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Research Article

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Sustainable Control Strategies for *Ustilago maydis* in Maize: Effects on Plant Growth and Yield

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ABSTRACT
Corn plays a significant role in global food security and the agro-industrial system. However, its productivity is increasingly affected by *Ustilago maydis* (corn smut), a fungal pathogen that induces significant yield and quality losses. As sustainable agriculture gains attention, the integration of different strategies for controlling diseases has become a research priority. The objective of this study was to examine the effectiveness of different biological and synthetic strategies for managing corn smut infestation and enhancing physiological performance, particularly growth and yield in maize under small-scale field conditions. A field study was conducted at the University of Debrecen experimental garden, using five treatment levels: Mycostart Bio (T1), Mycostart Bio + plant conditioner (T2), Genium (T3), Fungicide (Prosaro) (T4), and a Control (T5). Data were collected on plant height, yield, and incidence of Ustilago maydis infestation on various plant parts. Data gathered was subjected to analysis of variance using Genstat statistical software at 5% significance level. Our data showed no statistically significant differences ($P > 0.05$) across all the treatments. However, T2 exhibited the highest average plant height (2.85m) with minimal variability, indicating consistent growth-promoting effects. T4 achieved the highest average yield (12.62 kg), suggesting that fungicidal application remains effective for yield optimisation. Incidence of Ustilago maydis infestation was generally minimal across treatments, likely due to high temperature during the growing season, which is known to suppress fungal development. Our findings highlight the potential of biological treatments like T2 in promoting maize growth and the superior yield performance of synthetic fungicide T4. Our current studies contribute to the understanding of integrated disease management under varying environmental conditions and support the adoption of sustainable practices in maize production.

Keywords: Corn Smut, Ustilago Maydis, Biological Control, Fungicide, Yield, Plant Height

Introduction

Global concern about food security and safety has intensified in recent years, with population growth and climate change identified as major threats to sustainable food systems [1-3]. Among major staple crops, maize (Zea mays L.) plays a significant role in ensuring global food security, serving as a major dietary component for both humans and livestock. In addition to maize's nutritional significance, it is also a key industrial raw material used in the production of starch, oil, protein, alcoholic beverages, sweeteners, and biofuel [4,5]. Currently, the global production of maize has surpassed one billion metric tons per annum, highlighting its economic and agricultural importance [6]. Potential solutions or strategies to enhance maize productivity are thus central to addressing food security challenges, particularly in areas where maize constitutes a substantial share of cereal crop output [7-9].

Maize constitutes a significant component of Hungary's cereal crop production, with substantial quantities being utilised

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for both domestic consumption and international trade [10]. Among cereal crops in Hungary, maize occupies the largest cultivated area with approximately 1 million hectares sown annually. National production averages 6 – 8 million tonnes, with utilisation distributed across export (48%), livestock feed (33%), agro-processing industries (18%), and seed production (1%) [11]. Additionally, the crop also contributes to bioethanol production, with co-products such as distillers' grain supporting the livestock and energy sectors (Széles et al., 2019). However, the productivity and quality of maize are increasingly threatened by biotic stressors, particularly corn smut disease caused by the fungus Ustilago maydis [12]. This disease is relatively prevalent in maize production and significantly poses negative implications for seed yield and quality of maize. Symptoms of maize infected by corn smut disease include chlorosis, growth inhibition, and tumour formation on cobs, with yield losses ranging from 28.0% to 61.3% [13]. Corn smut disease can infect corn at all phenological phases, which then limits maize production worldwide (Galicia-García et al., 2016). Studies suggested that environmental factors such as high temperature and drought conditions further exacerbate corn smut disease incidence by influencing pollen and filament dissemination [14,15].

Given the limitations of conventional chemical control and the increasing demand for sustainable agriculture, integrated disease management strategies that combine synthetic and biological agents are growing in interest. Therefore, this research investigates the efficacy of various synthetic and biological control treatments, namely, Mycostart Bio (mycorrhiza preparation), Mycostat Bio (mycorrhiza preparation) + Plant conditioner, Genium (plant conditioner), and Fungicide (Prosaro) in the management of corn smut (Ustilago maydis) in maize. The study specifically evaluates their impacts on key physiological traits to identify effective and environmentally sound control measures for corn smut.

Material and Methods

This experiment was conducted at the practical garden of the University of Debrecen, Hungary, during the 2024 cropping season. An inoculum of smut spores was created in a laboratory setting. During the 2024 planting season, the average temperature recorded from the month of May to September was 18.95021505 ˚C, while the average relative humidity was 67.51281106, with the average rainfall during this period being 1.400890937mm. According to our data, the month of July had the highest temperature of 25 ˚C, while March had the lowest temperature of 9 ˚C. For the relative humidity, June had the highest of 73.8 %RH, and August had the lowest RH of 63.2 %RH. As for the rainfall, the month of June had the highest rainfall of 2.58mm, while March had the lowest rainfall of 0.3mm (Figure 1).

Experimental design and treatment

The experiment was laid out in a randomised complete block design consisting of five (5) different treatments replicated four times. The plot size was (3m*6m), containing twenty (20) plots. The experimental treatments were Mycostart Bio (mycorrhiza preparation), Genium, Solvitis Zn, Solvitis Mg, Solvitis Sk (plant conditioners), Prosaro fungicide (active ingredient: prothionconazole + tebuconazole), and a control (Table 1). After ninety (90) days of seed sowing, artificial infestation with corn smut inoculum was carried out in the field. Two hundred (200) plants were infested. Ten (10) plants were randomly selected from the twenty (20) experimental plots. The sowing time was 29.04.20254 and the cultivar was MV Koppány.

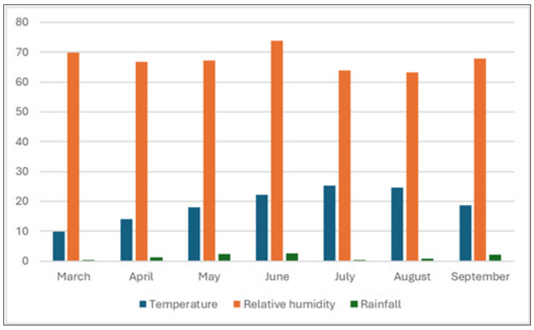

Figure 1: Meterological data at the practical garden of the University of Debrecen during the 2024 cropping season

Table 1: Different treatments, dosages employed during the growing season

Treatment	Dosage
Mycostart Bio (mycorrhiza preparation)	35 kg/ha
Mycostart Bio (mycorrhiza preparation) + conditioner Plant	35 kg/ha
Genium (plant conditioner)	4 l/ha
60 ml/ha	
Fungicide (Prosaro)	1 l/ha
15 m/15m2	
Control	NA

*Fungicide used was Prosaro with the active ingredients: prothionconazole + tebuconazole

Data Collection

During the collection of the data, we recorded the effect of the different treatments on the crop height using a measuring ruler, while for the crop yield, we used the weight measuring scale in kilogram and as for the number of infestations on the plants, we visually observed and recorded the place of infestation and the number of infestations.

Crop Height

There were twenty plots, and each plot had four rows. For the crop height, the two middle rows were used to collect the plant height, starting from the base to the apex of the plant was measured using a meter rule.

Crop Yield

The grains that were dried in the field were threshed, cleaned and weighed in kilograms for each plot using a weight measuring scale. The total weight of each plot gives the grain yield for the different treatments.

Number of Infestations

The data on the number of infestations and the place of infestation were visually observed and recorded. The place of infestation was also recorded (stem, cob and inflorescence).

Data Analysis

Data were entered into Excel, and analysis of variance was performed on the data using Genstat 18th edition. On the number of infestations, count data were transformed ($\sqrt{n+0.5}$) to homogenise the variance before performing analysis of variance; the least significant difference level at 5% was used to separate treatment means.

Results and Discussion

Effect of Synthetic and Biological Treatments on Maize Height

Based on the data, the analysis showed no statistically significant difference ($P > 0.05$) in maize plant height across the five treatments (Figure 2). The average crop heights were as follows: T1 (2.75m), T2 (2.85m), T3 (2.77m), T4 (2.74m), and the control plot T5 (2.8m) (Figure 2). Although statistically insignificant, a closer examination shows a 1 to 17% decrease in average height in T1, T3, and T4 when compared to the control plot. Treatment T2, a biological formulation, recorded the highest average plant height (2.85m) with minimal variability, suggesting both consistency and a potential growth-promoting effect. T3 also resulted in relatively high plant height (2.77m) but with slightly more variability than T2. Conversely, T4, which had the shortest height (2.74m), demonstrated limited variation, potentially indicating a uniformly less favourable impact on growth. However, T1 exhibited the greatest variability despite a moderate average height, implying inconsistent performance. These findings suggest that T2 may enhance plant height more effectively and reliably than other treatments, pointing to the potential of certain biological formulations to support vegetative growth. This is supported by Appiah et al, who found significant crop height increases with biostimulant applications [16]. Similarly, Thilagar and Bagyaraj. Observed improvements in plant height, shoot and root biomass and phosphorus uptake following mycorrhizal inoculation, especially under stress conditions [17].

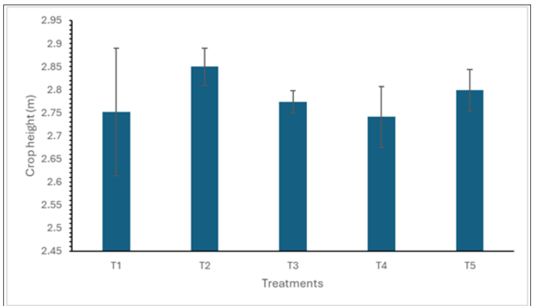

Figure 2: Effect of Synthetic and Biological Treatments on Maize Height

Effect of Synthetic and Biological Treatments on Maize Yield

Figure 3 illustrates the effects of different treatments on maize yield. Again, there were no statistical differences in yield between treatments ($P > 0.05$) (Figure 3). However, a notable trends were observed. T4 (fungicide Prosaro) achieved the highest average yield (12.62 kg), outperforming all other treatments, including the control T5 (7.85 kg). Additionally, T2 also produced relatively high and consistent yields, marginally surpassing T1. T1 yielded moderately but greater variability, while T3 showed both low yield and inconsistent results, with the control (T5) also recording the lowest yield and the widest variability. These results underscore the superior yield performance of T4, indicating that fungicidal application, particularly Prosaro, may be the most effective approach for maximising yield under the conditions of this study. Moreover, T2 also proved to be a promising biological alternative with consistent and improved yield over the control. These observations align with the studies by Waxman and Bergstrom, who reported that Prosaro fungicide significantly enhanced yields in treated winter wheat cultivars compared to the untreated cultivars. Similarly, Amanullah et al. reported a 20% yield increase in maize treated with arbuscular mycorrhiza compared to the untreated controls, supporting our findings on the potential of both synthetic and biological treatment to enhance productivity [18,19].

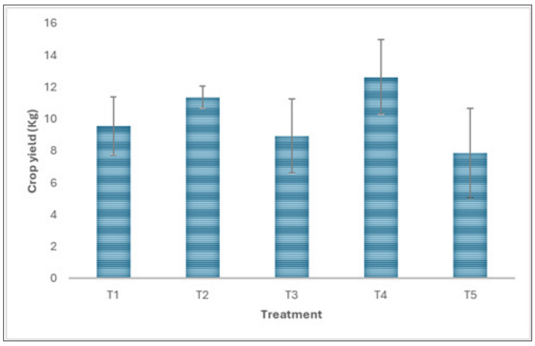

Figure 3: Effect of Synthetic and Biological Treatments on Maize Yield

Effect of Synthetic and Biological Treatments on infestations of Ustilago maydis on different parts of maize

The incidence of Ustilago maydis infestations in different maize organs, particularly the cob, stem, and inflorescence, is displayed in Figures 4, 5, and 6. The data analysis on the incidence of Ustilago maydis infestation rates across treatments indicated no statistically significant difference ($P > 0.05$). For cob infection, T4 recorded the highest number of infections, where T2, T3, and the control (T5) had similarly low levels (Figure 4). Stem infections were comparable in T1 and T2, with T3 showing fewer infections (Figure 5). For inflorescence infections, T1 and T2 demonstrated lower incidence than T3, T4, and T5, which had similar levels (Figure 6). Notably, out of the 100 plants that were infected, only 23 plants displayed the presence of the virus, indicating an overall low disease incidence. This low infection rate is likely due to high temperatures during the growing period, which created unfriendly conditions for the fungal proliferation. Our results are consistent with a study by Walióra et al. (2014), who reported that Ustilago maydis infection rate peaks at lower temperatures (between 0 and 17 ˚C). Similarly, Cao et al. and Maiorano et al. (2010) highlighted the role of low temperature and high moisture in promoting fungal growth and fumonisin production [20]. High temperatures reduce smut infection in pearl millet, suggesting a similar protective effect may occur in maize [21]. Waligóra et al. also showed that high temperatures reduced maize weevil infestation, which may indirectly lower smut infection risk by reducing vector-mediated kernel damage [22]. Our findings contribute to understanding that elevated temperatures can suppress corn smut infection in maize, even in the absence of significant treatment effects. This underscores the importance of integrating climatic factors when evaluating disease management strategies.

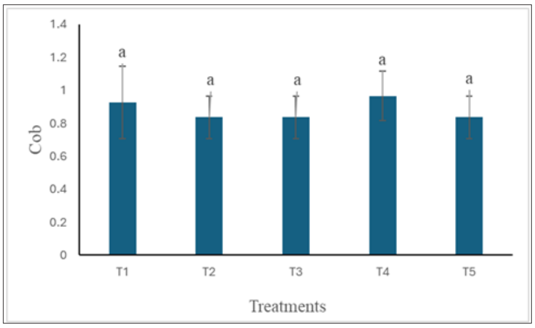

Figure 4: Effect of Synthetic and Biological Treatments on infestations of Ustilago maydis on maize cob

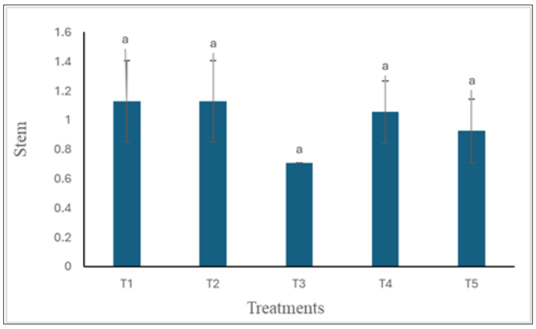

Figure 5: Effect of Synthetic and Biological Treatments on infestations of Ustilago maydis on maize stem

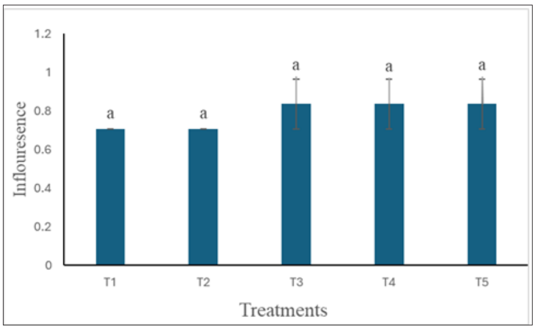

Figure 6: Effect of Synthetic and Biological Treatments on infestations of Ustilago maydis on maize inflorescence

Conclusion

This study evaluated the impact of various control substances on maize crop height and yield, and Ustilago maydis (Corn smut) infestation under field conditions. While statistical analysis showed no significant difference among treatments for crop height, yield, and infection rates, important trends were observed that provide an insight into effective disease and growth management strategies.

T2 (mycorrhiza + plant conditioner) consistently enhanced plant height and demonstrated stable performance, suggesting its potential as a reliable growth-promoting agent. In terms of yield, T4 (Prosaro fungicide) produced the highest average yield, indicating that fungicidal application may be the most effective strategy for maximising maize yield in the short term. However, no treatment significantly reduced Ustilago maydis infection; infestation rates across all treatments were generally low, likely due to high ambient temperature, which is known to inhibit fungal development and proliferation. These observations emphasise the role of climatic conditions in disease dynamics and the need to integrate environmental variables into future disease management planning. In conclusion, our study highlights the potential of both synthetic and biological treatments in supporting maize productivity, with T2 and T4 emerging as the most promising approaches. We also reinforce the importance of temperature as a natural constraint on corn smut incidence, suggesting that treatment efficacy may vary with climatic conditions. Future studies should focus on multi-season trials, exploring treatment-environment interaction, and addressing the long-term impacts of biological agents on soil health and plant resilience.

References

1. Godfray HCJ, Pretty J, Thomas SM, Warham EJ, Beddington JR. Linking Policy on Climate and Food. Science. 2011. 331: 1013-1014.
2. Gonzalez CG. Climate change, food security, and agrobiodiversity: Toward a just, resilient, and sustainable food system. Fordham Environmental Law Review. 2011. 493-522.
3. Wijerathna-Yapa A, Pathirana R. Sustainable agro-food systems for addressing climate change and food security. Agriculture. 2022. 12: 1554.
4. FOA. Agriculture Organization: Maize in Human nutrition FAO. 1992.
5. Maitra S, Singh V. Invited review on ‘maize in the 21st century’Emerging trends of maize biorefineries in the 21st century: Scientific and technological advancements in biofuel and bio-sustainable market. Journal of Cereal Science. 2021. 101: 103272.
6. García-Lara S, Chuck-Hernandez C, Serna-Saldivar SO. (). Development and Structure of the Corn Kernel. In Corn. Elsevier. 2019. 147-163.
7. Grote U, Fasse A, Nguyen TT, Erenstein O. Food Security and the Dynamics of Wheat and Maize Value Chains in Africa and Asia. Frontiers in Sustainable Food Systems. 2021. 4.
8. Ranum P, Peña-Rosas JP, Garcia-Casal MN. Global maize production, utilization, and consumption. Annals of the New York Academy of Sciences. 2014. 1312: 105-112.
9. Shiferaw B, Prasanna BM, Hellin J, Bänziger, M. Crops that feed the world 6. Past successes and future challenges to the role played by maize in global food security. Food Security. 2011. 3: 307-327.
10. Nagy J. Maize Production. 2008
11. Hungarian Central Statistical Office. 2021.
12. Robin J, Doehlemann HG, Wahl R, Hofmann J, Schmiedl A. Ustilago maydis infection strongly alters organic nitrogen allocation in maize and stimulates productivity of systemic source leaves. 2009. 152: 293-308.
13. Aydoğdu M, Boyraz N, Kaya Y. Effect on yield losses on maize (Zea mays L.) caused by smut disease (Ustilago maydis (DC) Corda). The Journal of Turkish Phytopathology. 2015. 44: 23-30.
14. Colhoun, J. Effects of Environmental Factors on Plant Disease. Annual Review of Phytopathology. 1973. 11: 343-364.
15. Galicia-García PR, Silva-Rojas HV, Mendoza-Onofre LE, Zavaleta-Mancera HA, Córdova-Téllez L, et al. Selection of aggressive pathogenic and solopathogenic strains of Ustilago maydis to improve Huitlacoche production. Acta Botanica Brasilica, 2016. 30: 683-692.

16. Appiah EA, Virág CI, Kutasy E. Biostimulant induce growth, chlorophyll content and fresh herbage yield of alfalfa (Medicago sativa L.) and variegated alfalfa (Medicago × varia Martyn) plant. Acta Agraria Debreceniensis. 2024. 1: 19-25.
17. Thilagar G, Bagyaraj DJ. Influence of Different Arbuscular Mycorrhizal Fungi on Growth and Yield of Chilly. Proceedings of the National Academy of Sciences, India Section B: Biological Sciences. 2015. 85: 71-75.
18. Amanullah MM, Ananthi T, Subramanian KS, Muthukrishnan P. Influence of Mycorrhiza, Nitrogen and Phosphorus on Growth, Yield and Economics of Hybrid Maize.Tamil Nadu Agricultural University, Coimbatore. 2011. 98: 62-66.
19. Waxman KD, Bergstrom GC. Evaluation of integrated methods for managing fhb and don in winter wheat in new york in 201. Dept. of Plant Pathology and Plant-Microbe Biology, Cornell University, Ithaca, NY 14853. 2010.
20. Cao A, Santiago R, Ramos AJ, Marín S, Reid LM, et al. Environmental factors related to fungal infection and fumonisin accumulation during the development and drying of white maize kernels. International Journal of Food Microbiology. 2023. 164: 15-22.
21. Moura RM, Pedrosa EMR, Guimaraes LMP. A rare syndrome of corn smut. Fitopatologia Brasileira. 2001. 26: 782-782.
22. Waligóra H, Weber A, Skrzypczak W, Chwastek E. The effect of weather conditions on corn smut infection and european corn borer infestation in several cultivars of sweet corn. Department of Agronomy, the Poznan University of Life Sciences. 2014.