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YIELD OF WINTER WHEAT (*TRITICUM AESTIVUM* L.) AFTER NON-TRADITIONAL PREDECESSORS IN SHORT-TERM FORAGE CROP ROTATIONS

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Topicality. *Winter wheat is the leading grain and food crop in Ukraine, which is often grown without considering requirements for its predecessors. This crop is widely used in short-term crop rotations, in which there are a number of problems arise in obtaining a high and stable winter wheat yield after non-traditional predecessors.* ***Purpose.*** *To determine the winter wheat yield in specialised fodder short-term crop rotation after the non-traditional predecessors for small farms.* ***Methods.*** *In 2018–2021, field trials were conducted in the Vinnytsia region on leached medium loam chernozems with a humus content of 4.2 %. Winter wheat was sown after three predecessors: fodder beet, pumpkin and potato.* ***Results.*** *The longest period from harvesting potato to sowing winter wheat was 49 days. After harvesting the pumpkin, 16 days remained before sowing winter wheat. The shortest period from harvesting fodder beet to sowing winter wheat was 6 days. The plant density of winter wheat after the potato was by 12.0 % higher than after the pumpkin and by 17.7 % higher than after the fodder beet. During the spring regrowth, the highest plant density of winter wheat was observed after the potato, which was 11.9 % more than after the pumpkin and 18.4 % more than after the fodder beet. At the end of the growing season, the highest number of productive stems was formed by winter wheat plants after the potato –773 pcs/m^2, after fodder beet – by 7.8 % less productive stems, and after the pumpkin – by 42.2 % less than after potato.* ***Conclusions****. The highest actual grain yield of winter wheat grown after potato amounted to 7.63 t/ha. After fodder beet, the winter wheat yield was 11.3 % lower than after potato and amounted to 6.77 t/ha. The winter wheat yield after the pumpkin was 40.6 % lower than after potato and 33.1 % lower than after fodder beet.*

Key words: *winter wheat, yield, predecessors, fodder beets, pumpkins, potatoes*

Introduction. In Ukraine, modern crop rotations are specialised in the following main areas: growing cereals, oilseeds, fodder and other industrial crops. Winter wheat (*Triticum aestivum* L.) plays a crucial role in all these crop rotations as one of the best predecessors, which allows to free the field early, prepare the soil for the next crop in the rotation, accumulate moisture, leave enough plant residues to replenish the soil nutrient reserves, improve its agrophysical properties and sanitary sustainability of the agroecosystem [1, 2].

Today, the structure of crop rotations is determined by the market, demand and price for agricultural production. These factors establish the general direction of Ukraine's agricultural sector, which is characterised by a significant reduction in the range of cultivated crops, and the formation of small farms with a narrow agricultural specialisation that does not allow maintaining multiple crop rotations on a limited area of arable land. Therefore, both small farms and large rental farms increasingly switch to short-term crop rotations [3, 4].

However, in the short-term crop rotation, the limited set of crops frequently returns to their original place. Crops are cultivated after the worst predecessors that not only affect their yield but also reduce soil fertility; it leads to degradation processes, the spread of pests, diseases and weeds [5, 6].

In conditions of proper short-term crop rotations, it is possible to achieve efficient utilisation of nutrients and moisture from the soil by plants, reduce the weed infestation and spread of diseases and pests, improve physical and chemical properties of the soil, and rational use of fertilisers, pesticides and machinery, which will reduce the cost of agricultural production [7, 8].

Consequently, the study of short-term crop rotations with a limited number and a specific set of crops for special uses is urgently required, since it would not only ensure high crop productivity but also contribute to improving the sustainability of agroecosystems enhancing soil fertility [9, 10].

As a result of the reform in the agricultural sector of Ukrainian economy, large agricul-

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tural enterprises stopped to engage in livestock production, but small farms are still in business, using manual labour along with mechanisation to harvest energy-intensive crops such as potatoes (*Solanum tuberosum*), fodder beet (*Beta vulgaris* L.), pumpkins (*Cucurbita pero*), perennial grasses for hay, and others. For these small-scale farms, it is necessary to develop an optimal crop rotation system, based on highly specialised short-term forage crop rotations [11, 12].

The low availability of agricultural machinery and the high level of manual labour in the economic activities of small farms require the development of short-term forage crop rotations with their saturation with grain crops, in particular winter wheat, in order to significantly reduce the share of manual labour [13, 14].

Winter wheat, a leading grain and food crop in Ukraine, is often cultivated regardless of its requirements for predecessors. Winter wheat is often grown in short-term crop rotations. These crop rotations have a number of problems with obtaining high and sustainable yield of winter wheat after non-traditional predecessors.

The purpose of the research is to determine the winter wheat yield after non-traditional predecessors in a specialised short-term forage crop rotation for small farms.

Materials and Methods. In 2018–2021, the field trials were conducted in the private farm Yurchenko-N in the Velyki Krushlyntsi village, Vinnytsia district, Vinnytsia region on leached medium loamy chernozems with a humus content of 4.2 %. The winter wheat was sown after the following crops: fodder beet of Ursus Poly variety, pumpkins of Ukrainskyi bahatoplidnyii variety and potatoes of Bellarosa variety. Tillage after harvesting the previous crops included disking to a depth of 10–12 cm and pre-sowing cultivation to a depth of 5 cm. Winter wheat was sown at a late date with an increased seeding rate of 6 mln seeds per hectare with a SZ-3.6 seeder.

Sowing was carried out with the Bohemia variety of the originator Selgen, a.s., Czech Republic. The variety is a mid-ripening, intensive type, belongs to strong awnless wheat. It tolerates late sowing. It is characterised by high grain quality and productivity. High grain yield reaches 8.0–9.0 t/ha with application of complete mineral fertiliser. It is characterised by high winter hardiness, resistance to powdery mildew and brown leaf rust. The protein content is 13.5 %, gluten is 28.0 %. The stem height is 95–98 cm. Seeding rate is 3.0–6.0 mln seeds/ha. Recommended growing areas are Polissia, Forest-Steppe, and Steppe.

Crop management was generally accepted, including the application of the ammonium nitrate phosphate fertilizer at a rate of $N_{30}P_{30}K_{30}$ at the time of sowing. In the spring, the crops were fertilised twice with ammonium nitrate at rates of N_{45} and N_{60}. The crop protection system included a single application of Grodyl Ultra herbicide, a double application of a tank mix of Alto fungicide with Chlorpyrifos insecticide and the addition of microfertilisers. Harvesting was carried out by direct combining.

The registration plot was 30 m^2 in four tiers. During the research, we carried out the following observations and records: plant density was determined in dynamics (during the period of full seedlings, the beginning of spring regrowth and before harvesting) on permanently fixed registration plots of 1/6 m^2, allocated in two non-contiguous tiers of 3 sites per plot. Weed infestation of crops was recorded quantitatively on 1 m^2 plots in the stem elongation stage. The spread of Septoria disease was recorded by the percentage of the affected leaf surface in the milk ripeness stage. Indicators of individual plant productivity were determined in the Laboratory of Seed Production of Vinnytsia National Agrarian University by analysing a sheaf sample. The thousand seed weight was determined by weighing the respective sample weights. The grain yield of winter wheat was determined by the method of continuous threshing of the entire experimental plot separately within each variant with the following conversion to hectare area [15].

Results and Discussion. The winter wheat predecessors were harvested at different calendar dates, which affected the system of soil preparation for sowing. Potatoes were harvested earlier than all the predecessors (12 August), allowing to prepare the soil for sowing and accumulate moisture for winter wheat seedlings. After harvesting the potatoes, the soil was cultivated for additional harvesting of potato residues, in mid-September, one month before sowing winter wheat, a single disking of the soil was carried out, and on the day of sowing, pre-sowing cultivation was carried out (Table 1).

Table 1. Dates of harvesting predecessors and soil preparation for sowing winter wheat, (average for 2018–2021)

Predecessor	Calendar date of harvesting predecessor	Tillage after harvesting predecessor	Period from harvesting the predecessor to sowing winter wheat, days	Calendar date of sowing winter wheat
Fodder beet	25 August	double disking, pre-sowing cultivation	6	1 October
Pumpkins	15 August	double disking, pre-sowing cultivation	16	1 October
Potatoes (control)	12 September	Post-harvest cultivation, single disking, pre-sowing cultivation	49	1 October

Pumpkins were fully harvested on 15 September. This significantly reduced the time required to prepare the soil for sowing winter wheat. In case of remaining pumpkin stems on the soil surface, they were raked up with a continuous cultivator or crushed and scattered over the field surface with appropriate choppers, if possible. Immediately after this operation, or in the absence of pumpkin stems disrupting the quality of tillage tools, disking was carried out twice, and on the sowing date was carried out pre-sowing cultivation.

The latest date for harvesting was 25 September for fodder beets. After harvesting, only two disking and pre-sowing cultivation were carried out on the sowing date.

Winter wheat was sown on 1 October, almost at the end of the optimal dates. Potatoes provided the longest period from harvesting the predecessor to sowing (49 days) that allowed preparing properly the soil and accumulating enough moisture for seed germination. After harvesting pumpkins, 16 days remained before sowing winter wheat, but this predecessor required special measures (crushing or raked up pumpkin stems). The shortest period (6 days) for soil preparation before sowing and, accordingly, accumulation of soil moisture was recorded after the fodder beet as a predecessor. This crop is quite moisture-loving, so after harvesting it, the soil is often overdried, which affects winter wheat seedlings.

In the winter wheat seedling stage, the highest plant density was observed after the potato (575 plants/m^2), which was 12.0 % higher than after the pumpkin and 17.7 % higher than after fodder beet. The lowest plant density of winter wheat was 473 plants/m^2 after fodder beet in the stage of full seedlings. This resulted from the late harvesting of fodder beet compared to other predecessors and soil overdrying (Table 2).

During the period of spring regrowth, the highest plant density of winter wheat was 528 pcs/m^2 after the potato, which was 11.9 % more than after the pumpkin and 18.4 % more than after fodder beet, where the plant density of winter wheat was the lowest and amounted to 431 pcs/m^2. This feature of the distribution of winter wheat plant density was observed during the stage of full seedling.

Table 2. Dynamics of plant density of winter wheat depending on predecessors, plants/m^2, (average for 2018–2021)

Predecessor	Plant growth and development stages			Number of productive stems at harvest date
	Seedling	Spring regrowth	the end of growth season	
Fodder beet	473	431	410	713
Pumpkins	506	465	411	447
Potatoes (control)	575	528	467	773

At the end of the growing season, the highest plant density of winter wheat remained after the potatoes and was 467 plants/m^2. At the same time, the density after fodder beets and pumpkins levelled out and amounted to 410–411 plants/m^2, which was 12.2 % less than the plant density after potatoes.

The number of productive stems determines the winter wheat yield. The largest number of productive stems (773 pcs/m^2) was formed by winter wheat plants grown after potatoes; after fodder beet, the number of productive stems was 7.8 % less, but also within the optimal number – 713 pcs/m^2. The lowest number of productive stems of winter wheat was 447 pcs/m2 after the pumpkin, which was 42.2 % less compared to potatoes that is explained by the strong overdrying of the soil by pumpkins. Pumpkins consume a lot of soil moisture during the initiation of productive stems, i.e. when the early spring moisture reserves have already been used up and late spring moisture is insufficient and not available in the soil.

Late sowing of winter wheat was carried out with an increased seeding rate of 6.0 million germinating seeds per hectare. Field germination was the highest at 96 % after potatoes, 84 % after pumpkins, and the lowest at 79 % after fodder beet. The seed germination of winter wheat was significantly influenced by precipitation after sowing and sufficiently warm weather, reducing the influence of predecessors on seed germination (Table 3).

Favourable conditions for the winter wheat crop in autumn made it possible the optimal tillering stage for all variants. This resulted in a percentage of deaths of only 8.1–8.5 %. Plant thinning continued until the end of the growing season. From the period of spring regrowth to full maturity, 4.9 % of winter wheat plants died after the fodder beet and 11.6 % after pumpkins and potatoes (as predecessors).

The thinning of winter wheat crops after the potato may be explained by a rather high plant density, while after the pumpkin it is due to a lack of moisture.

Table 3. Parameters of winter wheat plant preservation and tillering depending on predecessors, (average for 2018–2021)

Predecessor	Field germination, %	Plant death in winter, %	Plant death at the end of the growing season, %	General tillering	Productive tillering
Fodder beet	79	8.5	4.9	3.2	1.7
Pumpkins	84	8.1	11.6	3.5	1.1
Potatoes (control)	96	8.1	11.6	4.2	1.7

This fact is confirmed by the value of productive tillering of winter wheat plants after the pumpkin, which was the smallest and amounted to 1.1. At the same time, the value of productive tillering of winter wheat plants after the potatoes and fodder beet was the same and amounted to 1.7.

Total tillering of winter wheat plants after the potato was the highest (4.2), which is explained by favourable growing conditions. However, the total tillering did not affect the productive tillering. One of the reasons for this is the close sowing of winter wheat plants after potatoes. Therefore, winter wheat sowing rates after potatoes should be reduced to encourage plants to form greater numbers of productive stems with sufficient free space.

Total tillering of winter wheat plants after the pumpkin was 3.5. Compared to the potatoes, plant density was lower; however, it did not contribute to the growth of productive tillering due to insufficient soil moisture content after this predecessor. At the same time, after fodder beet, the total tillering of plants was the lowest (3.5), but it provided a high rate of productive tillering.

Despite the pest control of winter wheat crops, we found a certain number of harmful organisms in its crops. In particular, the number of weeds was 3.7–5.7 plants per m^2, which did not have a significant negative impact. The highest number of weeds was found after the potatoes, which was due to significant weed infestation of potato crops, especially in the second half of its growing season (Table 4).

Septoria disease was the main disease found in winter wheat crops. The smallest area of the affected leaf surface was found after the pumpkin (17 %), and the largest (33 %) after the fodder beet.

The analysis of the individual productivity of winter wheat plants after these predecessors revealed identical parameters of the number of rows of spikelets in an head (8), grains in an-

Table 4. Development of harmful pests in winter wheat crops depending on predecessors, (average for 2018–2021)

Predecessor	Weed infestation	Diseases
	Actual number of weeds, pcs/m^2	Affected leaf surface area of plants, %
Fodder beet	3.8	33
Pumpkins	3.7	17
Potatoes (control)	5.7	24

spikelet (4) and the total number of grains in one head (32), regardless of the predecessor (Table 5).

Differences between the variants of predecessors were observed in the thousand seed weight (40.0–41.9 g) and the number of spikelets per plant, taking into account the productive tillering. Therefore, grain weight per head of winter wheat plants varied from 1.28 g after the predecessor potatoes to 1.34 g after pumpkins. Differences in grain weight per head were determined by the difference in thousand seed weight of different variants, which depended on the plant density. The largest grain weight per plant, considering productive tillering, was recorded after the predecessors fodder beet and potatoes (2.18–2.20 g), while after pumpkins the grain weight per plant of winter wheat was 33.2 % less and amounted to 1.47 g.

Table 5. Individual seed productivity of winter wheat plants depending on the predecessors, (average for 2018–2021)

Predecessor	Number of heads per plant, pcs	Number of rows of spikelets per head, pcs	Number of grains per spike-let, pcs	Number of grains per head, pcs	Thousand seed weight, g	Grain weight per head, g	Grain weight per plant, g
Fodder beet	1.7	8	4	32	40.6	1.30	2.20
Pumpkins	1.1	8	4	32	41.9	1.34	1.47
Potatoes (control)	1.7	8	4	32	40.0	1.28	2.18

The actual grain yield of winter wheat grown after potatoes was the highest and amounted to 7.63 t/ha, which was largely determined by the higher plant density (Table 6).

After fodder beet, the winter wheat yield was 11.3% lower than after potatoes and amounted to 6.77 t/ha, which is determined by the high percentage of productive tillering in relation to the total tillering. The winter wheat yield after the pumpkin was 40.6 % lower than after potatoes and 33.1 % lower than after fodder beet. The low yield of winter wheat after pumpkins, compared to other predecessors, is a result of significant plant thinning and insufficient productive stem density due to low productive tillering due to extreme soil overdrying.

Table 6. Grain yield of winter wheat depending on the predecessors, (average for 2018–2021)

Predecessor	Grain yield, t/ha	Deviations from control, - / +	
		t/ha	%
Fodder beet	6.77	-0.86	-11.3
Pumpkins	4.53	-1.68	-40.6
Potatoes (control)	7.63	–	–

Conclusions. In short-rotation fodder crop rotations with high saturation of fodder beet, pumpkin and potato crops, the winter wheat should be sown after potatoes, which ensures grain yields of 7.63 t/ha under all technological practices and 6.77 t/ha after fodder beet.

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Ткачук О. П. Урожайність пшениці озимої (Triticum aestivum L.) після нетрадиційних попередників у короткоротаційних кормових сівозмінах. *Зернові культури. 2023. 7 (1). 156–162.*

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Актуальність. Пшениця озима є провідною зерновою і продовольчою культурою України, яка часто вирощується без врахування її вимог до попередників. Особливого поширення вона набула у короткоротаційних сівозмінах. Саме у таких сівозмінах виникає ряд проблем щодо одержання високої і стабільної урожайності пшениці озимої після нетрадиційних попередників. **Мета.** Визначити урожайність пшениці озимої за її вирощування після нетрадиційних попередників спеціалізованої кормової короткоротаційної сівозміни для малих фермерських господарств. **Матеріали та методи.** Польові дослідження проводилися впродовж 2018–2021 рр. в умовах Вінницької області на чорноземах вилугуваних середньосуглинкових з вмістом гумусу 4,2 %. Пшеницю озиму висівали після трьох попередників: кормових буряків, гарбузів та картоплі. **Результати.** Під посів пшениці озимої найдовший період від збирання попередника до сівби забезпечила картопля – 49 діб. Після збирання гарбузів до сівби пшениці озимої залишалось 16 діб. Найменше часу від збирання урожаю до сівби залишалося після попередника кормові буряки – 6 діб. Густота стояння рослин пшениці озимої після попередника картопля була на 12,0 % більша, ніж після попередника гарбузи та на 17,7 % більша, ніж після попередника кормових буряків. На період весняного відростання найбільша густота стояння рослин пшениці озимої спостерігалась після попередника картопля, що було на 11,9 % більше, ніж після попередника гарбузи та на 18,4 % більше, ніж після попередника кормові буряки. Найбільше продуктивних стебел на кінець вегетації сформували рослини пшениці озимої після попередника картопля – 773 шт./м^2. Після кормових буряків продуктивних стебел було на 7,8 % менше, а після попередника гарбузи їх було на 42,2 % менше, ніж після картоплі. **Висновки.** Фактична урожайність зерна пшениці озимої, вирощеної після картоплі була найвища і становила 7,63 т/га. Після кормових буряків урожайність пшениці озимої була на 11,3 % нижча, ніж після картоплі і становила 6,77 т/га. Урожайність пшениці озимої після попередника гарбузи була на 40,6 % нижча, ніж після картоплі та на 33,1 % нижча – ніж після кормових буряків.

Ключові слова: *пшениця озима, урожайність, попередники, кормові буряки, гарбузи, картопля*