Use of *Pistacia lentiscus* L. for phytoremediation

- The Sardinian Experience -

Bacchetta Gianluigi [1,2], Boi Maria Enrica [2,3], Cannas Carla [3], Cappai Giovanna [4], Carucci Alessandra[4], Dessì Ludovica [2], De Giudici Giovanni [3], Medas Daniela [3],

Meloni Francesca [1], Podda Lina [1], Porceddu Marco [2] , Tamburini Elena [5]

[1] Centre for the Conservation of Biodiversity (CCB) - University of Cagliari

[2] Sardinian Germplasm Bank (BG-SAR), Hortus Botanicus Karalitanus (HBK) – University of Cagliari

[3] Department of Chemical and Geological Science – University of Cagliari

[4] Department of Civil and Environmental Engineering and Architecture, University of Cagliari

[5] Department of Biomedical Science, University of Cagliari

Cofinancé par le programme Erasmus+ de l'Union européenne

Introduction

Sardinia was **one of the most important mine poles in Europe** during the **20th century**.

However, after mine closure, high quantities of polluted materials rich in metal(loid)s were left abandoned without reclamation.

Metal(loid)s contamination of

Soils Waters Biosphere

How to remediate?

Phytoremediation

Cofinancé par le programme Erasmus+ de l'Union européenne

Introduction

Phytoremediation

Technology that uses plants species able to degrade, extract, contain, or immobilize environmental contaminants.

- **Cost effective** and **efficient alternative** for reclamation of abandoned mining sites;
- **lower investment cost;**
- **long term** and **permanent solution;**
- **green and eco-sustainable.**

Several factors must be taken into account, such as the **local context** (geological and geographical characters), the **involved metals** and their bioavailability and speciation.

How to apply phytoremediation?

Phytostabilization

Phytoextraction

Cofinancé par le programme Erasmus+ de l'Union européenne

Introduction

Different autochthonous plant species were found suitable for phytoremediation

Cistus salviifolius L.

Euphorbia pithyusa L. subsp. *cupanii* (Guss. ex Bertol.) Radcl.-Sm.

Helichrysum microphyllum Cambess. subsp. *tyrrhenicum* Bacch., Brullo & Giusso

Scrophularia canina subsp. *bicolor* (Sibth. & Sm.) Greuter

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK

ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES

CIHEAM MAI CHANIA

INRGREF

BURSA TECHNICAL UNIVERSITY 2010

STVDIORVM UNIVERSITAS CARALITANA

Forêt Modèle de Provence

Pistacia lentiscus L.

Several studies have highlighted its importance in the restoration of woody Mediterranean communities
(Boularbah et al. 2006, Fuentes et al. 2007, Dominiguez et al. 2008)

- An **emblematic phyto-management case of study** is the **restoration after the accident of the Guadiamar River Valley** (SW Spain).
- In 1998, the **failure of a large mine tailing dam** at Aznalcóollar (Seville) **released about 4 million m^3 of trace element contaminated sludge (As, Cd, Pb, Zn)** into the **Guadiamar River.**
- After the accident, **one of the largest phyto-management program was set up**, involving **use of soil amendments** and the **revegetation using native woody plants.** → ***Pistacia lentiscus***
- While the **extremely high concentration of pollutants in the top-soil**, these were **less translocated in the epigean organs of *P. lentiscus***.

Cofinancé par le programme Erasmus+ de l'Union européenne

Applicability on Sardinian mine context

Pistacia lentiscus is occasionally found on mine wastes, where the substrate texture, the absence of organic matter and the extremely high metal concentration are limiting condition for plants.

However, it is well recognized all around these areas, growing anyway on soil with naturally high concentration of metals.

Can we try to use *Pistacia lentiscus* on polluted substrates of mine waste dumps?

Cofinancé par le programme Erasmus+ de l'Union européenne

The Sardinian experience

A multi disciplinary approach for seeing the matter from different points of view.

The *in situ* experiment

Plant Biosystems, Vol. 146, No. 4, December 2012, pp. 1054–1063
Taylor & Francis

A field experiment on the use of *Pistacia lentiscus* L. and *Scrophularia canina* L. subsp. *bicolor* (Sibth. et Sm.) Greuter for the phytoremediation of abandoned mining areas

G. BACCHETTA[1], A. CAO[2], G. CAPPAI[2], A. CARUCCI[2], M. CASTI[1,3], M. L. FERCIA[4], R. LONIS[4], & F. MOLA[5]

The *ex situ* experiment

Bull Environ Contam Toxicol (2015) 94:326–333
DOI 10.1007/s00128-015-1467-y

Use of Native Plants for the Remediation of Abandoned Mine Sites in Mediterranean Semiarid Environments

G. Bacchetta · G. Cappai · A. Carucci · E. Tamburini

Bioaugmentation-assisted phytoremediation

Bull Environ Contam Toxicol (2017) 98:310–316
DOI 10.1007/s00128-016-1866-8
CrossMark

Bioaugmentation-Assisted Phytostabilisation of Abandoned Mine Sites in South West Sardinia

E. Tamburini[1] · S. Sergi[1] · L. Serreli[1,2] · G. Bacchetta[2] · S. Milia[3] · G. Cappai[3,4] · A. Carucci[3,4]

Biominerals on roots

Environ Sci Pollut Res (2015) 22:19352–19361
DOI 10.1007/s11356-015-4808-9
CrossMark

ALTERATION AND ELEMENT MOBILITY AT THE MICROBE-MINERAL INTERFACE

Microscopic biomineralization processes and Zn bioavailability: a synchrotron-based investigation of *Pistacia lentiscus* L. roots

G. De Giudici[1] · D. Medas[1] · C. Meneghini[2] · M. A. Casu[3] · A. Gianoncelli[4] · A. Iadecola[4,5] · S. Podda[6] · P. Lattanzi[1]

The field sampling campaign

Water Air Soil Pollut (2015) 226:340
DOI 10.1007/s11270-015-2609-x
CrossMark

Zn, Pb and Hg Contents of *Pistacia lentiscus* L. Grown on Heavy Metal-Rich Soils: Implications for Phytostabilization

Sara Concas · Pierfranco Lattanzi · Gianluigi Bacchetta · Meri Barbafieri · Andrea Vacca

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK · ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES · CIHEAM MAI CHANIA · INRGREF · BURSA TECHNICAL UNIVERSITY 2010 · STVDIORVM CARALITANA · Forêt Modèle de Provence

The *in situ* experiment

A field experiment on the use of *Pistacia lentiscus* L. and *Scrophularia canina* L. subsp. *bicolor* (Sibth. et Sm.) Greuter for the phytoremediation of abandoned mining areas

G. BACCHETTA[1], A. CAO[2], G. CAPPAI[2], A. CARUCCI[2], M. CASTI[1,3], M. L. FERCIA[4], R. LONIS[4], & F. MOLA[5]

- Two-year study
- different **experimental plots** were created **with or without amendments** and **their combination**:
  1) no amendments
  2) compost
  3) zeolites
  4) zeolite + compost
  5) zeolite + fertilizer
- the **amendments increased the *P. lentiscus* survival**;
- *P. lentiscus* accumulated **metals mostly in the roots**;
- *P. lentiscus* proved to be a suitable species for **phytostabilization** and **environmental restoration**, both for its **resistance to metals** and **high phyto-mass production.**

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK

ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES

CIHEAM MAI CHANIA

BURSA TECHNICAL UNIVERSITY 2010

Forêt Modèle de Provence

The *ex situ* laboratory experiment

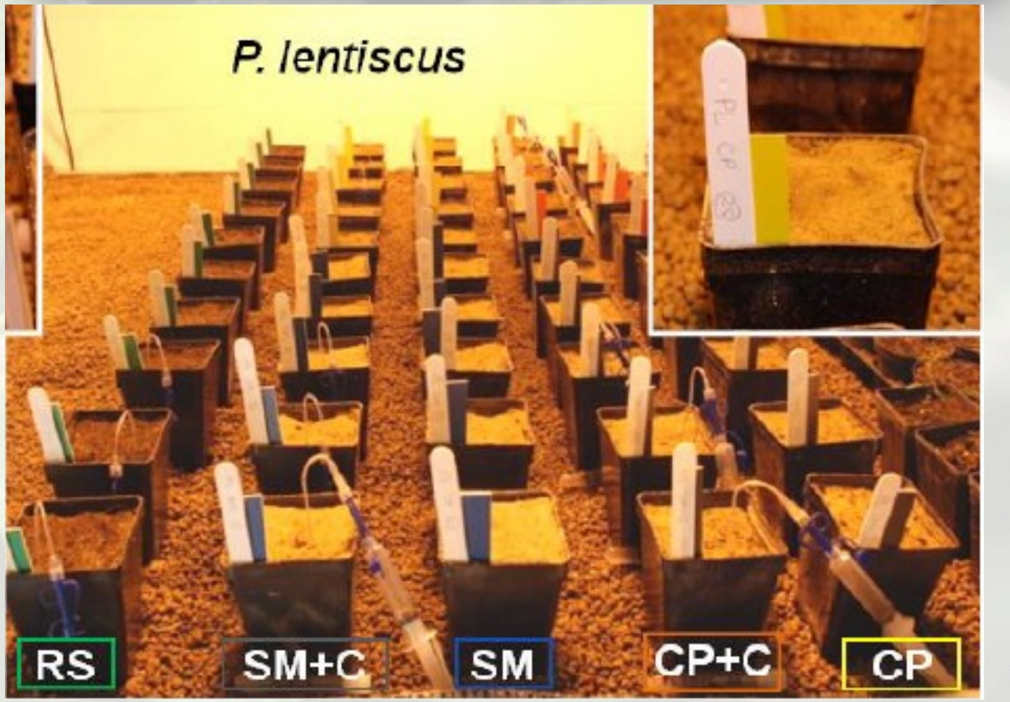
- **Six months** study at **green house controlled conditions;**
- **seedling** of *P. lentiscus* were planted in **different substrates**:
  1) unpolluted substrate
  2) mine waste
  3) mine waste + compost

- ***P. lentiscus* restricted the accumulation of Zn, Pb and Cd in the roots**, showing a high survival percentage in polluted substrates (from 77 to 100%);
- the **compost implementation decreased** the **metal uptake** and **improved the survival** of *P. lentiscus;*
- this study confirm the **suitability** of this species for **phytostabilization**.

Bull Environ Contam Toxicol (2015) 94:326–333
DOI 10.1007/s00128-015-1467-y

Use of Native Plants for the Remediation of Abandoned Mine Sites in Mediterranean Semiarid Environments

G. Bacchetta · G. Cappai · A. Carucci · E. Tamburini



from Bacchetta et al. 2015

Cofinancé par le programme Erasmus+ de l'Union européenne

Bioaugmentation-assisted phytoremediation

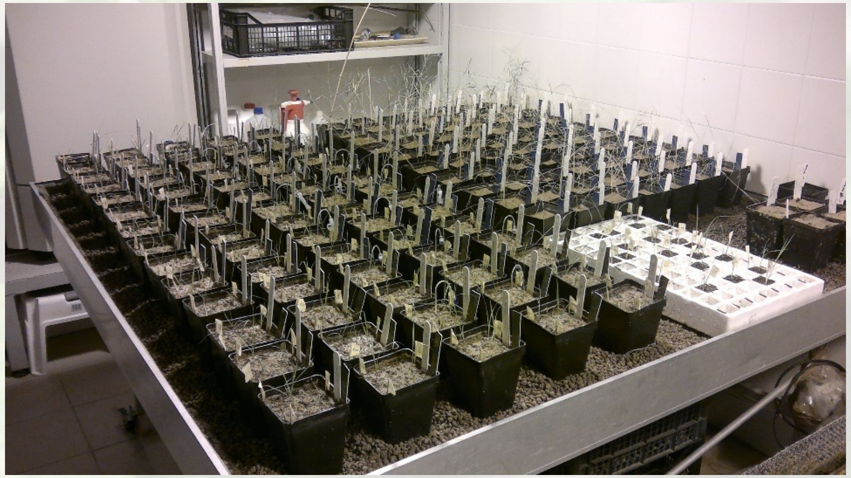
- **Exploitation** of the **synergistic partnership plant-microbe;**
- **two step experiment**;
- *first step:* **isolation of bacterial strains associated with roots of *P. lentiscus*** spontaneously growing in the abandoned mining areas;
- *second step:* **a selection** of five strains **was inoculated** in the greenhouse **phytoremediation test**;
- the strain *Variovorax* sp. RA128A was the most effective for bioaugmentation:
  - ❖ **enhance germination**
  - ❖ **increase length** and **weight of shoots and roots**
  - ❖ **Reduce accumulation of metals in the epigean tissues**
- to the best of our knowledge, **this is the first demonstration** of the **applicability of the bioaugmentation-assisted phytoremediation in *P. lentiscus*.**

Bull Environ Contam Toxicol (2017) 98:310–316
DOI 10.1007/s00128-016-1866-8

CrossMark

Bioaugmentation-Assisted Phytostabilisation of Abandoned Mine Sites in South West Sardinia

E. Tamburini[1] · S. Sergi[1] · L. Serreli[1,2] · G. Bacchetta[2] · S. Milia[3] · G. Cappai[3,4] · A. Carucci[3,4]



Biominerals on roots

- **Multi-techniques study**: **conventional XRD and SEM** combined to **synchrotron-based** techniques, **micro XRF, XAS;**
- investigation about the **process occurring in the substrate roots interface** and the **mechanisms of plant adaptation**;
- ***P. lentiscus* roots take up Zn, Al and Si** from rhizosphere minerals, **building biomineralization;**
- **Si-Al biominerals** coat the root epidermis within **amorphous Zn-silicate;**
- **interaction** between **root exudates, minerals** and **fluids;**
- **physico-chemical barrier** against organic and inorganic stresses;
- **Zn** is also **bound to organic molecules;**
- **a mechanism by which** *P. lentiscus* **excludes** the excess of **Zn.**

ALTERATION AND ELEMENT MOBILITY AT THE MICROBE-MINERAL INTERFACE

Microscopic biomineralization processes and Zn bioavailability: a synchrotron-based investigation of *Pistacia lentiscus* L. roots

G. De Giudici[1] · D. Medas[1] · C. Meneghini[2] · M. A. Casu[3] · A. Gianoncelli[4] · A. Iadecola[4,5] · S. Podda[6] · P. Lattanzi[1]

Nous ne pouvons pas afficher l'image.

from De Giudici et al. 2015

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK · ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES · CIHEAM MAI CHANIA · INRGREF · BURSA TECHNICAL UNIVERSITY 2010 · STUDIORUM UNIVERSITAS CARALITANA · Forêt Modèle de Provence

The field sampling campaign

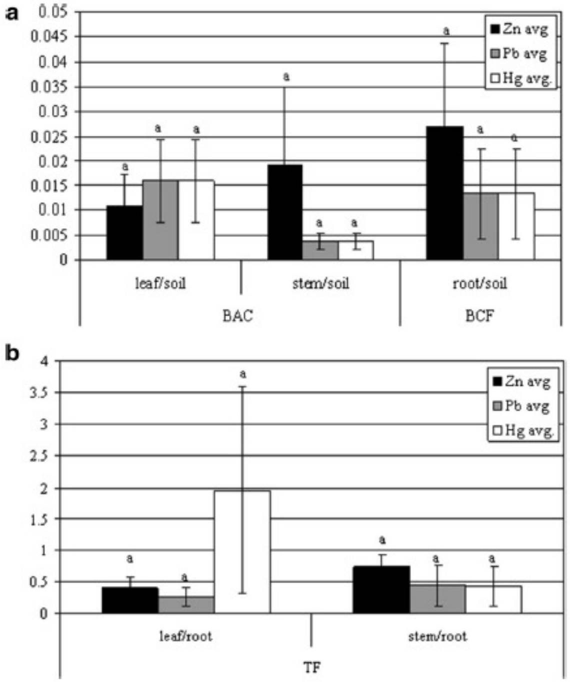
- The study was carried out on *Pistacia lentiscus* **growing** on both metal **naturally enriched soils** and **polluted substrates;**
- Chemical analysis confirm the **accumulation of Zn, Pb in the roots**, decreasing in the **order roots> stems> leaves;**
- it **support** the **concept of "exclusion strategy"** of metal tolerance;
- **it was evaluated also Hg** content, which was **higher in epigean part** than in the root tissues;
- however, it is possible to explain through **foliar absorption** of this toxic metal, because of its high volatility.

Water Air Soil Pollut (2015) 226:340
DOI 10.1007/s11270-015-2609-x

Zn, Pb and Hg Contents of *Pistacia lentiscus* L. Grown on Heavy Metal-Rich Soils: Implications for Phytostabilization

Sara Concas · Pierfranco Lattanzi · Gianluigi Bacchetta · Meri Barbafieri · Andrea Vacca

Fig. 3 a, b Bar diagrams showing the biological coefficients (as defined in the text) calculated for plants of this study. The *bars* indicate the standard deviation



from Concas et al. 2015

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK
ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES
CIHEAM MAI CHANIA
INRGREF
BURSA TECHNICAL UNIVERSITY 2010
Forêt Modèle de Provence

Conclusion

How can *Pistacia lentiscus* help in phytoremediation?

- **Tolerant species** towards Zn, Pb and Cd;
- **metals** are mainly **accumulated into roots**;
- **exclusion mechanism** of survival mediated by the **formation of biominerals**;
- **suitable for phytostabilization**;

How can we improve the ability of *Pistacia lentiscus* for phytoremediation?

- **By implementation of soil amendments** which **improve** the **survival** of the species and **reduce** the **metal uptake;**
- **by bioaugmentation of substrates** that **help and assist** the **plant growth.**

Cofinancé par le programme Erasmus+ de l'Union européenne

Conclusion

What have we learned from "the Sardinian experience"?

- A **multidisciplinary approach** can **help to project and optimize phytoremediation actions;**
- the **soil-plant or the substrate-plant interface** is a **sensitive and complex locus** where **botany, microbiology, chemistry and mineralogy, meet together;**
- the **understanding of all these aspect** must be **considered in order to know the behavior of tolerant plant** species and **for applying the most suitable actions;**
- **a crucial role** should be assigned to **environmental engineering.**

The **same approach can be used in other mine context,** also different from Sardinian one**, and on different plant species.**

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK

ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES

CIHEAM MAI CHANIA

INRGREF

BURSA TECHNICAL UNIVERSITY 2010

Forêt Modèle de Provence

Thank for your attention

Centro Conservazione Biodiversità (CCB)
Dipartimento di Scienze della Vita e dell'Ambiente
Università degli Studi di Cagliari
v.le Sant'Ignazio da Laconi 13
09123 Cagliari (ITALIA)

Tel. +39-070675 3508 (Uffici)
Tel. +39-070675 3681 (Laboratori)
E-mail: ccb@unica.it
Web page: www.ccb-sardegna.it

Sardinian Germplasm Bank (BG-SAR)
Hortus Botanicus Karalitanus (HBK)
v.le Sant'Ignazio da Laconi 9-11
09123 Cagliari (ITALIA)

Tel. +39-070675 3508 (Uffici)
Tel. +39-070675 3806 (Laboratori)
E-mail: bg-sar@unica.it
Web page: http://sites.unica.it/hbk/

Cofinancé par le programme Erasmus+ de l'Union européenne

MEDLENTISK · ASSOCIATION INTERNATIONALE DES FORETS MEDITERRANEENNES · CIHEAM MAI CHANIA · INRGREF · BURSA TECHNICAL UNIVERSITY 2010 · UNIVERSITAS STVDIORVM CARALITANA · Forêt Modèle de Provence