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DOI: 10.15199/180.2024.2.2

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BENEFITS OF STRIP-TILL IN WINTER WHEAT CULTIVATION

KORZYŚCI ZASTOSOWANIA UPRAWY STRIP-TILL U PSZENICY OZIMEJ

***Summary**: Winter wheat, as a cereal of greatest economic and food importance, is grown on the largest area of arable land in Poland. The great importance and significant acreage under cultivation result in a search for the methods of cultivating the discussed cereal which would ensure a sufficiently high yield and its quality and, at the same time, bring measurable economic and environmental benefits. One of such methods meeting the mentioned above requirements is strip-till, also referred to as strip cropping. This cultivation method has a number of multifaceted benefits. The application of this cultivation method has a positive impact on the yield and quality of winter wheat grain with simultaneous positives such as reduced fuel consumption and environmental benefits in the form of improved soil quality and reduced carbon dioxide emissions. The aim of this study was to synthesise the current state of knowledge on yield and its quality in winter wheat cultivated using the strip-till method on the basis of the available scientific literature and the results of our own research.*

***Keywords**: Strip-till, cultivar, cropping systems, winter wheat, yield, grain quality*

***Streszczenie**: Pszenica ozima jako zboże o największym znaczeniu ekonomicznym oraz żywnościowym jest uprawiana na największym areale użytków rolnych w Polsce. Duże znaczenie i znaczny areał uprawy powodują, że poszukuje się metod uprawy tego zboża, które zapewniłyby dostatecznie wysoki plon i jego jakość, a jednocześnie przynosiły wymierne korzyści ekonomiczne i środowiskowe. Jedną z takich metod, która spełnia te wymagania jest strip-till określany również jako uprawa pasowa. Ten sposób uprawy niesie za sobą szereg wieloaspektowych korzyści. Wykorzystanie tej metody uprawy wpływa korzystnie na plon i jakość ziarna pszenicy ozimej przy jednoczesnych pozytywach takich jak: zmniejszenie zużycia paliwa oraz korzyści środowiskowe w postaci lepszej jakości gleby oraz obniżonej emisji dwutlenku węgla. Celem pracy była synteza obecnego stanu wiedzy dotyczącej plonu oraz jego jakości u pszenicy ozimej uprawianej metodą strip-till na podstawie dostępnej literatury naukowej oraz uzyskanych wyników badań własnych.*

***Słowa kluczowe**: Strip-till, odmiana, systemy uprawy, pszenica ozima, plon, jakość ziarna*

Introduction

Wheat is a cereal species of a very high economic importance. In Poland, its cultivation in 2021 was at the level of 2.391 thousand hectares, of which a significant part was the winter variety (91%). The large area under wheat cultivation gives a high self-sufficiency in terms of internal market demand. In 2021, the wheat grain harvest reached 12119.0 thousand tonnes, of which 10907.1 thousand tonnes (90%) was the grain from winter wheat cultivation. Converting the yield per capita gives about 300 kg of wheat grain per year, while back in the 1980s it was 117 kg. The significant increase in wheat yields is the result of breeding progress combined with the application of modern solutions associated with the use of appropriate agrotechnology. Attention is also now being paid not only to the quantity of the grain obtained, but also to its quality and to reducing the negative effects of tillage on the environment. This is also reflected in the agricultural policy pursued by the European Union in the form of incentives promoting practices aimed at reducing carbon dioxide emissions from agriculture and promoting the so-called carbon farming. This term is understood as agricultural practices that realise a reduction in global carbon dioxide emissions and its uptake from the atmosphere, through the implementation of recommended agronomic practices. The main objective is to achieve a negative carbon balance through increased carbon sequestration in the soil. This creates the opportunities for ecological benefits with positive impacts on the soil health. A practice that embraces carbon farming is the use of simplified cultivation and the abandonment of traditional ploughing. Strip-till tillage disturbs the soil structure much less and does not damage the soil macropores so that the soil microbial balance is not disturbed either [18]. This is due to the higher number of macroaggregates by up to 51–54% in strip-till than in conventional plough tillage [22]. The popularisation of knowledge and benefits is influencing an increase in the number of proponents of strip-till among Polish producers, but the use of the traditional plough tillage system is still most popular. Encouragement to extend the use of reduced tillage is provided by pro-environmental payments referred to as eco-schemes, which are a component of direct payments, which also include tasks related to the use of reduced tillage. The implementation of these obligations is mandatory for the Member State, but voluntary for the farmer. The abandonment of plough tillage is most often carried out by farms with a large cultivated area, but simplified tillage is increasingly being used on smallholder farms as well. A particular type of reduced tillage that combines the advantages

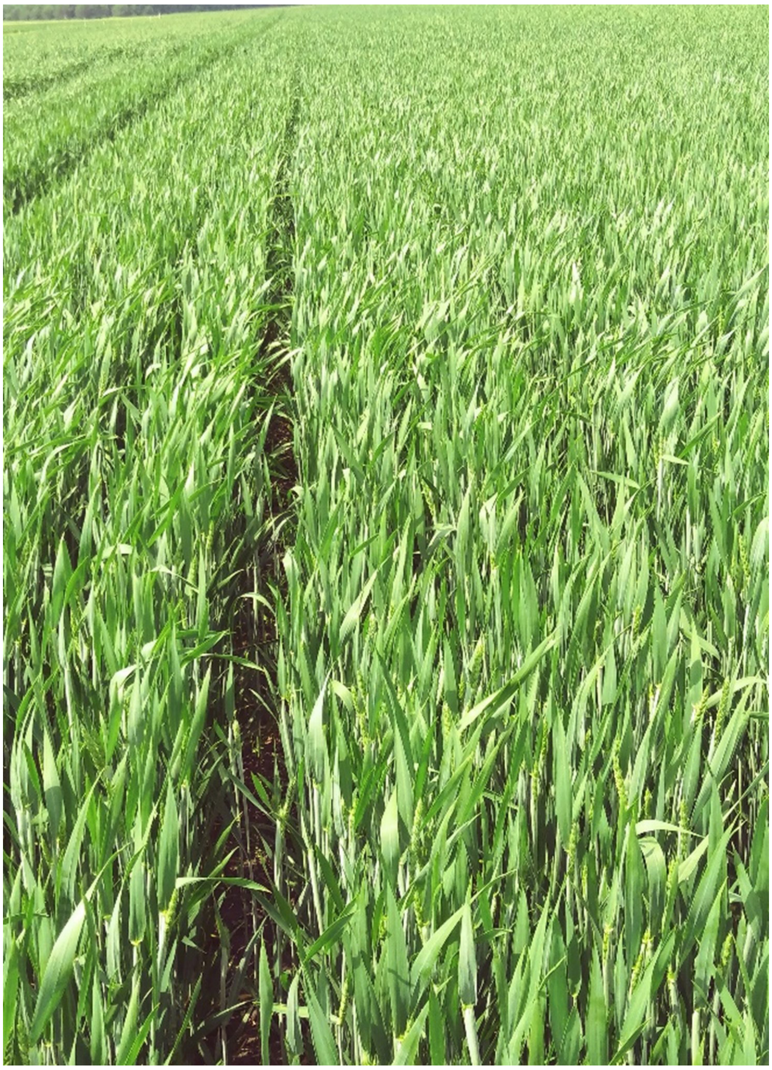

Photo 1. Intercropping with uncultivated soil provides an opportunity for plants to lean into this space and benefit from the greater availability of light (by M. Różewicz)

of plough and ploughless tillage is strip-till (also referred to as strip-till). The popularisation of this type of cultivation is also linked to the development of technical advances increasingly in the machinery industry, the latest proposals of which concern machinery that allows strip-till combined with seeding. The advantages of this method include: aeration of the soil in the rhizosphere, faster heating of the soil in the cultivated strip, prevention of loss of clay and silty soil particles – responsible for the soil sorption complex (the so-called wind erosion). The positives including faster soil warming are particularly important in cool climate zones, significantly increasing crop yields by an average of 3.64% compared to no-tillage [7]. In addition, the use of reduced tillage with leaving a large amount of crop residue in the field significantly contributes to the reduction of greenhouse gas emissions in wheat production [10]. New technologies in the design of strip-till machinery allow for the management of crop residues which, however, do not impede plant growth [3].

Scientific literature on strip-till cultivation in Poland is scarce. Preliminary studies carried out so far on the possibility of using strip-till sowing of wheat in Poland have shown beneficial effects of strip-till technology on winter wheat plants, their yield and grain quality, which became apparent especially in years with unfavourable agrotechnical and habitat conditions [26]. This is also confirmed by studies by other authors conducted in different countries [5]. Taking into account the increasingly frequent agricultural droughts and the economic importance of wheat cultivation, further research on this cereal species in strip sowing, is justified. Creating optimum conditions for plants reduces intraspecies competition for water and nutrient resources in the soil. In addition, uncultivated rows provide plants with the opportunity to benefit from greater light availability (due to the so-called marginal effect – photo 1), which also plays an important role in the intensity of photosynthesis, promoting better nutrition, disease resistance and lodging [9]. It also determines adequate green matter accumulation and higher productive tillering. It affects higher yield, but is also a factor in wheat's competitiveness with weeds. Wheat plant tillering is determined by the varietal factor [8], but is also related to sowing density. A factor that is important and differentiates the yield obtained and its quality is the genetic factor - cultivar. In the breeding of wheat cultivars, significant progress has been noticed in Poland for several years, but the use of the yield-forming potential of new cultivars is closely related to the applied cultivation technology [19]. This is indicated by numerous studies on the yield of individual wheat cultivars, both by the Central Research Centre for Cultivar Testing and scientific research [20, 29]. Biological progress in breeding new wheat cultivars has resulted in yield stability. The selection of a suitable cultivar is one of the non-input factors influencing crop yields, but it must be linked to the optimally selected cultivation technology and the prevailing habitat conditions [30].

A problem that implies the introduction of simplified arable farming is also the increasing problem of drought. The traditional ploughing system causes soil loosening and deterioration of water conditions by significantly drying out the soil. Drought is one of the most important environmental factors inhibiting photosynthesis and reducing plant growth and productivity. Both the cropping system itself and the wheat cultivar grown in it affect photosynthetic rates [28]. High temperatures with low rainfall during the growing season cause significant yield losses in wheat. Due to an increase in average temperature over the years and a warming climate in different regions of the world, it becomes necessary to adapt cropping systems to the changes taking place. Photosynthesis, carbon assimilation and transpiration are major determinants of the carbon balance and growth of wheat, and high temperatures and lack of soil water, significantly reduce the efficiency of these processes. The creation of suitable habitat conditions can to some extent minimise the negative effects of high temperatures on photosynthesis and thereby reduce yield losses [23].

Strip-till wheat cultivation and yield and quality

Farmers who are interested in introducing strip-till technology on their own farms may be encouraged by the range of benefits that from it. These include both the yield itself and the economic benefits associated with reduced fuel consumption and the ability to meet ecoschemes, as well as environmental benefits such as improved soil properties and reduced environmental impact. A study by Cheng et al. [2] showed that the use of strip-till and controlled-release nitrogen fertiliser contributes to better yields, reducing costs, and increasing income, while meeting the environmental objective. Studies show that wheat grown in strip-till system yields more than wheat grown in no-till and conventional systems. A study by Jaskulska and Jaskulski [16] shows that winter wheat gave a similar grain yield to that grown in the plough system, but definitely higher than in no-till. The higher grain yield obtained by Jaskulska and Jaskulski [15] in strip-till technology was due to better emergence of wheat grains, which translated into a higher number of ears and grain weight per ear. The findings of the cited authors regarding better emergence can be linked to the reported higher soil moisture found in strip-till. Similarly, Hossain et al [12] found higher wheat grain yield in strip-tillage compared to conventional (plough) tillage. Considering that adverse weather conditions will become more frequent during the growing season, research to determine the most effective methods under such conditions, seems very justified. According to research conducted by Saldukaitė-Sribikė et al [27], the additional introduction of ploughing or minimum tillage prior to strip-till does not result in higher winter wheat yields, but only increases fuel consumption and carbon dioxide emissions into the atmosphere. Previous research has shown that the factor that differentiates the productive and economic effects of strip-till can depend on genetic factors. This is due to their physiology related to their ability to grow and develop at a certain density. Strip sowing creates a special situation for wheat plants, where plants sown in two rows next to each other are separated by inter-rows of greater width. In our own research, it has been shown that the applied variation in post-harvest cultivation and cultivar have a significant effect on the yield obtained. The abandonment of post-harvest tillage by using only strip-till did not significantly affect the yield of the cultivars Desamo and Metronom, while in the case of the cultivar Formation, abandoning the previously applied ploughing reduced grain yield by 0.77 t/ha (9%) [24]. Thus, an important element of yield maximisation in the case of winter wheat cultivation in strip-till technology, is the appropriate choice of cultivar. The reason for the variation in the yield of cultivars is the role of the genetic factor in shaping the productivity of the cereal canopy caused by the different degree of resistance of cultivars to stem base and root diseases. These diseases are more prevalent under conditions of limited cultivation and left crop residues without being ploughed in, so cultivars showing higher resistance will also show higher yields. As demonstrated by the study of Chiriţă et al. [4], as the intensity of soil tillage decreases in winter wheat, it affects the yield reduction compared to plough tillage, the lowest being with zero tillage. The combination of suitable tillage and cultivar is therefore the main factor influencing yield. Mainly through better emergence and plant density per unit area, as well as number of ears and grain per ear especially in years with less favourable weather conditions [14]. A comparison of the results of our own research [24] on the yield obtained with the research of other authors [26, 27], showed that the forecrop plays an important role in the yield of winter wheat in strip-till cultivation (Table 1). In our own research where the forecrop was winter wheat, performing prior ploughing before applying strip-till resulted in higher yields than conventional strip-till without prior post-harvest cultivation. On the other hand, studies by Różniak [26] and Saldukaitė-Sribikė et al [27] showed that when the forecrop is oilseed rape, winter wheat showed a higher yield in a traditional strip-till than with a pre-till. Oilseed rape can be a good forecrop for wheat in strip-till because higher seed yields are also recorded for this species when strip-till is used [13]. The

Table 1. Winter wheat yield as a function of pre-crop and post-crop applied

Forecrop	Post-harvest cultivation	Grain yield (t/ha)	Author
Rapeseed	Ploughing	6,95	[27]
		9,07	[26]
Wheat		7,88	[24]
Rapeseed	Cultivation	6,96	[27]
Wheat		7,41	[24]
Rapeseed	Zero-tillage	7,27	[27]
		8,98	[26]
Wheat			[24]

cultivation of winter wheat following one another, reduces the grain yield in subsequent years [21], so proper crop rotation is an important element that has an impact on the yield obtained. Growing wheat one after another caries an increased severity of diseases, especially fungal diseases [11], which can affect yield reduction.

In addition to the yield obtained, equally important in the case of wheat is its quality, which determines the use of the grain for food purposes. According to a study obtained by Jaskulska et al [17], the application of strip tillage or traditional ploughing does not affect the quality traits of wheat grain, such as protein and gluten content in grain, sedimentation value, and volume and bread weight. The authors found that grain quality was more influenced by weather conditions in particular years. In contrast, their own research showed that traditional strip-till cultivation influenced a higher sedimentation index value, but did not affect gluten amount, gluten index and falling number [25]. The significant increase in sedimentation index in strip-till cultivation indicates that grain with good baking value can be obtained in this system. In contrast, Różniak [26] found a favourable effect of strip-till cultivation on total protein and gluten content. Strip-till as a compromise between ploughing and no-till is beneficial. According to a study by Buczek [1], grain yield and grain quality parameters such as gliadin and total glutenin content, are higher than without tillage. However, Dolijanović et al. [6] indicate that the conservation tillage system has a more favourable effect on the mineral composition of wheat grain. Grain from no-tillage contained more macronutrients (K and P) and, micronutrients such as Cu, Fe and Zn.

Conclusions

The cultivation of winter wheat with strip-till technology as one of the variants of conservation tillage, which combines the advantages of both plough and no-till, will gain popularity in Poland. This is related both to the positive impact on grain yield, but also to the reduction of labour input, as soil tillage, fertiliser application and sowing can be carried out in a single pass. It also allows for better economic and environmental results related to reduced fuel consumption and carbon dioxide emissions. This cultivation also contributes to increased grain yield in years with less favourable weather conditions. The use of this cultivation method compared to conventional ploughing, does not negatively or positively affect the quality of the yield. An important factor modifying the yield and its quality in the case of wheat is the cultivar. The right choice of winter wheat cultivar determines the positive effect of yield increase and its quality. However, proper crop rotation must be maintained, as growing winter wheat one after the other reduces yields. An additional incentive to make wheat strip-till cultivation more widespread, is also the possibility of implementing an ecoscheme within the framework of carbon farming. At present, there are no precise data showing the scale of the acreage under strip-till winter wheat cultivation, but many factors suggest that this crop will become much more popular in the near future.

References

[1] Buczek J., 2020. Quality and productivity of hybrid wheat depending on the tillage practices. Plant, Soil & Environment, 66(8), 415-420. DOI: 10.17221/266/2020-PSE

[2] Cheng Z., Bai L., Wang Z., Wang F., Wang Y., Liang H., Wang Y., Wang, Z., 2024. Strip-Till Farming: Combining Controlled-Release Blended Fertilizer to Enhance Rainfed Maize Yield While Reducing Greenhouse Gas Emissions. Agronomy, 14(1),136.

[3] Chen G., Wang Q., Li H., He J., Wang X., Zhang X., He D., 2024. Experimental research on vertical straw cleaning and soil tillage device based on Soil-Straw composite model. Computers and Electronics in Agriculture, 216, 108510. https://doi.org/10.1016/j.compag.2023.108510

[4] Chiriţă S., Rusu T., Urdă C., Cheţan F., Racz I., 2023. Winter wheat yield and quality depending on chemical fertilization, different treatments and tillage systems. AgroLife Scientific Journal, 12(1), 34-39. jhttps://doi.org/10.17930/AGL202315

[5] Ciociu A. I. 2010. Tillage system effects on input efficiency of winter wheat, maize and soybean in rotation. Romanian Agricultural Research, 27, 81-87.

[6] Dolijanović Ž, Nikolić S.R., Dragicevic V., Mutić J., Šeremešić S., Jovović Z., Popović Djordjević J., 2022. Mineral Composition of Soil and the Wheat Grain in Intensive and Conservation Cropping Systems. Agronomy. 12(6),1321. https://doi.org/10.3390/agronomy12061321

[7] Dou S., Wang Z., Tong J., Shang Z., Deng A., Song Z., Zhang W., 2024. Strip tillage promotes crop yield in comparison with no tillage based on a meta-analysis. Soil and Tillage Research, 240, 106085. https://doi.org/10.1016/j.still.2024.106085

[8] Feledyn-Szewczyk, B., Duer. I., 2006. Ocena konkurencyjności odmian pszenicy ozimej uprawianej w ekologicznym systemie produkcji w stosunku do chwastów. Journal of Research and Applications in Agricultural Engineering, 51(2), 30-35.

[9] Grzesik M., Janas R., Górnik K., Romanowska-Duda Z., 2012. Biologiczne i fizyczne metody stosowane w produkcji i uszlachetnianiu nasion. Journal of Research and Applications in Agricultural Engineering, 57(3), 147-152.

[10] Holka M., Bieńkowski J., 2020. Ocena emisji gazów cieplarnianych w cyklu życia produkcji pszenicy ozimej w różnych systemach uprawy roli. Agronomy Science, 75(3), 69-79.

[11] Horoszkiewicz-Janka J., Jajor E., Korbas M., 2012. Występowanie chorób pszenicy ozimej w zależności od wybranych czynników agrotechnicznych. Progress in Plant Protection, 52(4), 998-1004.

[12] Hossain M. I., Haque M. E., Meisner C. A., Sufian M. A., Rahman M. M., 2005. Strip tillage planting method for better wheat establishment. Journal of Science Technology, 3, 91-95.

[13] Jankowski K.J., Sokólski M., Szatkowski A., Załuski D., 2024. The Effects of Tillage Systems on the Management of Agronomic Factors in Winter Oilseed Rape Cultivation: A Case Study in North-Eastern Poland. Agronomy, 14(3), 437. https://doi.org/10.3390/agronomy14030437

[14] Jaskulska I., Jaskulski D., 2018. MZURI Pro-Til – technologia uprawy pasowe - Wzrost i plonowanie roślin!. Agro Profil, 2, 64-65.

[15] Jaskulska I, Jaskulski D., 2021. Winter Wheat and Spring Barley Canopies under Strip-Till One-Pass Technology. Agronomy. 11(3), 426. https://doi.org/10.3390/agronomy11030426

[16] Jaskulska I., Jaskulski D., 2020. "Strip-Till One-Pass Technology in Central and Eastern Europe: A MZURI Pro-Til Hybrid Machine Case Study" Agronomy 10, no. 7, 925.https://doi.org/10.3390/agronomy10070925

[17] Jaskulska I., Jaskulski D., Gałęzewski L., Knapowski T., Kozera W., Wacławowicz R., 2018. Mineral composition and baking value of the winter wheat grain under varied environmental and agronomic conditions. Journal of Chemistry, doi: https://doi.org/10.1155/2018/5013825

[18] Kaur P., Lamba J., Way T. R., Balkcom K. S., Sanz-Saez A., Watts D. B., 2024. Characterization of soil pores in strip-tilled and conventionally-tilled soil using X-ray computed tomography. Soil and Tillage Research, 239, 106035.

[19] Kołodziejczyk M., Szmigel A., Kulig B., 2009. Plonowanie wybranych odmian pszenicy jarej w zależności od poziomu agrotechniki. Fragmenta Agronomica 26(3), 58-67.

[20] Noworól M., 2018. Reakcja odmian pszenicy ozimej na poziom intensywności technologii produkcji. Praca doktorska, UR Rzeszów.

[21] Pawlonka Z., Ługowska M., 2010. Plonowanie pszenicy ozimej w monokulturze przy różnym poziomie ochrony chemicznej przed chwastami. Progress in Plant Protection, 2(50), 823-827.

[22] Paye W. S., Thapa V. R., Ghimire R., 2024. Limited impacts of occasional tillage on dry aggregate size distribution and soil carbon and nitrogen fractions in semi-arid drylands. International Soil and Water Conservation Research, 12(1), 96-106.

[23] Posch B. C., Kariyawasam B. C., Bramley H., Coast O., Richards R. A., Reynolds M. P., Trethowan R., Atkin O. K., 2019. Exploring high temperature responses of photosynthesis and respiration to improve heat tolerance in wheat. Journal of experimental botany, 70(19), 5051-5069.

[24] Różewicz M., Grabiński J., Wyzińska M., 2023. Wpływ metody strip-till na plonowanie i jakość ziarna pszenicy ozimej w zależności od odmiany i zakresu uprawy pożniwnej. Część I. Plon. Agronomy Science, 78(1), 19-28.

[25] Różewicz M., Grabiński J., Wyzińska M., 2023. Wpływ metody strip-till na plonowanie i jakość ziarna pszenicy ozimej w zależności od odmiany i zakresu uprawy pożniwnej. Część II. Jakość ziarna. Agronomy Science, 78(1), 29-40.

[26] Różniak. M. 2016. Ocena możliwości uprawy pszenicy ozimej w technologii strip-till. Praca doktorska, UTP Bydgoszcz.

[27] Saldukaitė-Sribikė L, Šarauskis E., Buragienė S., Adamavičienė A., Velička R., Kriaučiūnienė Z., Savickas D., 2022. Effect of Tillage and Sowing Technologies Nexus on Winter Wheat Production in Terms of Yield, Energy, and Environment Impact. Agronomy, 12(11),2713. https://doi.org/10.3390/agronomy12112713

[28] Sharifi P., Mohammadkhani N., 2016. Effects of drought stress on photosynthesis factors in wheat genotypes during anthesis. Cereal research communications, 44(2), 229-239.

[29] Wicki L. 2017. Changes in yielding of varieties of winter wheat and rye in variety testing in Poland. Roczniki Naukowe Stowarzyszenia Ekonomistów Rolnictwa i Agrobiznesu, 19(4), 224-230.

[30] Wojtkowiak K., Stepień A., Orzech K. 2018. Wpływ nawożenia azotem na elementy składowe plonów, zawartość makroskładników oraz wskaźniki technologiczne w ziarnie czterech odmian pszenicy ozimej (Triticum aestivum ssp. vulgare). Fragmenta Agronomica, 35(2), 67-79.

Article reviewed

Received: 29.03.2024/Accepted: 10.04.2024