" were also used, which highlighted the specific features of the growth and development of winter wheat plants in the conditions of Forest-Steppe and Steppe of Ukraine by Astakhova [1].

The structural elements of wheat yield (the number of productive stems, grains in the ear, the mass of 1,000 grains, the density of sowing) are considered as the basic indicators of productivity, described in accordance with methodological provisions, in particular, DSTU 7080:2009 [10], which considers the influence of the level of contamination on the formation of yield. For a comparative interpretation of the results between different technological approaches (intensive and resource-saving), the methodological foundations of the OECD were used [37], which allowed considering the phytotoxic effect of weeds or agrochemicals on cultivated plants.

Information on plant protection technologies (types of herbicides, terms of application, doses and methods of application) was based on materials from Syngenta [54] and Bayer Crop Science [4], which are adapted to the conditions of Ukraine. In addition, the regulations of the Ministry of Health of Ukraine on the registration of pesticides considered, specifically, the Register of Pesticides and Agrochemicals and the official “List of Pesticides and Agrochemicals Allowed for Use in Ukraine” [32]. This provided for the comparison of the potential chemical effect of plant protection products (PPP) for wheat, depending on the level of contamination. All collected data were processed by methods of variation statistics, followed by the standardization of indicators by the z-normalization method, enabling the comparison of data between years and experimental variants. The indicators were converted to unified units of measurement (cm, g, %, plants/m²). For a comprehensive analysis of the impact of contamination, methods using generally accepted similarity coefficients were used, identifying similarities in the structure of weeds under various agroecological conditions. Visualization was performed using Statistica 12.0 and MS Excel programs (correlation modules, charts).

Results

Analysis of productivity and crop structure of winter wheat

For a comprehensive analysis of the morpho-physiological and productive properties of the Duma Odeska winter wheat variety, a wide range of scientific and practical sources for the years 2020 ÷ 2024 was processed. According to the literature data of the state service of Ukraine for food safety and consumer protection [52], it is specified that in the germination phase, the Duma Odeska winter wheat variety is characterized by simultaneous germination even with low soil moisture and minimal seed sealing depth. During the first 25 ÷ 30 days after the emergence of seedlings, the intensive development of the leaf apparatus is observed, which contributes to the rapid closing of row spacing and partial suppression of weeds. The leaves have a rich green color with a pronounced waxy coating, which reduces transpiration.

In the tillering phase, three ÷ five productive stems are formed, the number of which depends on the level of moisture supply and nutrition. The bush is a semi-erect, of moderate density, which creates favorable conditions for lightening the lower tiers of leaves and reduces the likelihood of fungal infections. The root system is represented by a fibrous type with a penetration depth of 120 ÷ 140 cm, which ensures the use of moisture from deeper layers of the soil. The stem is strong, of medium thickness (3.5 ÷ 4.5 mm), and has increased resistance to lodging with high sowing density. The average height of plants is 95 ÷ 105 cm, the ear is double-row, elongated (8 ÷ 10 cm), with well-formed grains. Spikelet scales have awns of medium length, sometimes

curved, contributing to uniform maturation. The grain is characterized by a red color and an elongated oval shape; a mass of 1,000 grains – $42 \div 46$ g; nature – $780 \div 800$ g/L. The raw gluten content reaches $28 \div 30$ %, which provides good baking properties [5, 36].

The phase of entering the tube occurs on the 150th $\div$ 160th day after sowing; earing – on the 170th $\div$ 185th day; flowering lasts $4 \div 6$ days; the grain maturation period is between 35 and 40 days. At summer temperatures above $+3$ °C, during grain filling, the leaf apparatus of the upper tier retains photosynthetic activity until the waxy ripeness phase. The variety shows relative tolerance to spring-summer drought: in the conditions of a precipitation deficit in May/June, the yield is provided at the level of $3.5 \div 4.2$ t/ha with a medium level of agricultural technology, exceeding the results of other varieties, which in similar conditions reduce the yield by $15 \div 20$ % [12, 32, 51, 57, 67]. Resistance to major diseases (powdery mildew, septoria, brown rust) is rated as above average, which is associated with the genetic characteristics of the variety and the specifics of leaf mass formation. The main pest during the period of milk ripeness is *Eurygaster integriceps* (corn bug), but due to the strong shell of the grain, its harmfulness is limited. In the conditions of the Southern Steppe of Ukraine, the variety provides a yield of $4.5 \div 5.5$ t/ha with intensive technology and $3.5 \div 4.0$ t/ha with resource-saving which indicates its stable adaptability to agroecological conditions in the south of Ukraine Dmytruk et al. [8].

This stability was due to a combination of a deep root system, optimal plant height, stem strength and high grain quality (Table 1).

Table 1. Main biological and economic characteristics of the winter wheat variety Duma Odeska in the conditions of the south of Ukraine

Indicator	Mean values	Oscillation range
Growing season [days]	$280 \div 295$	-
Number of productive stems [pcs./plant]	$3 \div 5$	-
Plant height [cm]	$95 \div 105$	$90 \div 110$
Ear length [cm]	$8 \div 10$	$7.8 \div 10.2$
Mass of 1,000 grains [g]	$42 \div 46$	$41 \div 47$
Grain nature [g/L]	$780 \div 800$	$775 \div 805$
Raw gluten content [%]	$28 \div 30$	$27 \div 31$
Average yield [t/ha] (intensive technology)	$4.5 \div 5.5$	-
Average yield [t/ha] (resource-saving technology)	$3.5 \div 4.0$	-
Depth of root penetration [cm]	$120 \div 140$	-

Explanatory notes: summarized by the authors based on [8, 32, 36, 52]

In general, Duma Odeska was distinguished by a combination of productivity and adaptability to the arid conditions of southern Ukraine. At the same time, these ad-

vantages should be interpreted as relative rather than absolute. The variety did not fully compensate for weed pressure above 200 plants/m² under a moisture deficit, and its disease resistance was described as above average rather than complete. Therefore, the variety remains suitable for resource-saving systems only when weed pressure, sowing time, nutrition and phytosanitary monitoring are controlled.

Analysis of the species composition of weeds on winter wheat crops

In dry years (2020, 2022 and 2024), weeds not only competed with wheat for moisture but also suppressed its development due to allelopathic influences. The most pronounced effects were observed for weed cover densities of more than 300 plants/m², which were recorded mainly in thickened crops without effective control. Under such conditions, intense competition for resources led to a noticeable decrease in wheat biomass and productivity. In the structure of the weed flora, there were three main waves of germination – early, medium and late. The early wave, which formed within two ÷ three weeks after sowing, was the most threatening. During this period, mass emergence of common millet (up to 250 ÷ 300 plants/m²), oatmeal (more than 300 plants/m²), creeping mustard (up to 220 plants/m²) and common poppy (up to 250 plants/m²) was observed. These species formed shading for young wheat plants, actively consumed soil moisture from the upper layers and influenced the crop access to nutrients [19].

The medium wave of germination (tillering phase) was dominated by nettle (150 ÷ 200 plants/m²) and common fescue (up to 150 plants/m²), which, although they had less growth dynamics, still affected the state of wheat due to the dense root layer and the shadow effect. The late wave was less intense, but in the years with warm autumn, some species continued to grow until the pupation phase. The level of contamination greatly depended on the time of sowing. In the case of early sowing (the second decade of September), weeds had lower density – up to 150 plants/m², which corresponded to 15 ÷ 18 % of the area. This was explained by the fact that wheat seedlings outstripped the wave of weed germination and formed dense row spacing. However, with late sowing (early October), the density of weeds increased to 250 ÷ 300 plants/m², and the level of contamination exceeded 30 ÷ 35 % of the field area [6, 60]. Predecessors also affected the density of weeds: after corn and sunflower, the density of weed vegetation could exceed 300 plants/m², which is associated with an increased seed supply in the soil. After legumes (peas, lentils) or steam precursors, the level of contamination was recorded at the level of 12-17 %, with the typical density of no more than 120 ÷ 150 plants/m², which confirmed the positive effect of crop alternation in crop rotation. The Duma Odeska variety showed certain tolerance to competition with weeds due to the rapid development of the leaf apparatus and the ability to form dense row spacing. However, with the density of more than 200 weeds/m², espe-

cially in the conditions of moisture deficiency, even this variety could not fully compensate for pressure. In such situations, the yield decreased by $0.8 \div 1.2$ t/ha compared to net crops [11].

A clear link was also established between the level of contamination and the structural elements of the crop. As the number of weeds increased, the number of productive stems, the mass of 1,000 grains, the length of the ear and the number of grains in the ear decreased, according to Konovalova et al. [23]. Specifically, with the contamination of more than 30 %, the mass of 1,000 grains decreased by $4.3 \div 5.1$ g, the length of the ear – by $1.1 \div 1.6$ cm and the number of grains in the ear decreased by $4 \div 6$ pcs. compared to optimal conditions (Table 2).

Thus, the structure of contamination of winter wheat of the Duma Odeska variety was dominated by six ÷ eight species of highly harmful weeds that operated at different stages of vegetation. Timely detection of these species and the assessment of the intensity of contamination is a key task when planning control measures. The use of integrated control systems that consider the type of weed, its development cycle and harmful potential reduces the risk of crop loss without excessive use of herbicides.

Influence of weed vegetation on photosynthetic activity of winter wheat

One of the first consequences of contamination is a decrease in the area of the leaf surface of one stem. In pure crops with a low level of contamination (up to 100 weed plants/m²), the leaf surface area averages $48 \div 52$ cm², with an average level (150 ÷ 200 plants/m²) – $43 \div 46$ cm², while at a high level (more than 250 plants/m²) – decreases to $37 \div 39$ cm², which corresponds to the losses of 20 ÷ 25 %. This results from a decrease in photosynthetic activity due to shading and a lack of moisture. In the case of using a resource-saving technology with partial mechanical weed control and local fertilization, this indicator is kept at the level of $45 \div 48$ cm² even with medium contamination, which indicates a decrease in interspecific competition for light. Under the conditions of complete herbicide protection, the leaf surface area consistently exceeds 50 cm², which creates the most favorable conditions for photosynthesis [14, 17, 38, 45].

As noted in the scientific literature by Reed et al. [47], in addition to reducing the area, there is accelerated ageing of lower leaves, which lose their green color earlier by seven ÷ ten days, especially in the years with a lack of precipitation. It is known that under the conditions of resource conservation, partial shading is compensated by better preservation of lower leaves due to moisture stabilization, while, according to scientific works, intensive technology provides the greatest duration of photosynthetic activity due to complete control of contamination.

Table 2. Harmfulness of the main weeds on winter wheat crops Duma Odeska

Type of weed	Plant type	Germination period	Typical density (plants/m ²)	Area contamination (%)	Effects on wheat	Mechanism of negative action
Wild oats (<i>Avena fatua</i>)	Cereal	Early	> 300	30-35 (for late sowing)	Reducing the weight of 1,000 grains by 4.3 ÷ 5.1 g; reducing the length of the ear by 1.1 ÷ 1.6 cm	Moisture depletion, active competition, allelopathy
Common millet (<i>Chenopodium album</i>)	Dicotyledonous	Early	> 250	30 ÷ 35	Reduction of the number of grains in the ear (by 4 ÷ 6 pcs.), tillering delay	Shading of seedlings, depletion of the upper layers of the soil
Common poppy (<i>Papaver rhoeas</i>)	Dicotyledonous	Early	up to 250	up to 30	Reduction of stem density and lower number of productive stems	Rapid nitrogen consumption, seedling displacement
Nettle (<i>Urtica dioica</i>)	Multi-year	Medium – late	150 ÷ 200	20 ÷ 25	Decrease in plant height; deterioration of aeration in crops in the grain filling phase	Root competition, shadow in the second tier
Fescue (<i>Festuca pratensis</i>)	Cereal	Late	≤ 150	15 ÷ 18 (early sowing)	Slight reduction in grain weight at the density of up to 150 pcs./ m ²	Late pressure on weakened crops
Creeping mustard (<i>Polygonum aviculare</i>)	Dicotyledonous	During the growing season	180 ÷ 220	30 ÷ 35	Reduced productivity by 0.8 ÷ 1.2 t/ha when competition is faced >200 pcs./m ²	Solid coating, root nutrition suppression

Explanatory notes: summarized by the authors based on [6, 11, 19, 23]

The deterioration of food conditions in the conditions of competition with weeds also affected the formation of tillering nodes. According to the preliminary study [1], under the conditions of low contamination (up to 100 plants/m²), the average number of formed tillering nodes is $2.7 \div 3.1$ pcs./plant at a medium level – reduced to $2.3 \div 2.6$ pcs./plant, and at high – up to $1.9 \div 2.2$ pcs./plant. The use of resource-saving technology allows maintaining the tillering index at the level of 2.5 pcs./plant even with an average blockage, while an intensive approach provides stable values of more than 3.0 pcs./plant due to increased nitrogen availability and protection.

The estimated SPAD index, which characterizes chlorophyll content in assimilation organs, decreased under the influence of weeds. Since these values were derived from generalized literature data rather than direct field measurements, they should be interpreted as approximate ranges. Under low contamination, the estimated SPAD range was approximately $48 \div 49$ units; under medium contamination, approximately $44 \div 46$ units; and under high contamination, approximately $42 \div 44$ units. Under the resource-saving technology, the estimated range was approximately $46 \div 47$ units, while under the intensive technology, it approached 50 units [20, 34, 37, 64].

The influence of contamination was also manifested in the appearance and structure of the root system. In the case of low weed density, the depth of penetration of wheat roots reached $120 \div 130$ cm, while in the case of high contamination (more than 250 plants/m²) decreased to $85 \div 90$ cm. At the medium level, the depth was $105 \div 115$ cm. In the case of applying a resource-saving system, reduced soil compaction and mulching partially compensated for competition, reaching a depth of $110 \div 120$ cm. Generalized data indicate that under the influence of weed competition, a decrease in the SPAD index was observed, which reflects the content of chlorophyll in the leaf apparatus.

In the intensive version, the depth of penetration of the root system exceeded 130 cm, which was associated with the increased availability of moisture and nutrients in the lower horizons of Krut [24].

The accumulation of crude biomass before the grain filling phase also showed noticeable dependence on the level of contamination. In the control (low level), the total biomass of one plant reached $1.26 \div 1.35$ g/plant, with average contamination – $1.10 \div 1.18$ g/plant, while in the areas thickened with weeds (high level), this indicator did not exceed $0.91 \div 1.04$ g/plant. Under resource-saving conditions, the biomass decreased only to 1.15 g/plant, which indicated some performance retention. Under the conditions of intensive cultivation, the biomass of one plant can exceed 1.4 g, which is associated with ensuring the control of the agricultural background at all stages of vegetation [4]. The temperature gradient between the leaf surface and the air, which reflects the intensity of transpiration, also changed under the influence of contamination. In the case of low contamination, this indicator reached $3.0 \div 3.5^{\circ}\text{C}$, in the case of me-

dium contamination, it decreased to 2.2–2.8°C, while in the case of high contamination, it was only 0.8 ÷ 1.5°C. In the resource-saving system, due to the lower crop density, transpiration is maintained at 2.5 ÷ 3.0°C, and the intensive technology ensures a stable evaporation rate due to the full implementation of the leaf area, according to Panfilova et al. [40].

Table 3. Influence of contamination on morpho-physiological parameters of wheat

Indicator	Low contamination [up to 100 plants/m ²]	Average contamination [150-200 plants/m ²]	High contamination [more than 250 plants/m ²]	Resource-saving technology (reduced tillage, mulch/residue retention, local fertilization, partial mechanical weed control, reduced chemical load)	Intensive technology (complete herbicide protection, full fertilizer dose, regular weed control)
Leaf surface area [cm ²]	48 ÷ 52	43 ÷ 46	37 ÷ 39	45 ÷ 48	> 50
Number of tillering nodes [pcs./plant]	2.7 ÷ 3.1	2.3 ÷ 2.6	1.9 ÷ 2.2	~2.5	>3.0
Estimated SPAD index [units]	approximately 48 ÷ 49	approximately 44 ÷ 46	approximately 42 ÷ 44	approximately 46 ÷ 47	up to approximately 50
Root system depth [cm]	120 ÷ 130	105 ÷ 115	85 ÷ 90	110 ÷ 120	> 130
Biomass of one plant [g]	1.26 ÷ 1.35	1.10 ÷ 1.18	0.91 ÷ 1.04	~1.15	> 1.4
Temperature gradient (leaf-air) [°C]	3.0 ÷ 3.5	2.2 ÷ 2.8	0.8 ÷ 1.5	2.5 ÷ 3.0	consistently high
Evaporation rate [% relative to the control]	100	92 ÷ 95	84 ÷ 88	~95	~100

Explanatory notes: summarized by the authors based on [1, 10, 17, 24, 37, 39, 40, 47]

A decrease in these physiological parameters directly correlated with yield parameters, since both the source (photosynthetic power) and receiver (the ability of a plant to accumulate assimilants in grain) decreased. In the variants of the resource-saving technology, losses were reduced to 12 ÷ 15 % due to a reduction in the stress background, while the intensive system provided for maximizing the potential of the variety even in the conditions of increased contamination, as shown by Panfilova et al. [39]. In the conditions of weed density of more than 300 plants/m², potential crop losses reached 20 ÷ 25 %, which was critical without herbicide protection (Table 3). Con-

sequently, the contamination of winter wheat crops not only affected the structure of the crop, but also drastically worsened the morpho-physiological state of the crop. The most sensitive indicators were leaf surface area, chlorophyll content, root depth, tillering index and total biomass. Considering these parameters allows for more effective prediction of weed damage and optimizes control measures.

Influence of weeds on productive stems and grains per ear

At a low level of contamination (up to 100 plants/m²), the number of productive stems per unit area remained at a high level – 587 pcs./m², which corresponded to the optimal stem density to ensure high yield. In the conditions of the resource-saving technology, due to mulching, cover crops and reducing the frequency of mechanical processing, more stable preservation of this density was achieved even in the presence of weed foci. However, with the intensive technology based on repeated processing and application of SPR, as noted by Konovalova et al. [23], the indicator of productive stems varied more under the influence of contamination.

At a medium level of contamination (150 ÷ 200 plants/m²), the number of productive stems was reduced to 518 pcs./ m², and with high contamination (more than 250 plants/m²) – up to 446 pcs./ m², which indicated the inhibition of tillering and reduced the survival of productive stems in the stem elongation phase. In the resource-saving variants, even under these conditions, better stem preservation was observed due to less soil compaction and improved microbiological activity. A decrease in the number of productive stems was accompanied by a decrease in the number of grains in the ear. In the conditions of weak competition with weeds, this figure was 35.8 grains/ear, while in the conditions of medium contamination – 32.2 grains/ear, and in the conditions of strong – 29.4 grains/ear. Thereby, the resource-saving technology provided higher compensation capacity of plants, reducing grain losses in the ear, while with the intensive cultivation, a decrease in this indicator was more dramatic [24, 29, 44, 56].

The mass of 1,000 grains was also affected. In the control (low contamination), it was 43.9 g, which corresponded to the biological potential of the variety. At an average level of contamination, the mass decreased to 41.1 g, and at a high level of contamination – to 38.7 g. It is significant that in the conditions of resource-saving tillage, the mass of 1,000 grains decreased to a lesser extent, which is associated with better water retention capacity of the soil, the preservation of mulch and an optimal temperature regime in the grain filling zone. In total, this led to a marked decrease in the yield. If with the weed density of up to 100 plants/m², the grain yield was 5.48 t/ha, then with 150 ÷ 200 plants/ m² – it decreased to 4.75 t/ha, and with more than 250 plants/ m² – it did not exceed 3.92 t/ha, which is equivalent to the losses of up to 30 % without effective contamination control. Generalized data showed that resource-saving crops under

these conditions showed better yield stability, especially in the years with limited moisture, as shown by Hussain and Nair [15].

In addition to the absolute values, there was also the violation of a ratio between the components of the crop structure. In particular, with high weed density, the coefficient of ear sterility increased significantly, and the proportion of shrivelled grains exceeded $15 \div 18$ % of the total. This figure was lower in the resource-saving variants due to less stress during generative development, while the intensive technology was more vulnerable to the disruption of the balance of water and food elements [22, 41, 42, 59].

In the conditions of the increased contamination of winter wheat crops, it is important to search for resource-saving technologies that combine traditional and biologized elements. As noted by Shebanin et al. [50], the use of the elements of biologization in the cultivation of cereals and industrial crops contributes to the preservation of the environment in addition to improving the quality of products, which is consistent with the need to reduce the negative impact of contamination on the productivity of agroecosystems.

The contamination of winter wheat crops is one of the important environmental factors that greatly affects the vital activity of plants and their level of biosafety. Similar to other environmental hazards that, according to Shebanin et al. [49], reduce the stability of crops and worsen the conditions of their growth and development, the presence of weeds in crops creates a competitive environment, which leads to a decrease in the productivity of agroecosystems.

Increased competition also changed the architectonics of the stem: in the conditions of heavy contamination, the ear became shorter by $7 \div 11$ %, and the grain filling coefficient decreased by $12 \div 15$ % compared to the control. The resource-saving approach, due to the reduction of stress factors, provided better formation of the ear length and grain filling. The vegetative mass remained underdeveloped, and the efficiency of using productive moisture decreased due to a decrease in the total leaf surface area and SPAD index. In the resource-saving variants, there was a less intense decrease in these indicators, which is explained by the higher efficiency of using moisture and photosynthetic energy, even when competing with weeds, as shown by Moreau et al. [33].

Based on the data obtained, the level of contamination reduced the functional load of each plant, which was accompanied by a decrease in indicators associated with the formation of generative organs. In the years with a lack of precipitation in the earing – filling phase of grain, increased competition for resources was observed. The conditions of the resource-saving technology mitigated these effects due to a smaller moisture loss, better soil structure and lower biotic stress, while the intensive system was more sensitive to any deviations (Figure 1).

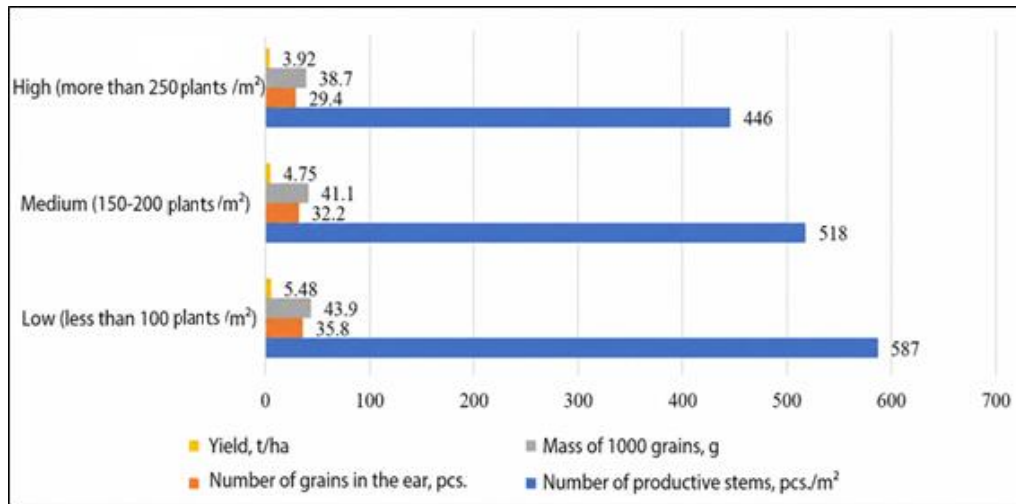


Figure 1. Dependence of crop structure elements on the level of contamination
Explanatory notes: summarized by the authors based on [15, 23, 24, 42, 50]

Thus, the results confirm that to preserve the integrity of the crop structure and realize the biological potential of the variety, it is necessary to limit the level of contamination of crops to 100 plants/ m², especially in the tillering phase, when productive stems are formed. This allows ensuring both the quantitative and qualitative characteristics of the crop, minimizing losses at each of its structural levels.

Discussion

The results obtained confirmed that the level of weed pressure during the growing season of wheat varies depending on the time of sowing and the specifics of the cultivation technology. Early crops usually form a less thickened weed environment at the initial stages of crop development, which creates prerequisites for a more efficient start and reduces competition for moisture and nutrients. The highest level of weed infestation is observed during the stem elongation phase, especially in late sowing dates and under resource-saving approaches. In such situations, the risk of reduced crop productivity increases due to the intensive use of limited resources by weed species during critical phases of organogenesis. Within the framework of intensive technology, the yield is characterized by greater stability, while the resource-saving system shows increased sensitivity to changes in the species structure of weeds.

The interpretation of these results is limited by the single-variety and single-location character of the analyzed material. The findings refer to Duma Odeska under the agroecological conditions of the Southern Steppe of Ukraine and should not be directly generalized to other varieties or regions. Potential confounding factors include

fertilizer rates, sowing dates, predecessors, moisture availability and protection regime; these factors were considered as contextual agronomic conditions rather than independent experimental variables.

Based on the results presented by Jalli et al. [18], the influence of crop rotations and tillage technologies on the formation of the phytosanitary state of spring wheat crops in temperate climates was characterized. In particular, a decrease in the number of pests due to crop rotation was described, but the assessment of the weed component was limited to the overall level of contamination, disregarding the phases of crop ontogenesis. The generalized data of the current study indicate that the species structure of weed vegetation can change during the growing season, depending on the combination of agrotechnical factors, sowing dates and protection systems. This study highlights that considering such a structure is an important element for the formation of adaptive systems for regulating phytosanitary stress in the conditions of climate instability.

As part of the publication by Kumar et al. [26], the effectiveness of agroecological methods for regulating the weed component in wheat agroecosystems under the conditions of rice-wheat crop rotation, was evaluated. Specifically, the expediency of using mulching, biological control and intermediate crops as an alternative to chemical means of protection is justified. A decrease in the total weed mass due to a crop change was confirmed, but no emphasis was placed on the species structure of weeds and their transformation during the growing season. The current study indicates the feasibility of a phased analysis of changes in weed composition during the tillering, stem elongation and milk ripeness phases as indicative periods of competition formation. The possibility of combining different protection systems with variable sowing dates for modelling phytosanitary scenarios in the context of increasing climate aridization is also considered. Such a multivariate analysis allows for assessing the potential of adaptive agricultural technologies to stabilize the phytocenosis and minimize resource losses.

Based on a generalization of Kocira and Staniak [21], the displacement of the ecological niche of individual weed species under the influence of climate change, which determines the need to introduce adaptive regulatory strategies, was underlined. The conceptual nature of the study is mainly focused on the construction of predictive scenarios for the formation of the weed component in agroecosystems. As part of this study, which concentrates on the phase structure of cultivated plant development, the emphasis is shifted to examining the dynamics of phytocenosis, considering species changes during key growing periods. Addressing the interaction between the type of technology and the ecobiomorphological characteristics of weeds helps identify the dominant groups – from wintering to late-appearing ephemeral species. Such differentiation contributes to improving the accuracy of phase-oriented integrated control strategies, where special attention is paid to predicting potential peaks of weed pressure and selecting means of influence, paying attention to the phytocenotic structure.

In the study by Stępień et al. [53], the effectiveness of crop alternation and herbicide protection in reducing the spread of chemically resistant weeds in rapeseed crops was reviewed. A positive effect of crop change is noted, but the limited analysis by one phase of development does not allow a comprehensive assessment of species shifts in the phytocenosis. There is also no cross-cultural context that would allow for tracing the specifics of weed groups in different agroecosystems. In this study, which was based on the phase structure of crop development, it was important to cover the full spectrum of ecobiomorphs at key stages of vegetation, which enabled the establishment of typical periods of intense competition between crops and weeds. Special attention was paid to the relationship between the tillage system, the germination time of certain eco-groups and their response to various protection options. Comparison with one-dimensional approaches showed the advantages of a multivariate analysis, allowing for flexible schemes of integrated regulation to be formed depending on the type of agricultural landscape and the time structure of weed pressure.

Lacroix et al. [27] analyzed the combination of mechanical processing with chemical regulatory agents as a component of the integrated wheat protection system. Data on a decrease in the total weed mass were obtained, but the analysis focuses mainly on the initial stages of vegetation without tracking changes in the structure of weed groups during the season. The constancy of sowing dates is also recorded, which narrows the possibilities of extrapolating results to a wider range of agroclimatic conditions. As part of this study, which focuses on time dynamics, it was important to consider the seasonal shift of contamination peaks depending on technological treatment options. Such shifts were found to be associated with both crop rotation options and soil moisture regimes. Reducing the species diversity of weeds under a combination of mechanical and chemical effects was considered within the framework of the concept of ecological compromise, balancing between the effectiveness of control and maintaining the stability of the agrophytocenosis. The current study provides an opportunity to complement regional integrated weed management practices in the context of green farming.

As follows from the study by Taab et al. [55], the *Trifolium resupinatum* sideration demonstrated the ability to reduce the contamination of wheat crops due to allelopathic effects. This approach is positioned as environmentally oriented, but the study pays closer attention to the impact of one crop without comparing different technological scenarios or conducting an in-depth analysis of weed communities. Instead, the present study reviewed species and phase shifts in contamination depending on the combination of sowing time and protection systems. In the current paper, it was shown that the adaptive approach allows tracking changes in dominant weed species during wheat ontogenesis. Special attention in this study is paid to the identification of species that remain viable in the late stages of vegetation and avoid traditional control

measures. Thus, the results of this study indicate that the materials obtained can be useful for the formation of targeted strategies in the most vulnerable periods of wheat development and improving the effectiveness of managing the risks of re-infestation of crops with weeds in the conditions of ecologically based agriculture.

In the AquaCrop simulation, Zhang et al. [65] identified optimal irrigation strategies for increasing winter wheat yield and water use productivity. The results confirm that an increase in irrigation rates during the critical phases of vegetation contributes to grain growth by $14 \div 18$ %. However, in modern theoretical approaches, the concept is becoming widespread, according to which yield stabilization is possible due to the rational management of agrotechnical factors – in particular, the density of standing, the level of fertilizer and the phytocenosis of sowing. Instead of directly affecting the water regime, adaptive agricultural practices are seen as a tool for achieving high efficiency in the use of natural moisture, even in the absence of irrigation infrastructure. This study confirms that agronomic parameters are the key lever for optimizing productivity in arid regions. The results of this study indicate that this approach provides practical flexibility and can be considered as an economically feasible alternative to irrigation in the face of water scarcity and climate threats.

Against the background of ecosystem interactions, Raatz et al. [46] analyzed the effect of semi-natural environments on wheat yields, linking reduced productivity to an increase in pest populations in these landscapes. It was stated that areas near biotopes have an increased risk of crop damage, despite the overall benefits for biodiversity. This study also recorded a close relationship between landscape structure and the intensity of agrotechnical intervention. Similar to these findings, the present study also took into account the factors of agrobiocenosis, but the results show no sharp correlation between proximity to natural zones and wheat weed damage – in the southern region of Ukraine, internal factors of agrocenosis were predominant. Compared to the paper of Raatz et al., this study is characterized by a higher level of data localization and analysis of not only pests, but also the full spectrum of weeds. This allows for better adaptation of the recommendations to the specific conditions of arid regions.

As part of the search for alternatives to chemical methods, Dominschek et al. [9] examined the effect of the temporary introduction of cereal and legume grass mixtures into crop rotation, proving that such biological breaks effectively reduce contamination even without herbicides. Observations confirmed a change in the species composition of weeds towards less aggressive forms. In this study, similar attention is paid to the response of the weed component to the agrophytocenotic structure of the field, however, in contrast to the work of Dominschek et al. [9], attention is focused not on changes in crop rotation, but on the seasonal dynamics and phase structure of weeds within the same growing cycle. This approach allows identifying peak periods of threat and optimizing point-based control measures. Therewith, in the absence of a rotational strategy,

the study demonstrates that effective management can improve yields even within the same culture. This provides a high practical value for farms with limited crop rotation potential.

In the conditions described by Barroso et al. [3], the effectiveness of cover crops as a means of water conservation and weed control in dry farming systems was assessed. It was discovered that the cover plant mass reduced evaporation, improved soil structure and suppressed weed germination, which contributed to an increase in the wheat yield by up to 12 %. In further theoretical developments, alternative approaches to achieving such an effect without involving green manure crops were considered. The researchers drew attention to the fact that increased crop density, agrotechnical regulation of phytocenosis and adaptive displacement of sowing dates could provide a similar result due to the internal stabilization of agrocenosis. This approach reduced the need for external interventions, did not require additional resources for cover crops and allowed integration into traditional crop rotations without complicating the technological process. The current study confirms that agrotechnical strategies for managing phytocenosis can be considered as economically feasible and scalable solutions for the regions with a lack of moisture and a high level of climate risks.

Within the optimization framework, Hussain et al. [16] investigated the effect of seeding rates and herbicide doses (with and without adjuvants) on the crop contamination and wheat yield. It was found that an increase in the crop density in combination with reduced herbicide doses contributes to effective weed control. The main focus of this study was on the phase sensitivity of the crop, but the emphasis was placed on the early stages of development without a comprehensive assessment of the species composition of weeds throughout the growing season. In contrast to this approach, in this analysis, weeds were examined bearing in mind the changes in species dominance and critical phases of competitive activity. This helped detail the time structure of threats and form the basis for phase-differentiated control.

From the standpoint of reduction, Masson et al. [30] examined how reducing the herbicide load and reducing the intensity of tillage affect the wheat yield under weed pressure. The results confirmed the possibility of crop retention by regulating exposure modes, with a focus on the type of dominant weeds. The same study did not analyze the species composition of weeds by phenological stages of the crop, which limits the ability to determine the phases with the greatest risk of loss. In contrast, this study identified species groups that are critical for individual vegetation phases, which allows forming recommendations with accurate intervention times without increasing the agrochemical load.

From an economic standpoint, the decisive issue is not only the biological suppression of weeds, but also the prevention of yield losses. In the analyzed material, the yield decreased from 5.48 t/ha under low contamination to 3.92 t/ha under high con-

tamination, which corresponds to a loss of 1.56 t/ha. Therefore, maintaining weed density below 100 plants/m² and preventing an increase above 150 ÷ 200 plants/m² is economically relevant because it preserves yield potential, while reducing the need for repeated mechanical and chemical interventions.

For the Southern Steppe of Ukraine, integrated weed management should combine sowing dates that allow wheat to close rows before the main weed wave, crop rotation with legumes or fallow precursors, monitoring of early- and medium-germinating weeds, partial mechanical control, residue or mulch retention, local fertilization and need-based herbicide use. Intervention becomes especially important when weed density approaches 150 ÷ 200 plants/m², while contamination above 250 plants/m² should be treated as a high-risk level requiring active control.

As a result of the comparative analysis, it was determined that the data obtained confirm the effectiveness of agrotechnical measures aimed at reducing the contamination of crops and increasing the productivity of winter wheat. In particular, compliance with crop rotations, the optimization of crop density, the regulation of a moisture regime and the use of cover crops contribute to improving the phytosanitary state of agrocenosis, suppressing harmful weed species and stabilizing yields without increasing the herbicide load.

Conclusions

1. The study showed that weed density can be used as a practical decision indicator for winter wheat Duma Odeska in the Southern Steppe of Ukraine.
2. The density of up to 100 plants/m² may be considered a low-risk level at which the main crop-structure indicators remain stable. The density of 150 ÷ 200 plants/m² should be treated as a warning threshold because productive stems decline to about 518 pcs./m², grains per ear to 32.2, 1,000-grain mass to 41.1 g and a yield to 4.75 t/ha. Weed density above 250 plants/m² represents a high-risk level because productive stems decrease to 446 pcs./m², grains per ear to 29.4, 1,000-grain mass to 38.7 g and a yield to 3.92 t/ha. Therefore, weed control should be prioritized before the crop passes from tillering to stem elongation, especially when early-germinating weeds dominate and a moisture deficit is expected.
3. A resource-saving technology can mitigate part of the negative effect through reduced tillage, mulch/residue retention, local fertilization, partial mechanical weed control and reduced chemical load, but it cannot replace timely integrated weed management.
4. The main limitation of the study is that the analysis is based on one variety and regional materials from the Southern Steppe of Ukraine; a fertilizer regime, sowing date, predecessor and protection system may modify the relationships observed.

Further studies should test the proposed thresholds in multi-variety and multi-location field experiments.

References

- [1] Astakhova Y.V.: Features of growth and development of winter wheat plants depending on the variety, sowing time, and predecessor in the northern Steppe of Ukraine. *Grain Crops*, 2022, 6(1), 140-147.
- [2] Babych A., Babych O., Havryliuk O., Statkevych O., Dziuman Y., Litvinov D., Zavgorodnyi V., Kaduk V., Prichodko D.: Managing populations of cyst-forming nematodes in agroecosystems of field crops. *Biosyst. Divers.*, 2024, 32(2), 203-209.
- [3] Barroso J., Reardon C.L., Singh S., Machado S., Gourlie J.A., Namdar G.F., Oreja F.H., Pritchett L.C., Kriete L., Calderon F.J., Berry P.A., McGee R.J., Durfee N., Adams C.B., Hagerty C.H.: Biomass production, weed suppression, and soil water use of cover crops in dryland wheat production systems. *Agron. J.*, 2025, 117(2), #e70053.
- [4] Bayer Crop Science. <https://www.bayer.com/en/>.
- [5] Bulgakov V., Adamchuk V., Arak M., Nadykto V., Kyurchev V., Olt J.: Theory of vertical oscillations and dynamic stability of combined tractor-implement unit. *Agron. Res.*, 2016, 14(3), 689–710.
- [6] Catalogue of Innovative Developments of the National Academy of Agrarian Sciences, 2020. [http://naas.gov.ua/upload/iblock/081/Katalog-2020_ToPress\(1\)_p001-120.pdf](http://naas.gov.ua/upload/iblock/081/Katalog-2020_ToPress(1)_p001-120.pdf).
- [7] Das T.K., Ghosh S., Das A., Sen S., Datta D., Ghosh S., Raj R., Behera B., Roy A., Vyas A.K., Rana D.S.: Conservation agriculture impacts on productivity, resource-use efficiency and environmental sustainability: A holistic review. *Indian J. Agron.*, 2021, 66(5), 111-127.
- [8] Dmytruk Y.M., Palamarchuk R.P., Zhukova Y.F., Stepanenko N.V.: Pedotransfer functions for predicting organic carbon content in typical and ordinary chernozems based on the example of the Left Bank Forest-Steppe of Ukraine. *Agrochemistry Soil Sci.*, 2025, 98, 19-35.
- [9] Dominschek R., Barroso A.A.M., Lang C.R., de Moraes A., Sulc R.M., Schuster M.Z.: Crop rotations with temporary grassland shifts weed patterns and allows herbicide-free management without crop yield loss. *J. Clean. Prod.*, 2021, 306, #127140.
- [10] DSTU 7080:2009. Soil quality. Conducting field experiments. https://online.budstandart.com/ua/catalog/doc-page.html?id_doc=58626.
- [11] European Weed Research Society, 2024. <https://www.ewrs.org/en/>.
- [12] Floqi T., Shumka S., Malollari I., Vezi D., Shabani L.: Environment and sustainable development of the Prespa park. *J. Envir. Protect. Eco.*, 2009, 10(1), 163–175.
- [13] Gándia M.L., Del Monte J.P., Tenorio J.L., Santín-Montanyá M.I.: The influence of rainfall and tillage on wheat yield parameters and weed population in monoculture versus rotation systems. *Sci. Rep.*, 2021, 11, #22138. <https://www.nature.com/articles/s41598-021-00934-y>.
- [14] Grinfelde I., Valujeva K., Zaharane K., Berzina L.: Automated cavity ring down spectroscopy usage for nitrous oxide emission measurements from soil using recirculation system. *Eng. Rural Devel.*, 2017, 16, 1111-1116.
- [15] Hussain A., Nair P.: Enhancing crop yield through weed density estimation and management: A comprehensive review. In: 2023 IEEE Int. Conf. ICT in Business Industry & Government (ICTBIG) (pp. 1–10). IEEE, Indore 2023.
- [16] Hussain M., Rafique N., Kaousar R., Haq U.I.S., Shan C., Wang G., Shizhou W., Lan Y.: Optimizing seed rate and herbicide doses with or without adjuvant for weed control and its influence on yield of winter wheat. *Pol. J. Environ. Stud.*, 2025, 34(1), 127-138.

- [17] Hutianskyi R.A., Popov S.I., Avramenko S.V., Kuzmenko N.V.: Weed infestation of winter wheat crops depending on growing conditions in a fallow-grain-row crop rotation. *Bull. Sumy Natl. Agrar. Univ. Ser. Agron. Biol.*, 2022, 48(2), 51-58.
- [18] Jalli M., Huusela E., Jalli H., Kauppi K., Niemi M., Himanen S., Jauhiainen L.: Effects of crop rotation on spring wheat yield and pest occurrence in different tillage systems: A multi-year experiment in Finnish growing conditions. *Front. Sustain. Food Syst.*, 2021, 5, #647335.
- [19] Kachanova T.V.: *Herbology. Methodical recommendations*. Mykolaiv National Agrarian University, Mykolaiv 2023.
- [20] Kerimkhulle S., Turtkarayeva G., Mussaibekov R., Ospanova N., Kuttykozhayeva S., Adalbek A.: Using Markov Chain Model to Forecasting of the Agricultural Industry Development. *Lect. Not. Networks Syst.*, 2025, 1489, 148-158.
- [21] Kocira A., Staniak M.: Weed ecology and new approaches for management. *Agriculture*, 2021, 11(3), #262.
- [22] Kokojka F., Bacu A., Shahini S., Medha G.: Tribenuron-methyl treatment affects glutathione metabolism and other physiological processes in bread wheat. *Int. J. Pest Manag.*, 2023, 69(3), 248-254.
- [23] Konovalova V., Tyshchenko A., Bazalii H., Fundyrat K., Tyshchenko O., Reznichenko N., Konovalov V.: Analysis of winter wheat varieties for drought resistance in the conditions of the Steppe of Ukraine (Part 1 – Years with sufficient moisture). *Agrar. Innov.*, 2023, 19, 140-150.
- [24] Krut M.: Innovations on scientific support of grain crop breeding for resistance to diseases and pests. *Interdep. Themat. Sci. Collect. Plant Prot. Quarantine*, 2020, 66, 137-145.
- [25] Kumar N., Upadhyay G., Chhetri K.B., Harsha B.R., Malik G.K., Kumar R., Jasrotia P., Samota S.R., Kumar N., Chhokar R.S., Gill S.C.: Pre- and post-harvest management of wheat for improving the productivity, quality, and resource utilization efficiency. In: *Wheat Science* (pp. 57–106). CRC Press, Boca Raton 2023.
- [26] Kumar V., Bana R.S., Singh T., Louhar G.: Ecological weed management approaches for wheat under rice–wheat cropping system. *Environ. Sustain.*, 2021, 4, 51-61.
- [27] Lacroix C., Pierreux J., Brostaux Y., Vandenberghe C., Dumont B.: Assessing the combined effects of mechanical and chemical weeding on weed dynamics in winter wheat. *Weed Res.*, 2025, 65(1), #e12677.
- [28] Leharwan M., Kumar Y., Kumar R., Kumar Saraswat P., Kumar R., Kumar Thaliyil Veetil A., Bhattacharjee S., Kumar A., Kumar S.: Assessing the effects of conservation tillage and in-situ crop residue management on crop yield and soil properties in rice–wheat cropping system. *Sustainability*, 2023, 15(17), #12736.
- [29] Maharramova S.I., Ehmedova S., Shamsadinskaya N.M., Salehzadeh G., Aghamaliyeva Y., Sesli Y.: Biodiversity dynamics and changes in ecosystem functions: in the context of climate change. *Adv. Bio. Earth Sci.*, 2026, 11(1), 184-202.
- [30] Masson S., Rueda-Ayala V., Bragazza L., Cordeau S., Munier-Jolain N., Wirth J.: Reducing tillage and herbicide use intensity while limiting weed-related wheat yield loss. *Eur. J. Agron.*, 2024, 160, #127284.
- [31] Minhas W.A., Mumtaz N., Ur-Rehman H., Farooq S., Farooq M., Ali H.M., Hussain M.: Weed infestation and productivity of wheat crop sown in various cropping systems under conventional and conservation tillage. *Front. Plant Sci.*, 2023, 14, #1176738.
- [32] Ministry of Environmental Protection and Natural Resources of Ukraine. State Register of Pesticides and Agrochemicals Permitted for Use in Ukraine, 2024. <https://mepr.gov.ua/upravlinnya-vidhodamy/derzhavnyj-reyestr-pestytsydiv-i-agrohimikativ-dozvolenyh-do-vykorystannya-v-ukrayini/>.

- [33] Moreau D., Busset H., Matějček A., Prudent M., Colbach N.: Water limitation affects weed competitive ability for light: A demonstration using a model-based approach combined with an automated watering platform. *Weed Res.*, 2022, 62(6), 381-392.
- [34] Musayeva N.M., Mammadova U., Huseynova A.T., Hordii N.M.: The Impact of Forest Fires on Soil Chemical Properties and Soil Recovery Processes in Forest Ecosystems. *J. Sustainable For.*, 2026. <https://doi.org/10.1080/10549811.2026.2666529>
- [35] Navi L., Mavarkar N.S., Kushal, Mopagar M.M.: Weed management strategies for conservation agriculture: A review. *Int. J. Res. Agron.*, 2024, 7(4), 313-321.
- [36] Odesa State Agricultural Research Station of the National Academy of Agrarian Sciences of Ukraine, 2020. http://www.hlebodarka.com/pdf/RecomM63/Posev_ozimuh.pdf.
- [37] OECD. Test No. 208: Terrestrial Plant Test: Seedling Emergence and Seedling Growth Test, 2006. https://www.oecd.org/en/publications/test-no-208-terrestrial-plant-test-seedling-emergence-and-seedling-growth-test_9789264070066-en.html.
- [38] Panchenko A., Voloshina A., Milaeva I., Luzan P.: Operating conditions' influence on the change of functional characteristics for mechatronic systems with orbital hydraulic motors. In: *Modern Development Paths of Agricultural Production: Trends and Innovations* (pp. 169-176). Springer International Publishing, Cham 2019.
- [39] Panfilova A., Korkhova M., Domaratskiy Y., Kozlova O.: Development of winter wheat productivity under the influence of biopreparations and different moisture conditions in the steppe zone. *Ecol. Eng. Environ. Technol.*, 2025, 26(3), 245-254.
- [40] Panfilova A., Korkhova M., Markova N.: Influence of biologics on the productivity of winter wheat varieties under irrigation conditions. *Not. Sci. Biol.*, 2023, 15(2), #11352.
- [41] Pilecka J., Grinfelde I., Valujeva K., Straupe I., Purmalis O.: Heavy metal contamination and distribution in the urban environment of Jelgava. *Res. Rural Devel.*, 2017, 1, 173-179.
- [42] Plaza E., Bastida F., Gibson D., Barro F., Giménez M., Pallavicini Y., Izquierdo J., González-Andújar J.: Grain quality as influenced by the structural properties of weed communities in Mediterranean wheat crops. *Agronomy*, 2022, 13(1), #49.
- [43] Pochkolina S., Melnyk A., Kohut I., Rudenko V., Vlasenko S.: Winter wheat yield depending on different soil tillage systems in short-term crop rotations under Black Sea region conditions. *J. Appl. Life Sci. Environ.*, 2025, 57(4), 629-647.
- [44] Pravdziva I., Khoroshko N.: Evaluation of winter bread wheat (*Triticum aestivum* L.) varieties based on grain quality indicators. *Sci. Rep. Nat. Univ. Life Envir. Sci. Ukr.*, 2025, 21(6), 9-21.
- [45] Prydatko V., Kovalyshyna H.: Growing season duration and productivity of soft winter wheat under different weather conditions. *Sci. Rep. Nat. Univ. Life Envir. Sci. Ukr.*, 2026, 22(2), 105-119.
- [46] Raatz L., Pirhofer Walzl K., Müller M.E., Scherber C., Joshi J.: Who is the culprit: Is pest infestation responsible for crop yield losses close to semi-natural habitats? *Ecol. Evol.*, 2021, 11(19), 13232-13246.
- [47] Reed B.M., Engelmann F., Dulloo M.E., Engels J.M.M.: *Technical Guidelines for the Management of Field and In Vitro Germplasm Collections*. International Plant Genetic Resources Institute, Rome 2004.
- [48] Remeshevska I., Trokhymenko G., Gurets N., Stepova O., Trus I., Akhmedova V.: Study of the ways and methods of searching water leaks in water supply networks of the settlements of Ukraine. *Eco. Eng. Envir. Tech.*, 2021, 22(4), 14-21.
- [49] Shebanin V., Drobitko A., Smirnova I., Piskunova L., Karpenko M.: Hazardous environmental factors and their impact on plant vital activity and biosecurity. *Sci. Horiz.*, 2025, 28(8), 89-101.
- [50] Shebanin V., Gamayunova V., Drobitko A., Smirnova I., Khonenko L.: Use of biologisation elements in the cultivation of grain and industrial crops to obtain high-quality products and preserve the environment. *Sci. Horiz.*, 2025, 28(5), 32-43.

- [51] Skarbøvik E., Perovic A., Shumka S., Nagothu U.S.: Nutrient inputs, trophic status and water management challenges in the transboundary lake skadar/shkodra, western Balkans. *Arch. Bio. Sci.*, 2014, 66(2), 667-681.
- [52] State Service of Ukraine on Food Safety and Consumer Protection. Register of plant varieties suitable for dissemination in Ukraine, 2025. <http://sort.sops.gov.ua/search/search>.
- [53] Stępień A., Wojtkowiak K., Kolankowska E.: Crop rotation and weed control as factors in the sustainable cultivation of winter oilseed rape. *Sustainability*, 2025, 17(11), #5065.
- [54] Syngenta, 2025. <https://www.syngenta.ua/>.
- [55] Taab A., Khazaie M., Andersson L., Bergkvist G., Radicetti E.: Ecological intensification using Persian clover to support weed management in winter wheat under semiarid conditions. *Crop Prot.*, 2023, 164, #106142.
- [56] Tkach V.V., Kushnir M.V., de Oliveira S.C., Ivanushko Y.G., Velyka A.V., Molodianu A.F., Yagodynets P.I., Kormosh Z.O., Dos Reis L.V., Luganska O.V., Palamarek K.V., Bredikhina Y.L.: Electrochemical Determination of Sudan Dyes and Two Manner to Realize it: a Theoretical Investigation. *Lett. Appl. NanoBioSci.*, 2020, 9(4), 1451-1458.
- [57] Tkach V.V., Kushnir M.V., de Oliveira S.C., Zavorodnii M.P., Brazhko O.A., Kornet M.M., Luganska O.V., Kopyika V.V., Ivanushko Y.G., Mytchenok M.P., Ahafonova O.V., Yagodynets P.I., Kormosh Z.O., Dos Reis L.V.: The theoretical description for a sucralose electrochemical cathodical determination over a 9-9'-diacridyl-modified electrode. *Orbital*, 2021, 13(3), 219-222.
- [58] Tsyliuryk O.I., Tkulich Y.I., Kolesnykova K.V., Rudakov Y.M., Tkulich Y.Y.: Modern trends and development directions of soil tillage systems in the world and Ukraine. *Agrology*, 2025, 8(1), 48-54.
- [59] Vinyukov O., Bondareva O., Likhushyna H., Orekhivskiy V., Marchenko Tetiana Y.: Influence of protection systems and regulation of growth processes on the formation of yield of Turanian wheat in the conditions of the Steppe of Ukraine. *Eco. Eng. Envir. Tech.*, 2025, 26(12), 15-25.
- [60] Voloshina A., Panchenko A., Boltynskiy O., Panchenko I., Titova O.: Justification of the kinematic diagrams for the distribution system of a planetary hydraulic motor. *Int. J. Eng. Tech(UAE)*, 2018, 7(4), 6-11.
- [61] Voloshina A., Panchenko A., Panchenko I., Zasiadko A.: Geometrical parameters for distribution systems of hydraulic machines. In: *Modern Development Paths of Agricultural Production: Trends and Innovations* (pp. 323–336). Springer, Cham 2019.
- [62] Woźniak A.: Grain yield, grain quality and weed infestation of winter wheat after various previous crops. *Agron. Sci.*, 2024, 79(2), 51-66.
- [63] Yanev M., Neshev N., Mitkov A., Nesheva M.: Control of mixed weed infestation in winter wheat. *Sci. Pap. Ser. A Agron.*, 2021, LXIV(2), 350-357.
- [64] Yunyk A.: The efficiency of fertilisation in the cultivation of high oleic sunflower on typical low humus chernozems. *Plant Soil Sci.*, 2021, 12(1), 39-49.
- [65] Zhang C., Xie Z., Wang Q., Tang M., Feng S., Cai H.: AquaCrop modeling to explore optimal irrigation of winter wheat for improving grain yield and water productivity. *Agric. Water Manag.*, 2022, 266, #107580.
- [66] Zhang Z., Li R., Zhao C., Qiang S.: Reduction in weed infestation through integrated depletion of the weed seed bank in a rice-wheat cropping system. *Agron. Sustain. Dev.*, 2021, 41, #10.
- [67] Zhao Y., Umair M., Gulzar F., Guliyeva S., Xabibullayev D.: The role of private natural heritage conservation areas in promoting sustainable development Goals Insight. *Eco. Indic.*, 2025, 176, #113658.

**KSZTAŁTOWANIE PRODUKTYWNOŚCI PSZENICY OZIMEJ W ZALEŻNOŚCI OD
STOPNIA ZANIECZYSZCZENIA UPRAW W WARUNKACH STOSOWANIA TECHNOLOGII
OSZCZĘDNOŚCIOWYCH W WARUNKACH POŁUDNIOWEJ UKRAINY**

Streszczenie

Wprowadzenie. Celem badań było określenie wpływu zróżnicowanego stopnia zachwaszczenia na cechy morfologiczne i fizjologiczne oraz elementy strukturalne plonu pszenicy ozimej odmiany Duma Odeska w warunkach Południowych Stepów Ukrainy.

Wyniki i Wnioski. Analiza danych wykazała, że Duma Odeska formował siewki nawet przy niedoborze wilgoci w glebie (wilgotność na głębokości 10 cm – 13,5 %) i wykazywał intensywny wzrost masy liści do $33 \div 35$ g/m² w fazie pędów. W fazie krzewienia średnia liczba produktywnych źdźbeł wynosiła $3 \div 5$ szt./roślinę, a współczynnik krzewienia wynosił 3,2, co przyczyniło się do wczesnego zamykania rzędów i częściowego tłumienia chwastów. Przy średnim poziomie zachwaszczenia ($150 \div 200$ roślin/m²) główne wskaźniki produktywności zmniejszyły się umiarkowanie: liczba produktywnych źdźbeł wynosiła 518 szt./m², liczba ziaren w kłosie – 32,2, masa 1000 ziaren – 41,1 g, a plon – 4,75 t/ha. Przy wysokim poziomie zachwaszczenia (powyżej 250 roślin/m²) liczba produktywnych źdźbeł zmniejszyła się do 446 szt./m², liczba ziaren w kłosie – do 29,4, masa 1000 ziaren – do 38,7 g, a plon – do 3,92 t/ha. Największe szkody wyrządziły następujące gatunki chwastów: proso pospolite, rajgras, gorczyca rozłogowa, mak polny, pokrzywa zwyczajna i kostrzewa pospolita. To właśnie te gatunki zdominowały trzy fale kiełkowania chwastów w sezonie wegetacyjnym. Odmiana wykazała względną tolerancję na suszę i wysoką temperaturę, w tym zachowanie powierzchni asymilacyjnej w warunkach stresu temperaturowego do $+35 \div +36$ °C w fazie kłoszenia oraz penetrację systemu korzeniowego do $120 \div 140$ cm. Jednak pozytywne cechy odmiany nie kompensowały w pełni presji chwastów powyżej 200 roślin/m², zwłaszcza w warunkach deficytu wilgoci. Praktyczne znaczenie badań polega na określeniu progów zagęszczenia chwastów, które mogą wspierać dobór środków regulacyjnych w Południowym Stepie Ukrainy.

Słowa kluczowe: ontogeneza kultury, ochrona roślin, struktura plonu, podejścia technologiczne, warunki agroekologiczne, Duma Odeska 