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Impact of tillage systems on maize emergence

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SUMMARY

In Europe, there has been a significant change in the way tillage is approached in recent years. This change is due to a growing awareness among farmers, politicians and society as a whole that soil is not a renewable resource in itself. From an agricultural point of view, the greatest impact on soil condition can be achieved through the use of the applied tillage systems. My research takes this approach as a basis when examining the different tillage systems and their impact on the environment. In this context, conventional and a variety of no-tillage systems are examined in this paper. As a next step, it is examined how the environmental conditions created by the different tillage systems influence the emergence of maize hybrids. The analyses are carried out in a multi-factorial, long-term tillage field experiment. The same batch of the same hybrid seed was sown in several crop years, and the effects of environmental conditions on the emergence process were examined. Environmental effects and emergence-related uptake were measured in the examined plots. Measurements of environmental effects included air temperature, precipitation, soil temperature measured at seeding depth, as well as % cover of stem residue on the surface in the treated plots. The first emergence time measurements of the sown crop in the plots of each treatment were compared and relationships between these factors were investigated.

Keywords: *maize planting; soil tillage systems; maize emergence rate*

INTRODUCTION

One of the foundations of precision farming is the use of sustainable soil management systems that meet the needs of the crop. A better understanding of the impact of soil management systems on the crop production process is essential for production practice. As climate is gradually becoming more extreme, the exposure of crop production to the weather becomes increasingly severe. The condition created by the used tillage system has an impact in strengthening or even mitigating certain biotic and abiotic effects (Diaz, 2002). Tillage and stubble management significantly affect soil physical properties, which greatly influence crop growth and productivity (Ranbir et al., 2018).

The basic element of tillage systems is the primary tillage practice. It determines to a large extent the type and form of the other cultivation practices used in the system. There are important differences between the various primary tillage practices. They differ from each other in terms of their operational characteristics, when classified according to the energy required for the process, and also in terms of the biological, chemical and physical properties of the soil structure they result in, lead to changes in soil use (Aziz et al., 2013). Classification takes place most often in terms of the physical parameters of the soil structure or the amount of stem residue on the surface. These individual characteristic differences will be of crucial importance for the crop in the tillage system at different times. For maize, the characteristics of the soil section from the soil surface to the zone of sowing depth are of key importance in the period from sowing to emergence. In the later period, the deeper soil layers also have an influence on the development of the crop and the supply of nutrients, as well as water and heat.

The on-farm productivity of maize is determined mainly by climate, meteorological and soil conditions, and agrotechnological practices (Kestutis, 2020). The sowing time of maize, followed by the emergence dynamics and the homogeneity of emergence, influence the development of the crop and yield (Nagy, 2021). Maize emergence is strongly influenced by soil moisture and soil temperature at the sowing depth (Hayhoe, 1987). These conditions, and their optimal level for emergence, are influenced by the applied tillage system.

The primary tillage used in the tillage system results in varying degrees of residual stalk cover on the soil surface. The stem residue affects the soil temperature, which influences maize emergence dynamics and subsequently influences the growth, development and morphology of maize leaves and, consequently, the grain yield of maize (Bollero, 1996). Other influences also affect early plant development, such as soil compactness and soil moisture content (Hill, 2000).

Several authors have addressed the relationship between maize emergence uniformity and yield. A homogeneous maize stand is the basis for a favourable yield. By densifying the crop stand, emergence non-uniformity increases stand heterogeneity, causing yield losses, as plants adjacent to the missing crops can only slightly compensate for the missing production (Tollenar, 1992; Duvick, 1997; Fasoula and Fasoula, 2000; Tokatlidis and Koutroubas, 2004). Yield is based on the emerging number of plants adapted to the production site. The homogeneity of maize emergence and subsequent development is also important and it is of great importance in maximising yield, since their joint development reduces competition between plants for available water, nutrients and sunlight (Karayel and Özmerzi, 2008). The uniformity of maize emergence

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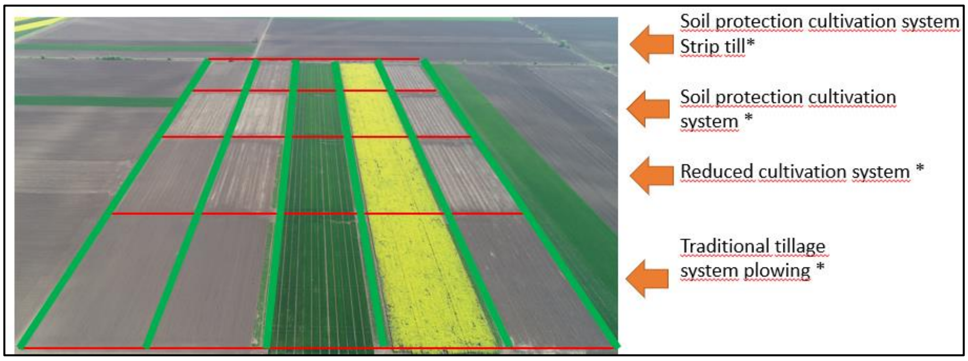
can be evaluated in time and space, based on the time of emergence and the spacing of ears.

MATERIALS AND METHODS

The experiment was conducted in the eastern region of Hungary at Nádudvar (47°25'49.3 "N 21°12'33.5 "E). Four different tillage systems were established in autumn 2016 and have been continuously applied since then. The experiment site layout is shown in *Figure 1*. In the first part of the field, a conventional tillage system was used, where the primary tillage machinery is a plough, the ploughing depth is 30 cm and there is no residual stalk on the surface. In the second part of the area, a reduced tillage system without tilling (Reduced) was used. In this part, the primary tillage implements are medium-depth cultivators equipped with a low-angle knife which had a mixing effect. In this primary tillage system, the entire surface is cultivated, with a depth of 30 cm for the loosening depth, and a maximum residual stalk residue of 15% on the surface. In the third area, the protective tillage system is used (Protect), using straight knife tillage with a maximum depth of 30 cm over the entire surface. After the primary tillage, a stem residue cover of over 30% remains. In the fourth area, a biological tillage system with strip-tillage was used as the primary tillage method. In this case, 40% of the total surface is cultivated at a width of 30 cm and a depth of 28 cm, with a residual stalk content of more than 30%. These primary tillage operations are carried out in the autumn, followed by sowing in the spring after a mulching/seedbed preparation operation.

Figure 1. **Theoretical layout of the experimental site**



Maize was planted in spring 2020 after rape as a previous crop and in spring 2021 after maize as a previous crop. In both years, Fornad (FAO-420) maize hybrids were sown.

Measurement methods

Soil temperature and soil moisture were measured on the experiment plots with different tillage systems. The temperature sensors were placed at a depth of 5 cm in the line of the sown row, which was determined by GPS coordinates during setting up. The theoretical measurement range of the sensors was -55 °C to +125 °C with a measurement resolution of 0.0625 °C. The moisture sensors were installed at a depth of 5 cm. The type of sensors used is DECAGON EC-5 with a measuring range of 0 to 100% and a resolution of 0.01%. These sensors were equipped with a data transmission unit and their measurements were transmitted every 10 minutes to a central data logging unit. Weather data were also measured in the experimental area with a resolution of 10 minutes. Air temperature was measured in °C (sensor resolution: 0.01 °C) and precipitation in mm (sensor resolution: 0.2 mm).

The surface cover of stem residue in different tillage systems at different times was determined. As a first step in this measurement, the area was surveyed using a drone equipped with a multispectral camera. The resulting images were analysed using the geospatial software ArcGis, providing a percentage value of surface coverage.

After sowing, an emergence survey was carried out. The first emerged crops were marked by sticking a coloured stick into the soil next to the emerged plant. After 24 hours of this measurement, the recording was repeated, this time using a different colour. This series of measurements was continued for six days.

RESULTS AND DISCUSSION

This part of work collates and summarizes the data collected and calculates totals or trends, statistically significant findings, etc., should be concise and clear.

This section may be divided by subheadings. It should provide a concise and precise description of the experimental results, their interpretation as well as the experimental conclusions that can be drawn.

Authors should discuss the results and how they can be interpreted in perspective of previous studies and of the working hypotheses. The findings and their implications should be discussed in the broadest context possible. Future research directions may also be highlighted.

Based on the analysis of weather conditions, differences were observed at the experiment site in both crop years. The observed differences were confirmed

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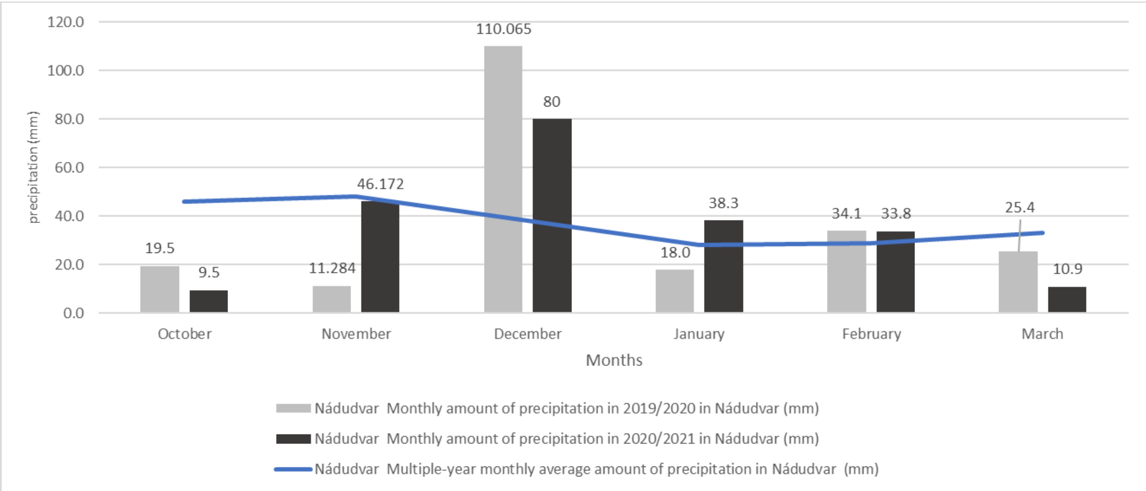
by the daily values of air and soil temperature (°C), relative humidity (%), wind speed (m s^{-1}), global radiation (W m^{-2}) and precipitation (mm), which were measured and recorded by the installed automatic weather station.

One of the most important factors is rainfall. The measured values are divided into two parts. The amount of pre-season rainfall (*Figure 2*) and the amount of rainfall during the growing season (*Figure 3*).

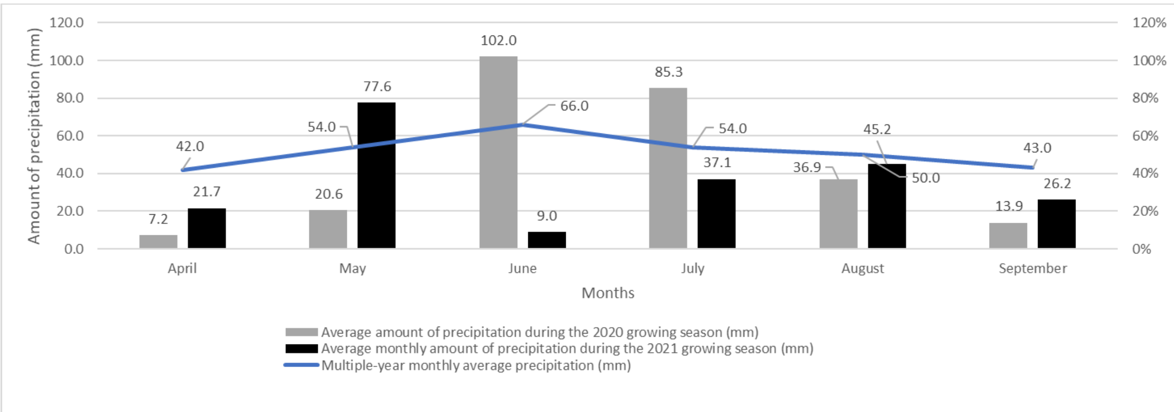
The average precipitation before the growing season was 222 mm per year. 218 mm rain fell both in the 2019/2020 season and the 2020/21 season. However, there are anomalies in the distribution of precipitation. In both growing seasons, below average rainfall was recorded in October and above average rainfall in December.

Figure 2. **Precipitation amounts before the growing season**



The rainfall during the growing season shows that the two growing seasons were completely different. While the multi-year average at the experimental site was 309 mm, the average amount of precipitation was 265 mm for the 2020 growing season and 206 mm for the 2021 growing season. Not only was it striking that the rainfall was below average, but the rainfall distribution was also different. In 2020, maize sowing and early development took place in a drier period.

Figure 3. **Precipitation amounts during the growing season**



In 2021, precipitation tended to be more favourable in the early part of the growing season, and then it was below the multiple-year average later in the growing season. In particular, June was extremely dry, with only 9 mm rainfall, compared to the multi-year average of 66 mm.

An important environmental parameter measured is the heat sum during the growing season (*Figure 4*).

Base temperature, or otherwise the minimum temperature above which the plant will develop, grow, or below which the rate of plant development is considered to be zero (Narwal et al., 1986; Kirby, 1995) is of considerable practical importance. In studies of germination, the base temperature is considered to be 8–10 °C (Alessi et al., 1971; Reed et al., 2019). With increasing temperatures, maize germinates more

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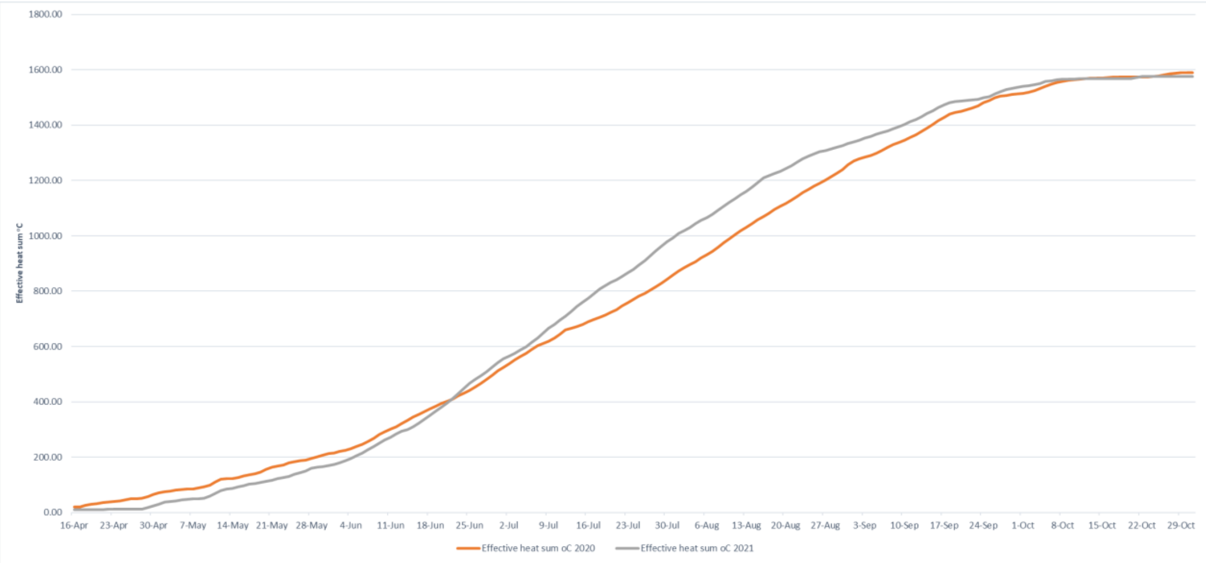
rapidly, with the fastest germination in the optimal range of 31–35 °C. For the sum of useful heat calculated from these values, it can be seen that the 2020 growing season tended to be warmer in the early development period, while 2021 was cooler in the early part of the growing season and then warmer in the later part.

Figure 4. **Heat sum during the growing season**



One of the clearest differences between the tillage systems used is whether stem residues remain on the soil surface after the different treatments. This condition was investigated and analysed (*Figure 5*).

In the two crop years, there were different previous crops for maize. In 2020, rapeseed was the previous crop, followed by a cover crop and after its termination, the tillage was performed. In 2021, maize was the main crop again after maize as a previous crop. The obtained results show that there is a significant difference in the averages of the cover percentage values between the tillage methods in both years (averages with the same letter are not different at the p= 5% probability level).

The temperature data for the study areas of each tillage method were further investigated in the period before sowing and until emergence. The used data were taken from temperature data measured at a depth of 5 cm in the plots of the different tillage systems from 14 April to 25 May 2020 and from 14 April to 25 May 2021. Within this time interval, temperature measurements were taken every 10 minutes, so that a large number of 4608 data points per plot were available (*Figure 6*).

Figure 5. **Mean land cover of the samples of each tillage system**

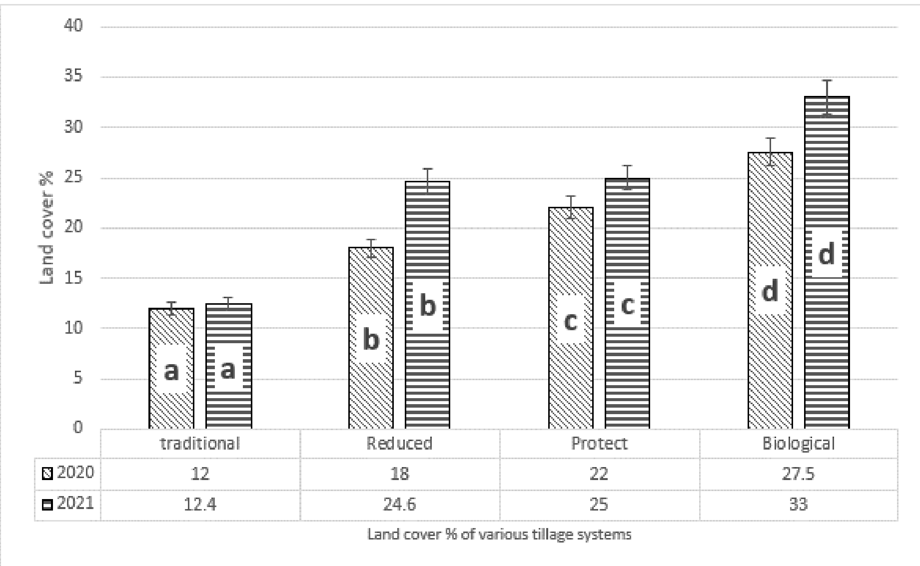


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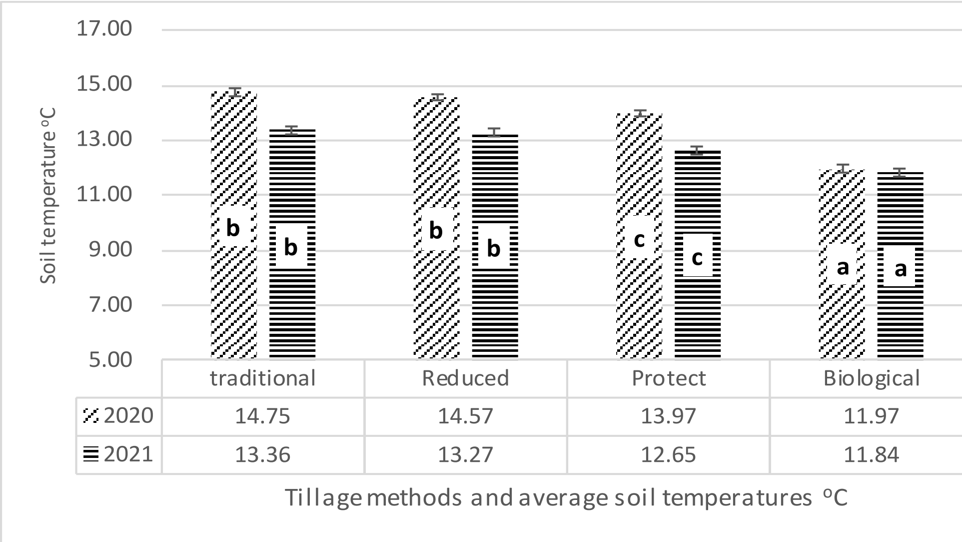
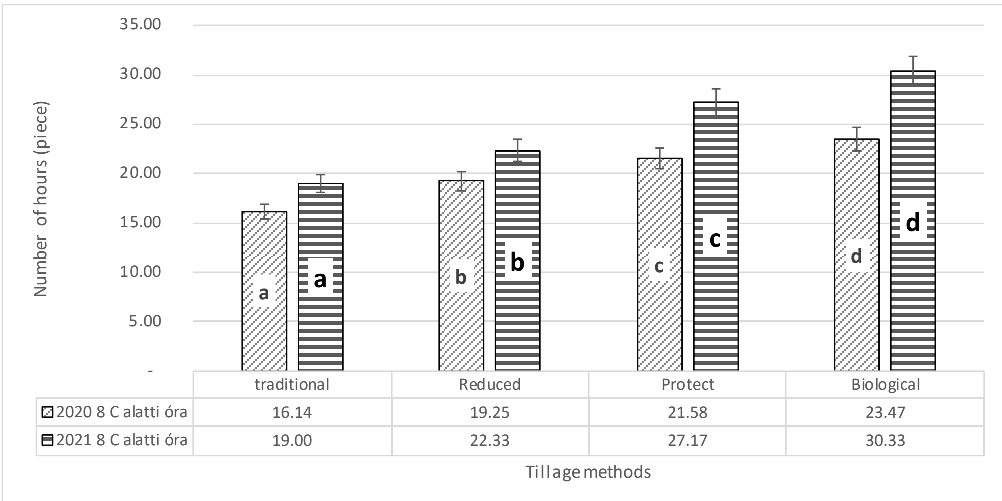
Figure 6. **Average temperature at sowing depth for each tillage method**



There were no significant differences between the tillage systems for the conventional and the reduced system. However, there was a significant difference (P < 0.05) between them and between the plots of the conservation and the biological tillage systems. Within the time interval shown above, the proportion of periods when the soil temperature at the sowing depth drops below 8 °C is particularly striking. This temperature limit is considered by most of the literature sources as the threshold below which germination and emergence of maize stops (Norwal et al., 1986).

The performed measurements show that there is a significant difference (P < 0.05) in the number of hours below 8 °C between the different tillage systems. This condition was observed for both crop years. The most favourable is the conventional tillage system, this system had the shortest period of 8 °C during the examined period. The duration of the soil temperature anomaly measured in the different no-tillage systems increases as the % of surface stem residue cover increased (*Figure 7*).

Figure 7. **Number of hours below 8 °C at sowing depth**



Differences were shown between treatments in terms of emergence times. The emergence of the first plants was significantly different (P < 0.05) between plots in both years. In the plots with less stem residue and warmer temperature, plants emerged earlier. The first plants to emerge appeared in both years in the conventional tillage system, followed by a one-day delay in the plots of the reduced system, and then another day in the plots of the other tillage systems (*Figure 8*).

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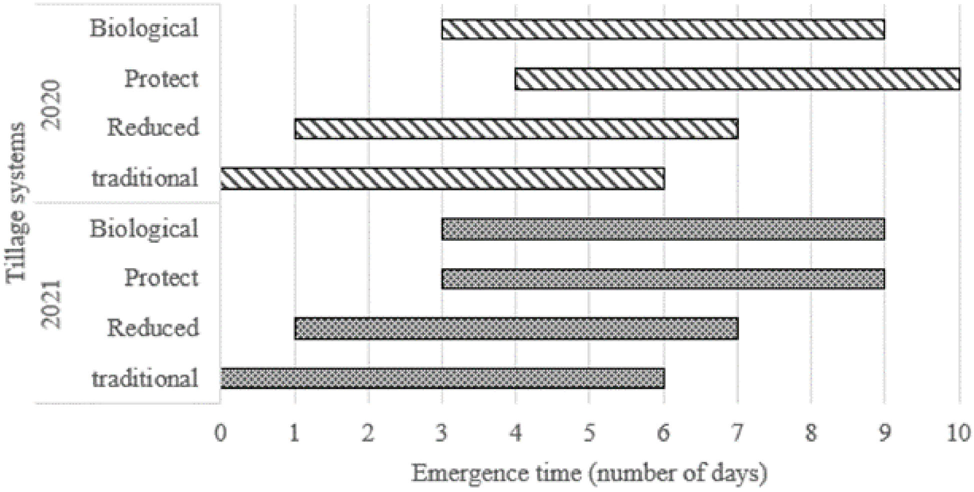
Figure 8. **Emergence cycles of the different treatments**



Based on the obtained research results, emergence dynamics in the examined periods were analysed. The 2020 season data for the plots of each treatment for were combined for comparability. The obtained data show that, within 24 hours after the first emergence, there is a significant difference ($P < 0.05$) in emergence dynamics between the conventional and reduced tillage crops, compared to the soil conservation and biological systems. From the second day of emergence, the results are not significantly different between the conventional, reduced and biological systems, but the percentage of emerged plants is significantly lower ($P < 0.05$) in the soil conservation system (*Figure 9*).

As the measurements for the 2021 crop year show, this period was colder than the 2020 crop year. For each tillage system, there is a significant difference ($P < 0.05$) between the emergence dynamics of the plants that emerged in the first 24 hours between the reduced and conservation tillage groups and the plants that emerged in the conventional tillage system, and the plants that emerged in the conservation tillage group. In the 0–24 h period, significantly lower numbers of plants emerged in each no-tillage group compared to tillage. This effect was also observed and similar for plants that emerged on day 2. There were no significant differences in the emergence dynamics of plants emerging on day 3 and subsequent days (*Figure 10*).

Figure 9. **Comparison of emergence dynamics 2020**

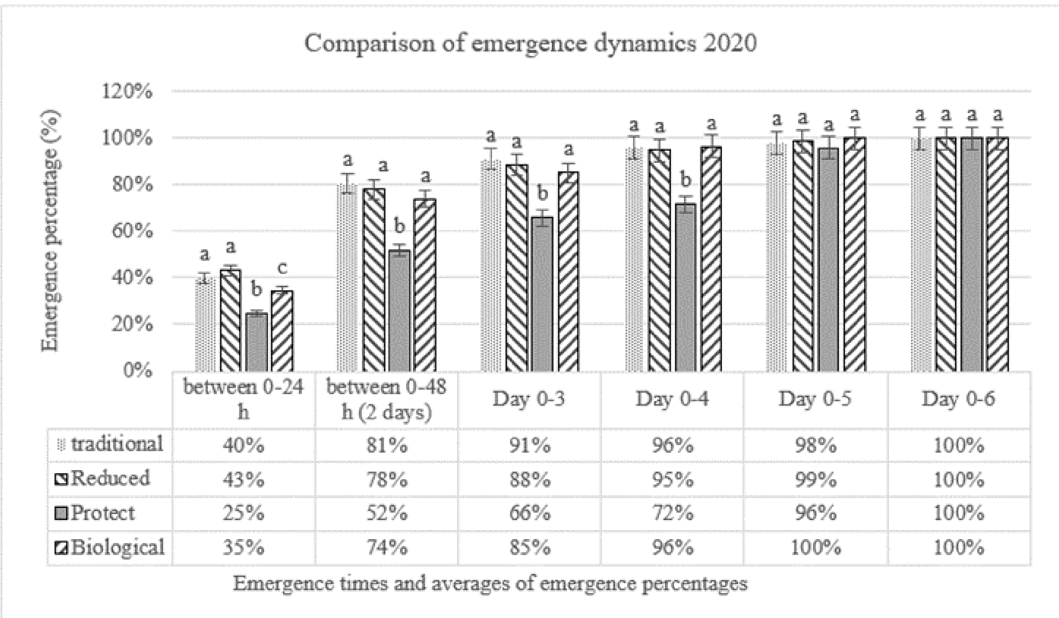


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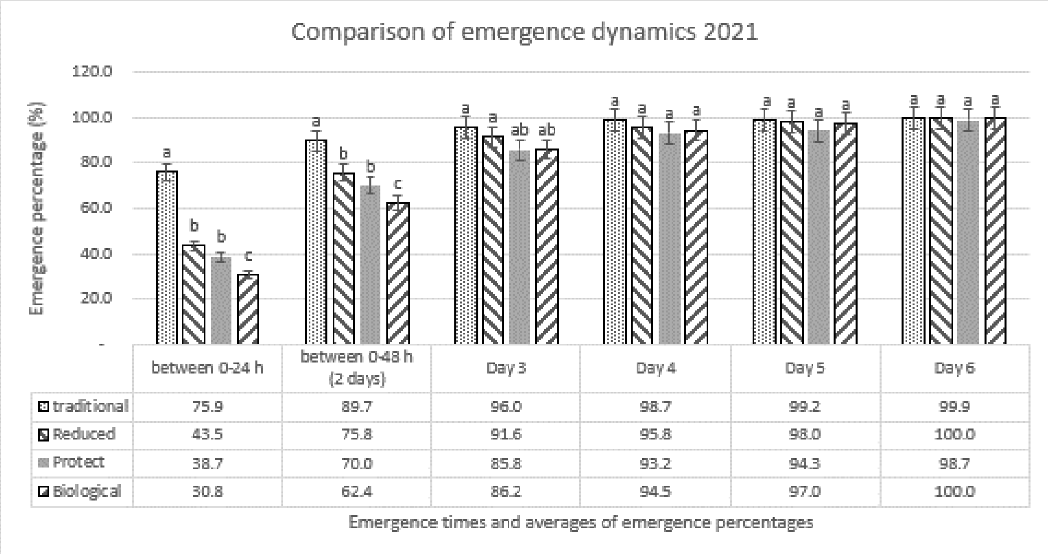
Figure 10. **Comparison of emergence dynamics 2021**



	between 0-24 h	between 0-48 h (2 days)	Day 3	Day 4	Day 5	Day 6
traditional	75.9	89.7	96.0	98.7	99.2	99.9
Reduced	43.5	75.8	91.6	95.8	98.0	100.0
Protect	38.7	70.0	85.8	93.2	94.3	98.7
Biological	30.8	62.4	86.2	94.5	97.0	100.0

CONCLUSIONS

For the examined tillage systems, soil temperatures measured at the sowing depth in the period before and after spring maize sowing differed significantly, partly due to the presence of stem residues on the surface, which, similarly to the measured temperatures, differed significantly between the different tillage systems. A particularly striking difference was the frequency of temperature periods below 8 °C between treatments. They are increasingly pronounced for tillage systems that leave increasing amounts of stem residue. These effects become apparent during maize emergence. The maize plant is very sensitive to temperature during emergence. The first maize emergence in plots under different tillage systems and with different temperature regimes occurs at different times. In the warmer areas, plants emerged earlier and, proportionally, the cooler areas had a more extended emergence period. The difference was reflected both in the date of first plant emergence and in the delay in emergence dynamics and less uniform emergence. In particular, the emergence dynamics of the first two days differed between tillage systems. In areas with colder soils, a more protracted emergence process was observed.

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