DOI: 10.34101/ACTAAGRAR/2/12574

Comparing the yield of maize (*Zea mays* L.) hybrids in organic and conventional agriculture

Ágnes Áldott-Sipos[1] – Eszter Csepregi-Heilmann[1] – Tamás Spitkó[1,*] – Csaba Szőke[1] – János Pintér[1] – Tamás Berzy[1] – János Nagy[2] – Csaba L. Marton[1]

[1]Agricultural Institute, Centre for Agricultural Research, Hungarian Research Network, H-2462 Martonvasar, Hungary

[2]Institute of Land Use, Engineering and Precision Farming Technology, University of Debrecen, H-4032 Debrecen, Hungary

[*]Correspondence: spitko.tamas@atk.hu

SUMMARY

The European Green Deal was published by the European Commission in 2019. The main aim of the program is to reach net zero greenhouse gas emissions by 2050, making Europe the first climate-neutral continent in the world. To achieve this, criteria are also set for agriculture: increasing the share of land under organic farming to 25%, reducing the use of fertilisers and pesticides. However, the benefits of organic farming are widely debated. The aim of our study was to compare the yield of maize (Zea mays L.) hybrids bred in Martonvasar in two different cropping environments. The silage yields of 20 different maize hybrids were evaluated in a three replicate small plot experiment in an organic field and an adjacent conventional field. The average green mass yield of the hybrids was 36.58 t ha^{-1} in the organic field and 43.03 t ha^{-1} in the conventional. The green mass yield in the organic area was 20% lower than in the conventional area, and the dry matter yield and digestible dry matter yield were about 18% lower. Hybrids of different maturity groups responded differently to organic cultivation. The yields of early hybrids decreased more and late hybrids less in the organic farming compared to the conventional production.

Keywords: *European Green Deal; organic farming; silage maize*

INTRODUCTION

The world's population has grown rapidly in recent decades. While there were 2.53 billion people living on our planet in 1950, today that number has risen to 8 billion. After 73 years, the population has more than tripled (KSH, 2023). As a result, global demand for agricultural products is rising. However, the intensification of agriculture is closely linked to high emissions of greenhouse gases (Beek et al., 2010). This drastic change has an impact on the Earth's climate (Vogel et al., 2019).

Keeping up with these climate changes in agriculture, while protecting the planet, has become a major issue in recent years. To address these challenges, the European Commission published the European Green Deal in 2019 (EUR-Lex, 2021). The main goal of the program is to achieve net zero greenhouse gas emissions by 2050, making us the world's first climate-neutral continent (European Commission, 2021a). Criteria in agriculture are also defined: increase the share of organically farmed land to 25%, reduce the use of fertilisers and pesticides (European Commission, 2021b).

In total, nearly 75 million hectares were under organic farming worldwide in 2020. However, if we look at the proportion of organic land as a percentage of the total, only 1.6% of the world's total land was under organic production. The organic agricultural area reached 17.1 million hectares in Europe in 2020, of which 14.9 million hectares were in the European Union. This means that 9.2% of the agricultural land used in EU was in organic farming, which is still far from the aimed 25% (Willer et al., 2022).

In Hungary, the total agricultural area was 5.05 million hectares, of which 293 thousand hectares were converted into organic farming in 2021 (KSH, 2022a; KSH, 2022b). The area of organic arable land was 91 thousand hectares, of which more than a third was cultivated with cereals (KSH, 2022b). The majority of the remaining ecological area (nearly 180 thousand hectares) was used for grazing and the smaller part for organic fruit and vegetable production. Statistics from the last 10 years show that until 2015, around 25 thousand hectares of cereals were grown on organic land. Then, there was a sharp increase in 2016, the cultivation of organic grain increased by nearly 10 thousand hectares. The next major increase occurred in 2019, when a total of 40.7 thousand hectares were used for organic cereals. This means, 0.77% of Hungarian agricultural land was farmed on organic land for cereals in 2019, and 0.78% in 2020. The latest results show, that the area dedicated to organic cereal farming decreased to 35 thousand hectares in 2021 (KSH, 2022a; KSH, 2022b). However, despite the slowly increasing trend, we are still behind the European idea. In order to achieve dynamic development, the Hungarian National Action Plan for the Development of Organic Farming, approved by the Ministry of Agriculture, was published in 2022. One of its main priorities is to increase the current organic area ratio from 6% to 10% by 2027 (Gov. HU., 2022; Drexler et al., 2022).

The benefits of organic farming are widely debated. In one hand, some promote it as a solution to sustainable food security challenges. According to these views, organic agriculture is a production system that maintains the health of the ecosystem and people (Meng et al., 2017). On the other hand, others criticise it for being underdeveloped. Traditional agriculture uses a diverse set of technologies and the best available knowledge (Trewavas, 2001; Connor, 2008). Several studies have confirmed that organic farming yields are on average 20% lower than conventional farming (De

DOI: 10.34101/ACTAAGRAR/2/12574

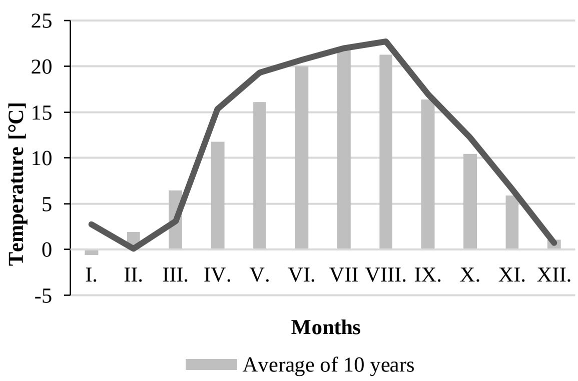
Ponti et al., 2012; Kniss et al., 2016). Presumably, the reason of this decrease in yields is the lack of fertilisers (especially nitrogen) and pesticides (De Ponti et al., 2012).

The aim of our study was to compare the yield of maize (*Zea mays* L.) hybrids bred in Martonvasar in two different cropping environments.

MATERIALS AND METHODS

The field experiment was carried out at the Centre for Agricultural Research in Martonvasar in 2018. Part of the field has been certified as suitable for organic agriculture since 2007, on which no chemicals are allowed. The rest of the experimental area was under conventional agriculture, with fertiliser, herbicide and insecticide application. The soil type was chernozem with forest residual and good nutrient supplies. In the autumn, 400 kg ha^{-1} of complex fertiliser (NPK 15–15–15) was applied to the conventional site. In the year of the experiment, 450 kg ha^{-1} fertiliser and 15 kg ha^{-1} soil disinfectant were applied before sowing. In the organic area only soil and seedbed preparation was done with a compactor. Sowing was carried out on the same day with a density of 70 000 plants ha^{-1}. Herbicide was applied in early May and mid-June and insecticide was done twice in July on the conventional area. Meanwhile in the organic area, only mechanical weed control was used by cultivator and hand hoe.

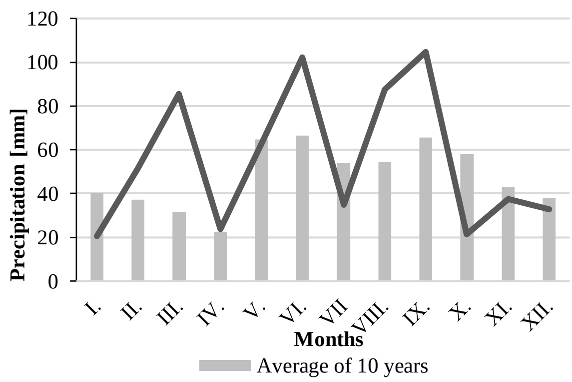
Figure 1. **Monthly medium temperature [°C] for the year and location of the field experiment**



The collected data was compared to the average of previous 10 years (2008–2017) for the same exact area.

Monthly medium temperature (*Figure 1*) and precipitation (*Figure 2*) data were recorded by the meteorological station located next to the field experiment. It was evaluated and compared to the 10 year mean (2008–2017). Overall the mean temperature for 2018 (11.87 °C) was slightly higher than the average of the last 10 years (11.04 °C). Exceptionally high average temperature was observed in May 2018, it was 1.45 °C hotter than the previous 10 years. Overall the precipitation was almost 90 mm above the 10 year average. There was heavy rainfall in June and September. In addition, the total rainfall during the growing season (April to September) was 415.8 mm against the 10 year average of 327.4 mm.

Figure 2. **Monthly precipitation [mm] for the year and location of the field experiment.**



The collected data was compared to the average of previous 10 years (2008–2017) for the same exact area.

Total of 20 maize hybrids (18 bred in Martonvasar and 2 standard hybrids) were tested using different cropping systems (conventional and organic) in a small plot field experiment with 3 replications and randomised block design. The hybrids belonged to three different maturity groups: early (FAO 300–399), medium (FAO 400–499) and late (FAO 500–599). During the growing season data were collected about flowering time (50% tasselling, 50% silking) and morphological characters (plant height, leaf number above the ear). To estimate the silage yield, 3 plants per plot were cut and chopped, fresh weight was measured. Harvesting time was on the same day for organic and conventional technologies. The obtained plot data were used to calculate the green mass yield per hectare, the dry matter yield per hectare and the digestible dry matter yield per hectare of maize genotypes.

Green mass yield per hectare (GMY, t ha^{-1}):

$$\frac{\text{individual weight (kg) * plant number per hectare}}{1000} \quad (1)$$

Dry matter yield per hectare (DMY, t ha^{-1}):

$$\frac{\text{green mass yield per hectare (GMY, t ha}^{-1}\text{) * dry matter (DM, \%)}}{100} \quad (2)$$

DOI: 10.34101/ACTAAGRAR/2/12574

Digestible dry matter yield per hectare (DDMY, t ha^{-1}):

$$\frac{\text{dry matter yield per hectare (DMY, t ha}^{-1}\text{) * digestible organic matter content (DIGOM, \%)}}{100} \quad (3)$$

The chemical compositions of the samples were measured by near infrared reflectance spectrophotometer (NIRS) using the INGOT calibration software. Data were analyzed by two-way ANOVA.

RESULTS AND DISCUSSION

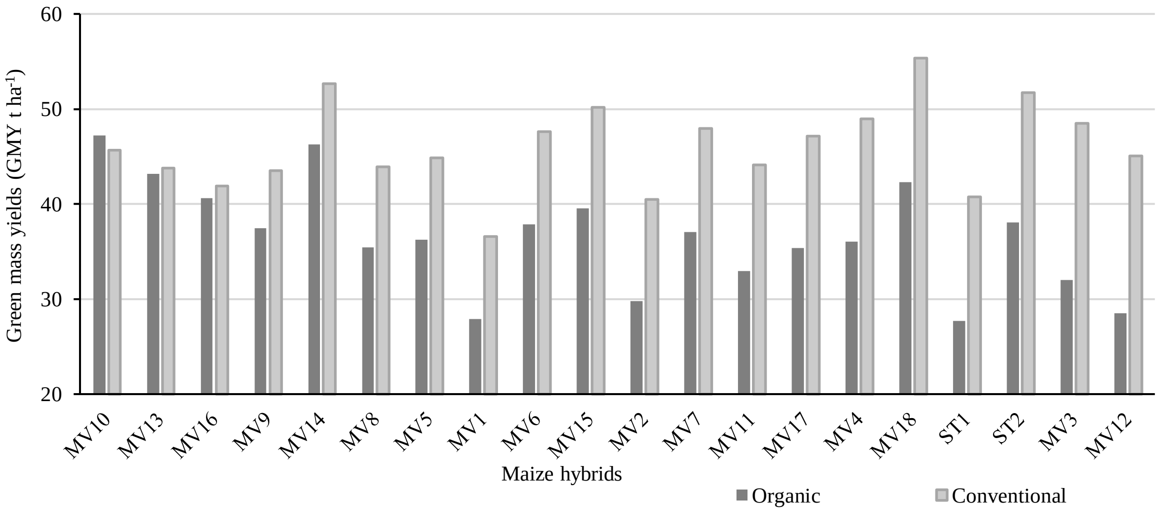
The average green mass yield of the hybrids in the organic area was 36.58 t ha^{-1}, while the average yield in the conventional area was 46.03 t ha^{-1}. Consequently the average yield of the organic area was 20% lower compared to the fertilized treatments. The dry matter yield and digestible dry matter yield of the organic area were approximately 18% lower than the conventional area. According to our results there was a significant difference between the average yields of the 2 locations (*Table 1*).

Table 1. **Green mass yield (GMY), dry matter yield (DMY) and digestible dry matter yield (DDMY) of maize hybrids in organic and conventional agriculture (t ha^{-1})**

Yields	Organic agriculture	Conventional agriculture	$LSD_{5\%}$
GMY (t ha^{-1})	36.58	46.03	2.0015 ***
DMY (t ha^{-1})	13.38	16.37	0.6922 ***
DDMY (t ha^{-1})	8.71	10.68	0.5194 ***

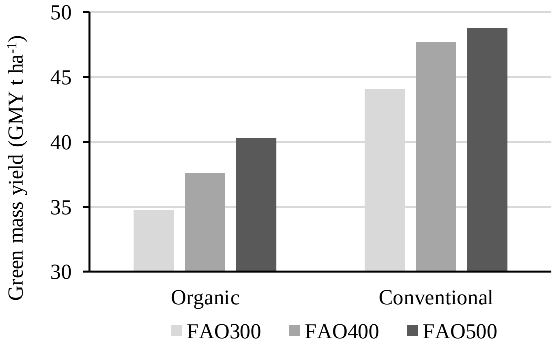
Comparing the green mass yield of twenty maize hybrids at 2 locations, we found considerable difference in the silage yield of the genotypes. Overall, the performance of the varieties was higher in conventional cultivation, but the tendency seems to be that the yield of some hybrids decreased less in ecological agriculture (*Figure 3*).

Figure 3. **Green mass yield (GMY, t ha^{-1}) of maize hybrids grown in different cropping systems**



Analyzing the yield data of the hybrids by maturity group indicated an important correlation. The green mass yield increased with the vegetation period of hybrid in both organic and conventional treatments (*Figure 4*). However, the change was more intensive in the ecological field than in the fertilized one. A similar trend was observed for the dry matter yield (*Figure 5*) and digestible dry matter yield (*Figure 6*). The yield increased with the FAO number of hybrid.

Figure 4. **Green mass yield (GMY, t ha^{-1}) of maize hybrids by maturity groups**



DOI: 10.34101/ACTAAGRAR/2/12574

Figure 5. **Dry matter yield (DMY, t ha-1) of maize hybrids by maturity groups**

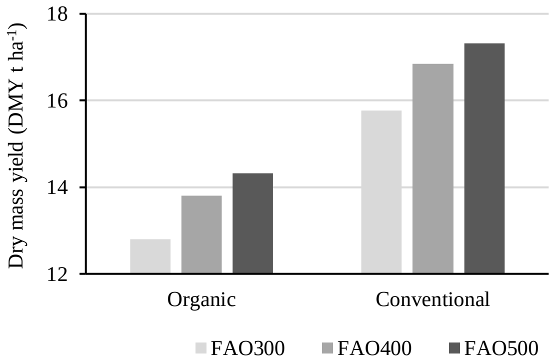
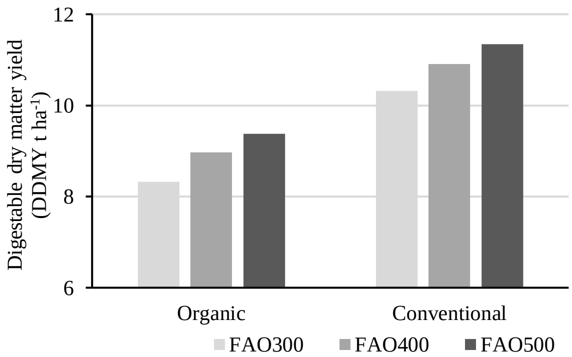
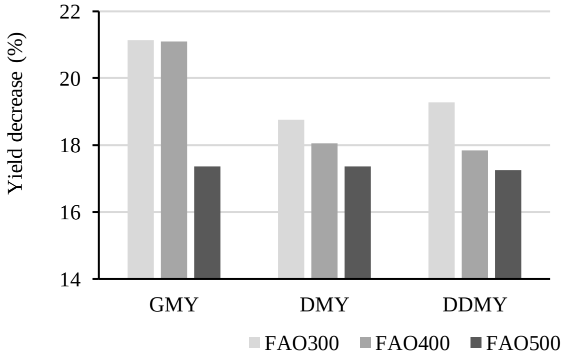


Figure 6. **Digestible dry matter yield (DDMY, t ha-1) of maize hybrids by maturity groups**



When the yields measured at the organic location were calculated as an average percentage of the fertilized treatment, it was determined that the yield gap between the two cropping systems decreased as the maturity group increased (*Figure 7*). Based on our results, it is preferred to grow maize hybrid of the late maturity group for organic agriculture.

Figure 7. **Yield decrease (%) at the organic agriculture compared to the conventional production by maturity group**



(GMY: green mass yield, DMY: dry matter yield, DDMY: digestible dry matter yield)

There were significant differences in flowering days. The time of 50% tasseling and silking occurred approximately 1 day later for the hybrids at the conventional location. However, this difference was not relevant agronomically. The plants were significantly higher in the conventional environment. While the average height of the plants was 291.9 cm in the organic production, they grew to 295.4 cm in the conventional field. Leaf number above the ear was not affected by the environment, there was no significant difference in the leaf number of the hybrids at the different locations (*Table 2*).

Table 2. **Agronomical and morphological traits of maize hybrids in different cropping systems**

Trait	**Organic agriculture**	**Conventional agriculture**	**$LSD_{5\%}$**
Days to 50% tasseling	63.5	64.1	0.3680 ***
Days to 50% silking	62.7	63.8	0.3438 ***
Plant height (cm)	291.9	295.4	3.1507 *
Leaf number above the ear	7.9	8.0	0.1611 ns

*** p = 0.001, * p = 0.05, ns: not significant

CONCLUSIONS

The aim of our study was to compare the yield of maize (*Zea mays* L.) hybrids bred in Martonvasar in two different cropping environments. The silage yield of 20 different maize hybrids was evaluated in a three replicate small plot experiment in organic farming and an adjacent conventional field. The average green mass yield of the hybrids was 36.58 t ha^{-1} in the organic field and 43.03 t ha^{-1} in the conventional land. Similarly as previous studies (De Ponti et al., 2012; Kniss et al., 2016), our results confirmed approximately 20% difference between yield in the two cropping systems. Hybrids of different maturity groups responded differently to organic cultivation. The yields of early hybrids decreased more, meanwhile late hybrids decreased less in the organic land compared to the conventional environment. The yield gap can be reduced by selecting late and very late hybrids.

ACKNOWLEDGEMENTS

Project no. TKP2021-NKTA-06 has been implemented with the support provided by the Ministry of Innovation and Technology of Hungary from the National Research, Development and Innovation Fund, financed under the TKP2021-NKTA funding scheme.

DOI: 10.34101/ACTAAGRAR/2/12574

REFERENCES

Beek, C.L. va.–Meerburg, B.G.–Schils, R.L.M.–Verhagen, J.–Kuikman, P.J. (2010): Feeding the world's increasing population while limiting climate change impacts: linking N_2O and CH_4 emissions from agriculture to population growth. *Environmental Science and Policy*, *13*, 2, 89–96. https://doi.org/10.1016/j.envsci.2009.11.001.

Connor, D.J. (2008): Organic agriculture cannot feed the world. *Field Crops Research*, *106,* 2, 187–90. https://doi.org/10.1016/j.fcr.2007.11.010.

Drexler, D.–Varga, K. - Allacherné Szépkuthy, K. (2022): A hazai ökológiai gazdálkodás fejlesztési terve az EU irányelvek tükrében. In: *XXVIII. Növénynemesítési Tudományos Napo*k, edited by Polgár, Z., I. Karsai, L. Bóna, J. Matuz, and J. Taller, 12–17. Keszthely, Magyarország: Magyar Növénynemesítők Egyesülete.

EUR-Lex 2021: https://eur-lex.europa.eu/legal-content/HU/TXT/?qid=1576150542719&uri=COM%3A2019%3A640%3AFIN (September 2021)

European Commission 2021a: https://ec.europa.eu/info/strategy/priorities-2019-2024/european-green-deal_hu (September 2021)

European Commission 2021b: https://ec.europa.eu/commission/presscorner/detail/hu/QANDA_20_885 (September 2021)

Gov. HU. 2022: https://kormany.hu/dokumentumtar/nemzeti-cselekvesi-terv-az-okologiai-gazdalkodas-fejleszteseert (September 2022)

Kniss, A.R.–Savage, S.D.–Jabbour, R. (2016): Commercial crop yields reveal strengths and weaknesses for organic agriculture in the United States. *PLoS ONE, 11*, 8, 1–16. https://doi.org/10.1371/journal.pone.0161673

Meng, F.–Qiao, Y.–Wu, W.–Smith, P.–Scott, S. (2017): Environmental impacts and production performances of organic agriculture in China: A monetary valuation. J*ournal of Environmental Management*, *188*, 2, 49–57. https://doi.org/10.1016/j.jenvman.2016.11.080.

KSH 2023: https://www.ksh.hu/interaktiv/grafikonok/vilag_nepessege.html (March 2023)

KSH 2022a: https://www.ksh.hu/stadat_files/mez/hu/mez0008.html (October 2022)

KSH 2022b: https://www.ksh.hu/stadat_files/mez/hu/mez0038.html (October 2022)

Ponti, T. De–Rijk, B.–Ittersum, M.K. Van. (2012): The crop yield gap between organic and conventional agriculture. *Agricultural Systems*, *108*, 1–9. https://doi.org/10.1016/j.agsy.2011.12.004.

Trewavas, A. (2001): Urban myths of organic farming. *Nature*, *410*, 6827, 409–10. https://doi.org/10.1038/35068639.

Vogel, E.–Donat, M.G.–Alexander, L.V.–Meinshausen, M.–Ray, D.K.–Karoly, D.–Meinshausen, N.–Frieler, K. (2019): The effects of climate extremes on global agricultural yields. *Environmental Research Letters*, *14,* 5, 054010. https://doi.org/10.1088/1748-9326/ab154b.

Willer, H.–Trávníček, J.–Meier, C.–Schlatter, B. (2022): The world of organic agriculture: Statistics and emerging trends 2022. Edited by Helga Willer, Jan Trávníček, Claudia Meier, and Bernhard Schlatter. *International Journal of Sustainability in Higher Education*. Frick, Switzerland: Research Institute of Organic Agriculture FiBL & IFOAM – Organics International, pp. 345. https://doi.org/10.1108/ijshe.2009.24910aae.004.