Conservation tillage effects on runoff reduction in rainfed maize of semi-arid zones of western Mexico

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Direct sowing of maize into partial-covering maize stubble, using animal traction, Mexico.

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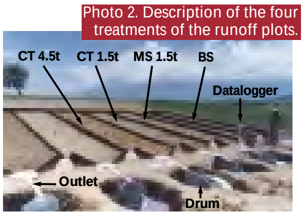
Between 1994 and 1999, a series of studies were done to try to quantify and to modelize the effects of conservation tillage (direct drilling of seeds into a residue mulch-CT) and particularly of a partial residue mulch on water dynamics in the soil-plant-atmosphere system under semi-arid conditions of western Mexico. They showed that with even a very minimal amount of residue (1.5 t/ha), CT begins to give worthwhile improvements in productivity (Scopel, 1994; Scopel et al.*, 1999), illustrating the important role of runoff reduction (30% less than with traditional tillage) in explaining benefits of this technique. This study set out to explain the mechanisms involved in this reduction of runoff losses, trying to separate the short term effects on water movement on the soil surface and the long term effects on water infiltration capacity (Findeling 2001).*

Material and methods

This study was conducted in 1998 in a semi-arid zone (between 400 and 600 mm of rain per year) of western Mexico, on a silty-loam soil with a 7% slope on average (Findeling 2001). On an experiment with a complete block design with two replications (each elementary plot was about 500 m^2) four treatments in particular were studied (photo 1):

- zero tillage without mulch (ZT),
- conservation tillage with 1.5 t/ha of residue mulch (CT 1.5t),
- conservation tillage with 4.5 t/ha of residue mulch (CT 4.5t),
- traditional tillage with an offset at a depth of 10 cm (TT).

Photo 2. Description of the four treatments of the runoff plots.



A macro-fauna inventory was made. Infiltration tests were conducted with the Beer-Kan method at depths of 0, 2 and 50 cm for each treatment (Findeling 2000a).

Close to and under the same conditions as the main experiment, 20 m^2 runoff plots were established (photo 2).

Four treatments in particular were studied:

- bare uncropped soil (BS),
- uncropped mulched soil with 1.5 t/ha of residue (MS 1.5t),
- CT 1.5t,
- CT 4.5t.

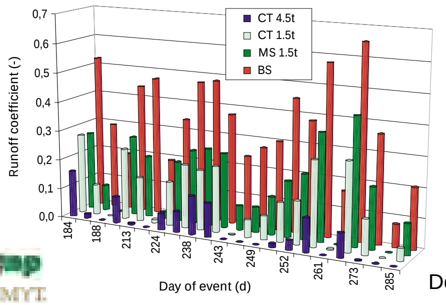
Photo 1. Description of the four treatments of the main plots.

Total runoff and runoff hydrograms were recorded for several rainfall events (Findeling 2000b). Velocity of runoff and friction factor were estimated for these plots during a specific experiment with artificial and constant flows of water.
The tortuosity of runoff trajectories was then estimated directly, comparing the direct distance and real length of the trajectory between two points.

Results

Runoff was studied for 21 events distributed between 07/02/1998 and 10/11/1998, during the crop season. In every case, runoff coefficients on cumulated data were greater without mulch (ZT), significantly reduced with a light 1.5 t/ha mulch (30 to 50% less), and lowest with a 4.5 t/ha mulch (50 to 80% less) (fig. 1).

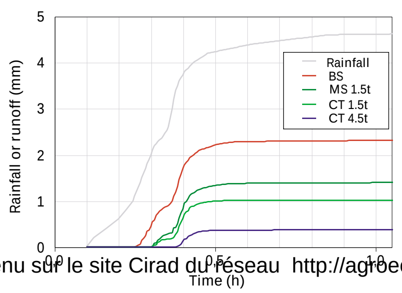
Fig. 1. Effect of treatment on cumulated runoff for 21 rainfall events distributed over the 1998 maize cycle.



On analysing all the hydrograms (fig. 2), it appears that mulch generally acts in two different ways explaining the differences between the treatments on cumulated runoff:

- by delaying the start of runoff after the beginning of the rain,
- by decreasing its intensity (lower slope for cumulated runoff in time).

Fig. 2. Effect of treatment on runoff dynamics during rainfall event 36 (08/11/1998).



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Results (following)

Part of this effect can be explained by the role of successive barriers played by small residue heaps, even with very little residue on the soil (photo 3). This is clearly illustrated by the differences between treatments in the tortuosity of the runoff pathways (photo 4), which increases with the amount of residue (table 1). The effects of mulch on runoff velocity and on friction factor (linked to superficial roughness) are also significant, but are more significant with 4.5 t/ha than with 1.5 t/ha of residue.

Photo 3. Experimental observation of the mulch elements dam effect on runoff (CT 4.5t).

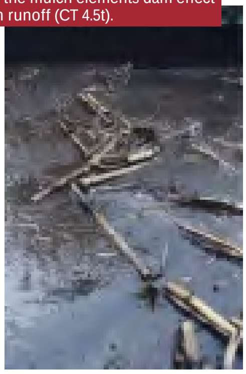


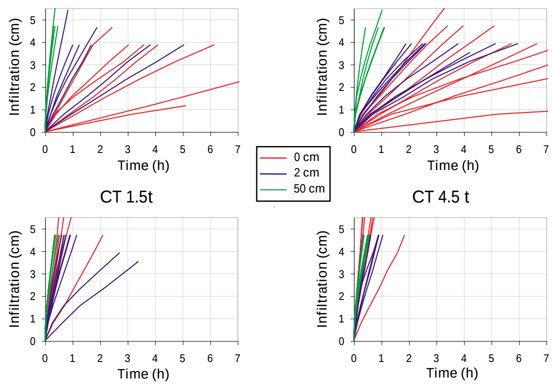
Photo 4. Experimental comparison of runoff pathways tortuosity of two contrasted treatments.

Table 1. Effect of treatment on tortuosity and friction factor.

Plot	Mulch biomass (t/ha)	Tortuosity	Friction factor
TT	0	1.09	0.49
ZT	0	1.09	0.27
MS-1.5t	1.5	1.28	0.38
CT-1.5t	1.5	1.28	0.38
CT-4.5t	4.5	1.46	1.15

Significant differences in infiltration velocity have been observed on the surface between treatments (fig. 3), with higher infiltration rates for mulched treatments after five years of conservation tillage. A major difference is created by the hydraulic conductivity of the 0-2 cm top layer, which tends to encrust without mulch, even in TT where the soil has been prepared mechanically at the beginning of the season.

Fig. 3. Effect of treatment on infiltration rate, after five years.



The practice of conservation tillage, with no tillage for several years and returning part of the organic biomass on the soil surface, activated the total macro-fauna population (fig. 4), whose constant activity and exchanges with the litter maintained high surface porosity (photo 5). At the same time, the intimate mixture of semi-degraded crop residue with soil in the first 2 cm helped to protect this favourable surface structure. Both phenomena explain this effect of the mulched treatments on surface hydraulic properties.

Fig. 4. Effect of treatment on total soil volumetric macro-fauna content (including earthworms, termites, and different Coleoptera larvae).

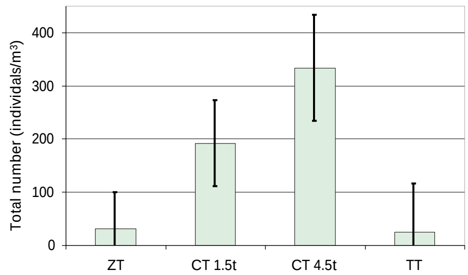
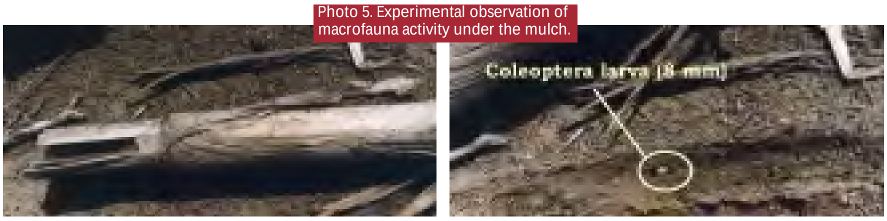


Photo 5. Experimental observation of macrofauna activity under the mulch.



Conclusion

This study confirmed the significant effects of very partial mulch on runoff reduction in conservation tillage systems, as already observed in previous studies (Scopel, 1994; Scopel *et al.*, 1998; Steiner, 1994). We demonstrated both a physical barrier effect of residue heaps and the maintenance of a high infiltration rate, by preventing crust formation on the soil surface (Findeling 2001). The first effect is continuous, which is probably why, in this context, very good yields of rainfed maize can be obtained with this technique, right from the very first years of CT application (Scopel, 1994). The second probably increases with time, accentuating the beneficial effect of mulched treatments on water storage year after year.

This mechanistic approach allowed us to better understand the benefits of CT for such semi-arid zones and opened up new prospects for modelling the effects of a partial mulch on runoff in a less empirical way than has been done before (Scopel *et al.*, 1998).

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