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Conservation agriculture: a solution to soil degradation and soil-borne diseases?

M. Mezzalama, B. Govaerts, K. Sayre, N. Verhulst

Background

The need to reduce tillage arose in the 1980s mainly to save manpower and energy, but also to offer long-term benefits, such as soil stability, reduced soil erosion, and more sustainable agriculture. However, soil-borne pathogens were a threat under reduced tillage. Conservation agriculture (CA) is defined as the combination of reduced tillage (no more than 20-25% of soil surface disturbed), adequate retention of residues on the soil surface, and crop rotation. Residue retention was considered the main modification that would substantially affect the populations of soil-borne pathogens (Boosalis et al. 1981). Increased soil moisture, lower soil temperature, changes in crop nutrient uptake patterns were recognized to also have a direct influence on pathogens (Bockus and Shroyer 1998). On the other hand, these physical and chemical soil modifications were also favoring soil beneficial microflora and activating biological control mechanisms (Cook 1990). Last but not least, crop rotation plays a major role in controlling soil-borne pathogens (Bockus and Shroyer 1998). There is a diverse range of these pathogens and of biological and physical characteristics among different soils, therefore it is necessary to investigate how to adapt CA principles and to find out the responses in each environment.

The strategic research platform at CIMMYT

At El Batán, in the subtropical highlands of central Mexico with highly degraded soils, the International Maize and Wheat Improvement Center (CIMMYT) established an experiment in 1991 to investigate the enduring effects on the performance of maize and wheat from (i) conventional tillage (CT), (ii) zero tillage (ZT, no tillage, direct sowing with the multi-crop/multi-use implement developed at CIMMYT), (iii) maize and wheat crop rotations, (iv) crop residue retention (at the soil surface with ZT or chopped and incorporated with CT), and (v) the removal of crop residues. The experiment also monitored those aspects that can make farmers unwilling to adopt CA, such as soil-borne pathogens. Improved soil management practices are expected to increase the income of farm household, while halting or even reversing chronic soil degradation processes associated with the current farmers' practices.

Improved physical and chemical soil quality results in high, stable yields

After 12 years, there were more rotten maize roots under ZT with residue retention than in CT. Nevertheless, these results were significant on primary roots and not on secondary roots that could guarantee a good anchoring of the plant to the soil and provide the basic root system for good assimilation of water and nutrients. Despite the increase in root rot with ZT and residue retention, the lowest yield was obtained under CT monocropping with residue removal. Wheat showed a low level of root rots under all treatments. There was less root rot under residue retention than when residue was removed. The best root conditions were observed under ZT, with residues retained. Interestingly and predictably, the rotation with maize increased root rot in wheat, as maize increases the population of *Fusarium* spp. Wheat in monoculture showed the lowest root rot incidence, confirming that wheat roots activate their own biological control through the production of exudates that favor specific beneficial micro-flora groups (Cook 2007).

Root rot symptoms on maize. – CIMMYT

Bipolaris sorokiniana, causal agent of common root rot, was frequently isolated from wheat. *F. oxysporum* was most frequently isolated from wheat roots in the treatments under ZT, retaining the residues, and where maize was rotated with wheat. It was the species most isolated over all treatments. Other *Fusarium* species were isolated both from maize and wheat.

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No correlation between yields and root rot incidence was found, showing that other components influenced the CA system and the yield potential of wheat and maize under these conditions. ZT with residue retention and crop rotation resulted in a soil with good physical and chemical qualities, and high, stable maize and wheat yields, compared with CT and ZT without residues (Govaerts et al. 2005).

Healthy, living soils through residue retention

Residue retention under ZT and CT induced greater microbial diversity, especially of higher total bacteria, fluorescent *Pseudomonas* and actinomycetes, both for maize and wheat cropping systems. Crop residue retention resulted in increased populations of beneficial microflora under both ZT and CT. The continuous uniform supply of carbon from crop residues serves as an energy source for microorganisms. Retaining crop residues also increases microbial abundance. ZT, in this experiment, was not responsible for increased microflora, but rather the combination of ZT with residue retention. The favorable effects of these two components are due to increased soil aeration, cooler and wetter conditions, less fluctuations of temperature, moisture, and carbon content in surface soil (Govaerts et al. 2008). The increased microbial activity produced under these conditions can be expected to create an environment more antagononistic to pathogens due to competition effects (Cook 1990).

Maize under zero tillage with residue retention (left of photo) and common farmer practice: maize monoculture, tillage, and removal of residues (right of photo) during 2009 dry cycle. – CIMMYT

Conclusions

CA is an integrated concept to improve soil health. Its application and implication will depend on the local agro-ecological environment. These findings reinforce the need to consider cropping systems holistically (including agro-ecosystem constraints) and to conduct further in-depth research on the effect of management practices on soil microflora communities and the subsequent effect on plant growth promotion and the suppression of soil-borne diseases.

Further reading

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About the authors

Mezzalama, M

Govaerts, B

Sayre, K

Verhulst, N

The authors are members of CIMMYT's research team. **Monica Mezzalama** is a plant pathologist and Head of Seed Health Laboratory. **Bram Govaerts** is a soil scientist – agronomist and Head of the Mexico based Conservation Agriculture Program. **Kenneth D Sayre**, an agronomist, retired from CIMMYT in 2010 but continues to work as a consultant with the CIMMYT Global Conservation Agriculture Program. **Nele Verhulst** is a Post Doc Agronomist in the Mexico based Conservation Agriculture Program.

Email:
m.mezzalama@cgiar.org

CIMMYT
International Maize and Wheat Improvement Center

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SP-IPM@cgiar.org
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