Ukrainian Journal of Ecology

*Ukrainian Journal of Ecology*, 2022, 12(1), 1-5, doi: 10.15421/2022_327

*ORIGINAL ARTICLE*

# Ecologization of winter wheat growing technology according to optimization of sowing depth

**V.V. Lykhochvor[1], Y.M. Olifir[2,*], M.L. Tyrus[1], R.M. Panasiuk[1], V.Y. Ivaniuk[1]**

*[1]Lviv National Agrarian University, 1 Volodymyra Velykoho St, Dublyany, Lviv Region, 80381, Ukraine*

*[2]Institute of Agriculture of the Carpathian Region NAAS, 5 Hrushevskoho St, Obroshyne, Lviv Region, 81115, Ukraine*

**Corresponding author E-mail: olifir.yura@gmail.com*

***Received:** 20-Dec-2021, **Manuscript No.** UJE-21-50280; **Accepted:** 21-Jan-2022, **Pre QC No.** P-50280; **Editor assigned:** 22-Dec-2021, **Pre QC No.** P-50280; **Reviewed:** 05-Jan-2022, **QC No.** Q-50280; **Revised:** 12-Jan-2022, **Manuscript No.** R-50280; **Published:** 31-Jan-2022.*

We found that the highest indicators of field germination (90%) of winter wheat were obtained when sowing at 2 cm and 3 cm. At the same depth of seed, sowing was created to intensify the tillering process. The tillering rate increased to 2.4 and 2.5. The density of the productive stems of winter wheat was also the highest for sowing by 2 cm and 3 cm, where it was, respectively, 634 pcs/m$^2$ and 652 pcs/m$^2$. The weight of the ear grain was lower (1.32-1.34 g) to sow at a depth of 2 to 4 cm, which is explained by the better conditions to create a higher density of ears in these variants. In variants with a higher or lower sowing depth, the conditions for tilling became the complicated and more yield depended on the weight of the grain from the ear. For the formation of the highest yield, the following combination of the main elements of the the density structure of productive stems and grain weight of the ear is optimal: 634 ears × 1.34 g and 652 ears × 1.32 g per m$^2$. The best conditions for realizing the genetic potential of the winter wheat productivity of the Reform variety and the yields of 8.22 t/ha and 8.30 t/ha are formed when sowing at a depth of 2 cm and 3 cm. Yields decreased with shallow and deep seed sowing. The variant with a sowing of 7 cm was the smallest and amounted to 7.30 t/ha.

**Keywords:** Sowing depth, Structure, Winter wheat, Yield.

## Introduction

Many factors influence the yield and quality of winter wheat, and sowing management plays a significant role. (Zecevic et al., 2014). The depth of the seed is one of the main indicators of the quality of winter wheat, and it largely determines the structure of the future seedling and the type of plant. The depth of sowing is based on plant biology and depends on many factors. The most important of them: soil moisture, its granularmetric composition, climatic conditions, biological characteristics of the variety, and seed quality. Field germination, timeliness and friendliness of shoots, location of the tillering site, winter hardiness of plants, and their resistance to lodging depend on seed sowing depth. The depth of sowing is essential for wheat, especially for germination, the emergence of shoots, and the absorption of nutrients affected by soil moisture (Roy et al., 2011). The depth to which seeds are sown is an essential factor that influences root length, diameter, density, fresh and dry weight, the ratio of shoot to root mass, number of secondary roots and root hairs, root penetration, root architecture, and growth rates at different stages of plant growth (Akman et al., 2013).

However, there is no unanimity among researchers on the depth of seed sowing. Thus, according to the Institute of Plant Growing by V.Ya. St. George's NAAS, the optimal depth of seed sowing in the north-eastern regions is 4-5 cm. In arid conditions, the sowing depth can be increased to 6 to 8 cm, but large seeds are used in such cases and the field must be rolled. Calculations of sowing rates are based on the need to obtain shoot density at the level of 400 pcs/m$^2$ for varieties with low tillering rates and varieties with more intensive tillering 350-380 pcs/m$^2$ (Kyrychenko et al., 2018).

According to the NAAS recommendations of the Odesa Breeding and Genetic Institute, in the South of Ukraine, in the presence of sufficient moisture in the soil, seeds should be seeded at a depth of 6 to 7 cm and not less, because winter hardiness is reduced. When the soil dries, the sowing depth can be increased to 8-10 cm. At late seed sowing dates in dry soil, seed sowing should be carried out to a depth of 5 to 6 cm (Sokolov et al., 2018). The same recommendations are given for the conditions of the Zaporizhia region (Shevchenko et al., 2017).

Winter wheat deep sowing is practiced to preserve and effectively use soil moisture in Mediterranean climates, including the northwestern region of the Pacific Ocean, parts of western and southwestern Australia, and central Chile. Winter wheat in an area with low rainfall (<300 mm per year) is sown 10 cm or even deeper with special drills to achieve sufficient moisture for germination (Schillinger et al., 2008). The emergence of wheat shoots at deep sowing is complex, and further detailed research is needed to understand the basic mechanisms. Seed weight does not significantly affect the emergence of shoots at deep sowing (Mohan et al., 2013).

Other researchers have concluded that more than 10 cm of winter wheat sowing should be avoided as it adversely affects grass strength and plant growth (Hadjichristodoulou et al., 1977). When seeds are sown at too shallow depth, this leads to poor germination due to insufficient moisture in the topsoil, while excessively deep sowing can significantly reduce germination and, finally, yield (Aikins et al., 2006). If the depth of the sowing is in the range of 2 cm to 6 cm, shallow sowing can increase the level and quality of the shoots and reduce the impact of wet conditions, so shallow sowing is one of the effective measures for use on wet soils. However, in shallow sowing, the tillering node is laid mainly at a depth of 2 cm, which does not contribute to resistance to freezing and drought, so they are suitable only for wet areas (Liu Xin et al., 2011). Research in Turkey has shown that grain yields and yield components correlate positively with coleoptile length. It is noted that there is a noticeable decrease in yield and quality indicators among varieties with shorter coleoptiles at the deepest sowing. Wheat sown at 5 cm yielded a higher yield than wheat sown at 3, 7 and 9 cm by 19.9, 22.3, and 62.5%, respectively (Yagmur et al., 2009).

According to the Myronivka Institute of Wheat, it is not practical to sow deeper than 6 to 7 cm because the increase in depth is not accompanied by a significant deepening of the tillering node. Thus, when the seeds were sown by 3 cm, the tillering node lay at a depth of 1.5 cm, and when sowing by 7 cm, at a depth of 2.9 cm. No matter how deep we seed, the tillering node is formed in the soil layers near the surface (2 to 3 cm). Therefore, under favorable conditions of moisture, the depth of sowing should not exceed the depth of the tillering site, which in most cases is 2.5 to 3.5 cm (Remeslo et al., 1982). In the Chernihiv region, it is recommended to sow at a depth of 2 to a 2-3 cm depth, not deeper than 4 cm (Volkogon et al., 2015). In the conditions of western Ukraine, the depth of seed sowing of winter grain crops in most soils is 3-4 cm, as the higher depth of sowing requires additional costs of nutrients for germination. With shallow sowing, seeds germinate faster, bush faster, forming synchronously developed shoots. In contrast, tillering occurs later; the seedlings of the second and following ones lag far behind in development from the main ones (Stasiv et al., 2019).

According to numerous research conducted in the 60-70 s in the western forest of Ukraine, the depth of winter wheat sowing was recommended within 3-5 cm. The introduction in the early 1980s in the production of intensive technology for growing winter wheat has radically changed views of sowing depth. Instead of the concept of deep seeding by 4-6 cm and its substantiation, theoretical and practical bases of shallower seeding are developed-no more than 2 to 3 cm. This depth of sowing is recommended to be applied by most researchers (Kavunets et al., 1997 ).

This issue is significant for the conditions in western Ukraine, where there is enough moisture and no severe winters that would damage the tillering site (dries at minus 17-19°C in the area of the site). Therefore, it is necessary to sow here in intensive technology on 2-3 cm. The elongation of the underground stem by 1 cm reduces the grain yield by 3-5% (Volkogon et al., 2015). When sowing to a depth of 2 to 3 cm, endosperm nutrients are spent on the growth of roots and leaves so that plants form a strong knot of tillering; there is intensive seedling and root formation, which increases the level of their productivity potential. When sowing to a depth of 6 cm, a significant part of the reserve nutrients is spent on epicotyl growth; the plant later comes to the soil weakened, and less bushy.

A further increase in seed sowing depth leads to the formation of a weakened tillering node, this type of plant does not form lateral shoots. Plants are not resistant to stressful situations, they are unproductive. With deep sowing of seeds, the risk of lodging, defeat of diseases increases, and low-productive plants are formed.

## Materials and Methods

To establish the optimal depth of winter wheat seed sowing in 2018-2020 in the research field of the Department of Plant Technology of Lviv National Agrarian University, field research was conducted/The soil of the experimental site is light dark gray podzolic loam with a humus content of 2.5-2.6%. The content of light hydrolysis nitrogen is 68.0-72.0 mg, mobile forms of phosphorus and potassium (according to Chirikov's method) are 85.0-88.0 mg and 89.0-95.0 mg per 1 kg of soil, respectively. The reaction of the soil solution is close to neutral; the pH of the salt extract is 5.9-6.0. Weather conditions in the years of research were quite contrasting and differed from the average long-term data in terms of precipitation and temperature. During the year in 2018 fell 760 mm, in 2019-818 mm, in 2020-710 mm with a long-term average of 615 mm. Precipitation in June 2018 and May 2019 created conditions of excessive moisture, which led to reduced yields. Air temperature during research was not a limiting factor of yield growth. In 2018, the average monthly temperature was 8.8°C, in 2019-9.1°C, in 2020-9.4°C, with a long-term average of 7.8°C. The calculated area was 50 $m^2$, and the experiment was repeated three times. Placement of plots were systematized.

The predecessor of winter wheat is winter rape. After harvesting the predecessor, disking was carried out, two weeks before sowing, plowing was carried out, and on the day of sowing pre-sowing tillage by the Compactor. The Reform variety was sown on September 30 with a 3.0 million/ha sowing rate with the CH-16 seeder. Width between rows-15 cm. Before sowing, the seeds were treated with Kinto Duo, 2.5 l/t (prochloraz, 60 g/l+triticonazole, 20 g/l) and Cruiser, 0.5 l/t (thiamethoxam, 350 g/l). In autumn, in the phase of 3 wheat leaves, the herbicide Marathon, 4.0 l/ha (pendimethalin, 250 g/l+isoproturon, 125 g/l), was applied to control weeds.

Nitrogen fertilizers were applied in the form of ammonium nitrate three times: $N_{60}$ during the restoration of spring vegetation (BBCH 25)+$N_{80}$ at the end of the tillering phase (BBCH 29)+$N_{40}$ in the earing phase (BBCH 59). The entire rate of phosphorus and potassium fertilizers was applied in three superphosphate ($P_{46}$), potassium chloride ($K_{60}$) under plowing.

In spring, wheat sowings were treated with Medax Top (mepiquat chloride, 300 g/l+prohexadione calcium, 50 g/l) at a rate of 1 l/ha at the beginning of plant emergence in the tube (BBCH 30) and Terpal (mepiquat chloride, 305 g/l+ethephon, 155 g/l) in the phase of appearance of the tongue in the flag leaf (BBCH 39). To protect against diseases, sowings were sprayed with Flexiti fungicides (metrafenone, 300 g/l) with a rate of 0.25 l/ha in the early phase of plant emergence in the tube (BBCH 30), Amistar

Extra drug (azoxystrobin, 200 g/l+cyproconazole, 80 g/l) with a rate of 0.75 l/ha in the flag leaf phase (BBCH 39), by Osiris Star fungicide (epoxiconazole, 56.25 g/l+metconazole, 41.25 g/l) with a rate of 1.5 l/ha in the flowering phase (BBCH 65). To control pests, sowings were sprayed twice with insecticides: Karate Zeon (lambda-cyhalothrin, 50 g/l) with a rate of 0.30 l/ha in BBCH 30 phase and Engio (lambda-cyhalothrin, 106 g/l+thiamethoxam, 141 g/l) with a rate of 0.18 l/ha in BBCH 39 phase.

The Reform variety was entered into the state registry of varieties in 2017. Originator RAGT Semences, France. Variety Lutescens. Mid-late, winter-hardy variety. A high ability characterizes it for tilling. Short (70-83 cm), resistant to lodging, shedding. The grain quality belongs to valuable wheat, gluten content-25.0-26.8%, protein-12.7-13.5%. Weight of 1000 grains-45-50 g. Potential yield 11.0-13.5 t/ha. The recommended sowing rate is 3.0-4.0 million units/ha.

Statistical processing of the research results obtained was performed using OriginPro 2019b software (Origin Lab Corporation, USA, 2019). Data were compared using the Tukey test, and differences between samples were considered statistically significant at $p < 0.05$. The data in the tables are presented as the arithmetic mean with standard deviation (x ± SD).

## Results

According to data from the Lviv National Agrarian University, the length of the root-like internode (distance from the primary root system to the tillering node) increased with increasing seed sowing depth and was the largest in the variant with sowing of 7-4.5 cm (Table 1). The growth of this underground part of the stem consumes the nutrients of the endosperm, so the surface of the plant comes to the soil surface weakened, and the formation of the root system slows down-impaired access of oxygen to the seeds. Productivity potential is significantly lost. In the first three variants, the tillering node was formed directly near the primary (embryonic) root system, and the length of the root-like internode was minimal. When sowing to a depth of 2 to 3 cm, the growth cone is located at a depth that meets the biological requirements of winter wheat. The underground internodes are close; the plant forms the most robust compact root system, which provides the best opportunities to develop the photosynthetic apparatus. Grain nutrients are not used for the growth of the underground part of the stem, but for forming roots and leaves. The root system was underdeveloped only in the variant in which the seeds were placed at a depth of 1 cm.

The highest indicators of field germination (88-90%) were in variants with a seed sowing depth of seed sowing of 1-4 cm. Sowing by 5 cm and deeper leads to a significant decrease in field germination (Table 1). Other researchers obtained by other researchers, where the change in seed sowing depth in the range of 2 to 4 cm did not affect field germination. When sowing deeper than 4 cm, shoots appear with a delay of about one day for each cm of the increase in sowing depth (Kalenska and Karpenko, 2015).

**Table 1.** Indicators of the structure of the yield of winter wheat according to the depth of seed sowing, 2018-2020, (x ± SD, n=6).

| Sowing depth of seeds, cm | Length of root-like internode, cm | Field germination of seeds, % | Overwintering of plants, % | Coefficient of tillering | The density of productive stem, pcs/m$^2$ | Weight of grain from the ear, g |
|---|---|---|---|---|---|---|
| 1 | - | 88 ± 1.7$^{a}$ | 97 ± 1.0$^{a}$ | 2.2 ± 0.12$^{ab}$ | 561 ± 10.1$^{a}$ | 1.40 ± 0.02$^{a}$ |
| 2 | - | 90 ± 2.0$^{a}$ | 98 ± 0.6$^{a}$ | 2.4 ± 0.12$^{a}$ | 634 ± 7.1$^{b}$ | 1.34 ± 0.03$^{b}$ |
| 3 | 0.4 ± 0.06a | 90 ± 2.1$^{a}$ | 97 ± 1.0$^{a}$ | 2.5 ± 0.06$^{a}$ | 652 ± 8.2$^{bc}$ | 1.32 ± 0.01$^{b}$ |
| 4 | 1.4 ± 0.10b | 88 ± 2.0$^{ab}$ | 98 ± 0.6$^{a}$ | 2.4 ± 0.10$^{a}$ | 619 ± 4.5$^{bd}$ | 1.32 ± 0.02$^{b}$ |
| 5 | 2.3 ± 0.06c | 83 ± 1.5$^{abcd}$ | 97 ± 1.0$^{a}$ | 2.3 ± 0.10$^{ab}$ | 552 ± 7.2$^{a}$ | 1.44 ± 0.02$^{a}$ |
| 6 | 3.3 ± 0.20d | 80 ± 2.6$^{cd}$ | 97 ± 0.0$^{a}$ | 2.0 ± 0.06$^{bc}$ | 462 ± 5.5e | 1.66 ± 0.01$^{c}$ |
| 7 | 4.5 ± 0.10e | 78 ± 2.6$^{d}$ | 97 ± 1.2$^{a}$ | 1.8 ± 0.15$^{c}$ | 405 ± 4.5$^{f}$ | 1.81 ± 0.01$^{d}$ |

**Note:** Values that have at least one identical letter within a table column do not differ when using the Tukey test ($p<0.05$).

The depth of seed sowing did not affect the level of overwintering. The opinion of some researchers that deeper sowing protects against freezing in the western forest-steppe and global warming is not confirmed.

The indicators of the tillering coefficient and the density of productive stems are interrelated. The plants were best bushed at the sowing by 2-4 cm. Increasing the depth led to a decrease in the intensity of productive tillering, increasing the depth of sowing to form a lateral shoot practically only the main. Lateral, in turn, forms its tillering node and gives seedlings of the second one. This leads to asynchronous tillering; later, many weaker seedlings die, and with its nodular roots, use for its growth many nutrients.

Such indicators determined the density of productive stems such as field germination, overwintering of plants, and tillering rate, so they varied in a wide range. It was the highest for sowing at 2 and 3 cm, respectively, 634 and 652 ears/m$^2$. Increasing the depth of sowing to 6 and 7 cm negatively affected the tillering process, which led to a significant reduction (462 and 405 pcs/m$^2$) of the number of ears. In these variants, sowing with a sowing rate of 3.0 million/ha does not provide the required density of ears, so for deep sowing of the seeds, the sowing rate of sowing should be increased to 5.0 million/ha.

The weight of the grain of the ear differed little and was in the range of 1.32 to 1.44 g in variants with a sowing depth of 1 to 5 cm. The increase in this indicator in the sowing by 6 cm and 7 cm is due to a sharp decrease in ear density and a more significant impact on crop formation in sparse sowings of grain mass from the ear.

In addition, based on regression analysis, the mathematical models were built and the relationship between the main indicators of the structure of winter wheat yield from the depth of seed sowing is reflected in the equations presented in Table 2.

The calculated mathematical models are 95% reliable according to Fisher's criterion and Student's criterion. They make it possible to predict a specific indicator of the structure of winter wheat (field germination, density of productive stems, grain weight from one ear) depending on the depth of seed sowing. It should be noted that there is a closer relationship between the weight of grain from one ear of winter wheat (R=0.991) from the depth of seed sowing compared to the dependence of seed germination in the field (R=0.967) and the productive stem density (R=0.976) of this indicator.

**Table 2.** The equation of the dependence of the main indicators of the structure of the winter wheat crop on the depth of seed sowing.

| Indicator | Equation | Multiple correlation coefficient, R | Determination coefficient, D |
|---|---|---|---|
| Field germination of seeds,% | $Y_1=87.5714+1.869X-0.4881X^2$ | 0.967 | 93.5 |
| Density of the productive stem, pieces/m$^2$ | $Y_2=505.5714+87.2381X-14.9762X^2$ | 0.976 | 95.3 |
| Weight of grain from one ear, g | $Y_3=1.5414-0.1661X+0.0296X^2$ | 0.991 | 98.2 |

**Note:** $Y_1$-field germination of seeds,%; $Y_2$-the density of productive stem, pcs/m$^2$; $Y_3$-the mass of grain from the ear, g; X-depth of seed sowing, cm.

The essential components of the yield structure are the grain density of the ears and the mass of grain from them per unit area. The mass of grain from the ear was greater than the sparse standing of the stems. The decrease in the average weight of grain from the ear at sowing by 2 to 3 cm is due to an increase in the density of productive stems and a more significant proportion of this indicator in the structure of the crop. Therefore, sowing the seeds at a depth of 2-3 cm creates the best conditions for tilling, and side seedlings are slightly behind the primary productivity. This is because the plant is formed with a developed tillering node. There is the possibility of almost synchronous development of the primary and side shoots. This type of development gives the most productive plants with high viability and resistance to adverse factors. Therefore, the highest grain yield in these variants was also 8.22 and 8.30 t/ha (Table 2).

The deepening of the seeds by 4 cm led to a decrease in yield by 0.22 t/ha. When sowing to a depth of 5 cm, the yield decreased by 0.43 t/ha. Increasing the sowing depth over 6 cm significantly reduced the yield. Thus, at 6 cm sowing, it decreases to 7.62 t/ha, or 0.68 t/ha. In the variant with seed sowing depth of 7 cm, the grain yield of winter wheat is reduced to 7.30 t/ha, which is less than the sowing depth of 3 cm by 1.00 t/ha (Table 3).

**Table 3.** The yield of winter wheat variety Reforms depending on the depth of seed sowing, (x ± SD, n=6).

| Sowing depth, cm | Year | | | Average | Yield change, +/- | |
|---|---|---|---|---|---|---|
| | 2018 | 2019 | 2020 | | t/ha | % |
| 1 | $7.81 \pm 0.04^{bcd}$ | $7.70 \pm 0.09^{cd}$ | $7.83 \pm 0.08^{bc}$ | $7.78 \pm 0.07^{bcd}$ | -0,52 | -6.3 |
| 2 | $8.20 \pm 0.23^{de}$ | $8.08 \pm 0.08^{de}$ | $8.38 \pm 0.08^{d}$ | $8.22 \pm 0.15^{cde}$ | -0.08 | -1.0 |
| 3 | $8.25 \pm 0.06^{de}$ | $8.16 \pm 0,07^{e}$ | $8.49 \pm 0.05^{d}$ | $8.30 \pm 0.17^{de}$ | - | - |
| 4 | $8.05 \pm 0.12^{cd}$ | $7.91 \pm 0.09^{cd}$ | $8.28 \pm 0.09^{d}$ | $8.08 \pm 0.19^{cd}$ | -0.22 | -2.7 |
| 5 | $7.81 \pm 0.07^{bc}$ | $7.78 \pm 0.09^{c}$ | $8.02 \pm 0.08^{bc}$ | $7.87 \pm 0.13^{bc}$ | -0.43 | -5.2 |
| 6 | $7.60 \pm 0.05^{b}$ | $7.46 \pm 0.06^{b}$ | $7.80 \pm 0.08^{b}$ | $7.62 \pm 0.17^{ab}$ | -0.68 | -8.2 |
| 7 | $7.25 \pm 0.06^{a}$ | $7.17 \pm 0.10^{a}$ | $7.48 \pm 0.09^{a}$ | $7.30 \pm 0.16^{a}$ | -1.00 | -12.0 |

**Note:** Values with at least one identical letter within a table column do not differ when using the Tukey test ($p<0.05$).

Yields also changed under the influence of meteorological conditions. It was the highest in 2020 and the lowest in 2019.

Therefore, the best conditions for the growth and development of winter wheat plants and the formation of high grain yields are created at sowing depths of 2 to 3 cm.

**Table 4.** Equation of dependence of winter wheat yield on seed sowing depth.

| Indicator | Equation | Multiple correlation coefficient, R | Determination coefficient, D |
|---|---|---|---|
| Yield, t/ha | $Y=7.5443+0.4075X-0.0646X^2$ | 0.960 | 92.2 |

**Note:** Y-yield of winter wheat, t/ha; X-depth of seed sowing, cm.

A mathematical model based on the experimental data obtained was developed, which reproduces the dependence of the depth of winter wheat yield on the seed sowing depth (Table 4). The multiple correlation coefficient (R=0.960) confirms the close relationship between the indicators included in the equations, and the given coefficient of determination (D=92.2) indicates a significant effect of seed sowing depth (argument-X) on winter wheat yield (function-Y).

## Conclusion

The highest indicators of field germination (90%), tillering coefficient (2.4 and 2.5), and the density of productive stems (634 pieces and 652 pieces) of winter wheat were obtained for sowing by 2 cm and 3 cm. For the formation of the highest yield, the following combination of the main elements of the structure of the the density of productive stems and grain weight of the ear is optimal: 634 ears × 1.34 g and 652 ears × 1.32 g per $m^2$. The best conditions for genetic potential, the productivity of the Reform variety (8.22 t/ha and 8.30 t/ha) were formed by sowing seeds at a depth of 2 cm and 3 cm.

## References


Aikins, S.H.M., Afuakwa, J.J., Baidoo D. (2006). Effect of planting depth on maize stand establishment. Journal Ghana Institution Engineering, 4:20-25.

Akman, H., Topal, A. (2013). Effects on wheat root growth and development of rhizosphere environment and stress factors. Journal Selcuk Universal Natural Applied Sciences ICOEST Conference, pp:824-838.

Hadjichristodoulou, A., Della, A., Photiades, J. (1977). Effect of sowing depth on plant establishment, tillering capacity and other agronomic characters of cereals. The Journal of Agricultural Science, 89:161-167.

Kavunets, V., Dvornyk, V., Malasay, V. (1997). Sowing depth is an important factor of yield. Land and people of Ukraine. 2:18-19 (In Ukrainian).

Kalenska, S.M., Karpenko, L.D. (2015). Field germination of spring wheat seeds depending on the depth of sowing. Agrobiology College Science. Bila Tserkva National Agrarian University, 1:15-18 (In Ukrainian).

Kyrychenko, V.V., Popov, S.I., Kobizeva, V.P. (2018). Peculiarities of sowing winter crops on farms of Kharkiv region for the 2019 harvest. Kharkiv. Institute of Plant Breeding named after V.Ya. Yuriev NAAS (In Ukrainian).

Liu, X., Yin, C., Li, H. (2011). Sowing depth and water logging time after wheat sowing affect on germination rate and seedling quality before winter. Chinese Agricultural Science Bulletin, 27:189-194.

Mohan, A., Schillinger, W.F., Gill, K.S. (2013). Wheat seedling emergence from deep planting depths and its relationship with coleoptile length. PLoS ONE, 8:e73314.

Remeslo, V.N., Cooperman, F.M., Zhivotkov, L.A. (1982). Selection and varietal agrotechnics of intensive wheat. Moscow Ear (in Russian).

Roy, J., Biswas, P.K., Ali, M.H., Rahman, A. (2011). Effect of sowing depth and population density on yield attributes and yield of wheat. Technical Journal of Engineering and Applied Sciences, 1:125-133.

Schillinger, W.F., Papendick, R.I. (2008). Then and now: 125 years of dryland wheat farming in the Inland Pacific Northwest. Agronomy Journal, 100:166-182.

Shevchenko, I.A., Polyakov, O.I., Zhuravel, V.M. (2017). Soil preparation and sowing of winter grain and oilseeds in Zaporizhia region in 2017. Zaporizhzhia. IOC NAAS (In Ukrainian).

Sokolov, V.M., Bushulyan, O.V., Lytvynenko, M.A., Linchevsky, A.A., Babayants, O.V. (2018). Recommendations for conducting a set of autumn field works in agricultural formations of Odessa region in 2018. Odessa. Astroprint (In Ukrainian).

Stasiv, O.F., Sedilo, G.M., Konik, G.S. (2019). Features of technologies of cultivation of winter grain crops under harvest of 2020 (autumn complex of works): recommendations. Lviv-Obroshino. Institute of Agriculture of the Carpathian Region NAAS (In Ukrainian).

Volkogon, V.V., Moskalenko, A.M., Berdnikov, O.M., Egorov, O.V. (2015) Recommendations for sowing winter crops in farms of Chernihiv region for the 2016 harvest Chernihiv. Institute of Agricultural Microbiology and Agroindustrial Production of NAAS (In Ukrainian).

Yagmur, M., Kaydan, D. (2009). The effects of different sowing depth on grain yield and some grain yield components in wheat (Triticum aestivum L.) cultivars under dryland conditions. African Journal of Biotechnology, 8:196-201.

Zecevic, V., Boskovic, J., Knezevic, D., Micanovic, D. (2014). Effect of seeding rate on grain quality of winter wheat. Chilean Journal of Agricultural Research, 74:23-28.



**Citation:**

Lykhochvor, V.V., Olifir, Y.M., Tyrus, M.L., Panasiuk, R.M., Ivaniuk, V.Y. (2022). Ecologization of winter wheat growing technology according to optimization of sowing depth. *Ukrainian Journal of Ecology.* 12:1-5.