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Maize production in Central and Eastern Europe – Perspectives and challenges

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Abstract. Maize production in Central and Eastern Europe has seen significant growth over the past decades, driven by favourable climate conditions and improved agricultural practices. However, the region faces numerous challenges, including increasing climate variability, pests, and diseases, which threaten both yield and crop quality. The adoption of modern agricultural technologies and the development of drought-resistant maize varieties are seen as key strategies to enhance productivity. Integrating sustainable farming practices and addressing market fluctuations are crucial for ensuring long-term growth supplemented by integrated plant protection.

Keywords: maize production, diseases, pests, cotton bollworm, corn leaf aphid, aflatoxins

1. Maize production in recent years in the EU, Romania, and Hungary

Corn (*Zea mays* L.) belongs to the order *Poales*, the family *Poaceae*, and the genus *Zea* [1]. The global average yield has tripled since the 1960s. While in 1961, the yield was around 2 tons per hectare, today this has increased to approximately 6 tons per hectare worldwide. The growth rate of production has followed the same trend, as over the course of nearly 60 years, production has increased from 200 million tons to nearly 1.2 billion tons today [1].

The USA is one of the largest and most important corn-producing countries in the world, with a cultivated area of around 33 million hectares. Within the EU, Hungary and Romania are also among the more significant corn-producing countries [2]. EU production had been mostly stable until 2014, after which a decline has been observed. Contributing factors include population growth [3], global warming [4], drought [5], and the emergence of new pests and pathogens [6].

In Hungary, the area dedicated to corn cultivation fluctuated between 778,000 and 906,000 hectares from 2022 to 2024. While the average corn yield in 2020 was approximately 8.5 million tons, by 2024, the production had decreased to just 5.8 million tons, primarily due to drought conditions. In Romania, the dynamics of corn production showed the following trends: the cultivated area remained above 2 million hectares, but while 8.5 million tons of corn were harvested in 2023, a decline was observed in 2024, with production reaching only 7.8 million tons. This decline is notable in comparison to the record year of 2018, when production peaked at 18.6 million tons [2], [7].

The European Union's MARS (Monitoring Agricultural Resources) agricultural monitoring system has notably revised downward its projections for Romania's corn production in 2024, primarily as a result of the severe drought conditions affecting southeastern Europe. Romania, which had previously been a major competitor with France for the title of the EU's largest corn producer, has experienced a significant reduction in its production forecasts.

According to MARS, the EU's average corn yield is now estimated to be 7.03 tons per hectare, a decrease from the July estimate of 7.24 tons per hectare, reflecting a 6% decline compared to the previous year's levels. In Romania, the impact of the drought has been particularly pronounced, prompting MARS to lower the country's corn yield estimate to 3.83 tons per hectare, down from the 4.08 tons per hectare projected in July 2024. This adjustment represents an 18% reduction relative to the previous year's yield [8].

Similar reductions in corn yield forecasts have been observed in other countries in the region, including Hungary, where the estimated yield has been revised to 6.46 tons per hectare, representing a 21% decrease compared to 2023. MARS attributes these substantial declines primarily to the extreme heat experienced in Romania, with temperatures across much of the country averaging 2.0 to 3.5°C above historical norms. The period from 1 July to 17 August 2024 has been recorded as the hottest in Romania's history, further exacerbating the adverse effects on crop yields [8].

2. Most important pests, diseases, and weeds

2.1. Pests

Frit fly – *Oscinella frit* (Linnaeus, 1758)
Corn root aphid – *Tetraneura ulmi* (Linnaeus, 1758)
Corn weevil – *Tanymecus dilaticollis* (Gyllenhal, 1834)
Sharp-tailed weevil – *Tanymecus palliates* (Fabricius, 1787)

Western corn rootworm – *Diabrotica virgifera virgifera* (LeConte, 1868)
European corn borer – *Ostrinia nubilalis* (Hübner, 1796)
Turnip moth – *Agrotis segetum* (Denis & Schiffermüller, 1775)
Cotton bollworm – *Helicoverpa armigera* (Hübner, 1808)
Aphids – *Aphididae* (Latreille, 1802) [9].

2.2. Diseases

Corn chlorotic mottle – *Sugarcane mosaic virus* (SCMV)
Maize stripe mosaic virus – *Maize dwarf mosaic virus* (MDMV)
Corn bacterial wilt – *Pantoea stewartii* ssp. *stewartia* (Smith, 1898)
Corn downy mildew – *Sclerophthora macrospora* (Thirum., C. G. Shaw & Naras., 1953)
Corn smut – *Ustilago maydis* (Corda, 1842)
Corn rust – *Puccinia sorghi* (Schwein, 1832)
Corn fusariosis – *Fusarium spp.* (Link, 1809)
Corn nigrospora dry rot – *Nigrospora oryzae* (Berk. & Broome, Petch, 1924)
Corn Kabatiella eye spot – *Kabatiella zeae* (Narita & Y. Hirats, 1959) [9].

2.3. Weeds

Hairy crabgrass – *Digitaria sanguinalis* (L.) Scop.
Barnyard grass – *Echinochloa crus-galli* (L.)
Couch grass – *Elymus repens* (L.) Gould
Green foxtail – *Setaria viridis* (L.) Beauv.
Johnsongrass – *Sorghum halepense* (L.) Pers.
Redroot pigweed – *Amaranthus retroflexus* (L.)
Common ragweed – *Ambrosia artemisiifolia* (L.)
Creeping thistle – *Cirsium arvense* (L.) Scop.
Common chickweed – *Stellaria media* (L.) Vill.
Field bindweed – *Convulvulus arvensis* (L.)
Common purslane – *Portulaca oleraceae* (L.) [10].

3. Challenges concerning new pests and diseases

3.1. Corn leaf aphid (Rhopalosiphum maidis)

Aphids (*Aphidoidea*) are phloem-feeding insects belonging to the class *Insecta* and the order *Hemiptera*. Their life cycle in temperate regions is predominantly synchronized. With the onset of bud break and rising temperatures, aphid colonies begin to emerge. The plant sap consumed by aphids is typically unbalanced in composition. It is rich in sugars but deficient in certain inorganic salts and essential amino acids required for their growth. To mitigate this imbalance, aphids excrete honeydew, while the necessary amino acids are obtained with the assistance of endosymbiotic bacteria living in mutualistic symbiosis with them [11].

The corn leaf aphid (*Rhopalosiphum maidis*) feeds on a range of host plants, including corn, sorghum, sugarcane, and other cereal crops [12]. Aphid colonies typically colonize the abaxial surfaces of leaves, although they may also be found on inflorescences. Initially restricted to Mediterranean regions, this aphid species has since spread throughout Europe [13].

Figure 1. Corn leaf aphid (*Rhopalosiphum maidis*) colony on maize

Due to their rapid asexual reproduction, these pests have become global threats, resulting in annual crop losses amounting to billions of US dollars [14]. Many of these pest species have developed resistance to a broad spectrum of synthetic pesticides, leading to escalating challenges in their management. With climate change contributing to global warming, one potential avenue for controlling these pests may involve exploiting heat stress as a control mechanism [15].

To cope with heat stress, aphids have developed various physiological and behavioural adaptations. Besides this, bacterial symbionts play a crucial role in enhancing the heat stress tolerance observed in aphids. The primary symbiont, *Buchnera aphidicola* has been shown to contribute to the synthesis of heat shock proteins, which aid in the aphids' ability to withstand elevated temperatures [16].

In addition to *Buchnera aphidicola*, aphids are associated with secondary, so-called facultative endosymbionts, including species from the genera *Serattia*, *Wolbachia*, *Rickettsia*, and *Hamiltonella*. Some studies have demonstrated that these bacteria can assist aphids in their adaptation by providing protection against heat stress, as well as defending them from parasitoid wasp attacks, among other benefits [17], [18], [19], [20].

3.2. Cotton bollworm (Helicoverpa armigera) and aflatoxins

The Heliothinae (Lepidoptera: Noctuidae) is a cosmopolitan subfamily of noctuid moths, consisting of over 400 species. *Helicoverpa armigera*, the old world bollworm, has been reported across Asia, Africa, Europe, and Australia [21]. The moths typically oviposit on maize silks, and the larvae feed on the kernels [22]. Concerns have been raised regarding integrated pest management and insect resistance management due to its biological and behavioural traits, as well as its rapid adaptation to chemical control measures [23].

Helicoverpa armigera is typically capable of completing its life cycle within a temperature range of 17.5–32.5 °C [24]. Both temperature and sowing time play a significant role in determining the extent of larval damage in crops, with lower infestation rates observed in early sowing periods [25]. Severe infestations can damage the chlorophyll tissues of leaves, leading to necrosis. Certain crops, such as soybean and tomato, are particularly vulnerable, as early infestations of *H. armigera* often affect the reproductive stages, hindering pod formation and significantly reducing seed yield [26].

Figure 2. Cotton bollworm (*Helicoverpa armigera*) damage on maize [27]

The damage caused by the cotton bollworm usually affects the corn cob. Due to extensive feeding at the tip of the cob, the kernels are damaged, and the moist, hard-to-dry frass that accumulates creates ideal conditions for pathogens to infect the cob. Since the damage can occur in a hidden way under the protection of the husk leaves, controlling the pest is difficult. Feeding at the tip of the cob leads to toxin formation, which threatens the quality of the crop and, indirectly, poses a significant risk to human health.

Aflatoxins are a group of mycotoxins, with aflatoxin B1 being the most studied and considered the most dangerous. The most detailed regulations have been developed for aflatoxin B1, caused by *Aspergillus flavus* fungi [28]. The main concern for human health is that aflatoxins cause poisoning. Several studies have linked aflatoxins to liver cancer. Aflatoxins are toxic even in small amounts; they damage the liver, can cause cancer, and harm the genetic material of cells and the immune system. In large amounts, they can cause acute poisoning, which can lead to severe liver failure and even death [29]. Acute aflatoxin poisoning is the most common in developing countries, where the climate favours *Aspergillus* species and toxin production.

Climate change is expected to considerably alter the patterns of fungal and mycotoxin contamination, with aflatoxin contamination in maize emerging as the primary mycotoxin concern in Europe [30]. *Aspergillus flavus*, the principal producer of aflatoxins, is commonly associated with a broad range of plant species, with aflatoxin production being most prevalent in crops that have higher oil content (maize, nuts, etc.). The distribution and proliferation of fungi in soil are influenced by a variety of factors, including geographical location, soil composition, climatic conditions, crop rotation practices, and pest dynamics [31]. Notably, higher fungal populations are typically observed in soils rich in organic matter and essential nutrients such as nitrates, phosphates, and potassium [32].

Analysis of maize samples from various growing regions in Hungary revealed that nearly two-thirds of the samples were contaminated with *Aspergillus flavus*, with approximately 20% of these also capable of producing aflatoxin [33]. In Romania, over 90% of the maize samples were contaminated by at least one mycotoxin. Specifically, around 30% of the samples were contaminated with aflatoxin B1 (AFB1), and in 20% of these cases, the toxin concentration exceeded the maximum levels permitted by European Union regulations [34].

4. Possible challenges and perspectives

Future maize production is expected to be increasingly constrained by environmental factors, including climate change, water scarcity, and land degradation. Given the significant scale of the maize economy, it is critical and urgent to explore strategies for climate change mitigation and adaptation, addressing both biotic stresses, such as pests and diseases, and abiotic stresses, including heat and drought [35].

Maize production is confronted with a range of agronomic challenges that affect both its yield and long-term sustainability. A major concern is the impact of climate change, which poses a threat to agricultural productivity through unpredictable weather patterns and an increased prevalence of pests and diseases [36]. Economic and market factors further complicate maize production. Economic challenges are exacerbated by limited access to education and training, which hinders the adoption of improved agricultural practices. Additionally, political instability and insufficient policy support exacerbate these issues by disrupting supply chains and restricting investment in agricultural research and infrastructure [37].

To enhance maize yields under variable climate conditions, practices such as optimizing sowing windows and selecting climate-adapted cultivars can be highly effective. However, the intensive use of land for maize cultivation often leads to habitat loss and reduced biodiversity. Moreover, the monocultural nature of maize farming diminishes ecosystem resilience, making crops more susceptible to pests and diseases. Sustainable agricultural practices, such as crop rotation and agroforestry, can help mitigate these negative impacts by promoting biodiversity and enhancing ecosystem services [38–37].

Adaptation strategies, including the adjustment of sowing dates and the development of climate-resilient maize varieties, are crucial for minimizing the adverse effects of climate change on maize production. Implementing these strategies will help ensure the stability and availability of maize, thereby contributing to global food security [35].

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