EFFECT OF REDUCED TILLAGE ON SOIL CHARACTERISTICS AND DURUM WHEAT GRAIN YIELD

Algeria, in a Mediterranean semi-arid climate type

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Dry-farming system is commonly used in the Algerian semi-arid High Plateaus. It is based on cereal/sheep production in a cereal-fallow rotation. This cropping system degrades the structure of the tilled horizon and reduces its organic matter content (Kribaa et al, 2001). Soil structure degradation is reported as a major constraint regarding water infiltration, redistribution and storage in the soil profile (Canolly, 1998). It often results from the disturbance induced by tillage-tools (Paglai et al, 1983).

The present study aims at investigating the impact of reduced tillage, reversing and unreversing soil, on the soil structural behavior and subsequent soil water properties in semi-arid Mediterranean conditions. Winter wheat crop yield in a cereal-fallow rotation has been also quantified.

This study has been carried out during the period 1991-1998 on a Calcisol (38.4% clay, 42.7% silt and 18.7% sand, 26.6% total CaCO3) (Lahmar et al., 1993) located in the eastern part of Algeria (36º 9'N; 5º 21' E, 1080m asl). Climate is semi-arid with a long term average annual precipitation of 380 mm.

MATERIALS AND METHODS

The experimental design was made up of five unreplicated strips each 6 m wide and 60 m long. C1, C2, D1 and D2 strips were seeded with a durum wheat variety. Z treatment was left uncropped.

DATA COLLECTION was made from four identified stations per strip to serve as replications.

Soil measurements were done at the tillering (January) and heading (April) stages while crop measurements were taken at crop maturity.

Near-saturated hydraulic conductivity K(h) was measured in situ using a triple-ring infiltrometer with multiple suctions (Vauclin et Chopart, 1992). K(h) was estimated during the steady state according to the method reported by Ankeny et al. (1991).

Retention curve was determined at low suctions.

Pore description was carried out on an undisturbed soil sample impregnated with a polyester resin containing fluorescent dye (Murphy et al., 1977).

Tillage treatments:

C1: Early Chisel-till;
C2: Late Chisel-till;
D1: Early Disc-till;
D2: Late Disc-till;
Z : Untilled Fallow.
Fallow tillage was done at two different dates:
in **January** (C1 and D1) eight months before seeding and,
in **November** (C2 and D2) few days before sowing.

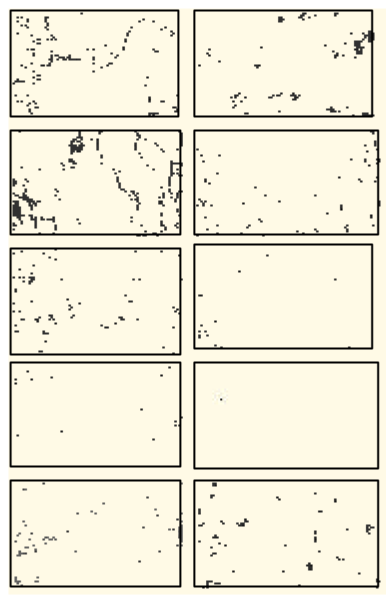

Figure 1: Binary images illustring the soil structure of the fives treatments in January and April (macropores in black)

IMAGE ANALYSIS was performed on thin sections.

Each image was digitized in a rectangular grid of 768 x 576 pixels with a spectral resolution of 256 grey levels and a spatial resolution of 100 mm per pixel so that only macropores were subjected to analysis. Grey level images were thresholded according to the method described by Hallaire (1994).

The specific porosity was expressed as the proportion of pixels belonging to the macropore space. Pore size was measured by its area on the binary image and pore shape by the elongation index (Coster and Chermant, 1989).

Porosity distribution was obtained by filling the macropore binary image with hexagonal structural elements using the opening morphology mathematical operation (Serra, 1982).

RESULTS

Results evidenced **modifications of pore space induced by both tillage treatments and soil biological activity** (fig. 2).

Under shallow tillage with chisel, structural evolution of ploughed layer was marked by a reduction of the inter-aggregates macro-porosity and by an improvement of the intra-aggregate porosity. As far as pore space was concerned, temporal structural modifications corresponded to a shifting from a structural porosity made of an assemblage of aggregates less compacted to a structural porosity fissured and made of an assemblage of compressed aggregates. Early fallow tillage allowed regeneration of the porosity due to biological activity in wide pores with large or complex forms. **Under shallow tillage with tandem disc**, ploughed layer was characterized by a dominance of dense micro-aggregates. Structural evolution conducted to a porosity made of an assemblage of reduced micro-aggregates, due to compaction favoured by the initial structural state. Early fallow tillage with a tandem disc, allowed pore space regeneration also due to soil biological activity.

An area of 3x3m was harvested at crop maturity to quantify above ground biomass production, grain yield and grain yield components.

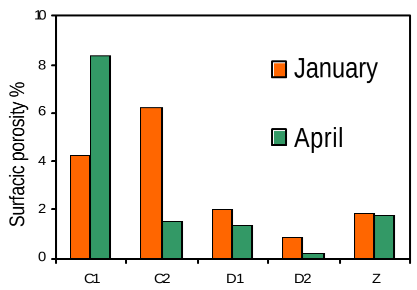

Figure 2: Specific surface macroporisity resulting from the five treatments in January and April (main values)

Bi-dimensional image analysis explained the temporal variability of soil pore space structure. Confrontation of pore characteristics to hydraulic conductivity and to water retention curves allowed defining water transfer and water retention behaviours. Macro- and mesopores played a determinant role in these behaviours.

In terms of fallow farming practices and their consequences on soil hydraulic functions; the main results are (fig. 1):

- **Fallow tillage creates an important macro-porosity** which diminished with time under the influence of episodic drought and re-humectation. However this porosity is maintained at a higher value comparatively to that from no-tilled fallow, even at the end of the crop cycle. The analysis of the pore space characteristics confirmed the pertinence of one pore category in the temporal variability of the pore space structure. These were small and medium sized pores, rounded or of large forms, resulting from biological activity and structural origins.

Participation of the pore space structural parameters as co-variables to explain water transfer and water retention properties was evaluated. The results showed that **fallow farming practices exerted a strong effect on hydrodynamic behaviour of ploughed horizon which is highly associated with the characteristics of pore space structure** (fig. 3, 4).

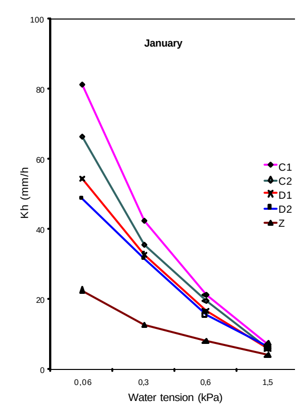

Figure 3: Near Saturation hydraulic conductivity (mean values).

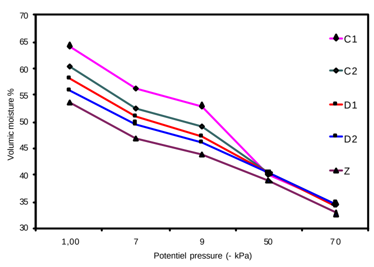

Figure 4 : Retention curves of the 8-25 cm horizon in April (mean values).

- Globally, **pore space structure affects water transfer and water retention of the tilled horizon**. The relationships established between pore space structure parameters, water transfer and water retention parameters indicated that the tilled horizon behaved differently according to the fallow farming practices. In terms of water retention and water transfer, the chisel tilled soil was better than the one tilled with tandem disc, no-tilled fallow being the last. Tillage efficiency depended also on soil humidity conditions of the period of tillage realization. Early till leaved more time for destroyed structure to regenerate and favoured the stability of the acquired structure. Our results suggested that early till is more interesting in the conditions of the semi-arid Algerian High Plateaus with a strong climatic variability.

Data analysis showed also that water alimentation is generally less favourable to wheat crop in this semi-arid region, where drought stress risk is highly related to the dry days' chronology, with drought period generally appearing by March. Duration of drought sequences is subjected to modifications introduced by the soil component which reduces or amplifies drought stress according to soil hydro-physic characteristics and to mean value of vapour pressure deficit. Real evapo-transpiration values explained variation in the grain yield and variation of the crop behaviour through the variation of soil water stock. Drought stress caused by the long dry spells during March and April reduced number of kernels per head and the number of kernels per m^2.

This investigation allowed identifying three different environments based on the variability of crop responses, which are:

- A favourable environment with WUE values higher than 12.5 kg of grains/mm of evapo-transpired water/hectare. Water transfer and retention in ploughed layer were favourable and the root density was reduced. This environment characterized the accumulated effects of an early and shallow fallow chisel tillage (C1);
- A moderately favourable environment with WUE values ranging between 7 and 12 kg/mm/ha where water retention and transfer were less favourable, with a moderate root density. This environment characterized the accumulated effects of early till with disc (D1) and late till with chisel (C2);
- An unfavourable environment with WUE values less than 7 kg/mm/ha where water retention and transfer were unfavourable, with a high root density. This situation characterized the effects of a late fallow till done with disc (D2).

CONCLUSION

Under the crop growth conditions of the Sétif High Plateaus, as far as soil humidity is concerned, it appeared clearly that fallow till gave best results than no-till. This may be explained by the surface crusting that seals soil and by the absence of pores connectivity in the no-tilled fallow which penalized crop at the beginning of the season through a low stand. Hence under the no-till option, chiselling i.e. no soil reversing seems required. Direct seeding on cover crop may also be explored in theses conditions.

References

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