Impact of deep compaction on root growth and yield of potato

Use of 'profil cultural' method to evaluate the effects of compaction

Vincent Tomis[1], Michel Martin[2], Annie Duparque[1], Hubert Boizard[3]

[1] Agro-Transfert Ressources et Territoires
[2] Arvalis-Institut du Végétal
[3] INRA Agro-Impact

ISTRO 2014, 26-30 may, Maringà, Brazil

Context

- Northern France : loess soils / oceanic climate
- Cropping systems with high proportions of root crops : sugar beet, potato and irrigated vegetables

- Heavy machineries at sowing/planting and harvesting
- High proportion of field areas affected by wheels tracks

- Lack of flexibility to choose the harvest date : agro-industries requests, external supply for operations…

  → Field operations sometimes performed in wet conditions

→ High risk of severe and deep soil compaction

ISTRO 2014, 26-30 may, Maringà, Brazil

Context

Farmers are not aware of deep compaction…

- Wide tires
- Rear tires out of line with the front tires

→ No ruts

- **Difficulty to identify deep compaction by farmers and advisors** (farmers are very sensitive to the condition of soil surface)
- **Potato is a compaction-sensitive crop**

→ What is the effect of compaction on potato growth ?

Objectives of the study

- To characterize the conditions of potato root growth in relation with soil structure, with the aim to optimize the use of water

- To quantify the impact of soil compaction on root growth and crop yield, according to water supply

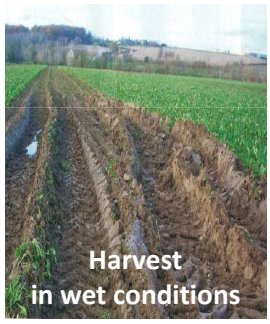
Methodology (1/4)

Research conducted since 2010 : farmers' fields and experimental plateform

In each site, several experimental modalities were carried on, with variants on the level of compaction

Farmers' fields

• Several compaction levels according to previous beet harvest conditions



Arvalis – **Experimental plateform**

• Deliberately-caused compaction

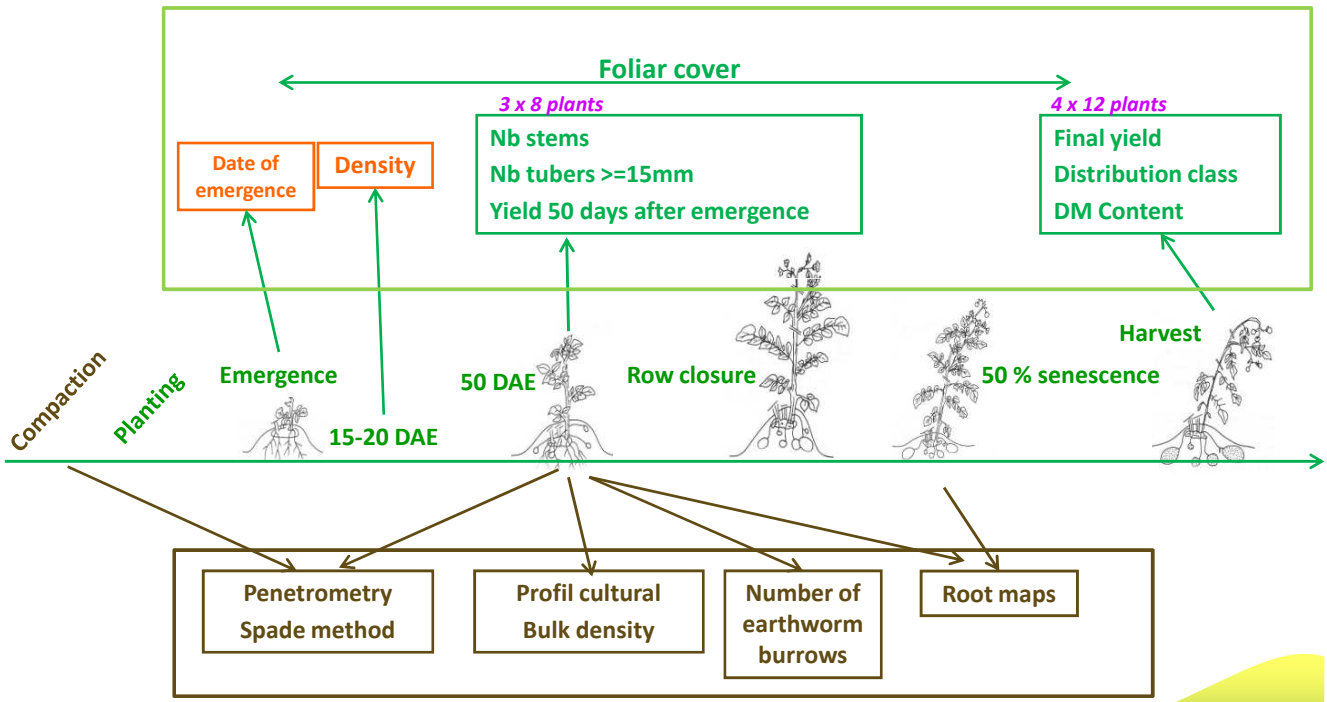
• Various amount of water supply with irrigation

- Diverse climatic conditions : Dry in 2011, wet in 2012
- Various soil textures : loam, loamy sand, loamy clay and sandy clay
- Different cultivars : Bintje, Lady Claire, Franceline, Saturna

We verified that compaction created in the experiment was in the range of compaction found in commercial farms

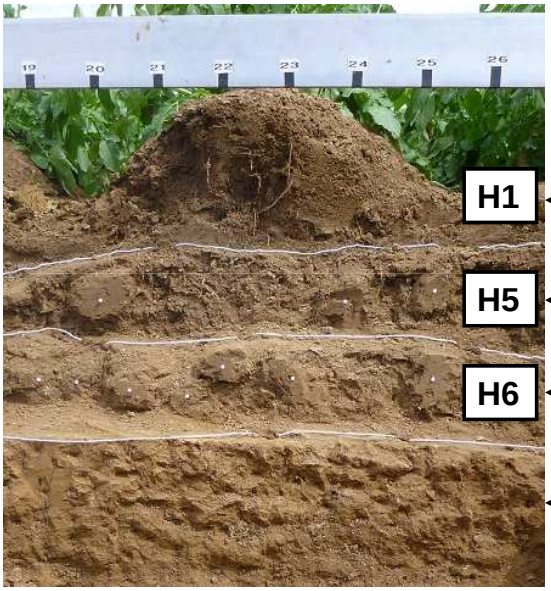
Methodology (2/4)

Field measurements :



Methodology (3/4)

'Profil cultural' :

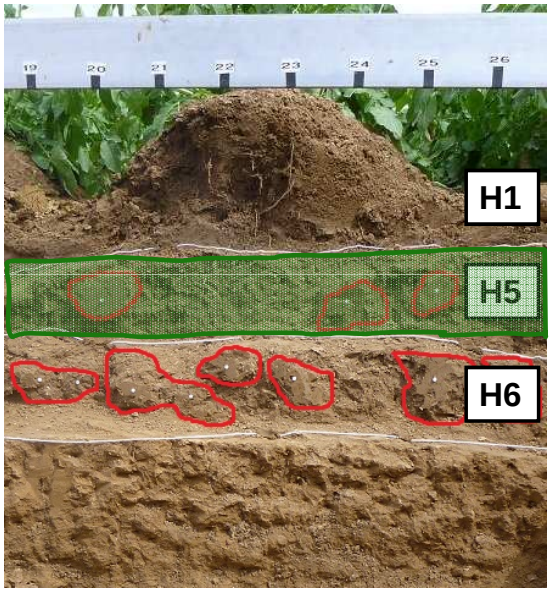


- H1 ← Cultivated layer with rotary tillage
- H5 ← Ploughed layer without secondary cultivation since the last ploughing
- H6 ← Ploughed layer from deepest ploughing (old deep plowing up to 40 cm)
- Subsoil

Soil layers distinguished by working depth of successive tillage operations

Methodology (3/4)

'Profil cultural' :



Few Φ clods were observed : we included Φ clods in Δ zones

Main indicator used to assess soil structure :

% Δ zones (without visible macropores) in each layer :

← Δ zone

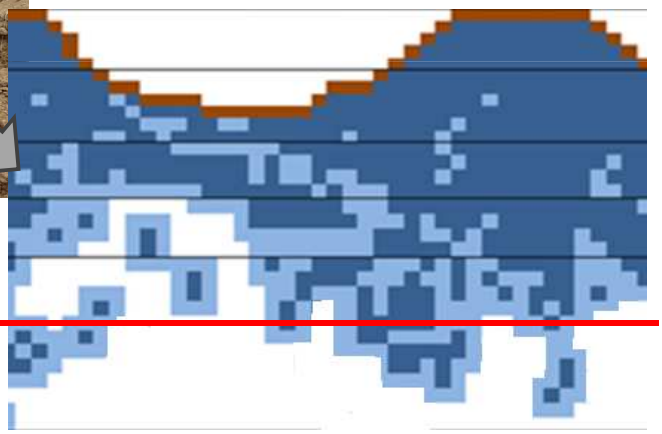
- **In H5 :** Ratio $\frac{\text{Area of } \Delta \text{ zones in H5}}{\text{Whole area of H5}}$ m²/m²
- **In H6 :** Ratio $\frac{\text{Area of } \Delta \text{ zones in H6}}{\text{Whole area of H6}}$ m²/m²
- **In H5 + H6 :** $\frac{\text{Area of } \Delta \text{ zones in H5 + H6}}{\text{Whole area of H5 + H6}}$

ISTRO 2014, 26-30 may, Maringà, Brazil

Methodology (4/4)

Potato root maps to evaluate root growth

- Grid with a mesh of 2 cm
- The presence / absence of root in each cell (2 x 2 cm) of the grid was recorded up to 80 cm depth



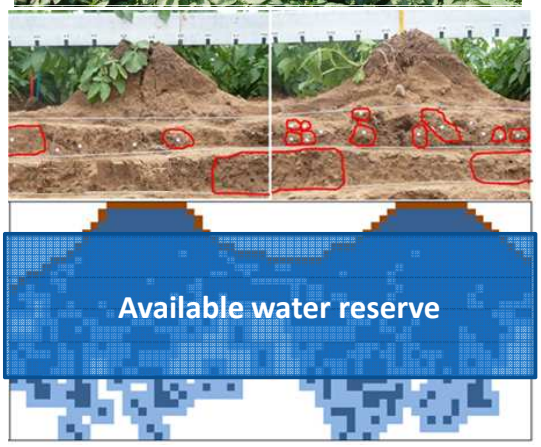
Indicators for root growth:

- Root density : % of colonised cells
- Roots exploration : area affected by roots
- ‘‘Effective’’ rooting depth

Method used : depth below which horizontal roots exploration falls below 50% (O. Scheurer)

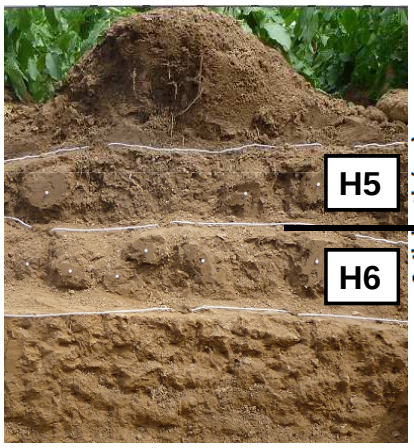
Results (1/7)

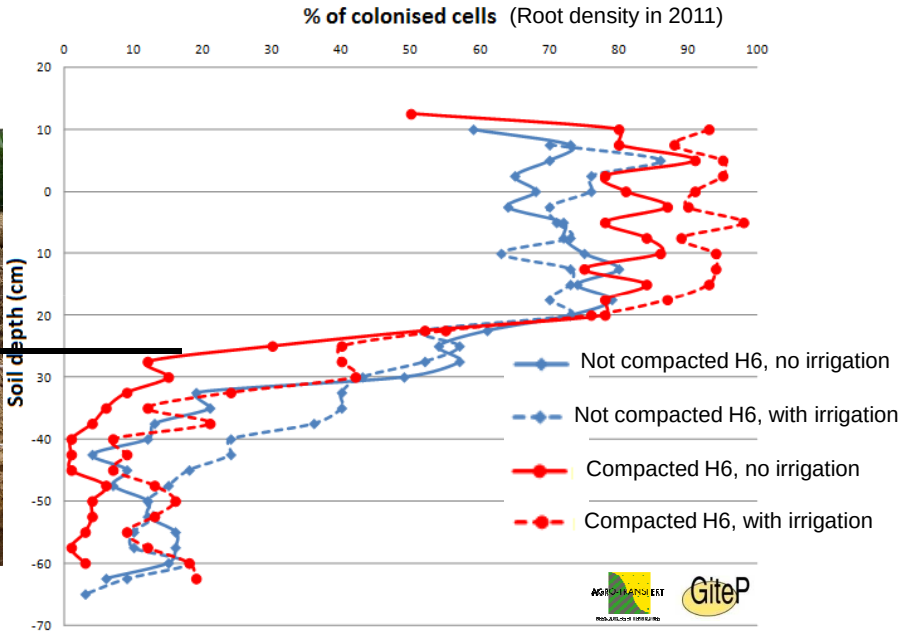
Relationship between ‘profil cultural’, root map, water access and vegetation development



Results (2/7)

Relationship between soil structure and root growth



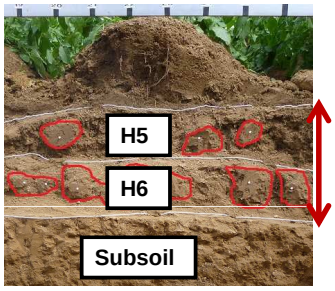


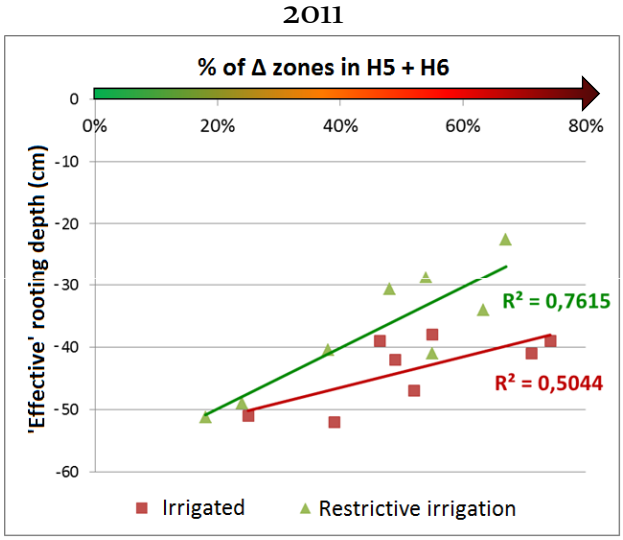
→ Different root distribution as a function of soil structure :

Concentration of roots in H5 and reduced exploration of subsoil by roots when deep compaction

Results (3/7)

Relationship between soil structure and root growth





Dry climate in 2011
irrigated
restricted irrigation

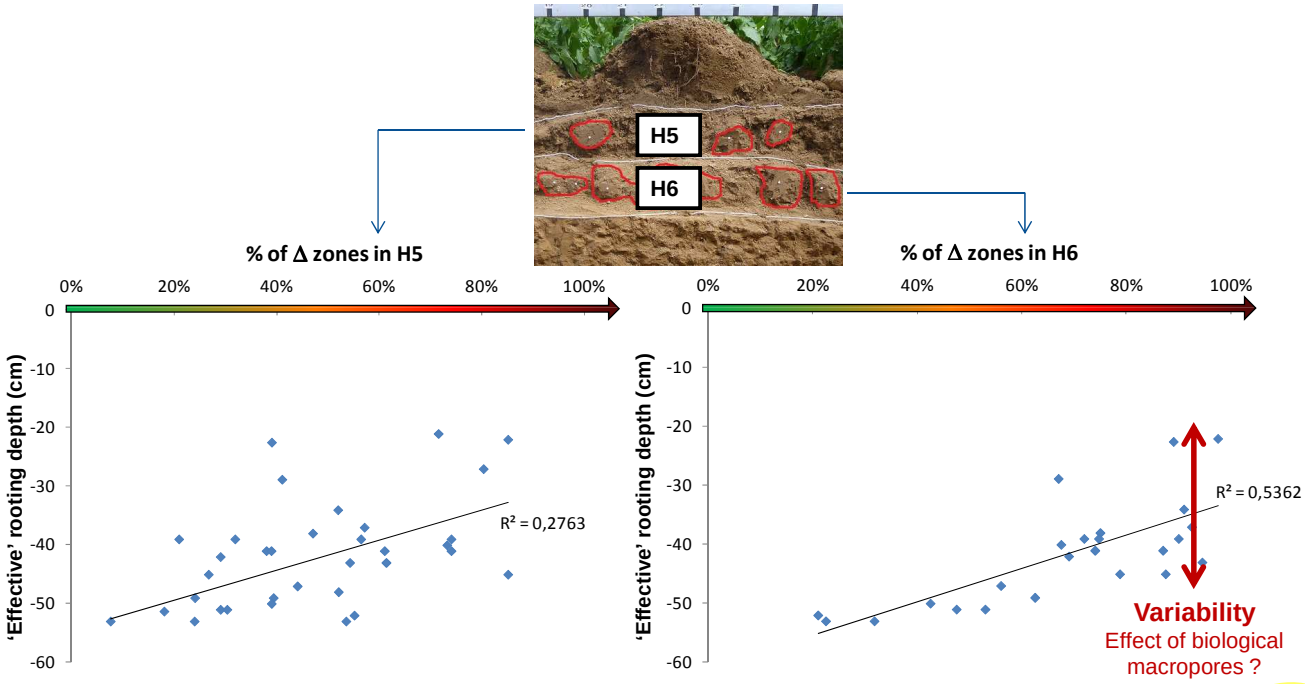
→ **Root depth decreases under compacted zones**

→ **Effect of soil moisture on the compaction response :** Effect of compaction is highlighted with restricted irrigation

→ **The same trends are observed every year,** despite the diversity of situations

Results (4/7)

Relationship between soil structure and root growth (from 2010 to 2012)



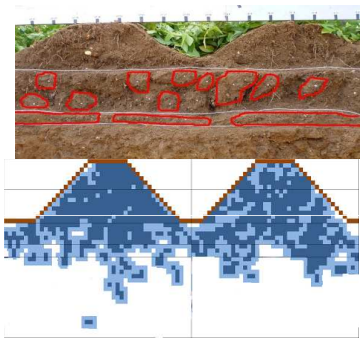
Δ zones in H6 explains more the rooting depth

→ Importance of soil structure in H6 on rooting depth

Results (5/7)

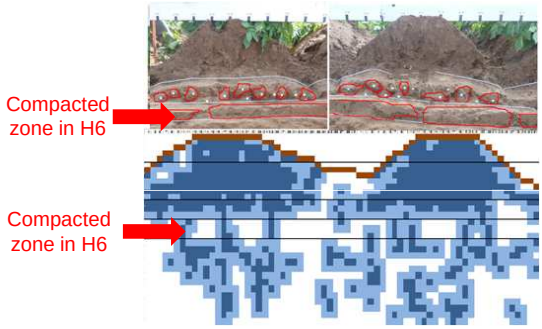
Effect of macropores network on subsoil exploration by roots

Degraded soil structure in H6



Bad subsoil exploration by roots

Degraded soil structure in H6 but many earthworm burrows



Penetration of potato roots through compacted zone

Indicator used to assess biological activity :

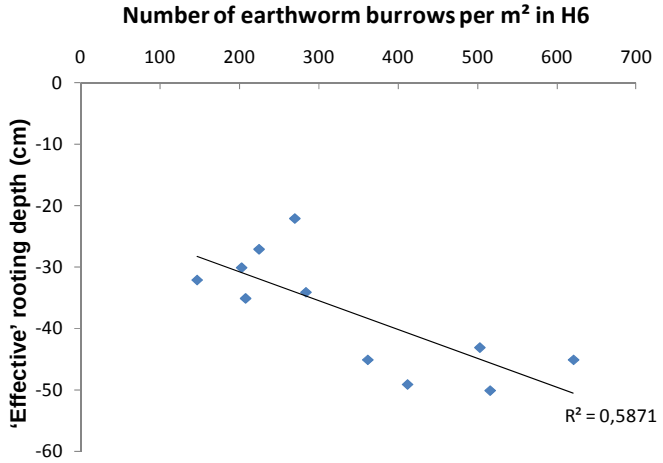
Number of earthworm burrows per m² on a horizontal surface, in the H6 layer

Earthworm burrows were counted at the same location where the grid was placed for the root map

Results (6/7)

Relationship between earthworm burrows and subsoil exploration by roots

Selection of compacted fields under the plowing (in the H6)

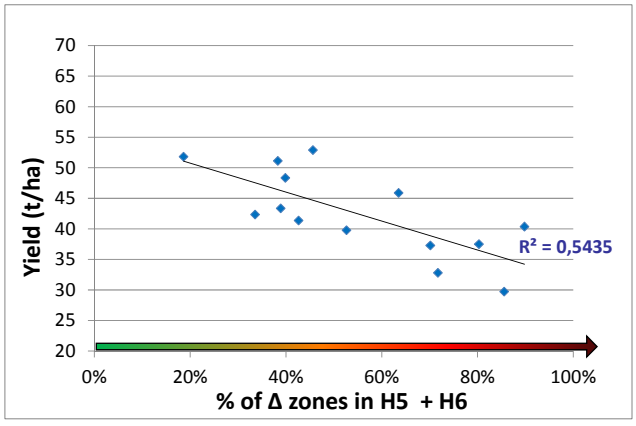


→ **In compacted fields, the number of earthworm burrows under the plowing layer may explain the exploration of subsoil by roots**

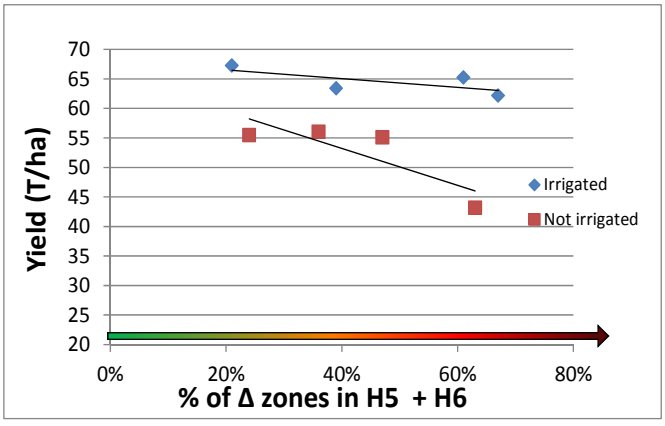
Results (7/7)

Effect of soil structure on potato yield

2012



2013



Essais EAUPTION PLUS / Sol-D'Phy, 2012, 2013

→ **Possible depressive effect of compaction on potato yield**

→ **The correlation between compaction and potato yield is not systematic and depends upon year and irrigation/rain**

Conclusion

- Interest of the 'profil cultural' method and Δ zones indicator to assess the effect of soil structure
- Significant and systematic effect of compaction on root growth for potatoes, higher in dry condition (dry years and no irrigation)
- Importance of biological porosity on rooting depth
- Possible depressive effect of compaction on potato yield, but depends of climatic conditions

Thank you for your kind attention

Abstract (1/2)

Northern France is an area of intensive agriculture where loess soils are cultivated under oceanic climate. Crops are frequently grown, sown and harvested using heavy machineries, sometimes in wet conditions. When this happens, the risk of deep compaction is high, particularly if crop sequences encompass cropping systems with high proportions of sugar beet, potato and irrigated vegetables.
A research has been conducted since 2010 to quantify the impact of soil compaction on root exploration and potato yield. The experiment was carried out in farmers' fields and in an experimental centre. In each site, several experimental treatments, varying with the level of compaction and the quantity of water supplied by irrigation were carried on. The "profil cultural" method (Manichon, 1987) was selected for its ability to reveal the spatial organization of soil structure. The method was combined with observation of roots in a grid that was placed on the vertical face of the soil profile (Tardieu, 1988). The presence / absence of roots in each cell (2 x 2 cm) of the grid were recorded, providing an accurate picture of root density throughout the soil profile. Moreover the number of earthworm burrows was counted on a horizontal face at 30cm depth to assess biological activity (2012, 2013).

Abstract (2/2)

When present, results show that a deep compaction, at 25-35 cm depth, can severely limit plant development and root growth. But roots density also depended on the number of earthworm burrows in the deep layer. The activity of earthworms, creating networks of macropores, can provide improved exploitation of subsoil by roots. This promotes the necessity to better take into account the biological activity to assess the impact of deep compaction on soil properties. Foliage installation or ground biomass at the end of tuber initiation (45 days after plantation) can be reduced by 50% by the deep compaction without irrigation. The correlation between compaction and potato yield was not systematic and depended of the year and irrigation regime. Even with irrigation supply, an adverse effect of severe compaction on potato yield was observed.

Keywords: deep compaction, soil visual assessment, rooting in depth, growth, earthworm burrows, potato

References :

Manichon H., 1987. Observation morphologique de l'état structural et mise en évidence d'effets de compactage des horizons travaillés. In: Monnier, G., Goss, M.J. (Eds.), *Soil Compaction and Regeneration*. Balkema, Rotterdam, the Netherlands, 39–52.

Tardieu F., 1988. Analysis of spatial variability of maize root density. I. Effect of discontinuous wheel compactions on spatial arrangement of roots. Plant Soil, 107, 267-272.