Is plastic mulching a risk for Deoxynivalenol/Nivalenol soil contamination in strawberry cultivation?

K. Muñoz[1], M. Schmidt-Heydt[2], D. Diehl[1], R. Geisen[2] and G. E. Schaumann[1]

[1]*Institute for Environmental Sciences, Group of Environmental and Soil Chemistry, University Koblenz-Landau, Landau, Germany*

[2]*Max Rubner-Institut, Department for Safety and Quality for Fruits and Vegetables, Karlsruhe*

INSTITUTE FOR ENVIRONMENTAL SCIENCES LANDAU

Introduction

Mycotoxin-producing fungi are an integral part of soil microbiology. Therefore, the production and fate of mycotoxins in soil can be affected by modifications on soil environmental conditions. Plastic mulching (PM) has been widely used in agriculture because it increases <u>*soil temperature and water conservation*</u> (Lamont, 2005; Steinmetz et al. 2016), which lead to *i)* an early production of commodities, *ii)* crop cultivation despite of sub-optimal climate conditions and *iii)* extended productive seasons. The aim of this study is to assess which modification in soil under different mulching conditions (Organic mulching, 2-years and 4-year plastic mulching) influence the fate of the mycotoxins Deoxynivalenol (DON) and Nivalenol (NIV) in strawberry cultivated soils.

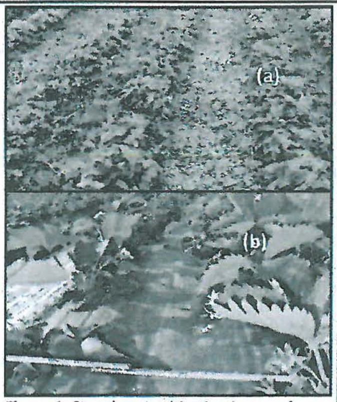

Figure 1: Strawberry cultivation in organic (a) and plastic (b) mulching

Conclusions

The type of mulching and duration of the treatment affect considerably the soil microbiology and physicochemistry:

1) Production of mycotoxins was evident under PM; although a lower fungal biomass was observed (Fig. 2).
2) Although Fusarium species were not representatively observed at the sampling time (Fig. 4), the higher DON/NIV levels observed under PM (Fig. 5) can be a consequence of:
   1) Limited degradation of DON by bacteria/fungi due to the slightly alkaline soil pH values (He et al., 1992; Islam et al., 2011) and a reduction of species richness (Shima et al. 1997)
   2) Reduced soil wash-out due to the impervious matter of the plastic films.

Based on these observations, the use of PM may implicate a risk for DON/NIV soil contamination. Further studies are needed to assess in which extent modification of soil microclimatic conditions under PM affect the mycotoxin production and how the use of PM in agriculture can have an effect on residual DON/NIV levels in food commodities.

Acknowledgments

The authors want to thank the financial support by the Ministry for Education, Sciences, Further Education and Culture of the State of Rhineland-Palatinate (MBWWK) and by the Prof B. Gedek and W. Gedek foundation.

Results

Influence of the mulching treatment on soil microbiology and fungal diversity

- Organic mulching supports the growth of microbial species in soil (Kallenbach and Grandy, 2011; Almeida et al. 2011), which was reflected in high C_{mic} and N_{mic} values. But, the use of PM lead first to a reduction of the microbial biomass (2y-PM). However, after 4-years PM C_{mic} and N_{mic} values were comparable to those observed under OM (Fig. 2a-b).
- The use of PM resulted in a reduction of soil fungal biomass (Figure 2c), probably as a consequence of a modified soil physicochemistry (Fig. 6a-c). (Fernández-Calviño and Bååth, 2010).

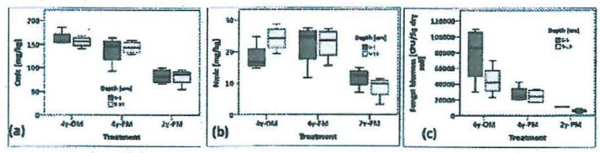

Figure 2: Microbial parameters (a-c) reflecting two different soil depths of strawberry-cultivated fields with either organic mulching (OM) or plastic mulching (PM) treatment

- In comparison to PM, OM supports a higher fungal biomass and species richness (Fig. 2 and 4)
- After 2y-PM the fungal diversity decreased significantly, with a dominance of *Aspergillus* and *Talaromyces* species. After 4y-PM, a clear dominance (>70%) of *Preussia* species was observed, mainly *P. terricola*. This species is characterized for inhabiting shaded soil and plant materials

Figure 3: *P. terricola* isolated from PM soils

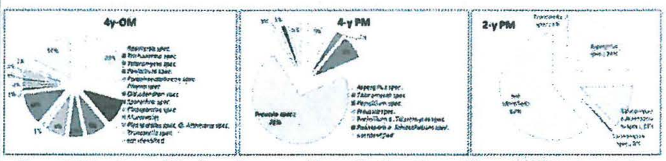

Figure 4: Structure of the fungal communities reflecting three different soil treatments in strawberry-cultivated soils. Samples correspond to a soil depth from 0-5 cm.

Occurrence of DON/NIV in soil samples from strawberry crops

- DON and NIV were detected in soil samples from all treatments. The distribution of the mycotoxins among the samples and along the soil column was heterogeneous (Figure 5). A relationship between soil properties and DON/NIV content was not statistically observed ($p > 0.05$)
- The highest DON/NIV concentrations were observed after 2-years PM. The lowest concentrations, in organic mulching.
- DON values did not correlate with soil biological parameters. However, NIV concentrations positively correlated with C_{mic} and N_{mic} values ($p < 0.05$), and negatively with soil fungal biomass ($r = -0.600$, $p = 0.002$). Which may support the hypothesis that mycotoxin production is an stress-mediated response against artificial environmental conditions (Schmidt-Heydt et al., 2008)

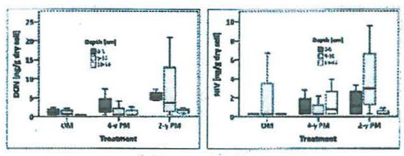

Figure 5: Occurrence of the mycotoxins DON and NIV in mulched treated soil samples from strawberry crops.

Effect of the mulching type on soil physicochemical properties

- Multivariate analysis of variance showed that soil physicochemical parameters were strongly affected by the treatment and duration of coverage, as well as by the soil depth ($p < 0.005$).
- The use of PM resulted in higher ***water content, pH values*** (>7.5) and dissolved organic content, compared to OM, specially at the 10-30 cm depth (**Fig. 6a-c**). The slightly alkaline pH influenced as well the mobility of cations in soils, which was reflected in a higher ***cation exchange capacity values*** after 4y-PM.

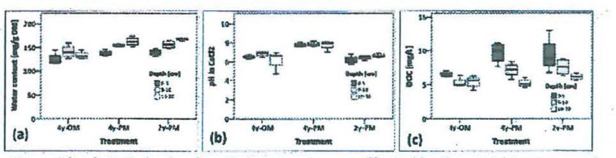

Figure 6(a-c): Soil physicochemical parameters as affected by the mulching type and soil depth in strawberry cultivation.

Methodology

Crop description and sampling: Soil samples from organic (OM) and plastic (PM) mulched soils were collected in May 2015 at the strawberry fields located in Offenbach an der Queich, Germany. In total 36 pooled samples were collected from three different fields: 4y-OM, 2y-PM and 4y-PM. Three different depths were selected: 0-5, 5-10 and 10-30 cm. Strawberry fields (Figure 1) were artificially irrigated and treated with pesticides at different time points.

Soil physico-chemistry: The type of soil consisted of Silt Loam (16% clay, 54% silt and 30% sand). Soil physicochemical analysis consisted of: Water content (WC), ISO 11465:1993; pH DIN ISO 10390:2005-12; Cation exchange capacity (CEC_{eff}), ISO 11260:2011. Dissolved organic carbon (DOC), DIN EN 1484. Elemental Carbon (C_{tot}) and Nitrogen (N_{tot}), Vario micro cube, Elementar Analysensysteme GmbH, Germany. Mycotoxin analysis was performed via solid-liquid extraction and LC-HRMS (Muñoz et al. 2015)

Soil microbiology: Microbiological analysis was done at the soil depths 0-5 and 5-10 cm. Soil microbial biomass was determined using the chloroform fumigation-extraction (CFE) and analysis of microbial biomass C and N (C_{mic}, N_{mic}) (Vance et al. 1987). Mycobiome was quantified via serial dilutions. After incubation the total colony-forming unit (CFU) was determined and statistically evaluated (Muñoz et al., 2015).

References: Almeida, D.d.O., Klauberg Filho, O., Almeida, H.C., Gebler, L. and Felipe, A.F., 2011. Soil microbial biomass under mulch types in an integrated apple orchard from Southern Brazil. Scientia Agricola 68: 217-222., **Lamont**, W.J., 2005. Plastics: Modifying the microclimate for the production of vegetable crops. Horttechnology 15: 477-481., **Steinmetz**, Z., Wollmann, C., Schaefer, M., Buchmann, C., David, J., Troger, J., Munoz, K., Fror, O. and Schaumann, G.E., 2016. Plastic mulching in agriculture. Trading short-term agronomic benefits for long-term soil degradation? Sci Total Environ 550: 690-705., **Schmidt-Heydt**, M., Magan, N. and Geisen, R., 2008. Stress induction of mycotoxin biosynthesis genes by abiotic factors. FEMS Microbiology Letters 284: 142-149. **Shima**, J., Takase, S., Takahashi, Y., Iwai, Y., Fujimoto, H., Yamazaki, M. and Ochi, K., 1997. Novel detoxification of the trichothecene mycotoxin deoxynivalenol by a soil bacterium isolated by enrichment culture. Applied and environmental microbiology 63: 3825-3830. **Muñoz**, K., Schmidt-Heydt, M., Stoll, D., Diehl, D., Ziegler, J., Geisen, R. and Schaumann, G.E., 2015. Effect of plastic mulching on mycotoxin occurrence and mycobiome abundance in soil samples from asparagus crops. Mycotoxin Res 31: 191-201, **Islam**, R., Zhou, T., Christopher Young, J., Goodwin, P.H. and Peter Pauls, K., 2011. Aerobic and anaerobic de-epoxydation of mycotoxin deoxynivalenol by bacteria originating from agricultural soil. World Journal of Microbiology and Biotechnology 28: 7-13., **He**, P., Young, L.G. and Forsberg, C., 1992. Microbial transformation of deoxynivalenol (vomitoxin). Applied and environmental microbiology 58: 3857-3863., **Fernández-Calviño**, D. and Bååth, E., 2010. Growth response of the bacterial community to pH in soils differing in pH. FEMS Microbiology Ecology 73: 149-156.

Project financed by:

Contact Dr. Katherine Muñoz
Institute for Environmental Sciences Landau
Group Environmental & Soil Chemistry
www.uchemie.uni-landau.de
munoz@uni-landau.de

UNIVERSITÄT KOBLENZ · LANDAU