THE EFFECT OF SOIL VOLUME ON CANOPY AND ROOTS GROWTH OF *Opuntia ficus-indica*

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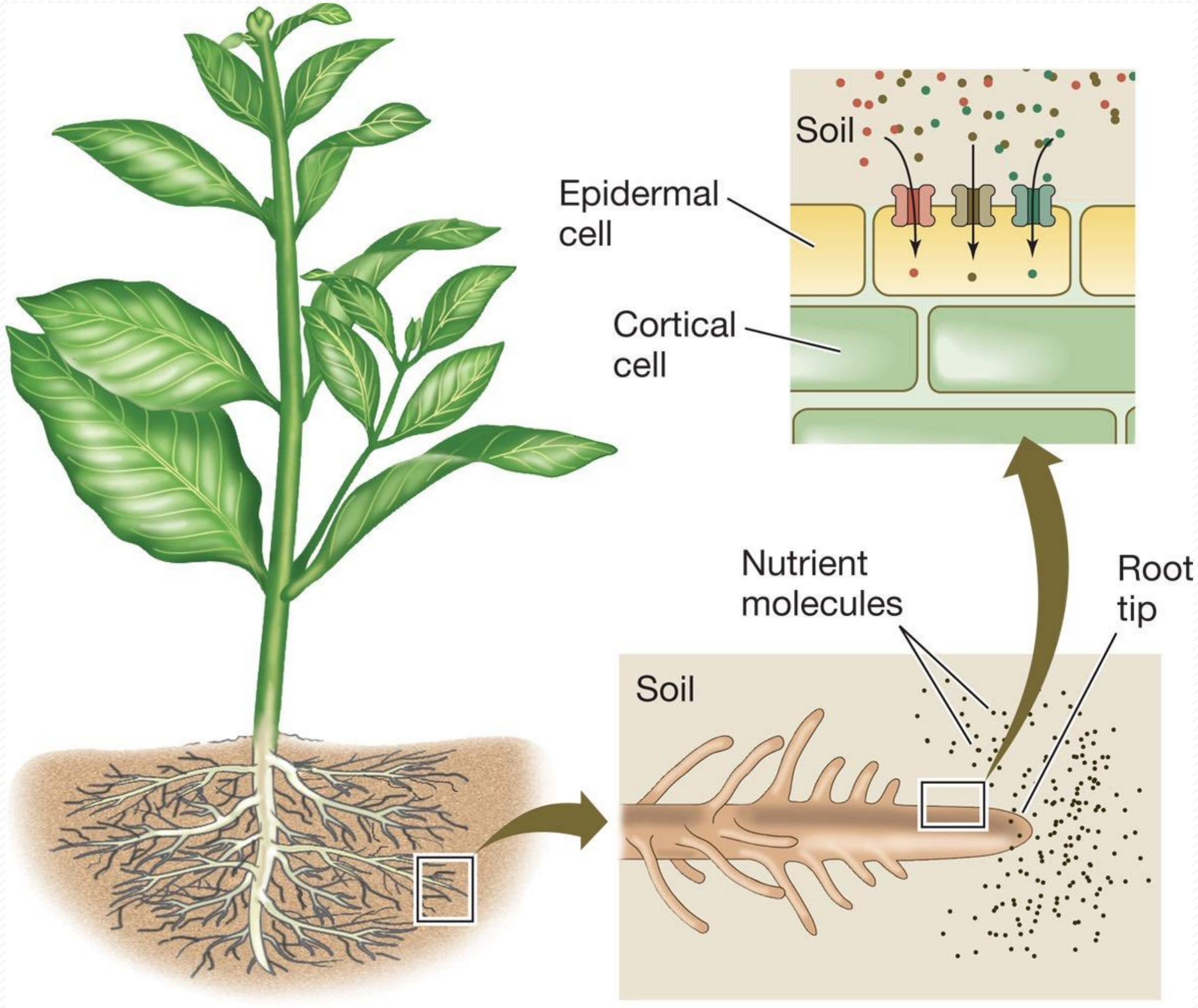
DOCTORATE IN AGRICULTURAL SCIENCES, FORESTRY AND ENVIRONMENTAL
XXIX CYCLE

Introduction

- The reduction of the soil volume implies:
- physiological and morphological changes of the roots system and the allover plant growth (Aphalo and Rikala, 2003)
- modification of the functional balance between roots and shoots (Tonutti and Giulivo, 1990)
- controlling shoot growth in plant but without producing signs of nutrient deficiency (Rieger and Marra, 1994)
- changes in transportation and carbohydrates metabolism (Ray and Sinclair, 1998; Ronchi et al. 2006)
- Nevertheless, plant response to soil volume might be species specific



LIFE 10e, **Figure 36.3**
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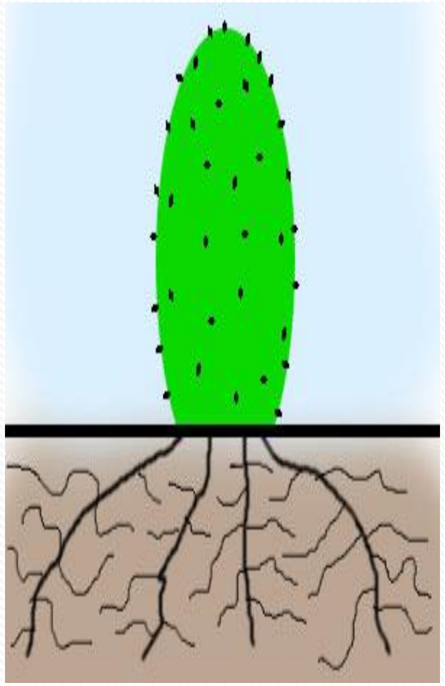
Introduction

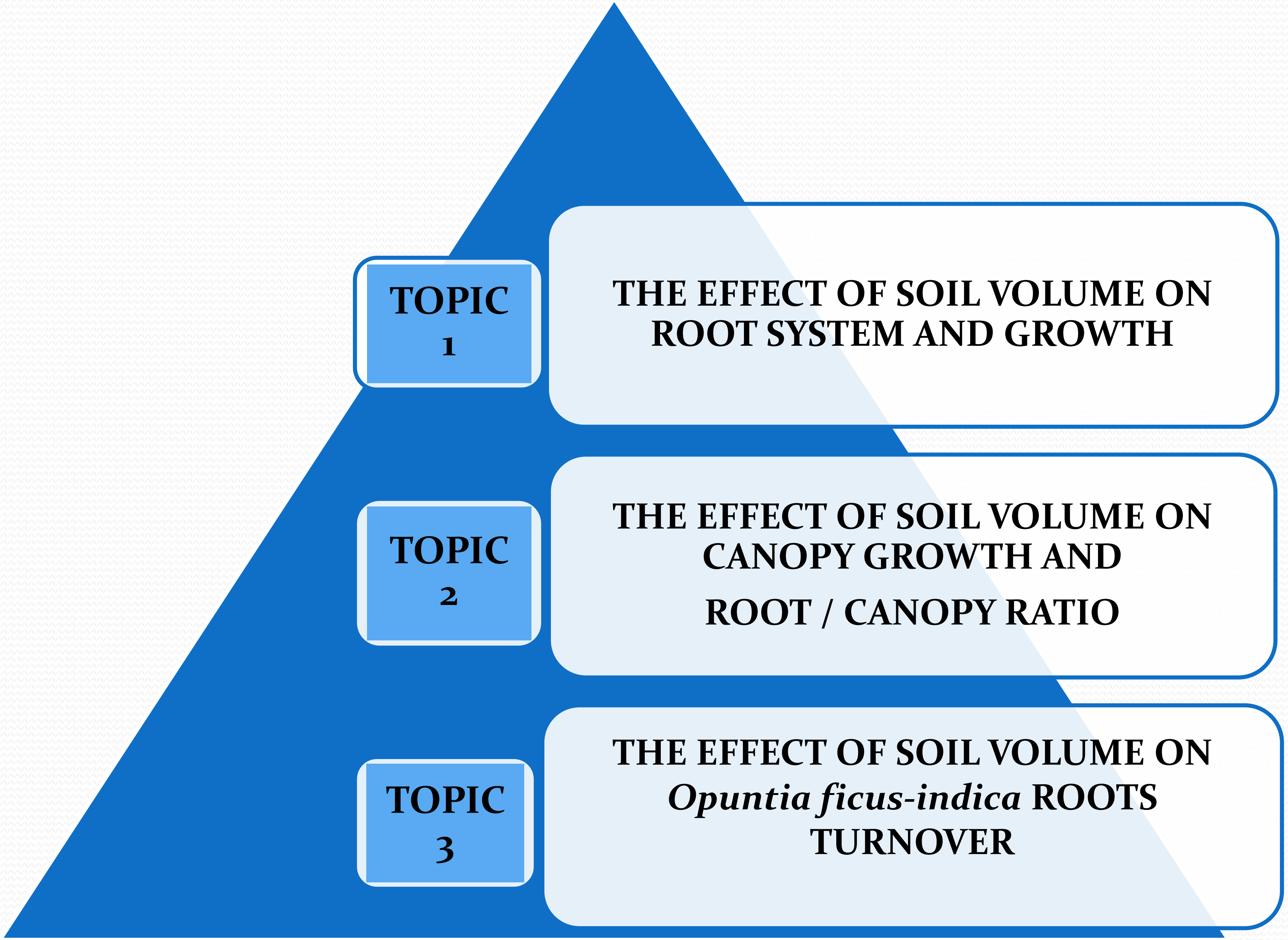
- *Opuntia ficus-indica* (L) Mill) is propagated by cuttings planted in the field. The use of containers to produce propagation can insure and increase the orchard uniformity. However, the container size may affect the plant growth and development (Inglese and Pace, 2000).
- Moreover, *O. ficus-indica* is more than often grown either in the arid and semi-arid areas or under intensive orchard plantation. In both cases the root are experiencing reduced soil volume due of shallow soils or the high plants density.

- Thus, the knowledge of the effect of the root restriction on *O. ficus-indica* roots and canopy behavior is required to explore the potential of this species where soil volume is limited.

Objective

This study investigated the effect of soil volume restriction on below and above ground growth of *Opuntia ficus-indica* through understanding the limit imposed by root restriction via different soil volumes.

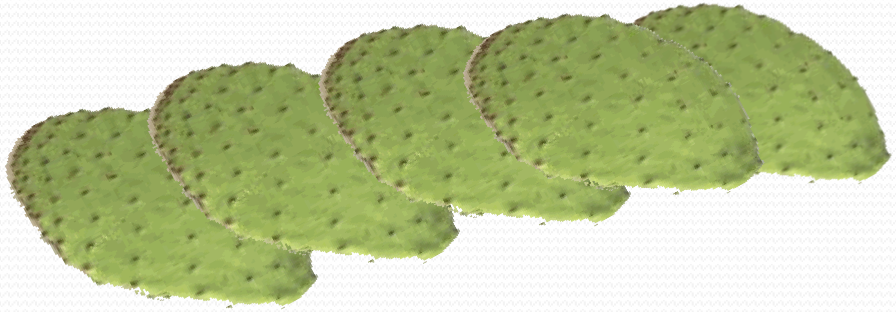



TOPIC 1
THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH
TOPIC 2
THE EFFECT OF SOIL VOLUME ON CANOPY GROWTH AND
ROOT / CANOPY RATIO
TOPIC 3
THE EFFECT OF SOIL VOLUME ON *Opuntia ficus-indica* ROOTS TURNOVER

TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Materials and Methods

One-year-old *Opuntia ficus-indica* cladodes of the cultivar "Gialla" were cut and dried for two weeks in the shade



Five different sizes of pots:
50, 33, 18, 9 and 5 Liters

These pots filled with dry fine, sandy loam soil
field capacity was 35% ; wilting point 20% (g/g); pH: 6.8;
organic matter: 80 g kg^{-1} and total Nitrogen : 10 g kg^{-1}

TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Materials and Methods

- May 2014, cladodes were planted in pots with half of their length in the soil
- Plants were watered regularly to maintain soil water content and to avoid any visible sign of water stress.
- Four different sampling dates were used (6, 12, 18 and 24 months).
- For each sampling date, three replicates (pots) were planted
- The experimental design was a completely randomized design in possible combinations of the two factors, soil volume and date of the sampling, with three replications.

TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Materials and Methods

- Roots of each plant were divided visually into three groups depending on its diameter: fine roots less ≤ 2 mm, Medium roots (2-5 mm) large roots > 5 mm.

- The roots of each group were measured with a ruler to a precision of 1 mm.

- Roots surface area was measured using VegMeasure software®

TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Materials and Methods

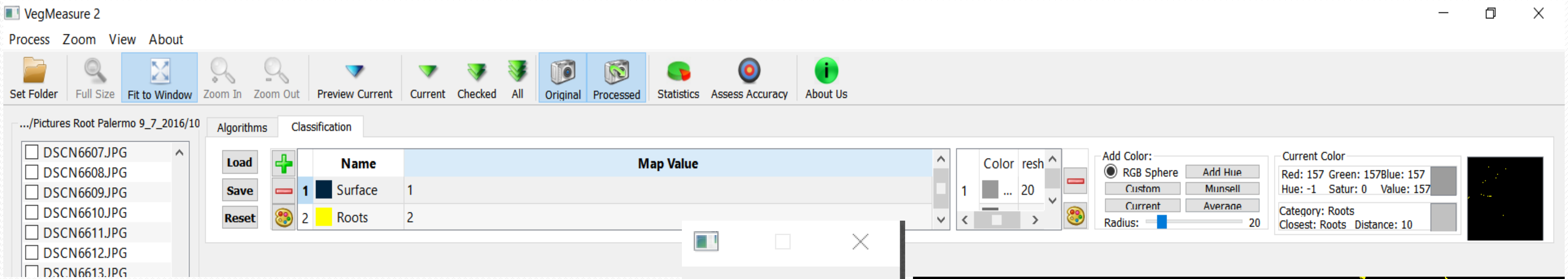
Hardware

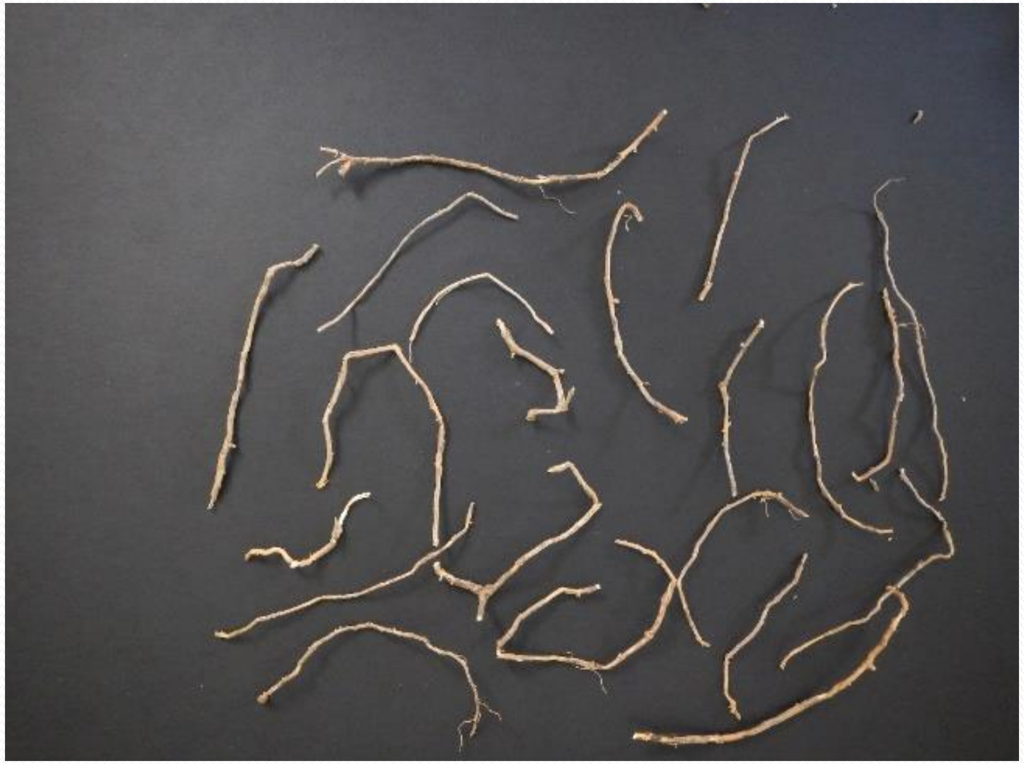
Digital Photgraphy

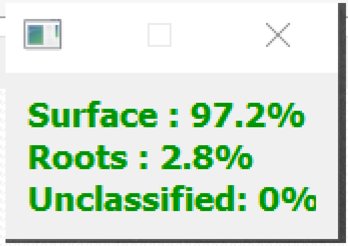
Software

Image Processing

Digital Image Processing: VegeMeasure Version 2.0







The total surface area of yellow roots from the image classification was calculated by summing the total area occupied by pixels classified as roots surface area. These values were multiplied by π "3.14"

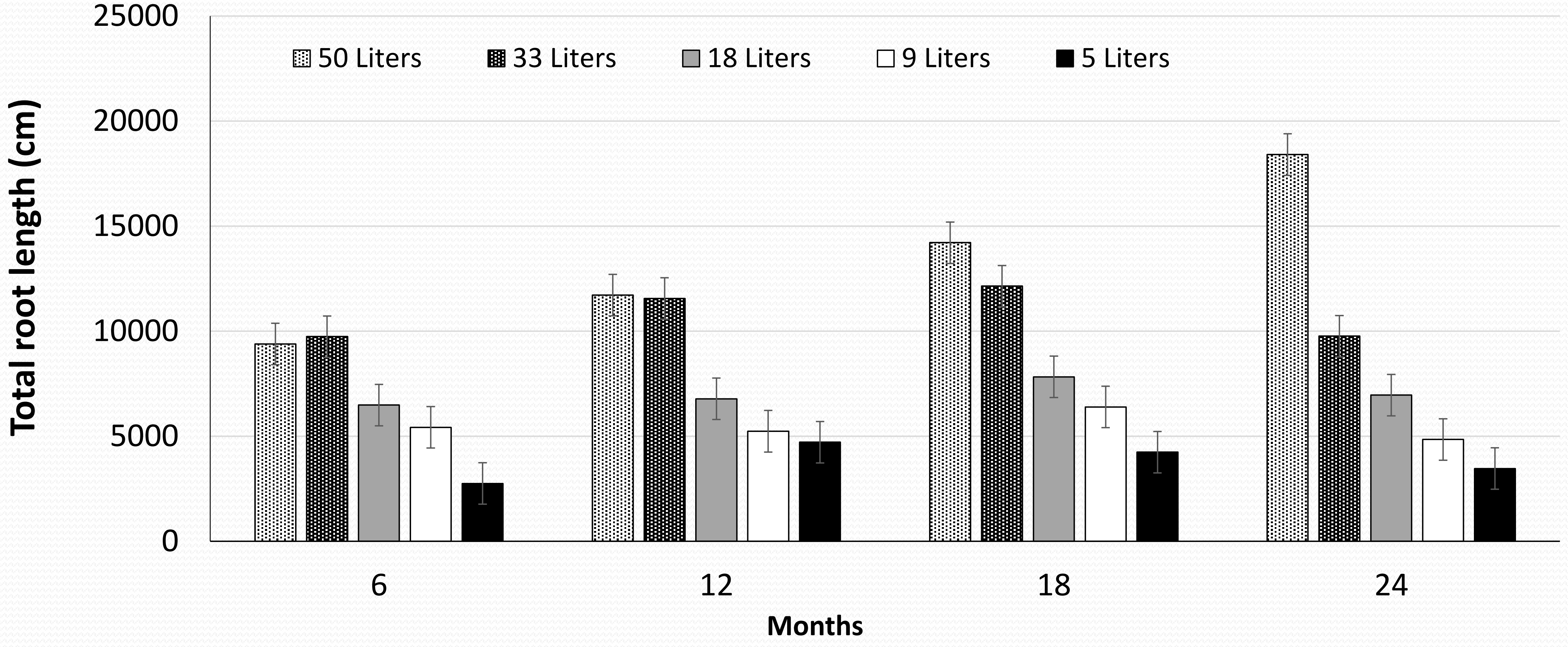
TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Materials and Methods

- Root volumes were calculated from surface area and root length by assuming that roots are cylindrical.
- three random subsamples from each group/ pot. Samples were weighed and dried at 75 °C for 72 h and the dry weight for each group was calculated.
- Root density : the total root volume/soil volume (cm^3 L^{-1})
- Root length density per soil unit (RLD): the total root length/soil volume (cm L^{-1})

TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Results



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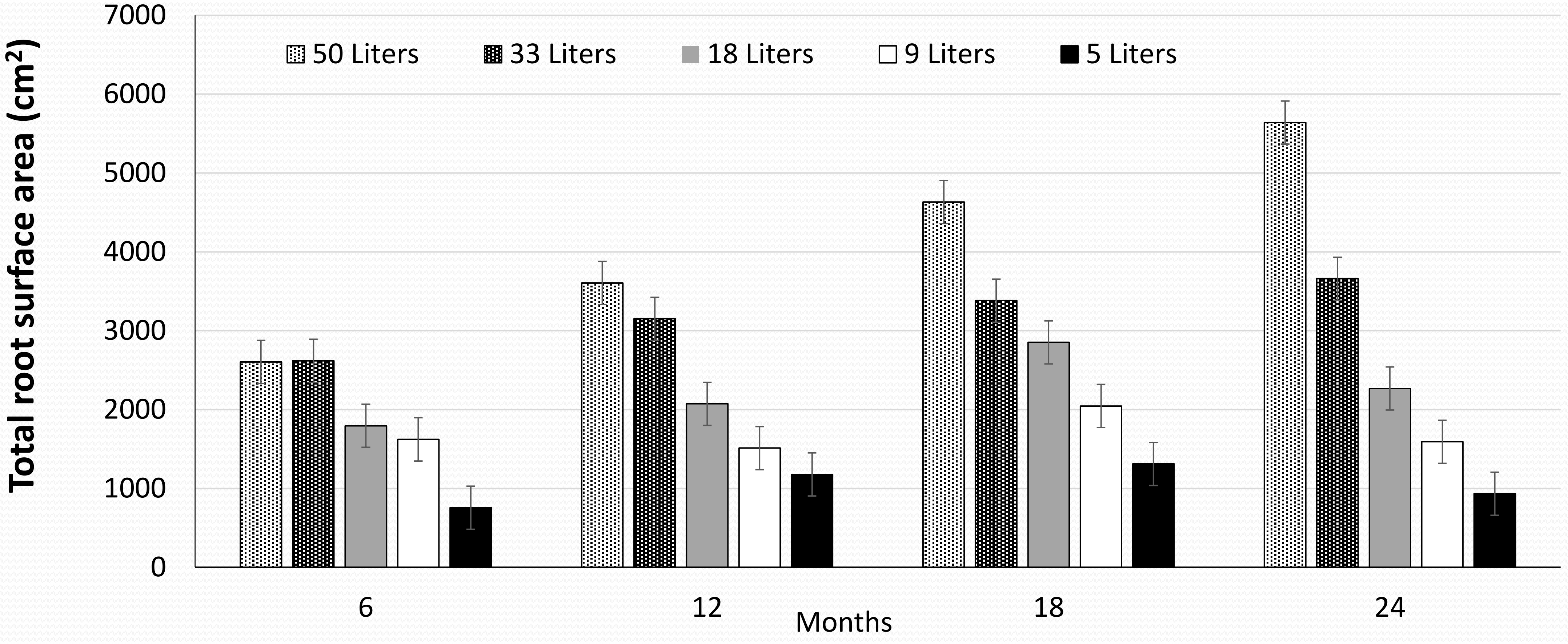
Results



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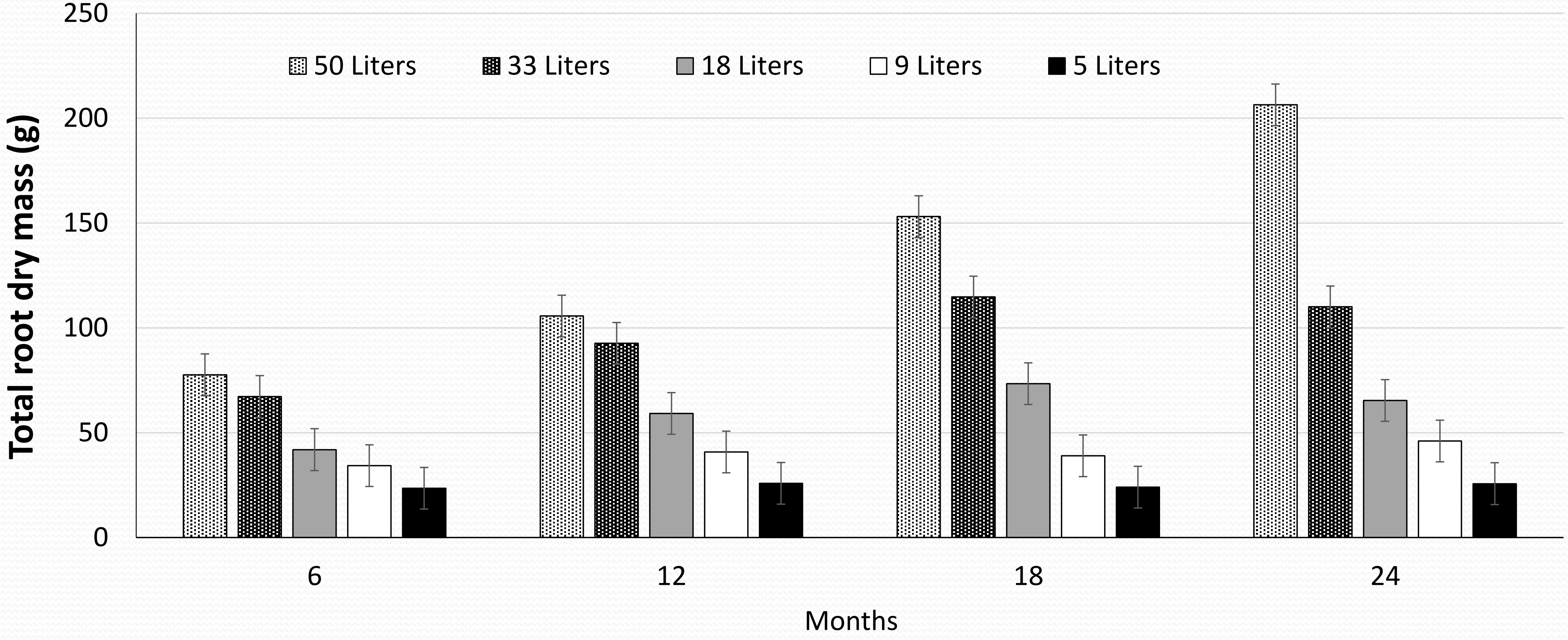
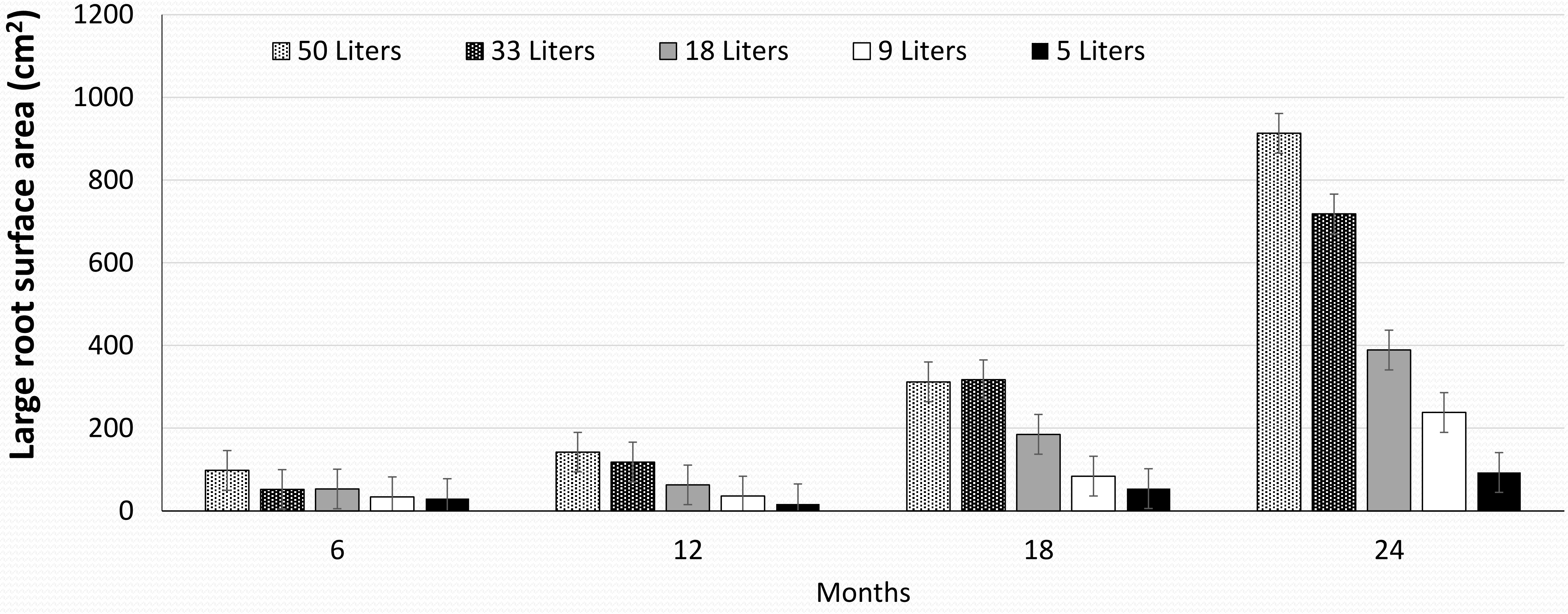


TOPIC 1: THE EFFECT OF SOIL VOLUME ON ROOT SYSTEM AND GROWTH

Results



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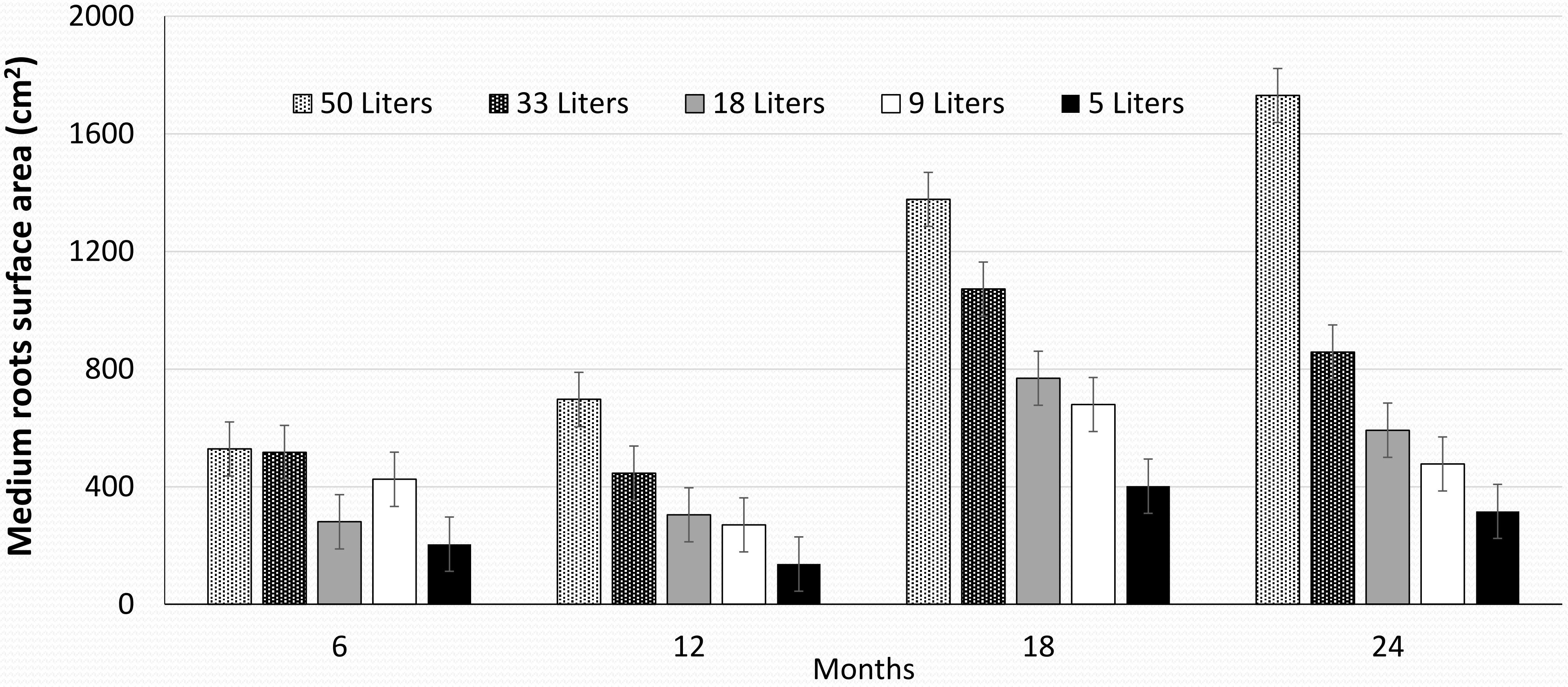

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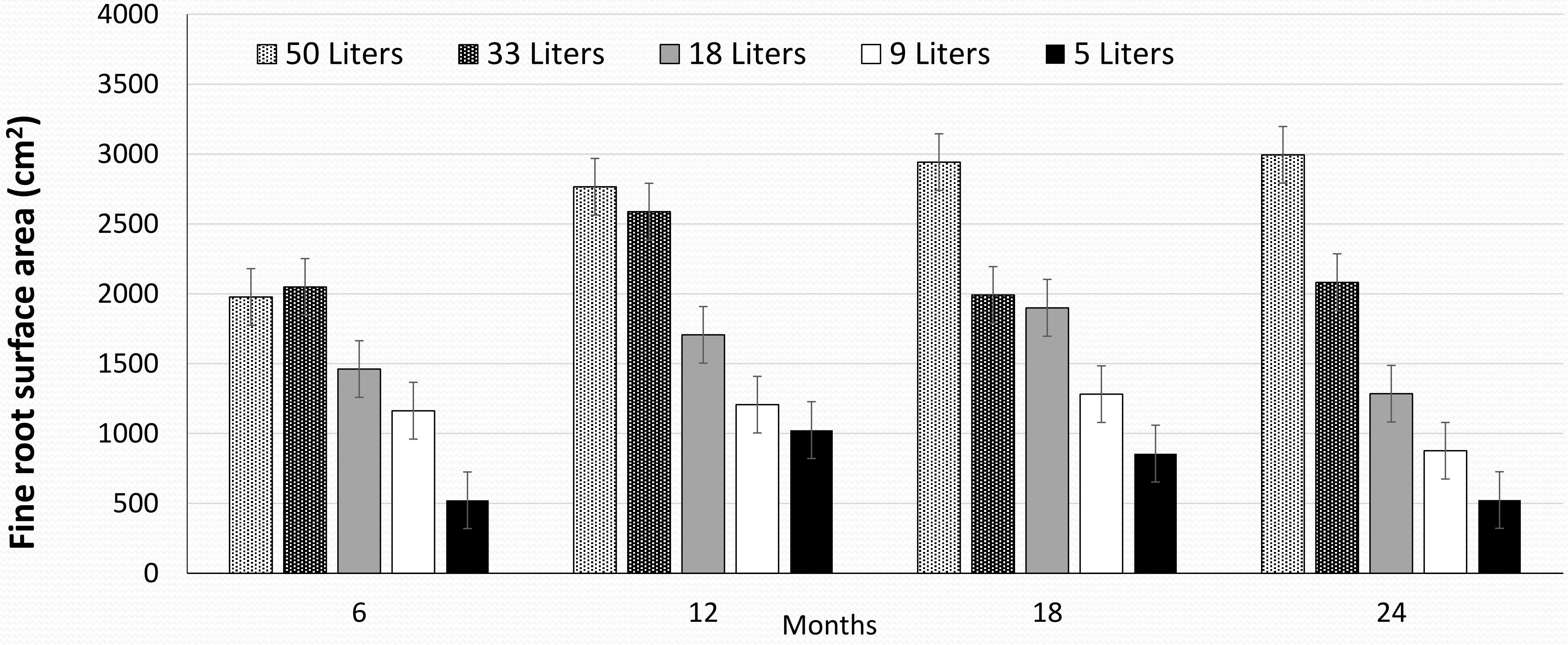

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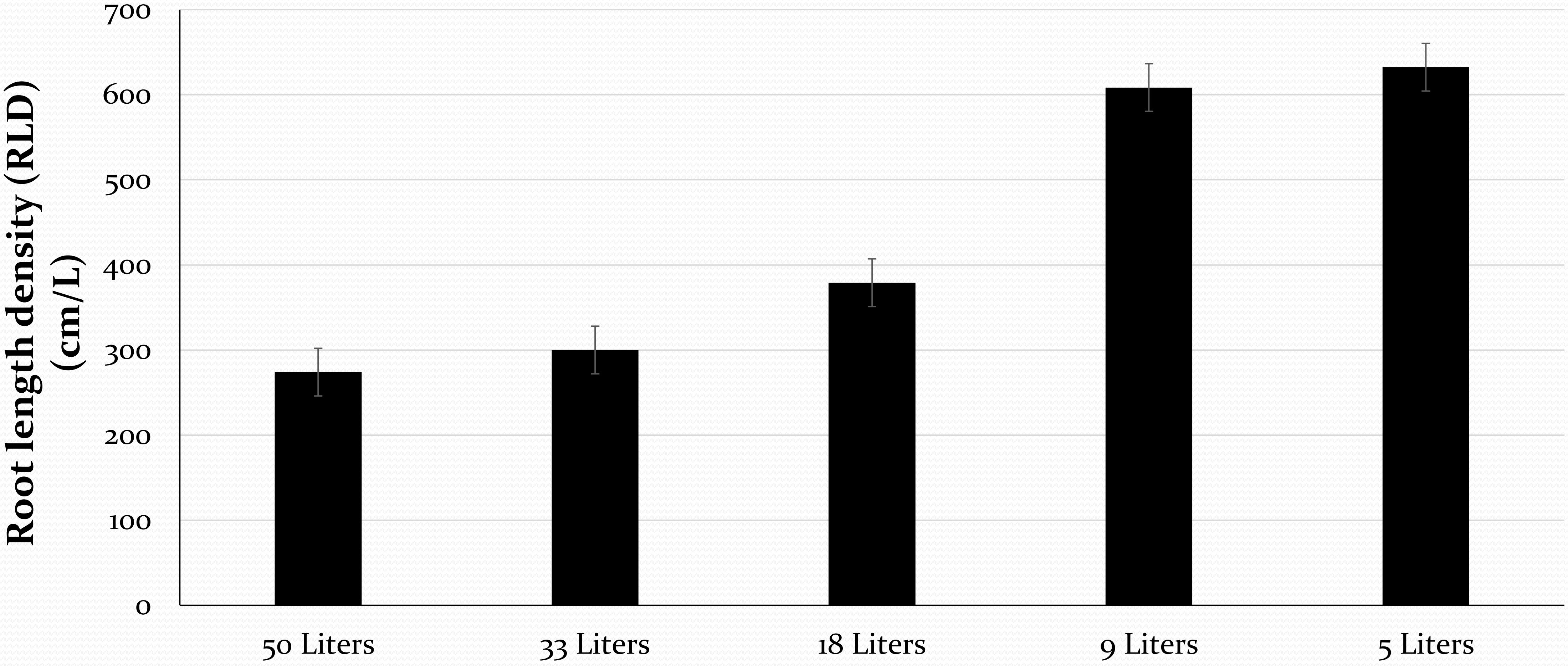

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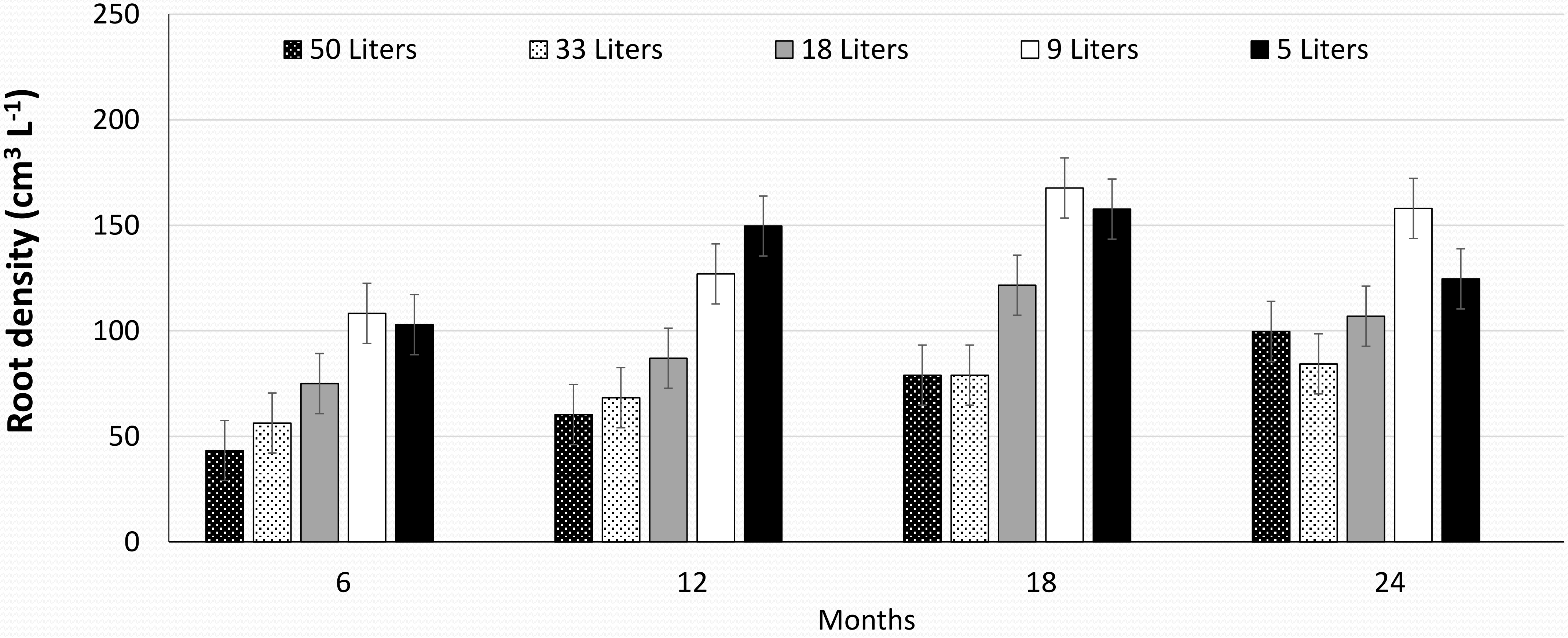


Conclusion

- The total root length, surface area, dry mass, volume as well as the surface area of the large roots were inhibited by the soil volume restriction. While there was increase in fine roots growth in the soil volume unit which means plant develops more fine roots when soil/nutrient sources are not available.

- The effect of soil restriction on roots seems to be minor or moderate at the early stages of the plant growth but increases later.

- The more finer root system per soil volume of *O. ficus- indica* seems to be a kind adaptive strategy in order to enable the plants to increase the possibility of exploring new nutritive resources

TOPIC 2: THE EFFECT OF SOIL VOLUME ON CANOPY GROWTH AND ROOT GROWTH/ CANOPY TH RATIO

Materials and Methods

Cladodes of each plant in each pots were counted and numbered according to its age.
Cladodes were clustered into three groups: mother cladodes, first generation cladodes and second generation cladodes. The total number of the cladodes in each group was recorded.

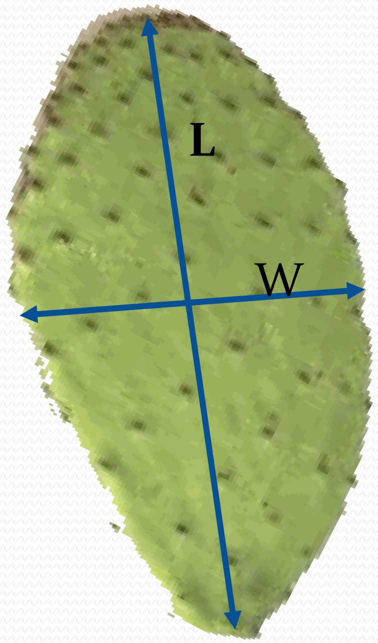
The cladodes thickness was measured in mm with a vernier caliper

TOPIC 2: THE EFFECT OF SOIL VOLUME ON CANOPY GROWTH AND ROOT GROWTH/ CANOPY GROWTH RATIO

Materials and Methods

The width and length of each cladode were measured; these values were used to estimate the area of the cladode using the formula

$X = (W/2)*(L/2)*\pi$

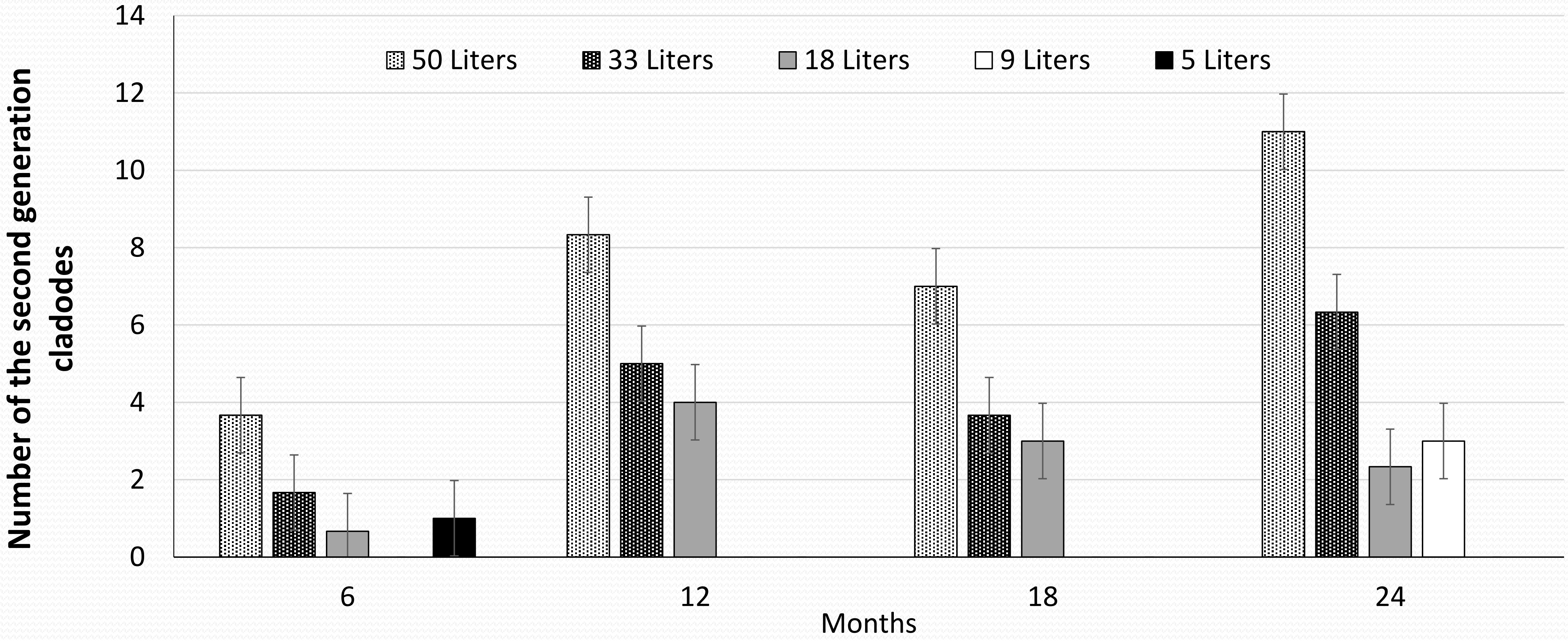


The fresh weight of each cladode was taken, three subsamples of each cladodes were cut weighed and dried in a forced-draft oven at 75 °C for 72 h to estimate the dry weight.

The root: shoot ratio was calculated (Dry weight for roots/dry weight for canopy)

TOPIC 2: THE EFFECT OF SOIL VOLUME ON CANOPY GROWTH AND ROOT / CANOPY GROWTH RATIO

Results



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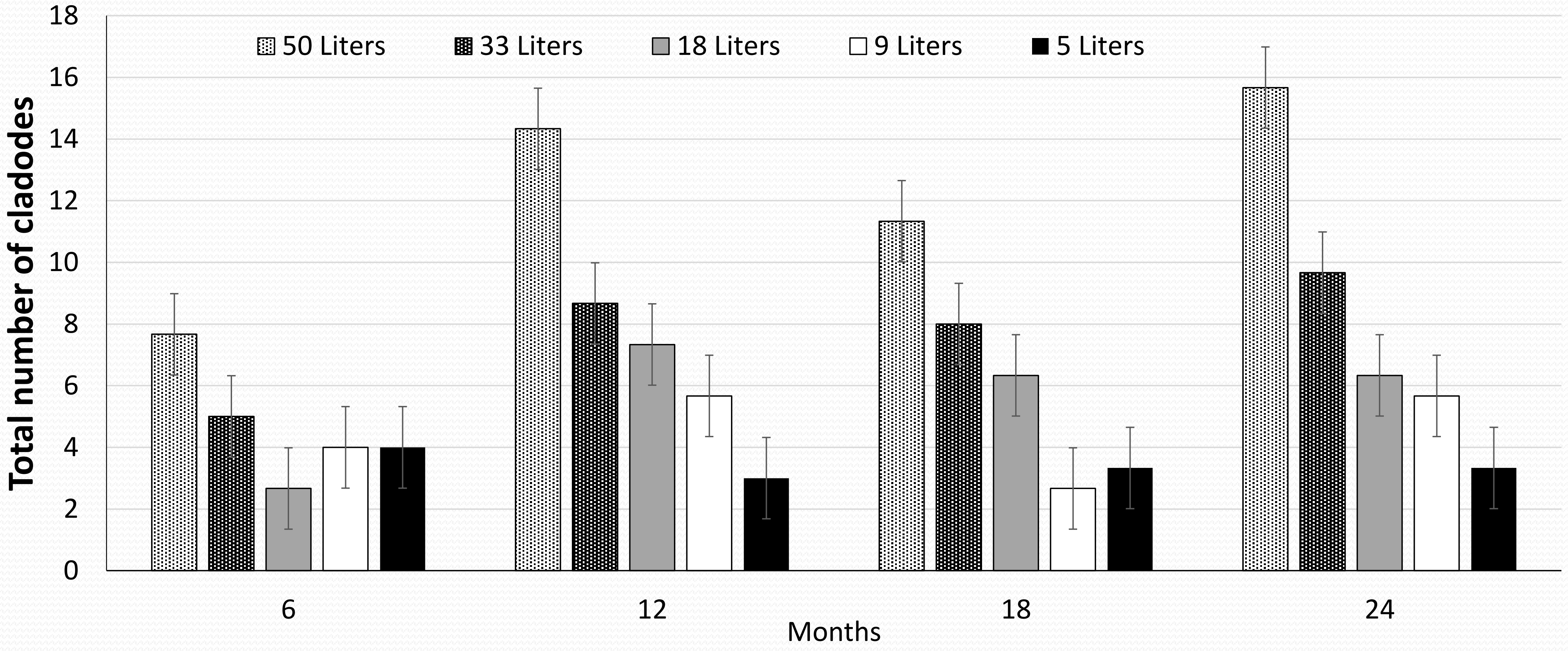

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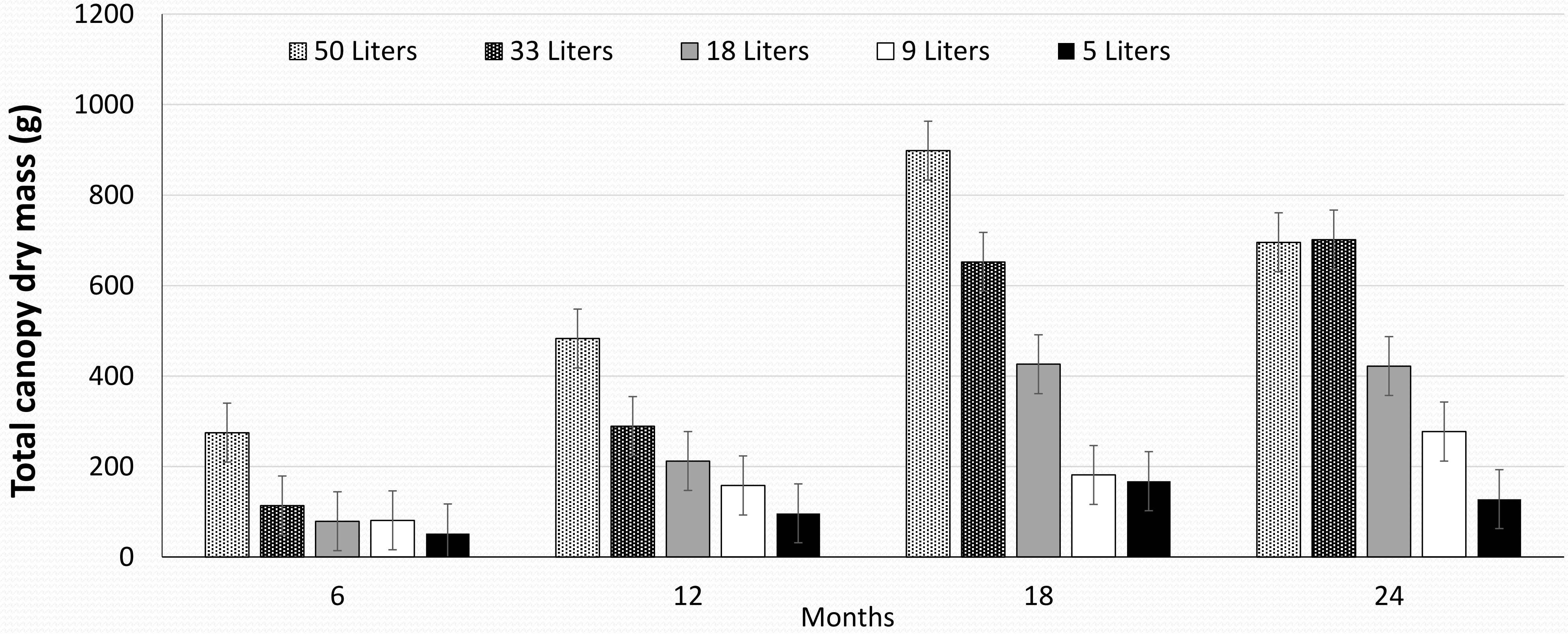

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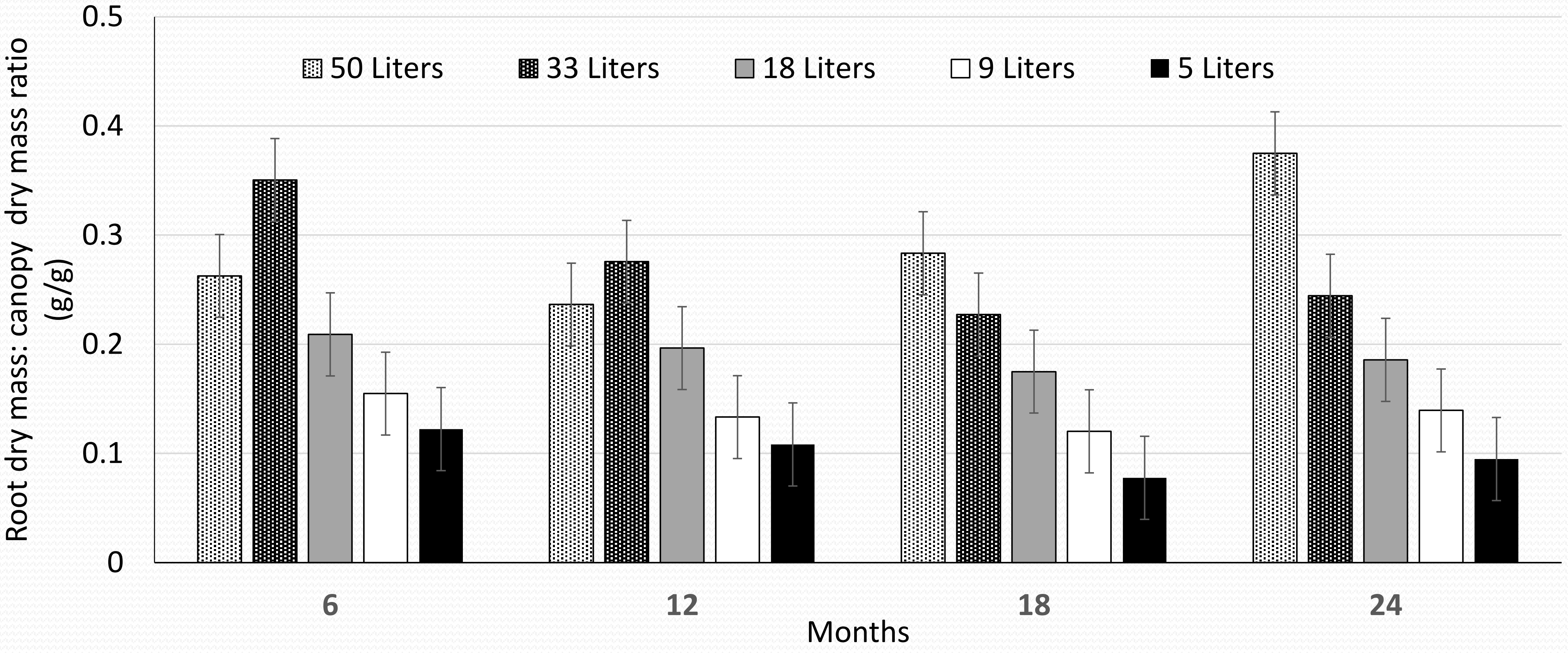


Conclusion

- The soil volume restriction can affect the roots and canopy growth of *Opuntia ficus-indica* leading to reduction in canopy growth and canopy dry matter accumulation

- This reduction was associated to a lower cladode number

- The root: canopy dry mass ratio increased with the soil volume increase

- Plants under small soli volume tended to have stable root: canopy ratio overtime

TOPIC 3: *Opuntia ficus-indica* ROOTS TURNOVER

Materials and Methods

The $\delta^{13}C$ measured using an EA-IRMS (elemental analyser isotope ratio mass spectrometer Carlo Erba Na 1500,model Isoprime (2006), Manchester, UK.)

% of Carbon derived from *Opuntia ficus- Indica*(OFI) root turnover (OFI-C contribution)

C signature of Soil organic matter derived from OFI

$$\boldsymbol{New\ carbon\ derived\ from\ OFI(Ncd)} = \frac{\delta^{13}C_{OFI} - \delta^{13}C_{old}}{\delta^{13}C_{biomass\ OFI} - \delta^{13}C_{old}}$$

Carbon isotopic signature of OFI-C biomass

Carbon isotopic signature of C_3 soil

TOPIC 3: *Opuntia ficus-indica* ROOTS TURNOVER

Materials and Methods

Old Carbon derived (Ocd)= 1 – Ncd

The C content in the bulk soil for each pot (g)

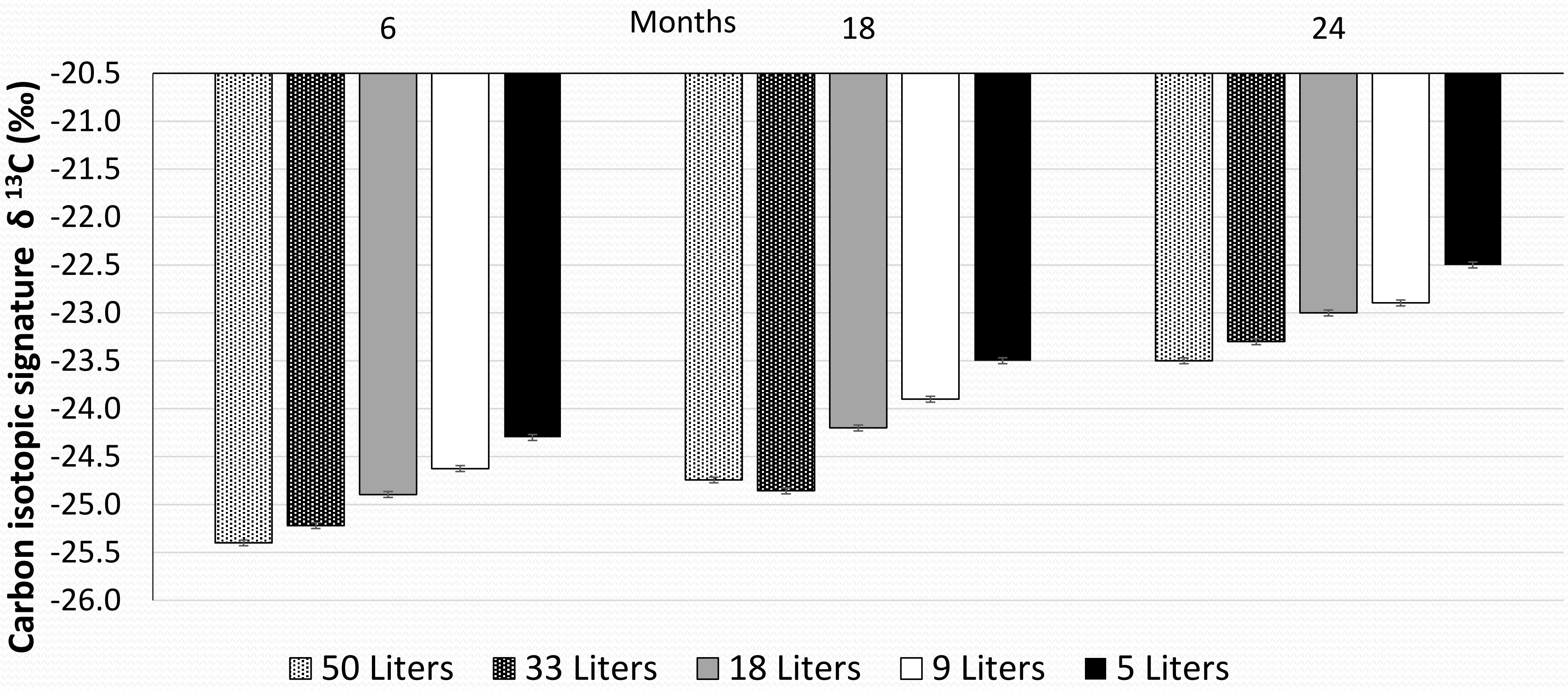
$$\textit{Root turnover}\ (\%) = \frac{\textit{New C derived} * SOC}{\textit{Root weight} * C_{root}} * 100$$

Root dry weight (g) in each pot

The concentration of C in the root biomass (g kg^{-1})

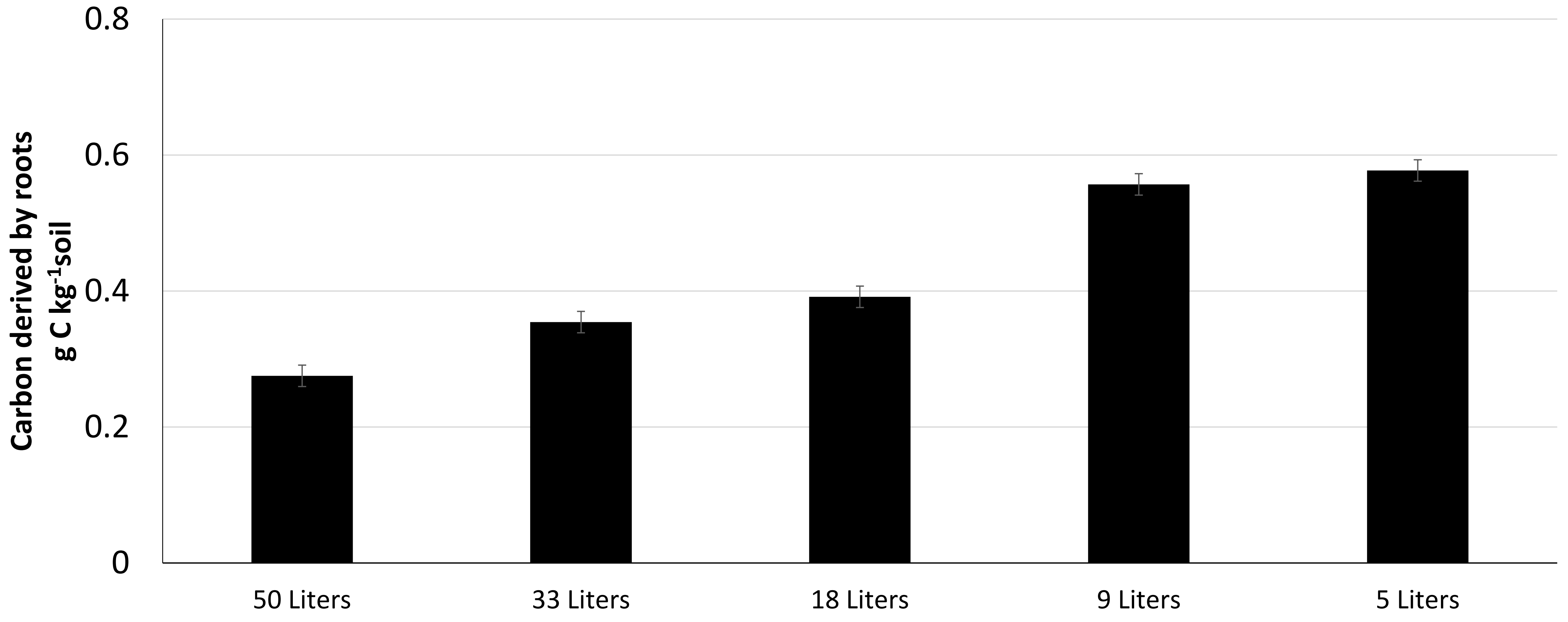
TOPIC 3: *Opuntia ficus-indica* ROOTS TURNOVER

Results



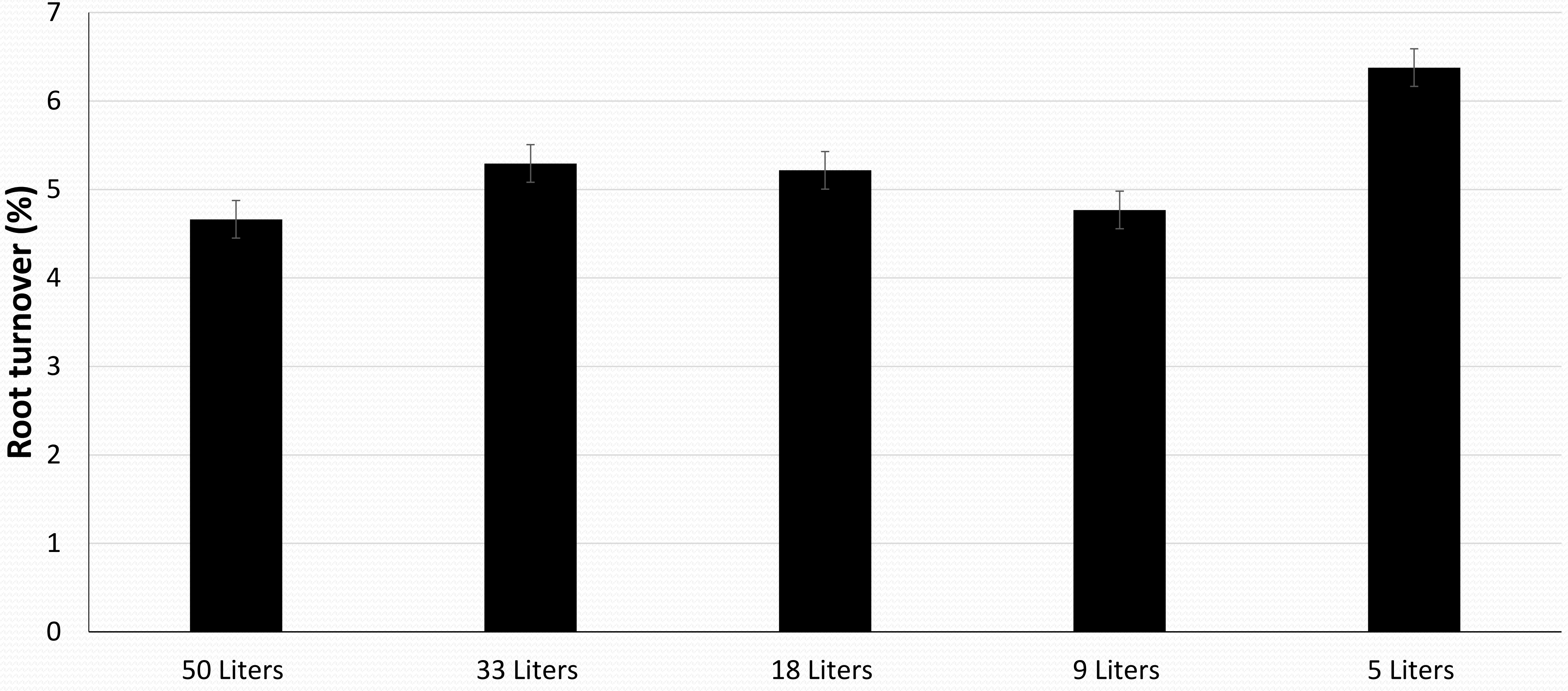
TOPIC 3: *Opuntia ficus-indica* ROOTS TURNOVER

Results



TOPIC 3: *Opuntia ficus-indica* ROOTS TURNOVER

Results



Conclusion

- The restricted soil volume enhanced the C stock

- Plants placed in the smallest soil volume (5 Liters) stopped producing new second cladodes after the first sampling date as all the investments were put into the roots growth resulting in the highest percentage of the roots turnover

- These results confirmed the importance of the *Opuntia ficus-indica* as a potential plant that can survive under low soil volume with ability to balance its growth under the harsh environments

- *Opuntia ficus- indica* provide reasonable organic carbon amount that improve the quality of the soil leading to healthy ecosystems