Unravelling the mycotoxins issue in silage corn and contributing environmental and agronomic factors

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Scope of the problem

- Silage corn (*Zea mays* L.) producing areas of the Great Lakes region of North America suffer from ear and stalk rot fungi that produce toxic secondary metabolites (mycotoxins)[1].
- Interaction of pathogen (inoculum), host, environment, additional external factors (e.g., insect injury) determine the severity of the problem[2] (Figure 1).
- Elevated mycotoxin concentration makes silage corn unfit for animal consumption causing feed refusals, vomiting, hormonal imbalance, and fluid build ups leading to oedema.

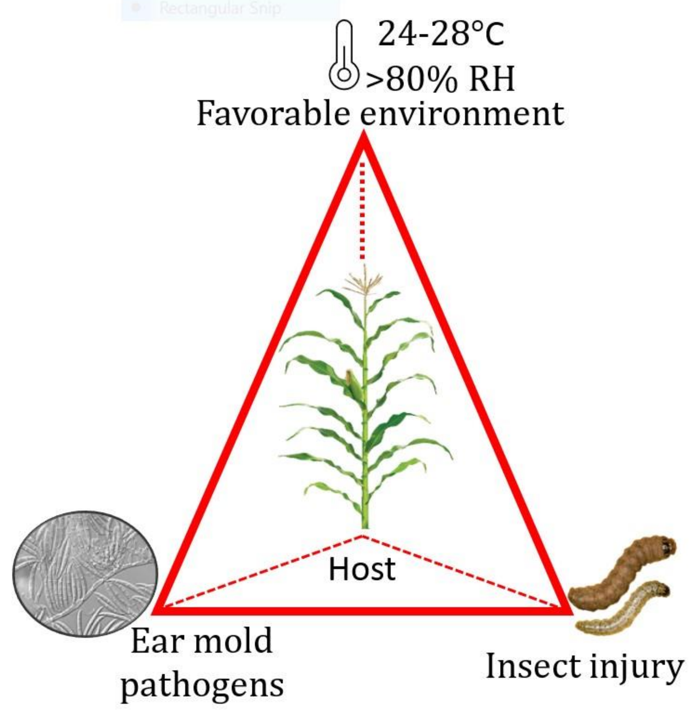


Figure 1: Epidemiological triad for ear mold development in silage corn

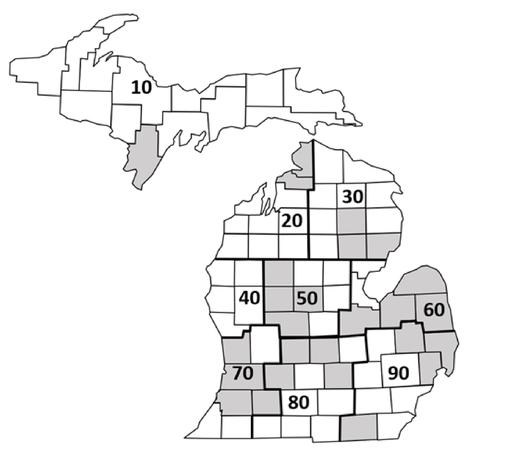
- In addition to environment, field management decisions play an important role in determining inoculum levels and infections that result in ear rots and mycotoxins[3].
- Silage corn is rarely sold in local markets and is mostly fed on-farm, hence most mycotoxin contamination goes unidentified. Therefore, it is important to identify the scope of this problem and understand agronomic and environment relations affecting it.

Objectives

(i) Develop a database for occurrence of various mycotoxins in silage corn across Michigan farms by collecting silage maize samples from grower fields.

(ii) Quantifying the impact of agronomic factors on mycotoxin accumulation.

Materials and Methods



Crop reporting zone	Regions
Zone 10	Upper Peninsula
Zone 20	North-west Michigan
Zone 30	North-east Michigan
Zone 40	Western Michigan
Zone 50	Central Michigan
Zone 60	East Michigan
Zone 70	South-west Michigan
Zone 80	South-central Michigan
Zone 90	South-east Michigan

Figure 2: Michigan counties from which silage samples were submitted for analysis (shaded) in 2019-2021. Counties were grouped into zones (separated by bold lines) based on United States Department of Agriculture crop reporting zones.

Sample Collection:

- Samples were collected (2019-2021) from Michigan grower fields in several counties, grouped into zones based on geography, climate, and cropping practices (Figure 2).
- An information sheet on field history and management practices was also submitted (Figure 3).
- Samples were dried, ground, and tested for mycotoxins.

Data Analysis:

- Data obtained from coordinates of all collected samples were interpolated using kriging in R studio. The R packages used for this analysis were sp, rgdal, splancs, maps, gstats, and RColorBrewer.
- To quantify the co-occurrence of mycotoxins, Pearson correlation co-efficient (r) for various toxins were obtained using PROC CORR in SAS 9.4 software.
- PROC GLM (α = 0.10) was used to determine the impact of agronomic factors on mycotoxin concentration. Data presented here is only from agronomic factors that showed significant differences.

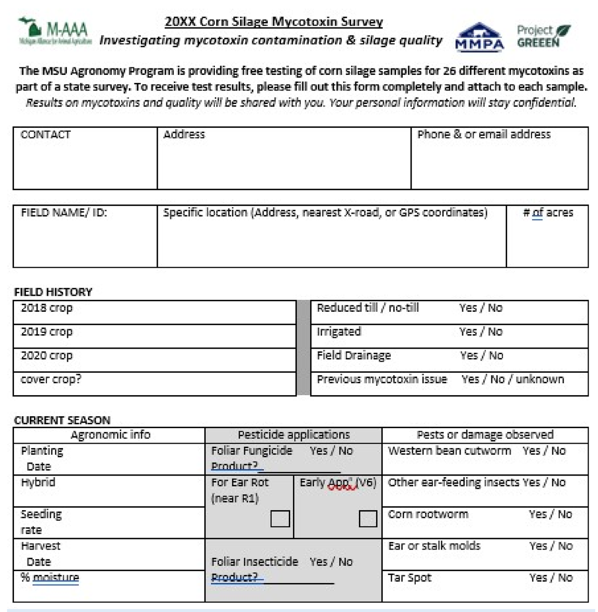


Figure 3:Grower survey sheet with questions on field history and management practices.

Results and Discussion

- 122 silage corn samples were submitted from >20 counties in Michigan over three seasons (n = 34 in 2019, 51 in 2020, and 37 in 2021). 100% samples tested positive for Deoxynivalenol (DON); averaging 1.34 μg g^{-1}.
- Other most frequently occurring mycotoxins were enniatins and beauvericin (averaging 0.03 and 0.34 μg g^{-1}, respectively), followed by zearalenone (ZEN), fumonisins, and moniliformin (averaging 0.12, 0.21, and 0.02 μg g^{-1}, respectively).

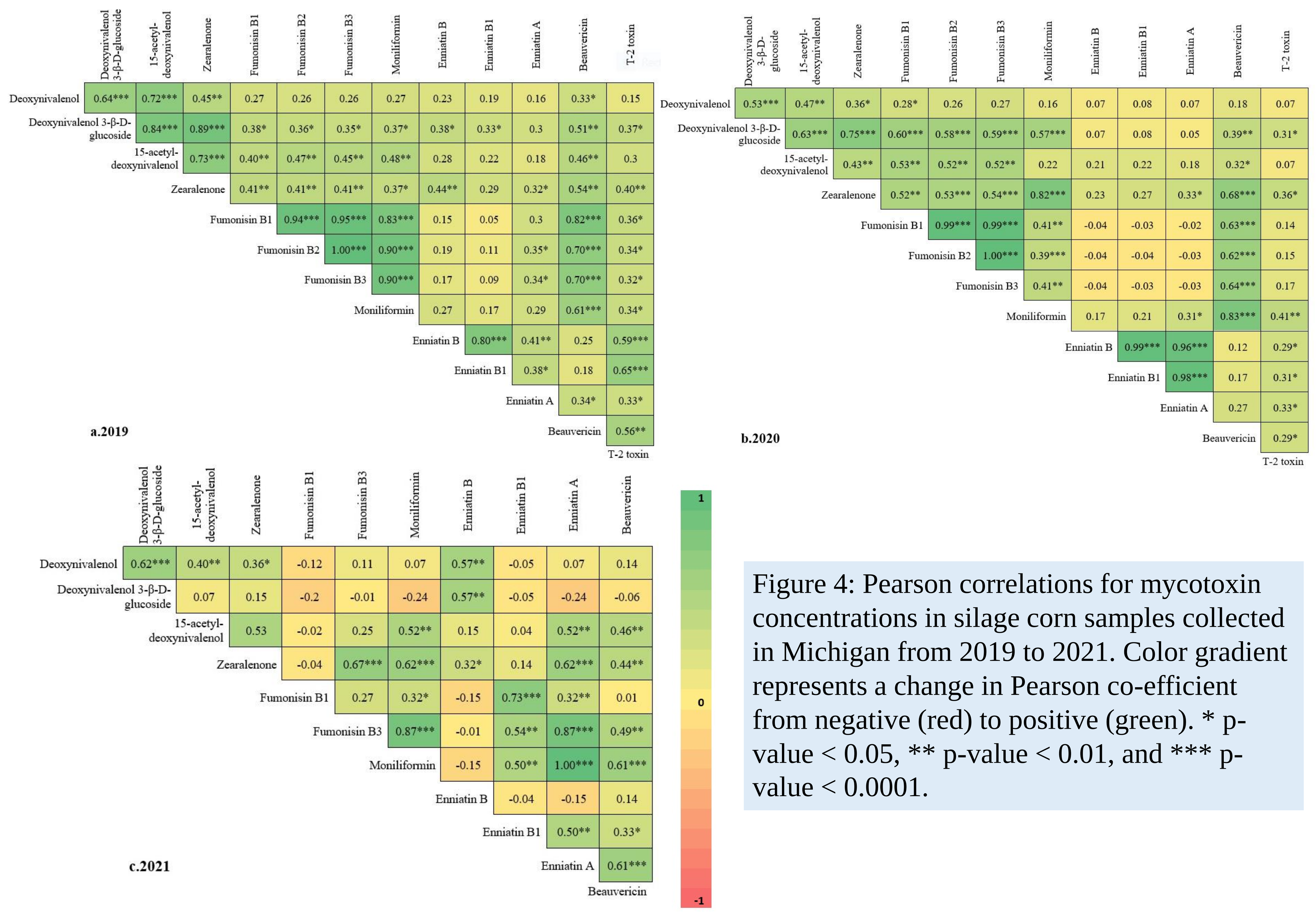


Figure 4: Pearson correlations for mycotoxin concentrations in silage corn samples collected in Michigan from 2019 to 2021. Color gradient represents a change in Pearson co-efficient from negative (red) to positive (green). * p-value < 0.05, ** p-value < 0.01, and *** p-value < 0.0001.

- At least seven mycotoxins occurred in every sample.
- On average, 15, 7, and 10 toxins occurred per sample in 2019, 2020, and 2021, respectively.
- Strong correlations were observed between DON, deoxynivalenol 3-β-D-glucoside, and 15-acetyl-deoxynivalenol (Figure 4), probably because these mycotoxins are derivatives of DON.
- DON, ZEN, and BEA were strongly correlated, indicating that same ear rot fungus (*F. graminearum*) produces these toxins; while fumonisins were weakly correlated.

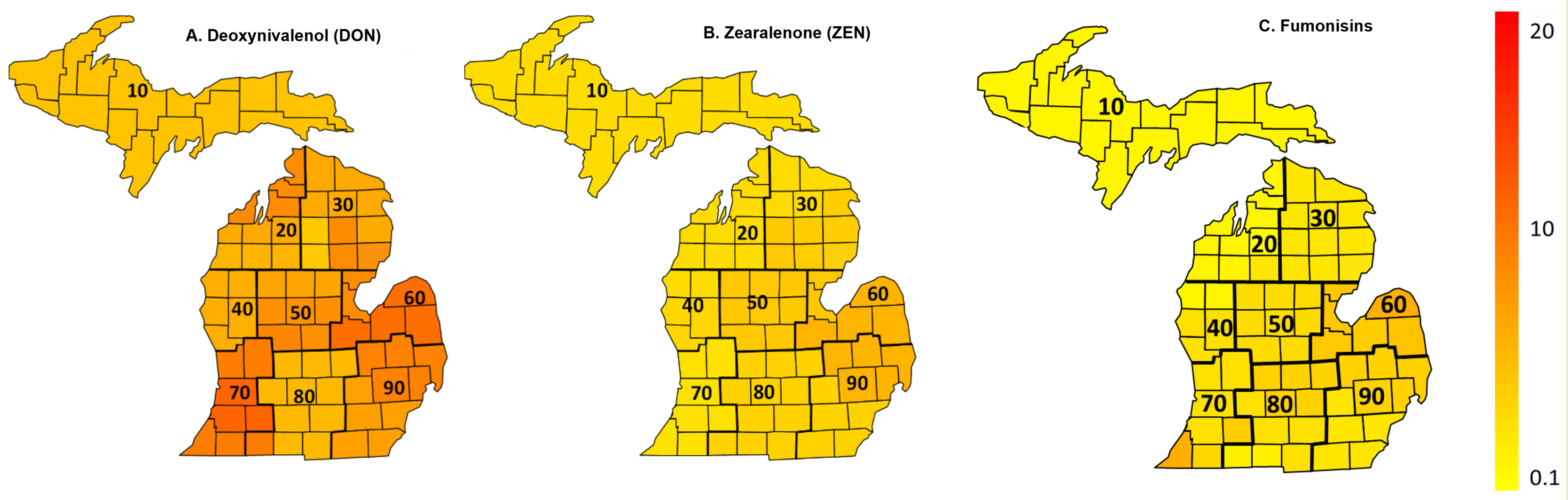


Figure 5. Average mycotoxin concentrations from silage corn samples collected in Michigan from 2019 to 2021, by crop reporting zones (as defined by United States Department of Agriculture). Color gradient represents average concentrations (μg g^{-1}) from lower (yellow) to higher (red).

- Zones 60 and 90 had the highest mycotoxin concentration, probably due to cool (20-24 °C) and humid (>70% R.H.) weather around corn silking and higher ear-feeding insect injury reported in these zones, contributing to ear wounds[5].
- Zones 60 and 70 are near the coast of Lake Huron and Lake Michigan (two of the Great Lakes), providing a humid environment that is favorable for fungal infections.
- Fumonisin and ZEN were lower both in frequency and concentration across state.

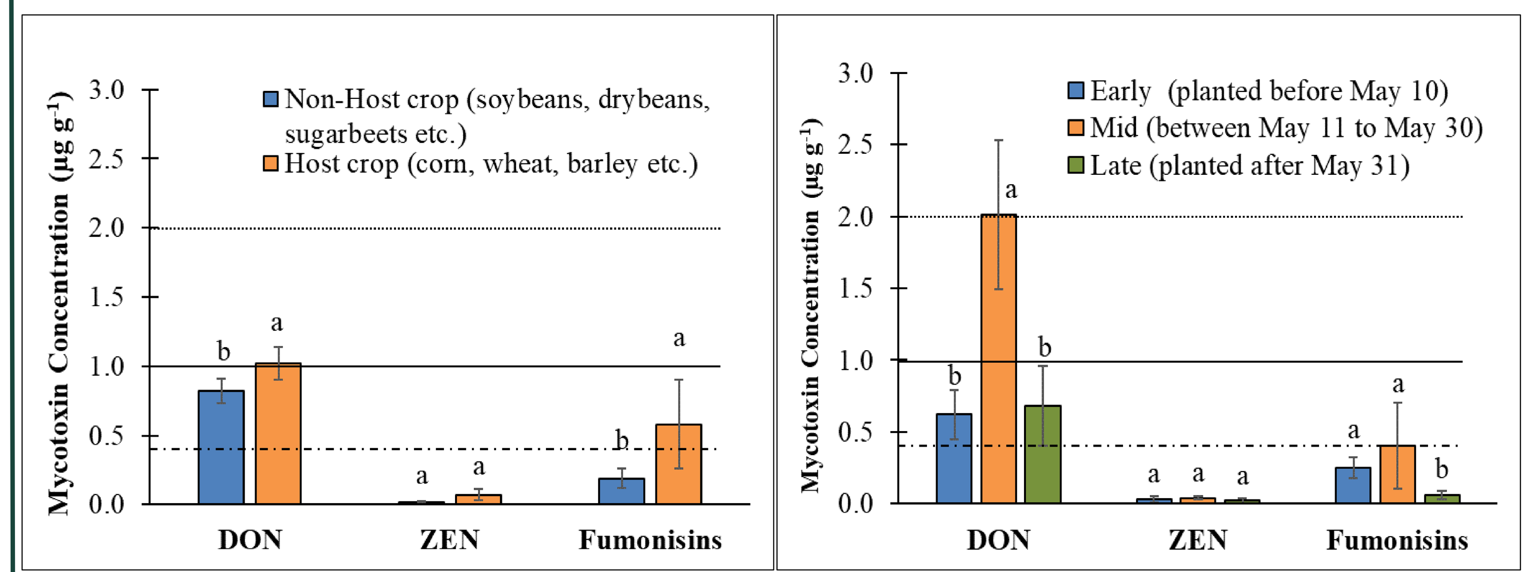


Figure 6. Impact of crop history (A) and planting date (B) on DON (deoxynivalenol), ZEN (zearalenone), and Fumonisin concentration in silage corn samples collected in Michigan from 2019 to 2021. The horizontal dashed line, bold line, and dotted line represent DON, ZEN, and Fumonisin concentration beyond which health problems are more frequent and severe in dairy cattle[4].

- Silage corn following a *Fusarium* host crop had 20 and 67% greater DON and fumonisins, respectively than non-host crops (Figure 6A).
- Mid-planted silage corn had 69 and 65% higher DON than early and late plantings. Fumonisin was lowest for planting after May 30 (Figure 6B).
- Planting time determines corn silking window. Mid-planted corn silks in late July and early August (averaging 25.5 °C and 83.1 mm rain) causing high humidity (>75%) that favor infection and result in more mycotoxins.
- No differences in mycotoxins between till and no-till fields, although a trend (p =0.21) towards higher DON in tilled fields.

Conclusions and Future Directions

- Mycotoxins are prevalent in Michigan and often co-occur; however, their average concentration is mostly below the defined thresholds.
- Mycotoxin co-occurrence shows that exploring pathogen relations and mycotoxin derivates can potentially be used to develop economical testing techniques.
- Mycotoxin concentration varies due to differences in humidity, rainfall, and temperature conditions; driven partly by the proximity of certain regions to the Great Lakes region.
- Field management decisions such as crop rotation with non-host crops and timely planting lower mycotoxin risk in silage corn and should be incorporated in the integrated management system along with hybrid selection, fungicide application, and timely harvest.
- Overall, it is critical to improve our understanding of mycotoxin occurrence by conducting extensive research with samples covering wider geographical area in relation to field-specific environmental conditions and management decision to mitigate the issue of mycotoxin accumulation in silage corn.

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References

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